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GROUND-WATER POLLUTION
in the
SOUTH PLATTE RIVER VALLEY
BETWEEN DENVER AND BRIGHTON, COLORADO

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
South Platte River Basin Project
Denver, Colorado

December 1965

SOUTH PLATTE RIVER BASIN PROJECT
U.S. Public Health Service

Background and Objectives

On July 18, 1963 the Governor of Colorado requested the Secretary of Health, Education, and Welfare to assist the State in determining sources of pollution and quality of waters of the South Platte River Basin within the State of Colorado.

The First Session of the Conference in the matter of Pollution of the South Platte River Basin was held in Denver, Colorado on October 29, 1963 under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466g). It was established at this Conference that a study would be undertaken by facilities of the U.S. Public Health Service. Findings and recommendations from this study would lead to a program of pollution abatement to be developed jointly by the South Platte River Basin Project, Public Health Service, and the Colorado State Department of Public Health.

The long-range goals and objectives of the Project are as follows:

1. Determine the legitimate water uses and locate the sources of pollution having an adverse effect on those uses.
2. Through field investigations determine the physical, chemical, and biological responses of the River to pollution and evaluate the previously located sources of pollution with respect to the conditions in the River.
3. Compute the waste load reductions necessary to obtain desired water quality and recommend water quality control measures needed to effect the desired waste load reductions.

Organization

The South Platte River Basin Project consists of engineering and associated professional and clerical personnel. The Project Headquarters offices are located in downtown Denver and the Laboratory has been established at the Colorado State Department of Public Health, Denver, Colorado. The Project is administratively attached to the Water Supply and Pollution Control program of the Public Health Service, U.S. Department of Health, Education, and Walfare, Region VIII, Denver, Colorado.

ACKNOWLEDGEMENTS

The assistance and cooperation of many State, local, and Federal agencies are gratefully acknowledged by the Public Health Service. Particular appreciation is expressed to the following for data and advice furnished by their staff members:

Colorado State Department of Public Health
Engineering and Sanitation Division
Denver, Colorado

Colorado Water Conservation Board
Denver, Colorado

State Engineer of Colorado
Ground-Water Section
Denver, Colorado

Colorado Public Utilities Commission
Denver, Colorado

Colorado State University
Engineering Research Center
Fort Collins, Colorado

Tri-County Health Department
Aurora, Colorado

City of Brighton
Brighton, Colorado

City of Thornton
Thornton, Colorado

North Washington Water and Sanitation District
Denver, Colorado

Northwest Water Corporation
Denver, Colorado

South Adams Water and Sanitation District
Commerce City, Colorado

Town and Country Mutual Water Company
Commerce City, Colorado

U.S. Bureau of Reclamation, Region 7
Denver Development Office, Denver, Colorado

U.S. Geological Survey
Water Resources Division, Branch of Ground Water
Denver, Colorado

U.S. Department of Agriculture
Soil Conservation Service
Brighton, Colorado

U.S. Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
Denver, Colorado

U.S. Army Engineer District, Omaha
Corps of Engineers
Omaha, Nebraska

U.S. Department of Army
Rocky Mountain Arsenal
Denver, Colorado

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SUMMARY AND CONCLUSIONS

The fresh water-bearing formations occurring in the South Platte River valley between Denver and Brighton, Colorado consist of the bedrock formations and the overlying valley-fill deposits. Water wells completed in the bedrock aquifers yield small to moderate amounts of good quality water in most of the area. The water-bearing characteristics of the valley-fill aquifer are very favorable for developing large water supplies from shallow wells located throughout much of the valley.

Over 1,076 wells currently withdraw water from the valley-fill aquifer. Approximately 15,500 acres of farm land are irrigated with this water. Withdrawals from irrigation wells were about 22,000 acre feet in 1963 and comprised about 70 percent of the total ground-water pumpage. The valley-fill aquifer is the chief source of water for the majority of the public water systems. Withdrawals from shallow public supply wells continue to increase, averaging 7.1 million gallons per day (8,510 acre feet per year) in 1964.

Over a period of years, discharges from the valley-fill aquifer are balanced by recharge. The chief source of recharge to the aquifer is from seepage derived from South Platte River water diverted to the irrigation ditches in the area. Approximately 50 percent of the river water diverted to the irrigation ditches enters the shallow aquifer.

Two incidents of ground-water contamination by gasoline spills or leakages have occurred. Portions of the shallow aquifer in these two localities most likely remain contaminated.

Much of the valley-fill aquifer in Sand Creek valley is probably contaminated by petroleum wastes. In the Commerce City area, two public supply wells owned by Town & Country Mutual Water Company have been contaminated by hydrocarbons since 1957.

Alkyl benzene sulfonate (ABS) is found throughout most of the valley-fill aquifer. Most shallow public supply wells yield water containing significant concentrations of ABS. The principal source of ABS in the aquifer is sewage-laden recharge water from the South Platte River, Sand Creek and Clear Creek.

Nearly all bacteria are removed by infiltration through the saturated zone. However, residual bacteria may be found after travel over appreciable distances. Bacteriological data from two public water supplies adjacent to the South Platte River indicate fecal coliforms were present in the aquifer 300 feet from the river.

The principal source of nitrates in the shallow aquifer is fertilizers applied to irrigated farms. Feedlot operations and sewage-laden waters diverted from the River have also contributed nitrates to the aquifer. Highest nitrate concentrations generally occur in and near the irrigated lowland areas where nitrates commonly exceed 35 parts per million (ppm) and are as high as 90 ppm. Two public supply wells owned by the South Adams Water and Sanitation District yield water having nitrate concentrations of 50 parts per million. Nitrate concentrations of water from the City of Brighton's wells currently range from 55 to 72 ppm. Waters from these public supply wells contain nitrates in excess of 45 mg/l, the upper limit of the U.S. Public Health Service Drinking Water Standards, and is potentially dangerous when used for infant feeding. One case of infant methemoglobinemia in 1962 was attributed to the use of Brighton's well water.

The shallow aquifer underlying approximately 12 square miles in the vicinity of the Rocky Mountain Arsenal has been severely contaminated by chemical wastes discharged into unlined holding ponds and First Creek prior to 1957. Contaminants known to be present in the shallow aquifer include chloride, fluoride, arsenic, chlorate, the herbicide 2, 4-D, and the pesticides aldrin and dieldrin. Severe damages to crops and ground-water supplies have resulted from the contamination. Contamination in the vicinity of the Rocky Mountain Arsenal will persist for many decades in the future, principally due to the relatively slow movement of ground water in the heavily contaminated parts of the aquifer.

The possibility of Arsenal-contaminated ground water moving directly into the City of Brighton's water well field is remote at this time. However, it is conceivable that the contaminated water could be induced directly to Brighton over a long period of time under circumstances of progressively increasing ground-water withdrawals immediately north of the contaminated zone.

Saline water from the shallow contaminated zone in the vicinity of the Arsenal has likely entered the underlying bedrock aquifers through at least three defective deep wells. However, the actual number of defective wells is unknown since relatively few of the 61 deep wells located in or near the contaminated shallow zone have been sampled since 1959.

RECOMMENDATIONS

The Colorado State Department of Public Health and other agencies as indicated below should undertake and implement the following measures.

A. In view of the shallow aquifer's great susceptibility to contamination, it is recommended that the following measures be taken to minimize pollution and contamination in the future:

1. Seal settling ponds and ditches used for the treatment of industrial waste with an impermeable material.

2. Provide municipal sewage treatment systems for the densely populated suburban localities, thereby eliminating existing septic tank discharges directly into the shallow aquifer.

3. Construct linings in feedlot pens and areas used for manure storage with an impermeable material and properly drain to prevent seepage directly into the aquifer. In addition, these waters should be adequately treated before discharging to a surface water course.

4. Improve the quality of waste water discharged to the South Platte River and its tributaries. Since a large part of flow in these streams consists of industrial and municipal effluents, and nearly all recharge to the aquifer originates from these surface flows, the chemical quality of ground water will be influenced to a great extent by the character of wastes discharged to the streams.

B. In view of the possibility of large scale petroleum contamination of the shallow aquifer in Sand Creek Valley and parts of the main valley, it is recommended that the following measures be taken:

1. Conduct a detailed investigation to determine the areal extend of petroleum contamination and effects on public and domestic ground-water supplies.

2. Investigate effectiveness of methods for detecting leakage from pipelines, storage tanks and other facilities of the petroleum industries in the area.

C. In view of the probability that pollution of the valley-fill aquifer will persist for many decades in the future, public water systems in the area should consider replacing their shallow ground-water supplies with water from outside sources. Many of these public water systems are presently considering other sources of water and are engaged in negotiating for outside sources of water.

D. In view of the occurrence of significant and often excessive concentrations of nitrates in the aquifer and the large number of domestic wells in use, it is recommended that the following measures be taken:

1. Conduct periodic detailed field inventories of all domestic water wells in the area, and obtain and record the following information:

   a. Water sample for chemical analysis.
   b. Pertinent well information, including owner's name, location, driller's log, depth, perforated interval, casing size, and water level.

2. If excessive nitrates are found, the well user should be notified in writing as to the results of the chemical analysis and the hazards, especially to new-born babies, of using these waters; another source of drinking water should be obtained.

E. In view of the possibility of continued expansion the contaminated zone in the vicinity of Rocky Mountain Arsenal, water well monitoring programs of the Tri-County Health Department and Colorado State Department of Public Health, and the Arsenal should be continued. It is recommended that the following additional measures be taken by the Colorado State Department of Public Health and the Rocky Mountain Arsenal:

1. Prevent large increases in ground-water withdrawals from the valley-fill aquifer in areas lying immediately outside of the contaminated zone.

2. Acquire approximately 12 additional sampling wells along and immediately outside of the east and west edges of the contaminated zone in Sections 2, 3, 12, 13, 24, 25, and 36 of T. 2 S., R. 67 W., and in Sections 21, 27, 28, 34, and 35 of T. 2 S., R. 67 W. Water samples should be collected from these sampling wells at least once annually near the end of the irrigation pumping season, preferably during the last week of August or the first week of September.

3. Obtain samples from all deep wells located in or near the contaminated zone at least once annually for chemical analysis in order to detect possible contamination. All contaminated deep wells should be completely plugged with cement.

4. Laboratory analysis of water samples should include the determination of all contaminants known to be present in the contaminated zone.

F. In view of the continued high degree of saline contamination in most of the area underlying the Arsenal, it is recommended that the Rocky Mountain Arsenal study this problem in detail and include the following items:

1. Conduct pumping tests on sampling wells located in the thinner and less permeable areas of the contaminated zone for the purpose of determining rates of groundwater movement in these areas.

2. Obtain several continuous cores of the interval between the abandoned pond bottoms and the base of the shallow aquifer for the purpose of determining the existence of possible sludge deposits.

G. In view of the possibility that leakage could occur at any time from the Arsenal's lined Pond F, recording amounts of waste input and removal should be continued. It is recommended that the Rocky Mountain Arsenal undertake the following additional measures:

1. Flush the aquifer in the vicinity of the pond with fresh water in order to permit detection of significant changes in chloride concentrations from pond sampling wells.

2. Utilize additional sampling wells located on the perimeter of the pond.

3. Conduct periodic well performance tests on the waste disposal well in order to determine trends of possible plugging.

INTRODUCTION

The investigation of ground-water conditions in the South Platte River Valley between Denver and Brighton was undertaken as a part of the water pollution study of the Denver metropolitan area currently being conducted by the South Platte River Basin Project.

Ground water is used extensively in the area for public, domestic, industrial and irrigation supplies. The principal source of large ground-water supplies is the shallow valley-fill deposits which are very susceptible to contamination. The rapidly expanding urban and industrial growth of the area has resulted in continued development of water supplies from ground-water sources.

The purpose of the ground-water study was to determine sources and extent of pollution in the water-bearing formations in the area. In assessing these conditions the geology and water-bearing characteristics of the aquifers were considered.

This study is based on published and unpublished information obtained from many Federal, State and local agencies, and field investigations of the area. A large number of chemical analyses of water from wells were made available by the Colorado State Department of Public Health, Tri-County Health Department, and Rocky Mountain Arsenal. The Geological Survey furnished the results of their inventory of ground-water pumpage in the area in 1963. The Ground Water Section of the Office of the State Engineer of Colorado made available their records on water wells. Officials of public water systems cooperated in furnishing information about their water systems, and permitted collection of water samples and measurements.

Locations of wells and some sampling points in the report area are described by using a numbering system based on the U.S. Bureau of Land Management's system of land subdivision. The numbering system is explained in Appendix A.

AREA OF INVESTIGATION

The area considered in this investigation is the valley of the South Platte River lying between Denver and Brighton, Colorado. As shown in Figure 1, the valley covers about 110 square miles in southwest Adams County. The population of the principal towns in the area in 1960 (1) was: Brighton, 7055; Commerce City, 8970; Derby, 10,124; and Thornton, 11,353. Approximately 15,500 acres of farm land are presently irrigated in the main valley. The principal crops are alfalfa, corn, sugar beets, truck garden vegetables, and small grains. The principal industries in the area include oil refineries, feedlots, meat packing plants, a beet sugar processing mill and a cannery.

The South Platte River flows northeastward along the western side of the main valley. The valley is bordered on the west by a steep face of consolidated rocks and on the east by rolling uplands of consolidated rocks. The main valley consists of gently rolling hills sloping toward the broad terraces that border the flood plain of the river. Elevation of the flood plain ranges from about 5,150 feet above sea level at the south end of the area near Denver to about 4,950 feet at the north end near Brighton.

Sand Creek and First, Second, and Third creeks drain the east side of the valley. The flows in these streams are intermittent, except along the lower reaches of Sand Creek and First Creek where these streams receive sewage treatment plant effluents, and/or treated and untreated industrial wastes. Burlington, O'Brian, and Fulton ditches convey large quantities of water from the South Platte River for use on irrigated farms in and outside of the area, and for irrigation storage in Barr Lake. The west side of the valley is drained by Clear Creek, which is a perennial tributary of the South Platte River. Gardener's, Brantner, and Brighton ditches divert water from the South Platte River for irrigation use on the west side of the valley.

GEOLOGY AND OCCURRENCE OF GROUND WATER

The main valley lies near the deepest portion of the Denver-Julesburg Basin: a large asymmetrical structural basin extending from central Pueblo County through northeastern Colorado into southeastern Wyoming and western Nebraska.

The upper 1,400 feet of bedrock materials of late Cretaceous and Tertiary age contain fresh water. These formations are made up of largely clay, shale and siltstone and contain many layers of poorly consolidated sandstone, gravel, and conglomerate. Ground water in the bedrock formations generally occurs under artesian conditions. Water wells completed in the bedrock formations yield small to moderate quantities of water for domestic, stock, industrial and public supply use. Waters from the bedrock aquifers are usually of good quality except in some localities where they contain relatively high concentrations of sulfate and chloride. Wells tapping the bedrock aquifers have yields ranging from 5 to 200 gallons per minute (gpm), although most large capacity deep wells yield about 50 gpm. The low transmissivity of the water-bearing materials in the bedrock formations in this area precludes the development of large ground-water supplies from this source. Records of the State Engineer of Colorado show 139 deep water wells have been drilled in the valley through March 1964. Depths of these wells range from about 100 to 1525 feet below the land surface.

The valley-fill deposits, chiefly Quaternary in age, consist of sand, gravel, some cobbles, and thin beds of silt and clay. The valley-fill deposits blanket most of the valley. The boundary of the valley-fill deposits is shown on Figure 1. The greatest thicknesses of sand and gravel were deposited in the main channels that were cut into the bedrock by the ancestral South Platte River and its tributaries. A map prepared by the Geological Survey (2) shows the thickness of the saturated valley-fill deposits. Thicknesses of up to 60 feet of saturated valley-fill deposits occur in an ancient channel that underlies the flood plain of the present course of the South Platte River. Two buried channels, that extend northwestward across Rocky Mountain Arsenal, have saturated thicknesses of up to about 80 feet. The ancestral South Platte River originally flowed through the valley now occupied by Beebe Draw. This ancient channel traverses the area in a general northeast direction roughly conforming to the present course of O'Brian Ditch. Thicknesses of the saturated fill in this ancient channel ranges up to about 100 feet beneath Barr Lake. The valley-fill deposits underlying Barr Lake are largely separated from those of the main valley by a narrow ridge of bedrock that extends northward from the southwest shore of the lake. Depths to the water table in the valley range from less than a foot beneath the flood plain to about 65 feet beneath the land surface in the southeastern part of the area.

The valley-fill deposits are the principal source of the largest supplies of ground water in the area. Geologic conditions and water-bearing characteristics of these deposits are very favorable for developing large low-cost water supplies from wells located throughout much of the area. The Geological Survey (2) estimated about 300,000 acre feet of recoverable ground water in storage in 1957. Pumping tests conducted by the Geological Survey in the area reveal the coefficient of transmissibility of the aquifer ranges from 50,000 to 500,000 gallons per day per foot. The coefficient of permeability averages about 5,500 gpd per

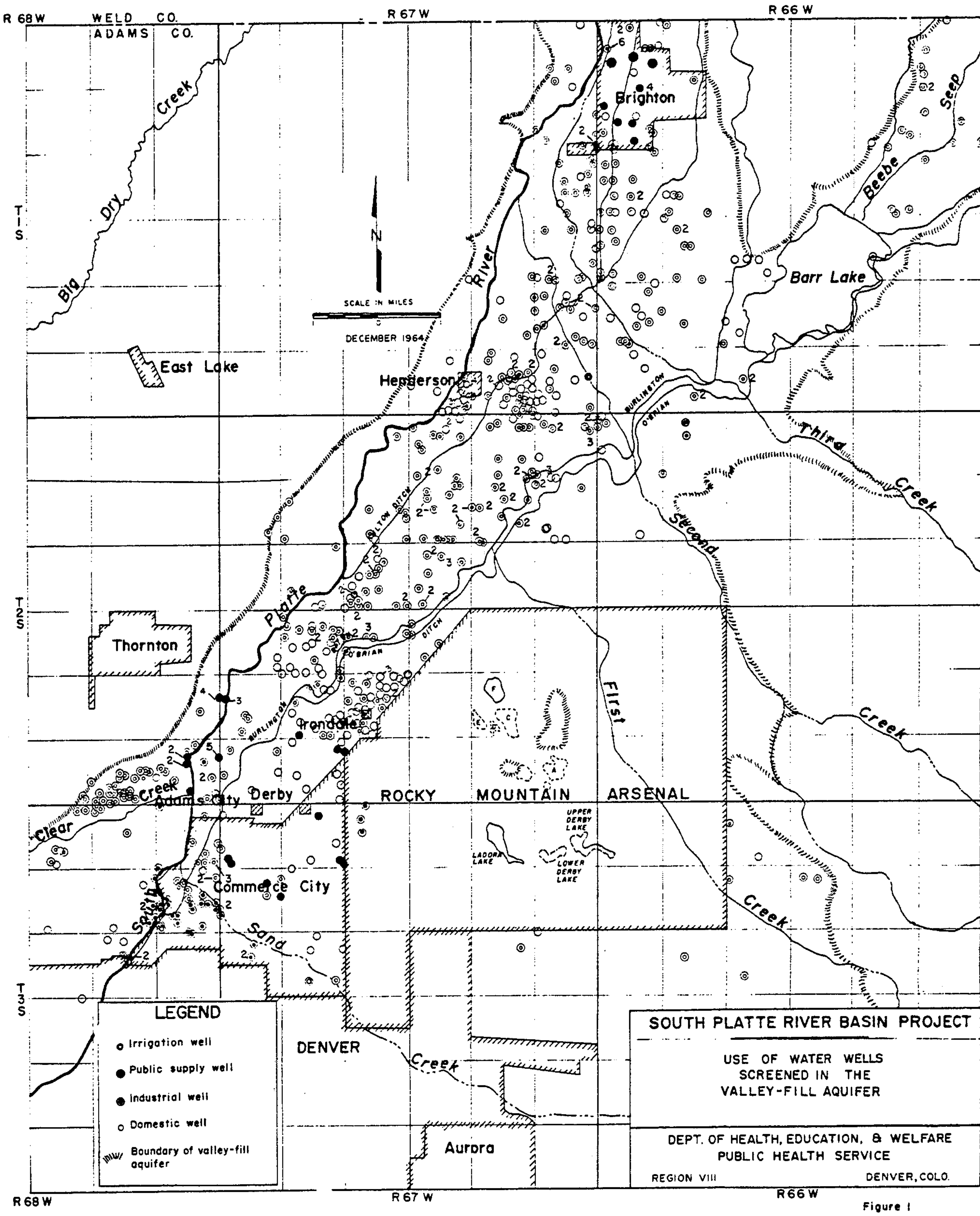
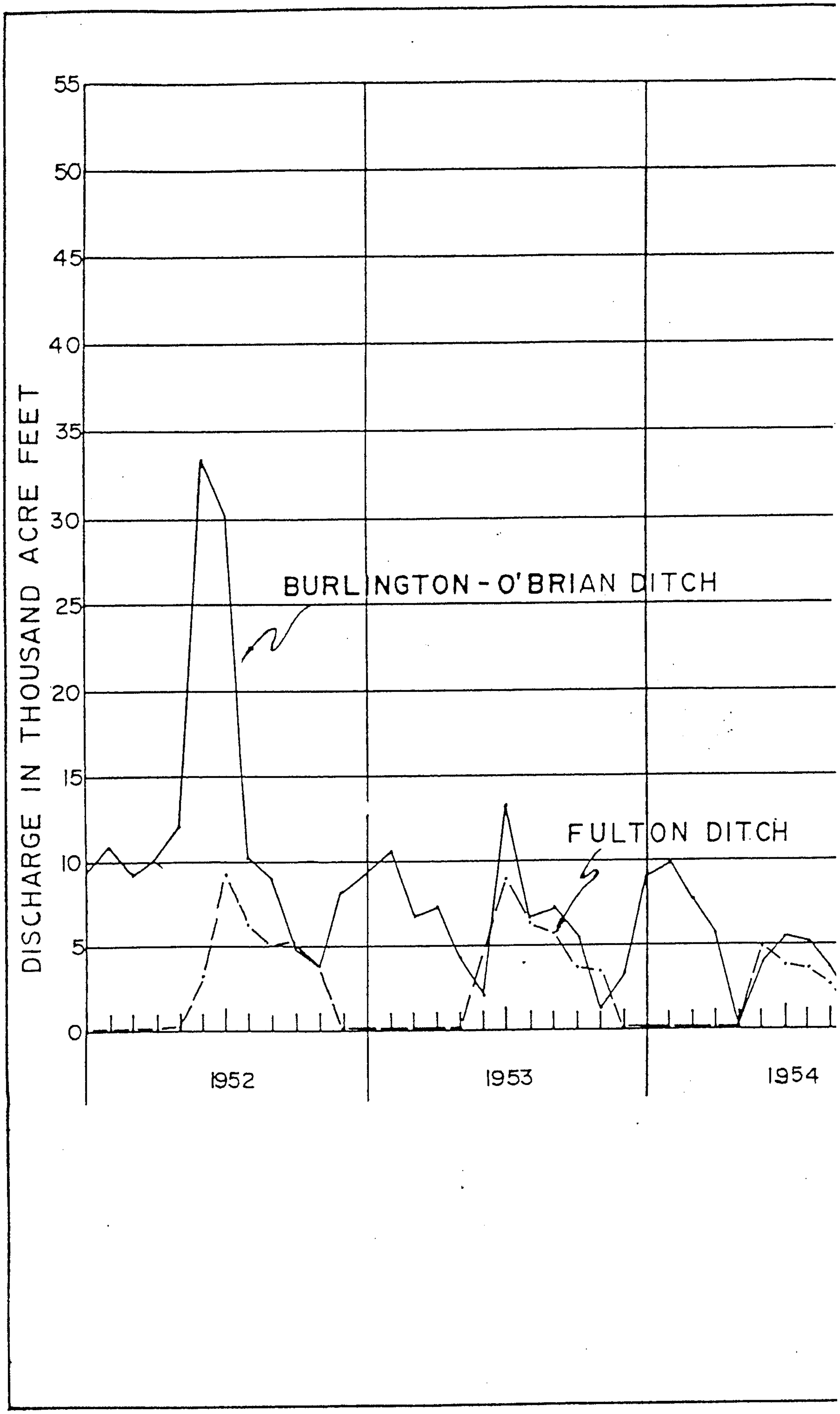
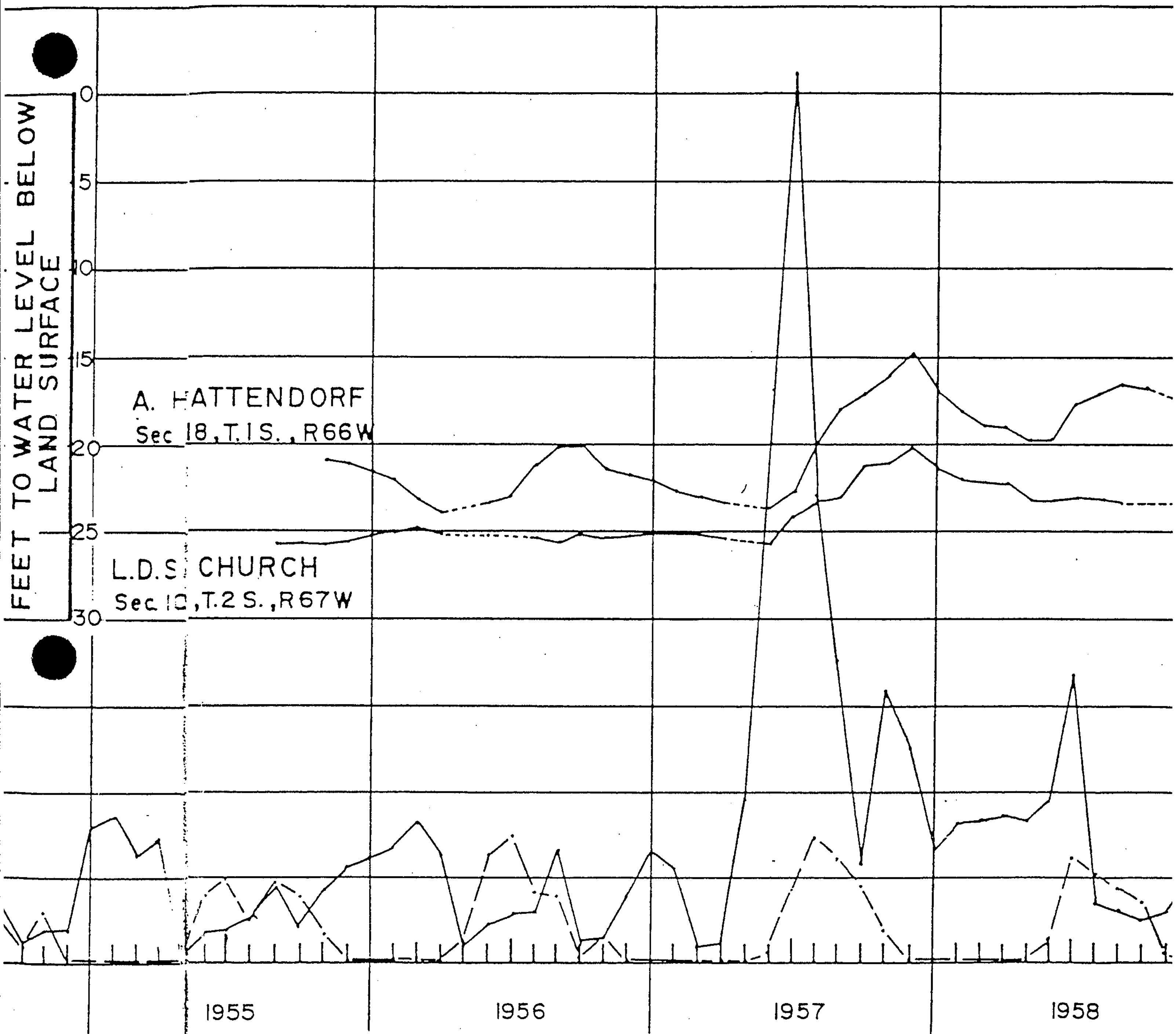

R 68 W
WELD CO.
ADAMS CO.
R 67 W
R 66 W
T 1 S
T 2 S
T 3 S
Big Dry Creek
Brighton
Beebe Seep
Barr Lake
River
Platte
South
N
SCALE IN MILES
DECEMBER 1964
East Lake
Henderson
Burlington
O'Brian
Third Creek
Second
Fulton Ditch
Thornton
Irondale
Clear Creek
Adams City
Derby
ROCKY MOUNTAIN ARSENAL
First Creek
Upper Derby Lake
Ladora Lake
Lower Derby Lake
Commerce City
Sand Creek
DENVER
Aurora
LEGEND
Irrigation well
Public supply well
Industrial well
Domestic well
Boundary of valley-fill aquifer
SOUTH PLATTE RIVER BASIN PROJECT
USE OF WATER WELLS SCREENED IN THE VALLEY-FILL AQUIFER
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.

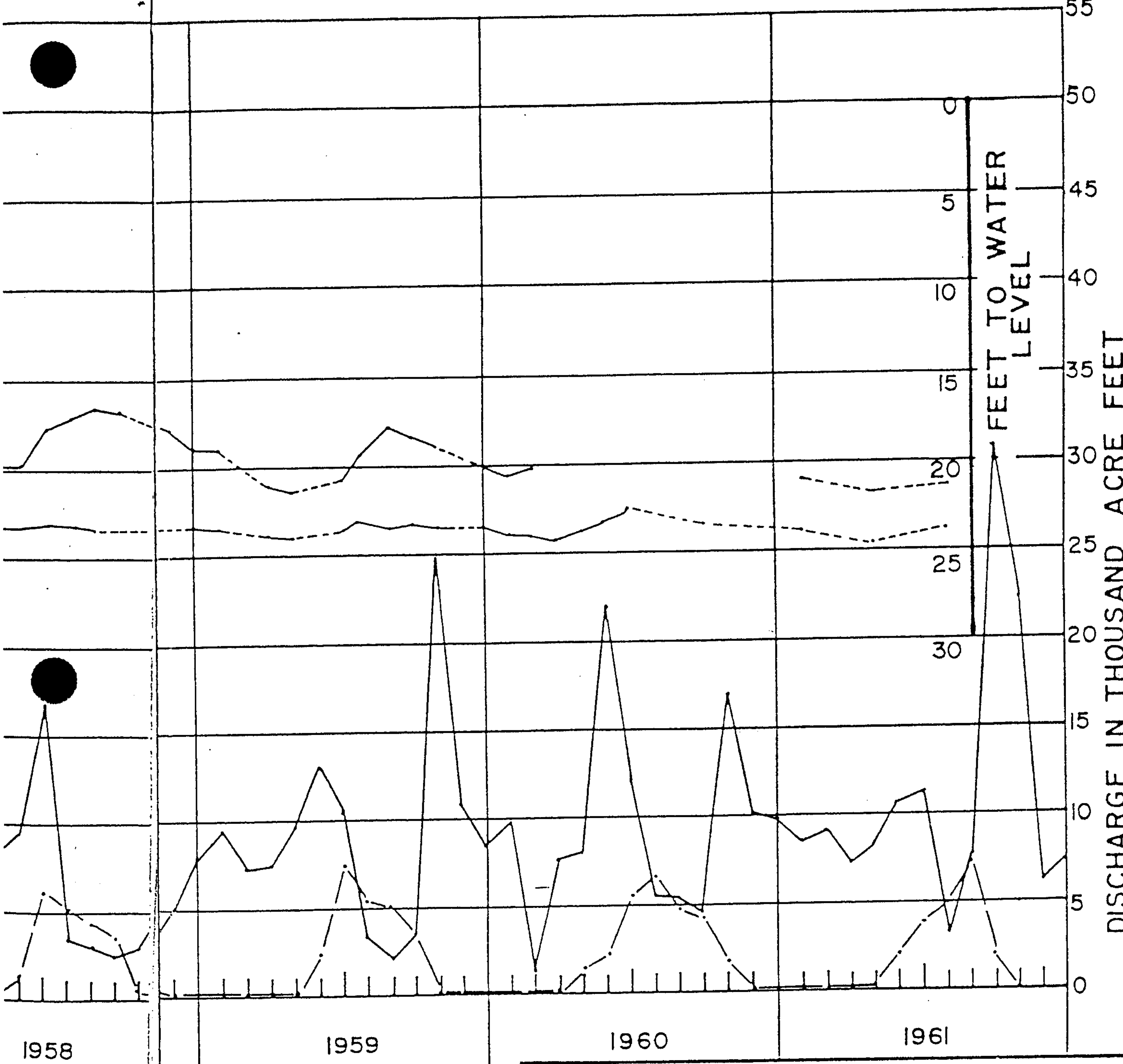
Figure 1



DISCHARGE IN THOUSAND ACRE FEET
55
50
45
40
35
30
25
20
15
10
5
0
BURLINGTON - O'BRIAN DITCH
FULTON DITCH
1952
1953
1954



FEET TO WATER LEVEL BELOW LAND SURFACE
0
5
10
15
20
25
30
A. HATTENDORF
Sec 18, T.1S., R66W
L.D.S. CHURCH
Sec 10, T.2S., R67W
1955
1956
1957
1958



SOUTH PLATTE RIVER BASIN PROJECT

WATER LEVELS IN WELLS & DIVERSIONS TO MAIN IRRIGATION DITCHES

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE

REGION VIII DENVER, COLORADO

FIGURE 2

square foot. Yields of large capacity wells are reported to range up to 2,000 gpm and yields of 500 gpm are common.

WITHDRAWALS FROM THE VALLEY FILL AQUIFER

Over 1,076 shallow wells withdraw water from the valley-fill aquifer in the area. Figure 1 shows the location and use of most of the large capacity wells in the area and is based largely on a recent inventory by the Geological Survey (3) supplemented by records of the Colorado State Department of Public Health, Tri-County Health Department and field investigations by the South Platte River Basin Project. A public supply is defined in this report as a water system that supplies water to a relatively large population. Sizes of public water systems in the area range from 121 to 7600 service connections. A domestic supply is defined as a privately owned well-system which serves residences, trailer courts, motels and similar establishments. The following tabulation is based largely on the number of shallow water wells less than 100 feet in depth recorded by the State Engineer of Colorado through March 1964.

Principal Use o Well	Total Wells
Irrigation	397
Public Supply	38
Industrial and Commercial	85
Domestic	546
Stock	10
Total	1,076

Large capacity irrigation wells having yields in excess of 200 gpm are located principally in the lowland areas west of Burlington and O'Brian ditches. Of the six public water systems, well fields operated by the Northwest Water Corporation, the North Washington Water and Sanitation District and the City of Thornton are located on the flood plain of the South Platte River in the southern part of the area; those of the South Adams Water and Sanitation District and the Town & Country Mutual Water Company are located in and near Commerce City; and the wells serving the City of Brighton are located within its corporate limits in the extreme northern part of the area. Most of the large capacity industrial wells are located in Brighton, and in the Commerce City industrial district. There is a heavy concentration of shallow domestic wells in the Adams City-Derby-Irondale locality. Available records show 412 domestic wells occur in this locality. There are over 104 domestic wells in the locality bounded by Brighton, Barr Lake and Henderson. Because of the relative ease of drilling shallow wells in the main valley, the actual number of wells used for domestic and lawn irrigation purposes may be several times that reflected by available records.

The Geological Survey (2) determined total withdrawals from large capacity wells in the area averaged about 40,000 acre feet per year during 1956 and 1957. Total withdrawals in 1963 were determined at about 32,000 acre feet. A large part of the reduction in total pumpage is attributed to decreases in irrigated acreage in the vicinity of Adams City, Derby and Irondale, resulting from increases in residential and industrial development. The Geological Survey estimated withdrawals from 325 irrigation wells were 22,210 acre feet in 1963 or about 70 percent of the total amount of ground water withdrawn in the area; approximately 6,140 acre feet of ground water was pumped from public supply wells and 3,580 acre feet was withdrawn from industrial wells.

The valley-fill aquifer is the principal source of water for most public water systems in the area. The average daily deliveries of water in 1964 and the amounts contributed by pumping from the valley-fill aquifer reported by public water systems in the area are shown in the following tabulation.

	Total Water Delivered	Pumpage from Valley Fill Aquifer		
	(MGD)	(No. Wells)	(MGD)	(Percent)
City of Brighton	2.16	11	2.16	100
North Washington W&S District	0.98	4	0.74	76
Northwest Water Corporation	0.29	1	0.22	75
South Adams W&S District	2.11	8	1.56	74
City of Thornton	4.94	12	2.29	46
Town & Country Mutual Water Co.	0.09[a]	2	0.09[a]	100
Total	10.57	38	7.06	67

a/ Estimated.

Withdrawals from shallow wells of public supply systems have increased from an average of 5.48 million gallons per day (6,140 acre feet per year) in 1963 to an average of 7.06 million gallons per day (8,510 acre feet per year) in 1964.

RECHARGE AND DISCHARGE

Sources of recharge to the valley-fill deposits in the area include precipitation, ground-water inflow, and seepage from irrigation ditches, irrigated farms, and influent tributary streams. Recharge water enters the valley-fill deposits and moves slowly down the valley toward points of withdrawals from wells and toward the natural discharge areas in and near the South Platte River. A water-table map prepared by Geological Survey (2) shows the hydraulic gradient varies from 11 to 30 feet per mile.

An analysis was made of amounts of recharge to and discharge from the valley-fill deposits in that portion of the main valley lying between the mouth of Clear Creek and the northern boundary of the area for the period of 1952-1961 inclusively. A summary of this analysis is shown in Table I. Some of the quantities of water used in this analysis are approximate. The analysis did not include recharge from runoff in intermittent streams along the margins of the main valley as this runoff is believed to be relatively small. Also, the determination of induced recharge of river flow by heavy seasonal pumping of wells located adjacent to the River is beyond the scope of this investigation. However, it is believed this amount makes up only a small part of the total recharge to the aquifer. The analysis indicates the order of magnitude of principal amounts of recharge to and discharge from the valley-fill deposits.

The chief source of recharge to the aquifer is seepage from the main irrigation ditches and seepage of waters applied on the irrigated farms. During the period of 1952-1961 inclusively, an annual average of 146,750 acre feet was diverted to irrigation ditches in the area (4). Approximately 92,100 acre feet of the total annual diversions to the main irrigation ditches are consumed in the area leaving about 54,700 acre feet available for use outside of the study area. Seepage from irrigation ditches in the area of analysis was estimated to be 79,000 acre feet per year or 54 percent of the ditch flow. Seepage from water stored in Barr Lake was not included in the analysis, since nearly all of the seepage from the lake moves toward Beebe Seep. Approximately 25,000 acre feet of water from wells and 13,100 acre feet of ditch water was applied annually on the irrigated farm lands. Seepage from the irrigated farms was estimated to average 15,200 acre feet per year, or about 40 percent of total water applied on the farms. Recharge from rainfall and snow melt in the area was estimated to average 5,400 acre feet per year, or about 10 percent of the average annual precipitation of 13.5 inches that fell on the outcrop of the valley-fill deposits. Recharge from subsurface inflow of the water-bearing valley-fill deposits located immediately upvalley was determined by the Geological Survey (2) at 9,600 acre feet per year in 1957.

TABLE I

SUMMARY OF RECHARGE TO AND DISCHARGE FROM THE VALLEY-FILL DEPOSITS 1952-1961

	Acre feet per year
Recharge to the valley-fill deposits:	
Seepage from irrigation ditches	79,000
Seepage from water applied on irrigated farms	15,200
Precipitation	5,400
Ground-water inflow	9,600
Total	109,200
Discharge from the valley-fill deposits:	
Water well pumpage	32,000
Return flow to South Platte River	39,000
Evapotranspiration	34,200
Ground-water outflow	4,000
Total	109,200

Accretions to the flow in the South Platte River occur from discharges of water from the valley-fill aquifer. River gain studies (5) indicate an average annual gain in river flow of about 34,800 acre feet between Henderson and Fort Lupton, a distance of 13.3 miles, during the period of 1952-1961, inclusively, or a gain of about 2,600 acre feet per year per mile. Based on the river gain shown above, discharges from ground-water return flow in the area of analysis were estimated to average about 39,000 acre feet per year. Total annual withdrawals from large capacity wells were estimated to average about 32,000 acre feet per year, of which 25,000 acre feet was pumped from irrigation wells and 7,000 acre feet was pumped from industrial and public supply wells. The amount of ground water leaving the study area by underflow through the valley-fill deposits was estimated to be about 4,000 acre feet per year. Discharge from the valley-fill deposits by evapotranspiration was estimated to be 34,200 acre feet per year. A consumptive-use rate of 2 acre feet per acre per year is considered to be applicable by the Geological Survey (2) in portions of the South Platte River valley where the water table is less than 20 feet below the land surface.

The analysis indicates a major portion of the recharge water is derived from seepage of river water diverted to irrigation ditches. The effect of seepage from ditches and farm lands is shown in Figure 2. Water levels in most wells rise rapidly throughout the irrigation season and decline during the winter months. In some localities where wells are closely spaced, temporary declines in water levels occur during heavy pumping periods. Records of water levels in wells (2) (3) (6) (7) located throughout most of the area do not show long-term net declines, indicating over a period of years, discharges from the aquifer are balanced by recharge.

CHEMICAL QUALITY OF WATER IN THE VALLEY-FILL AQUIFER

Recent chemical analyses of water from selected water wells in the area are presented in Appendix B. The chemical composition of water in the valley-fill deposits varies widely, although in most instances, total hardness of the shallow waters exceeds 200 mg/l, with concentrations of total dissolved solids and sulfates in excess of the recommended upper limits of 500 mg/l and 250 mg/l, respectively, of the U.S. Public Health Service Drinking Water Standards (8).

In the southern part of the valley between Denver and Irondale, the shallow ground water is predominantly of the calcium bicarbonate type. Total dissolved solids range from 604 to 1,510 ppm; sulfate ranges from 139 to 533 ppm and commonly exceeds 300 ppm; chloride normally ranges from 45 ppm to 180 ppm, although chlorides as low as 19 ppm and as high as 270 ppm occur in water from some wells located along the South Platte River. Alkyl benzene sulfonate (ABS) and nitrate concentrations are significant in some parts of this locality, and will be discussed in detail in a subsequent section of this report.

In the vicinity of Rocky Mountain Arsenal, the shallow ground water is highly mineralized as a result of saline contamination from past industrial waste disposal practices. Waters in the contaminated zone are of the calcium chloride and sodium chloride types. Total dissolved solids range from 1,307 to 6,370 ppm; chloride ranges from about 220 ppm to 3,000 ppm. The contamination in the vicinity of the Arsenal will be discussed in a subsequent section of this report.

In the northern part of the valley, water in the valley-fill aquifer is predominantly of the calcium bicarbonate type. Total dissolved solids normally range from 664 to 1,110 ppm; sulfate from 191 to 489 ppm and commonly exceeds 250 ppm; chloride from 90 to 155 ppm. Some shallow wells, which are also screened in the shallow bedrock formations yield water containing sulfate concentrations in excess of 1,000 ppm and chlorides greater than 200 ppm. Nitrate concentrations in this area commonly exceed 45 ppm [a] which is the upper limit of the U.S. Public Health Service Drinking Water Standards. ABS occurs throughout most of this locality.

Water quality data are not available over a sufficient period to determine long-term changes in mineralization of ground water in most of the valley. Except in the locality affected by saline contamination from Rocky Mountain Arsenal, available data indicates the shallow aquifer in most of the valley has increased slightly or remained essentially at the same level of mineralization since intensive sampling of wells began in 1955. A limited amount of data indicates localized increases in mineralization in the northern end of the valley near the City of Brighton. In 1964, chloride and nitrate concentrations of waters from Brighton wells averaged about 128 ppm and 65 ppm, respectively. Analyses of samples collected from Brighton's wells No. 1, 2, and 3 indicate chloride and nitrate concentrations have increased 41 ppm and 31 ppm, respectively, since the wells were first sampled in 1943. Increases in mineralization of the Brighton locality are attributed largely to movements of ground water from the adjacent irrigated area lying upgradient south and southeast of the city. Mineralization of the shallow ground water underlying the heavily irrigated area has probably increased over a long period of time due to concentration of dissolved salts by continued recycling of ground water by pumping.

[a] As NO_3

Comparison of chemical analyses of ground waters with those of waters collected by the Geological Survey (2) (9) (10) (11) (12) (13) from the South Platte River and the main irrigation ditches show similar concentrations of chloride and bicarbonate. ABS occurs in both surface and shallow ground waters in the area. These similarities indicate a close relationship between the surface waters entering the area and water in the valley-fill aquifer. Concentrations of sulfate in the valley-fill aquifer are generally much higher than those in the surface waters.

Tenneco currently discharges about 0.6 mgd of waste water into Sand Creek. Records of the Colorado State Department of Public Health show oil concentrations of three grab samples of Tenneco's effluents in 1963 ranged from 8.6 to 58 ppm. Composite samples obtained by the South Platte River Basin Project on October 7 and 9, 1964 showed oil concentrations of Tenneco's effluents averaged about 3 ppm.

Continental Oil Company currently discharges about 0.3 mgd of waste water into Burlington-O'Brian Ditch. Records of the Colorado State Department of Public Health show oil concentrations of five grab samples of Continental's effluent in 1963 ranged from 13.2 to 22.1 ppm. A large part of the effluent from Continental's outfall enters the valley-fill aquifer through the bed of Burlington-O'Brian Ditch.

In the main valley west of Irondale, two springs of the State Fish Hatchery, located in Section 20 of T. 2 S., R. 67 W (2-67-20cca), were contaminated by gasoline, reportedly, in about 1955 (2) (3). These springs discharge water from the valley-fill aquifer near the base of a terrace that borders the flood plain of the South Platte River. Approximately 2,300 feet southeast of the springs, a water well (2-67-29bcd) owned by Jake and Mary Kramer reportedly yielded appreciable amounts of gasoline in about 1954 (14). The well was about 50 feet in depth and used for domestic and irrigation purposes.

The springs were abandoned as a source of water for hatching fish and replaced by a deep well screened in the bedrock aquifer. Similarly, the contaminated shallow well owned by Jake and Mary Kramer was abandoned and replaced by a deep well as a source of potable water. Contamination of these water supplies could have been due to leakage from nearby petroleum product pipelines and storage tanks owned by Wyco Pipe Line Company. However, the pipeline company reported their investigation revealed that no leakage had occurred in the pipeline or storage tanks. The storage tanks and connecting pipeline are located about 4,000 feet southeast and 800 feet southwest of the Fish Hatchery springs, respectively. The contaminated water well lies about 2,100 feet north of the storage tanks and 1,500 feet northeast of the connecting pipeline. The water table at the springs and well lie downgradient from the storage tanks and portions of the connecting pipeline. A portion of this area remains contaminated, since one of the Fish Hatchery springs continues to issue small amounts of petroleum.

Alkyl Benzene Sulfonate

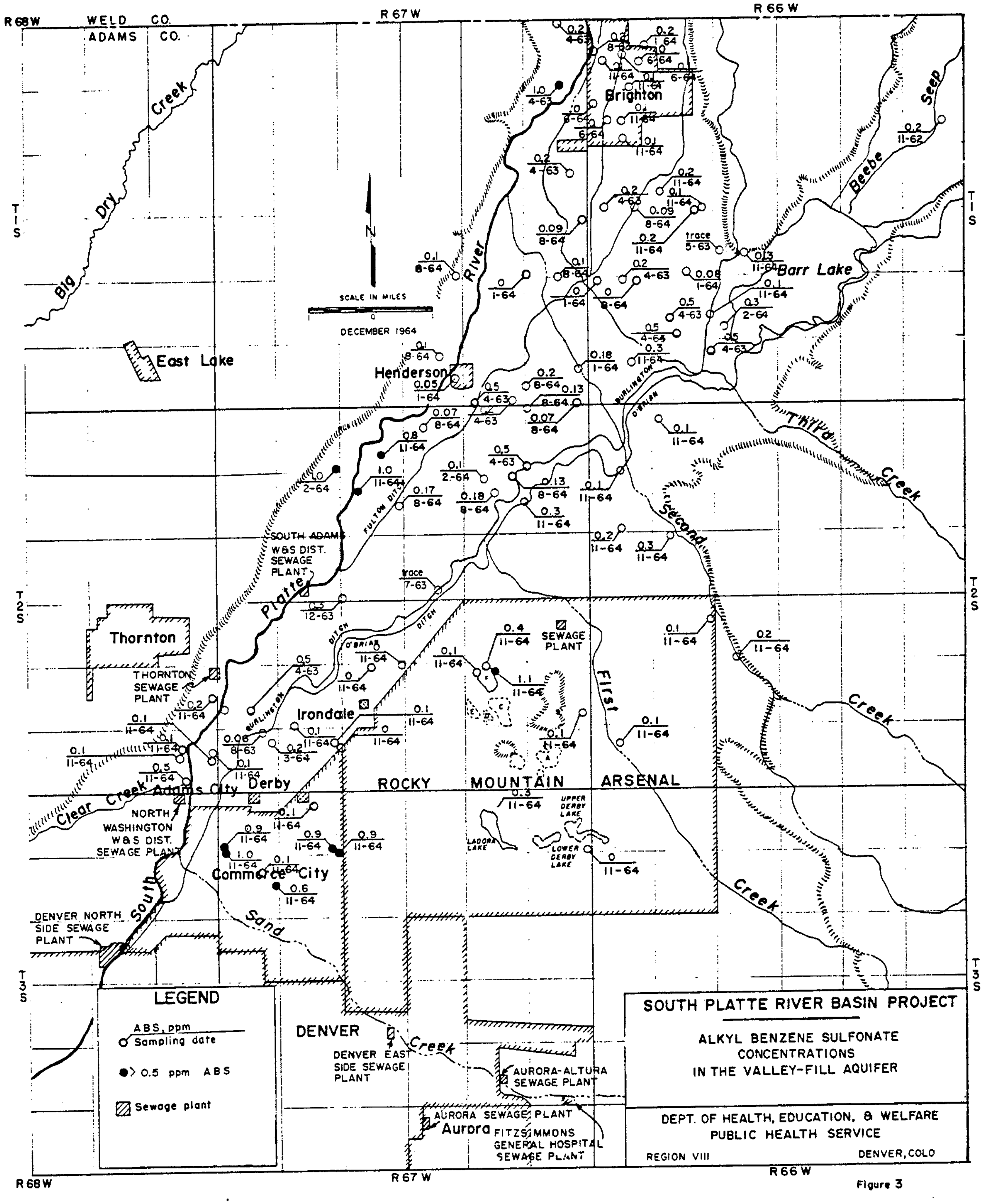
ABS has been detected in most shallow well waters in the main valley. Figure 3 shows ABS concentrations in waters from wells screened in the valley-fill aquifer.

Public water supplies in the area obtain all or a large part of their water from wells screened in the valley-fill aquifer. Table II shows ABS concentrations in water samples obtained from many of the shallow public supply wells in the area.

ABS concentrations, in excess of the upper recommended limit of 0.5 ppm of the U.S. Public Health Service Drinking Water Standards, occur in water from one well owned by the Town & Country Mutual Water Company located in Commerce City. An analysis of a water sample collected in November 1964 from Well No. 1 by the Project shows 0.6 ppm ABS. An analysis of water from this well by the Public Health Service (19) in 1957 revealed similar concentrations of ABS. Chemical analyses of waters from four shallow wells owned by the South Adams Water and Sanitation District reveal ABS concentrations ranging from 0.9 to 1.0 ppm in November 1964.

Northwest Water Corporation and North Washington Water and Sanitation District obtain a large portion of their water supplies from shallow wells or galleries located on the flood plain on the west side of the South Platte River in Section 36, T. 2 S., R. 68 W. During heavy pumping periods of the summer months, much of the water pumped from these wells and galleries is derived from induced infiltration of flows in the South Platte River. During August 1963, the Colorado State Department of Public Health (20) collected 17 grab samples from the Northwest Water Corporation well. Analyses of these water samples show ABS concentrations averaged 0.55 ppm during this period. A sample collected from the well in November 1964 by the Project showed an ABS concentration of 0.5 ppm. Analyses of water samples collected by the Project in November 1964 from two galleries owned by North Washington Water and Sanitation District revealed ABS concentrations of 0.1 ppm each.

The City of Thornton obtains most of its ground-water supply from two well fields located in and near the flood plain of the South Platte River (21). Well Field No. 1, consisting of 7 shallow wells and one deep well, is located on the west side of the river in Section 25, T. 2 S., R. 68 W., and Section 30, T. 2 S., R. 67 W. Much of the water pumped from the shallow wells in Well Field No. 1 is derived from induced infiltration of the river flow. An analysis of a sample taken from one of these wells in November 1964 by the Project showed an ABS concentration of 0.2 ppm. Well Field No. 2, consisting of five shallow wells, is located on the east side of the river in Section 36, T. 2 S., R. 68 W. Analysis of water samples collected from two wells in this field in November 1964 by the Project revealed ABS concentrations of 0.1 ppm each.



R 68 W
R 67 W
R 66 W
WELD CO.
ADAMS CO.
T 1 S
T 2 S
T 3 S
Big Dry Creek
East Lake
Brighton
Henderson
Barr Lake
Beebe Seep
Third Creek
Second Creek
First Creek
Platte River
South Platte
Clear Creek
Sand Creek
Thornton
THORNTON SEWAGE PLANT
SOUTH ADAMS W&S DIST. SEWAGE PLANT
Adams City
Derby
Irondale
Commerce City
NORTH WASHINGTON W&S DIST. SEWAGE PLANT
DENVER NORTH SIDE SEWAGE PLANT
ROCKY MOUNTAIN ARSENAL
SEWAGE PLANT
UPPER DERBY LAKE
LOWER DERBY LAKE
LADORA LAKE
FULTON DITCH
BURLINGTON
O'BRIAN DITCH
SCALE IN MILES
DECEMBER 1964
N
DENVER
DENVER EAST SIDE SEWAGE PLANT
AURORA-ALTURA SEWAGE PLANT
AURORA SEWAGE PLANT
Aurora
FITZSIMMONS GENERAL HOSPITAL SEWAGE PLANT
LEGEND
ABS, ppm
Sampling date
> 0.5 ppm ABS
Sewage plant
SOUTH PLATTE RIVER BASIN PROJECT
ALKYL BENZENE SULFONATE CONCENTRATIONS IN THE VALLEY-FILL AQUIFER
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO

Figure 3

TABLE II

ABS CONCENTRATIONS IN WATER FROM PUBLIC SUPPLY WELLS

	Location (T-R-Sec.)	Owner's Well No.	Well Depth(ft)	Sampling Date	ABS ppm	Analyst[a/]
City of Brighton	1-66-7abb	1,2,3	40,50,40	11/9/64	0.1[b/]	P
	1-66-7abac	4	33	6/3/64	0.1	C
	1-66-6dacd	6	50	6/3/64	0.0	C
	1-66-7dbcd	7	55	11/9/64	0.1	P
	1-66-6cbdd	8	35	11/9/64	0.1	P
	1-66-6dbbc	10	42	6/3/64	0.0	C
	1-66-7dccb	11	62	11/9/64	0.1	P
	1-66-7cabc	12	66	6/3/64	0.0	C
	1-66-7bcbd	13	65	6/3/64	0.0	C
North Washington W.S.D.	2-68-36bda	Gallery #1	18	11/9/64	0.1	P
	2-68-36bda	Gallery #2	25	11/9/64	0.1	P
Northwest Water Corp.	2-68-36dcbc	#1	29.5	8/5-28/63	0.55[c/]	C
	2-68-36dcbc	#1	29.5	11/9/64	0.5	P
South Adams W.S.D.	2-67-29cdc	#2(S-9)	80	11/12/64	0.1	P
	2-67-32adc	#2(S-8)	100	11/12/64	0.0	P
	2-67-32adc	#3	93	11/12/64	0.1	P
	3-67-5abcd	#2(S-7)	80	11/12/64	0.1	P
	3-67-5dddd	#2(S-5)	80	11/12/64	0.9	P
	3-67-5dddd	#3(S-6)	80	11/12/64	0.9	P
	3-67-6ccdc	#2(S-2)	43	11/12/64	0.9	P
	3-67-6ccdc	#3(S-3)	45	11/12/64	1.0	P
City of Thornton	2-68-25daaa	#5	26	11/16/64	0.2	P
	2-68-36aada	#12	29	11/16/64	0.1	P
	2-68-36aadd	#15	29	11/16/64	0.1	P
Town & Country Mutual Water Co.	3-67-7addd	#1	42	7/26/57	0.65[d/]	P
	3-67-7addd	#1	42	11/24/64	0.6	P
	3-67-7acaa	#2	22	11/24/64	0.1	P

a/ P - U.S. Public Health Service; C - Colorado State Department of Public Health.
b/ Composite of 3 wells.
c/ Average of 17 grab samples.
d/ Carbon filter operated July 17-26, 1957.

ABS was detected in many of the City of Brighton's well waters. Analyses of water samples obtained from eleven of Brighton's wells by the Project and the Colorado State Department of Public Health during 1964 show ABS concentrations of 0.1 ppm occurred in seven wells; ABS was not detected in four.

The high concentrations of ABS in well waters in the Commerce City area are due largely to recharge water derived from industrial and sewage plant effluents discharged into Sand Creek. A substantial part of the flow enters the valley-fill aquifer through the sandy bed of the creek and continues to move downgradient toward the main valley. Sand Creek currently receives an average of 5.7 mgd (6385 acre feet per year) of effluents from five sewage treatment plants and an average of 1.2 mgd (1344 acre feet per year) from industrial outfalls. Samples obtained from the surface flow near the mouth of Sand Creek in September 1964 by the Project revealed an average ABS of 1.6 ppm.

Although discharges from sewage treatment plants probably contribute the major portion of ABS to the creek, some industrial discharges are also significant. Samples taken from a Stapleton Airport outfall on Sand Creek in September and October 1964 by the Project showed ABS concentrations ranged from 22 to 64 ppm and averaged 44 ppm. The following tabulation, based on records from the files of the Colorado State Department of Public Health, shows ABS in grab samples of effluents discharged by refineries.

Refinery	Outfall	Sampling Date	ABS ppm
Oriental Ref. Co.	Sand Creek	Nov. 1963	0.24
Empire Pet. Co.	Sand Creek	Nov. 1963	0.39
		Mar. 1964	0.30
Tenneco Oil Co.	Sand Creek	Nov. 1963	3.2
		Mar. 1964	3.5
Continental Oil Co.	Burlington Ditch	Nov. 1963	2.7
		Mar. 1964	1.75
		July 1964	0.9

Septic tanks most likely contribute significant amounts of ABS to the valley-fill aquifer. A total of over 685 domestic wells in the study area would indicate a similar number of septic tanks in use. Many shallow domestic wells in the suburban area near Adams City, Derby, and Irondale and the rural area bounded by Brighton, Barr Lake and Henderson yield water containing ABS derived from septic tank effluents. As shown in Figure 3, the effects of septic tanks are most apparent in the rural area lying east of O'Brian Ditch, where ditch water is not applied on the irrigated farms.

The occurrence of ABS in the valley-fill aquifer underlying the Rocky Mountain Arsenal resulted from previous waste disposal practices of conveying industrial wastes in unlined canals and discharging these wastes into unlined holding ponds. Discharges from the Arsenal's sewage treatment plant contribute small amounts of ABS to the aquifer in the vicinity of First Creek. An analysis of a water sample obtained by the Project in November 1964 from First Creek showed an ABS content of 0.2 ppm.

The principal source of ABS in the valley-fill aquifer in the main valley is recharge water originating from sewage treatment plant discharges into the South Platte River, Clear Creek and Sand Creek. A large portion of these sewage-laden waters are diverted to the irrigation ditches in the area, and in turn, enter the shallow aquifer from seepage in the ditches and irrigated farms.

The Denver Northside treatment plant currently discharges an average of 70.3 mgd (78,775 acre feet per year) of partially treated sewage into the South Platte River. Two smaller sewage treatment plants discharge an average of 4.1 mgd (4,594 acre feet per year) to the South Platte River between Clear Creek and Fulton Ditch. Clear Creek currently receives an average of 16 mgd (17,929 acre feet per year) from nine sewage treatment plants. Table III shows ABS concentrations in the waters of the streams and main diversion ditches in the area. A study conducted by the U.S. Geological Survey (22) during 1961-1963 indicates the Denver Northside sewage treatment plant is a major source of ABS in the South Platte River. During 1962, ABS concentrations increased an average of 1.0 ppm immediately downstream from Denver's sewage treatment plant. Significant amounts of ABS occur throughout the South Platte River and its tributaries, Sand Creek and Clear Creek. Similar amounts of ABS occur in river water diverted to Burlington, O'Brian and Fulton ditches.

ABS concentrations in the valley-fill aquifer are generally lower than ABS concentrations in the streams and irrigation ditches. Results of laboratory infiltration studies conducted by the U.S. Geological Survey (22) indicate ABS is reduced by seepage through the unsaturated zone above the water table. Some ABS removal occurs during infiltration through the saturated zone. ABS concentrations in water from wells located near the River, that probably induce infiltration from the River during heavy pumping periods, are consistently lower than ABS concentrations in the river water but nevertheless significant.

TABLE III

ABS CONCENTRATIONS IN SURFACE WATERS

Water Course	Location of Station: Miles below N. Denver STP	Location of Station: Other	Period	No. of Samples	ABS, ppm: Range	ABS, ppm: Average	Analyst[a]
So. Platte River	---	0.2 mile above N. Denver STP	2/62-11/62	10	0.4-0.9	0.7	G
	1.1	---	2/62-11/62	9	0.8-2.6	1.7	G
	3.3	---	8/63	17	0.6-1.3	0.9	C
	12.8	---	2/62-11/62	9	1.2-2.2	1.8	G
Burlington Ditch	1.0	---	3/64-11/64	6	0.3-2.4	1.3	P
	5.7	---	10/62-4/63	2	2.4-3.0	2.7	G
	12.5	---	10/62-4/63	3	1.6-4.0	2.7	G
	17.8	---	10/62-4/63	3	1.3-2.0	1.7	G
O'Brian Ditch	11.5	---	11/62	1	1.6	1.6	G
	17.8	---	3/64-6/64	5	0.8-2.4	2.0	P
Fulton Ditch	8.8	---	7/64	10	1.0-2.6	1.9	P
	15.6	---	10/62-4/63	3	0.3-3.0	1.7	G
Sand Creek	---	Mouth	9/64	3	0.5-2.9	1.6	P
Clear Creek	---	Mouth	8/63	17	0.7-1.2	0.8	C
	---	Mouth	9/64	2	0.1-1.1	0.6	P

a/ C - Colorado State Department of Public Health
G - U.S. Geological Survey
P - U.S. Public Health Service

Bacteria

Bacteria are significantly reduced by infiltration through the aquifer, although complete removal of bacteria over relatively short distances may not be accomplished. A pond located near the confluence of Clear Creek and the South Platte River is excavated below the water table. A large capacity public supply well owned by Northwest Water Corporation is located on the west edge of the pond. The pond is about 150 feet from the River and about 650 feet downstream from the outfall of North Washington Water and Sanitation District sewage treatment plant on Clear Creek. During sustained periods of pumping from the well, most of the water in the pond is induced infiltration from the River.

Grab samples of South Platte River water taken in August 1964 by the Project at a sampling point located about two miles upstream from the pond showed a median total coliform density of 7,900,000 per 100 ml and a median fecal coliform density of 5,950,000 per 100 ml. Samples taken near the mouth of Clear Creek by the Project in September 1964 showed a median total coliform density of 254,000 per 100 ml and a median fecal coliform density of 101,500 per 100 ml. Samples of pond water collected by the Project on a weekly basis in September, October and November 1964 showed total coliform densities ranged from 49 to 1,300 per 100 ml and fecal coliform densities ranged from less than 1.8 to 4.5 per 100 ml.

Similar removal of bacteria occurs in water produced from two public supply galleries owned by North Washington Water & Sanitation District, located about 2,500 feet north of the confluence of Clear Creek and the South Platte River. The galleries are located about 300 feet west of the River. Samples of water collected from the two galleries on a weekly basis by the Project in September and October 1964 showed total coliform densities ranged from less than 1.8 to 23 per 100 ml; fecal coliform densities ranged from less than 1.8 to 2 per 100 ml.

Nitrate

The U.S. Public Health Service Drinking Water Standards (8) state the nitrate content of water should not exceed an upper limit of 45 ppm. Domestic water containing excessive amounts of nitrate is potentially dangerous when used for infant feeding.

As shown in Figure 4, the highest nitrate concentrations in the valley-fill aquifer generally occur in and near the irrigated lowlands lying between Brighton and Commerce City. Nitrate concentrations in this area commonly exceed 35 ppm. The lowest concentrations generally occur near the South Platte River and in the non-irrigated upland areas.

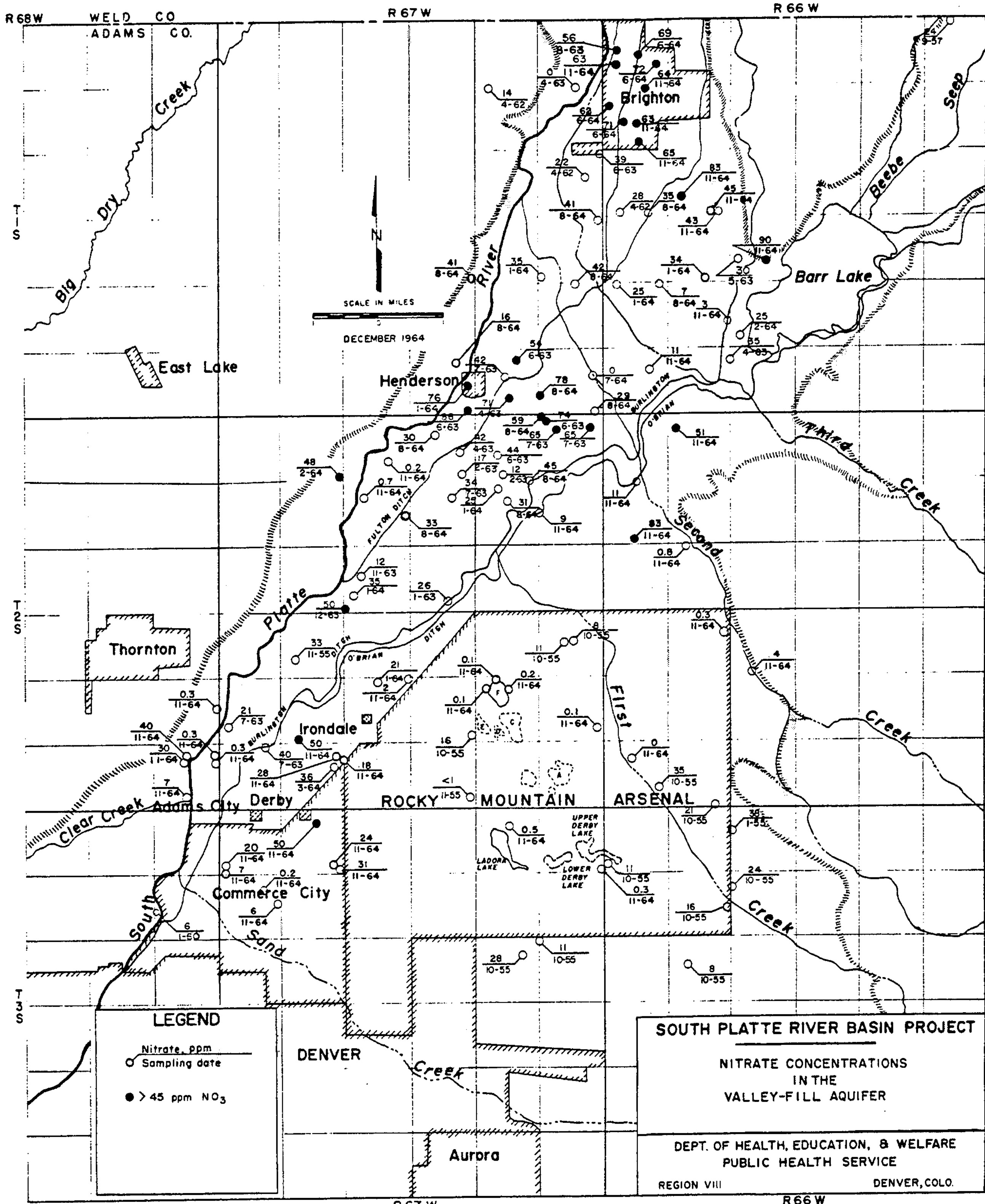

R 68 W
R 67 W
R 66 W
WELD CO
ADAMS CO.
T 1 S
T 2 S
T 3 S
Brighton
Henderson
East Lake
Barr Lake
Thornton
Irondale
Adams City
Derby
Commerce City
DENVER
Aurora
ROCKY MOUNTAIN ARSENAL
Big Dry Creek
Platte River
South
Clear Creek
Sand Creek
First Creek
Second Creek
Third Creek
Beebe Seep
Fulton Ditch
Burlington
O'Brian
Upper Derby Lake
Lower Derby Lake
Ladora Lake
SCALE IN MILES
DECEMBER 1964
LEGEND
Nitrate, ppm
Sampling date
> 45 ppm NO3
SOUTH PLATTE RIVER BASIN PROJECT
NITRATE CONCENTRATIONS IN THE VALLEY-FILL AQUIFER
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.

Figure 4

Available analyses show 40 wells in the study area yield water having nitrate concentrations in excess of 45 ppm, of which 12 are public supply wells, at least 7 wells are used for domestic purposes, and one well is used to supply process water to a cannery. Detailed information on these wells is shown in Table IV.

Water from 11 wells currently used by Brighton have nitrate concentrations ranging from 55 to 72 ppm. Available analyses indicate high nitrates have existed in Brighton's water supply for at least 21 years. A sample collected from Well No. 10 in 1960 revealed a nitrate concentration of 59 ppm (3). Four composite water samples collected from Wells No. 1, 2, and 3 during the period of 1943-1945 contained nitrates ranging between 20 and 32 ppm (23). Water from Wells No. 1, 2, and 3 had a nitrate concentration of 63 ppm in November 1964; these data indicate an increase of 31 to 43 ppm since the 1943-1945 period. One case of infant methemoglobinemia in 1962 was attributed by the Tri-County Health Department to high nitrates in Brighton's ground-water supply (24).

Nitrate concentrations in the valley-fill aquifer are excessive throughout the Brighton area. A cannery and beet sugar processing mill in the Brighton area obtain process water from shallow wells screened in the valley-fill aquifer. A water sample taken by the Tri-County Health Department from one of the cannery's wells in August 1963 shows a nitrate concentration of 56 ppm.

In the southern part of the valley, analyses of water from a well (3-67-6ab) near Adams City revealed nitrates varied from 24 to 48 ppm during the period of 1945-1945 (23). Analyses of water from wells in this locality show essentially the same level of nitrate concentrations occurred in 1964.

Two shallow wells owned by the South Adams Water and Sanitation District, located in the Commerce City area, yield high nitrate waters. Water samples collected by the Project from Wells No. S-7 (3-67-5abcd) and S-9 (2-67-29cdc) in November 1964, revealed nitrate concentrations of about 50 ppm.

A report by Colorado State University (23) indicates high nitrate concentrations occurred in South Platte River water as early as 1945. Samples taken at a point located immediately below the North Denver sewage treatment plant outfall show the following: nitrates were not detected in samples collected in November 1943, April 1944 and November 1944; 32 ppm nitrate was detected in a sample collected in March 1945.

TABLE IV

NITRATE CONCENTRATIONS IN WATER FROM SELECTED WATER WELLS

Location (T-R-Sec.)	Owner	Use of Water[a/]	Well Depth (ft)	Sampling Date	Nitrate ppm	Analyst[b/]
1-66-6ac	C. Baker	N.R.	30	4/4/63	54	C
1-66-6ac	M. Poff	N.R.	30	4/4/63	54	C
1-66-6bb	L. Knodel	N.R.	30	4/3/63	63	C
1-66-6cba	Kuner-Empson	C,P	30	8/12/63	56	C
1-66-6cbdd	Brighton #8	P.S.	35	11/9/64	62.9	P
1-66-6dacd	Brighton #6	P.S.	50	6/3/64	72	C
1-66-6dbbc	Brighton #10	P.S.	42	9/21/60	59	G
1-66-6dbbc	Brighton #10	P.S.	42	6/3/64	69	C
1-66-7abac	Brighton #4	P.S.	33	6/3/64	55	C
1-66-7abb	Brighton #1, 2,3	P.S.	40,50 40	11/9/64	62.9	P
1-66-7babd	Brighton #13	P.S.	65	6/3/64	62	C
1-66-7cabc	Brighton #12	P.S.	66	6/3/64	71	C
1-66-7dbcb	Brighton #7	P.S.	55	11/9/64	62.9	P
1-66-7dccb	Brighton #11	P.S.	62	11/9/64	64.7	P
1-66-17cbdc	L. Darras	I	28	11/23/64	82.9	P
1-66-21cad	Barr Lake Inn	D	50	11/9/64	89.5	P
1-66-21dc	L. Herbeck	N.R.	55	5/13/63	53	C
1-67-34daab	R. Miller	D	18	1/6/64	76	C
1-67-34da	M. Burbach	D	26	6/17/63	83	C
1-67-34da	M. Burbach	I	13	6/17/63	89	C
1-67-34da	R. Scott	N.R.	15	6/17/63	88	C
1-67-34da	C. Nichols	N.R.	15	6/17/63	90	C
1-67-34da	A. Ross	N.R.	15	6/17/63	83	C
1-67-34ddcd	A. Adams	I	10	6/10/63	88	C
1-67-35abd	W. Johnson	N.R.	--	6/24/63	54	C
1-67-35dcbb	J. Carlson	N.R.	32	4/18/63	71	C

a/ C - Cooling, D - Domestic, I - Irrigation, L.I. - Lawn Irrigation, N.R. - Not Reported, P - Processing, P.S. - Public Supply, S - Stock.

b/ C - Colorado State Department of Public Health, G - U.S. Geological Survey, P - U.S. Public Health Service, U - Colorado State University.

TABLE IV (Continued)

Nitrate Concentrations in Water from Selected Water Wells

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Nitrate ppm	Analyst[b]
1-67-36cbcc	C. Shaw	D	38	8/11/64	78	C
1-67-36	D. Gilmer	N.R.	40	4/17/63	61	C
2-66-5caa	E. Kallsen	S	42	11/23/64	51	P
2-66-7dcdc	S. Wawok	D	55	11/23/64	82.9	P
2-67-1adbb	G. Squires	I	34	7/16/63	65	C
2-67-1bbbb	J. Salthouse	D	46	8/11/64	59	C
2-67-1bb	R. Weaver	N.R.	44	6/24/63	74	C
2-67-1bdbb	G. Squires	I	40	7/16/63	65	C
2-67-2db	J. Erger	N.R.	45	7/30/63	50	C
2-67-5dddd	T. Abbott	N.R.	--	2/10/64	48	C
2-67-16cccc	D. Latorra	N.R.	50	12/17/63	50	C
2-67-29cdc	S. Adams WSD Well #2(S-9)	P.S.	80	11/12/64	50.1	P
2-67-32ab	E. Bungard	N.R.	45	8/6/63	58	C
3-67-5abc	S. Adams WSD Well #2(S-7)	P.S.	80	11/12/64	50.1	P
3-67-5cd	D. Pfeif	N.R.	65	8/6/63	58	C
3-67-6ab	R.E. Murfine	D	32	11/5/43	48	U

a/ C - Cooling, D - Domestic, I - Irrigation, L.I. - Lawn Irrigation, N.R. - Not Reported, P - Processing, P.S. - Public Supply, S - Stock.

b/ C - Colorado State Department of Public Health, G - U.S. Geological Survey, P - U.S. Public Health Service, U - Colorado State University.

Records of chemical analyses of surface water by the Geological Survey (2) (9) (10) (11) (12) (13) show the following: Analyses of South Platte River water at a sampling point located 0.8 mile below the Denver Northside treatment plant outfall show nitrate concentrations averaged 36 ppm between September 1955 and May 1956. Nitrate concentrations of Burlington ditch water, obtained at a sampling point located 0.7 mile below the Denver sewer outfall, averaged 31.5 ppm between September 1955 and April 1956, and averaged 1.1 ppm between October 1962 and September 1963. Nitrate concentrations of South Platte River water at the Henderson station averaged 9.8 ppm between July 1955 and September 1957, and averaged 0.8 ppm between October 1962 and September 1963. The amounts of nitrate contributed to the valley-fill aquifer from sewage-laden waters diverted for irrigation use in the area are believed to be very significant but cannot be fully assessed from available records. Available analyses of surface waters do not include determinations of ammonium and nitrite concentrations which are probably converted to the nitrate form of nitrogen after entering the shallow valley-fill deposits.

The use of fertilizers on irrigated farms in the area probably contributes the major portion of nitrates to the valley-fill aquifer. Large quantities of commercial nitrogen fertilizers are applied annually on about 15,500 acres of land in the valley. Information provided to the Project by the Soil Conservation Service office at Brighton indicated that 50 to 100 pounds per acre of commercial fertilizers are applied annually on irrigated farms, with nitrogen contents of 10 to 20 percent by weight. In addition, large quantities of liquid anhydrous ammonia are added directly to the water applied on many of the irrigated farms in the area. Approximately 40 percent of the water applied on the irrigated lands enters the shallow aquifer through permeable soils of the valley-fill outcrop.

Six feedlots are located between Denver and Henderson. Surveys by the Project indicate an estimated 26,500 to 28,500 cattle and about 11,000 sheep are held within these feedlots. Large quantities of manure, accumulated on the sandy soils of the valley-fill deposits, are subject to leaching from precipitation and waste water. Thus, recharge water derived from leaching and drainage from these accumulations readily enters the shallow valley-fill aquifer. Feedlot operations probably contribute substantial amounts of nitrate to the aquifer in local areas, although available data indicate these operations are not the principal source of nitrate pollution in the main valley.

Previous waste disposal practices by the Rocky Mountain Arsenal are not a major source of nitrates in the valley; however, available data indicate the Arsenal has contributed some nitrates to the shallow aquifer in the immediate vicinity. Analyses of contaminated saline water from wells located on the Arsenal property show nitrate concentrations range from 0.1 to 16 ppm. The 1954-56 Geological Survey study (13) of saline contamination revealed nitrate concentrations in two unlined holding ponds and an unlined ditch ranged from 1.8 to 22 ppm; water samples collected from First Creek, below the outfall of Arsenal's sewage treatment plant, had nitrate concentrations ranging from 3 to 49 ppm. A sample collected by the Project from First Creek in November 1964 shows a nitrate concentration of 12.8 ppm.

Contamination in the Vicinity of Rocky Mountain Arsenal

Previous waste disposal practices by the Rocky Mountain Arsenal have resulted in contamination of the valley-fill aquifer in the area between Irondale and Henderson. Numerous investigations of the effect and extent of this contamination have been conducted by Rocky Mountain Arsenal (25) (26) (27) (28) (29) (30) (31), Geological Survey (2) (13), Public Health Service (32) (33) (34) (35), Colorado State Department of Public Health (13) and others (36).

During the period of 1943 through September 1955, chemical wastes were conveyed in unlined canals and discharged into unlined holding ponds located in Sections 25, 35 and 36 of T. 2 S., R. 67 W; the holding ponds were designated as ponds A, B, C, D, E, F and the caustic waste basin (27). Records are not available of total amounts of wastes discharged into these holding ponds. Measurements made in 1955 by Ralph W. Parsons Company (29) showed the average input to the ponds amounted to about 570 gpm at that time. In addition, saline water was discharged into First Creek from the Arsenal's sewage treatment plant, shown on Figure 3. The Geological Survey (13) reported the sewage treatment plant discharged about one to two cfs (449 to 898 gpm) in 1956. Samples collected from First Creek on November 17, 1954, October 6, 1955 and March 9, 1956 showed chloride concentrations were 850, 1330 and 1080 ppm, respectively.

Available laboratory analyses (13) (27) indicate the character of wastes at Rocky Mountain Arsenal during the period of 1954-1956. Some of the principal chemical constituents of the wastes are shown in the following tabulation:

Source of Sample	Sampling Date	pH	Cond. µmhos	Ca	Na	SO_4	Cl	As	TDS
				Parts per million					
Sewage Plant Effluent	Mar. 1956	--	5040	--	660	615	1240	--	--
First Creek	Mar. 1956	--	4850	--	650	780	1080	0.04	--
Pond "C"	Nov. 1954	6.6	10100	18	2270	368	3020	0.3	10000
Pond "A" Drainage Ditch	Nov. 1954	9.7	9180	13	2220	369	2050	3.4	6120

Additional contaminants found to be present in the wastes include fluoride and phosphorous (13), and the herbicide, 2,4D (31).

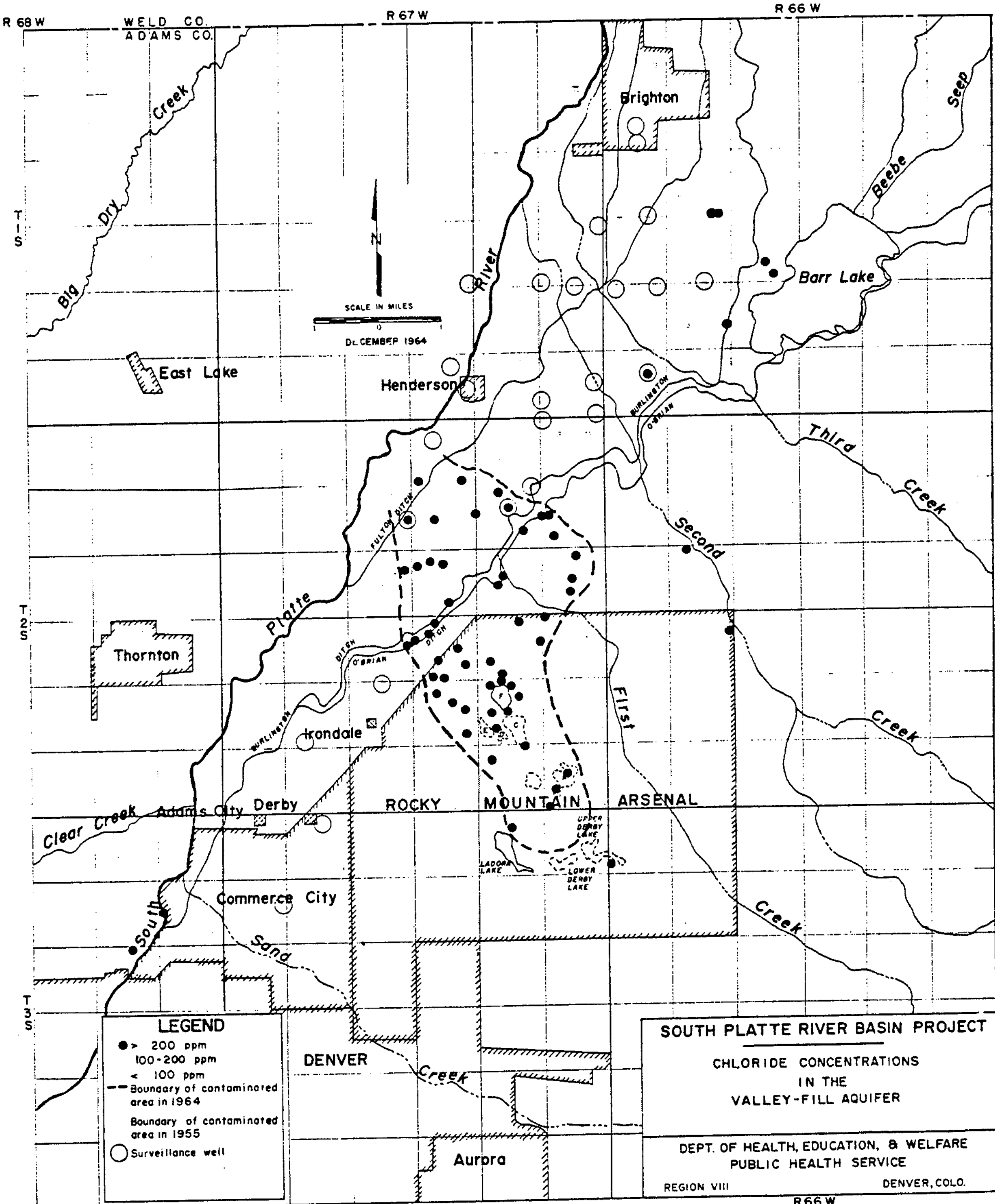
Most of the liquid wastes discharged to the holding ponds percolated directly into the shallow aquifer and moved slowly downgradient in a general northwest direction toward the South Platte River. A large part of the saline discharges from the Arsenal sewage treatment plant entered the shallow aquifer through the bed of First Creek.

The rate of ground-water movement within the contaminated zone varies widely. The 1954-56 Geological Survey study (13) indicates an average rate of movement of about 4,800 feet per year in the aquifer northwest of the Arsenal. The approximate time between initial use of Pond A in 1943 and the first effects of contamination in the Nesom wells (2-67-22bcc) in 1951, located about 2.8 miles northwest, indicate an average velocity of about 1,850 feet per year. A much slower rate of ground-water movement is possible in parts of the Arsenal where the aquifer is relatively thin and probably less permeable.

Figure 5 shows the approximate areal extent of saline contamination in 1964. In most cases, waters from shallow wells containing chlorides in excess of 200 ppm were considered to be contaminated (32), although waters from some shallow wells located outside of the contaminated zone do contain chloride concentrations greater than 200 ppm. Waters from shallow wells normally have chloride concentrations ranging from about 50 to 150 ppm. Chloride concentrations of water from shallow wells, shown in Figure 5, are listed in Appendix C. The present area of contamination by high chloride water covers approximately 12 square miles. Since 1955, the east edge of the contaminated zone has moved slowly northward approximately three-fourths of a mile, covering about 2.8 additional square miles. Most of the contaminated water continues to move slowly northwestward in the direction of the natural hydraulic gradient. Movements northward are due to seasonal changes in the hydraulic gradient caused by the pumping of irrigation wells located near the northeast edge of the contaminated zone. Some fluctuations in the width of the zone have occurred in local areas, depending upon amount of pumpage from irrigation wells located in and near the zone. For example, the chloride concentration in water samples collected from the Irondale Trailer Court well, located in the northeast corner of Section 28, T. 2 S., R. 67 W. (2-67-28aaaa) varied from 191 to 220 ppm during the period of 1955-1956 and varied from 142 to 264 ppm in 1959; and was 106 ppm in November 1964. The contaminated zone could expand again to the trailer court well, depending upon future distribution of heavy pumpage in this locality.

Chloride concentrations in the contaminated zone continue to be excessive. In 1964, chloride concentrations of well waters commonly exceeded 400 ppm and ranged to as much as 3075 ppm. Chlorides in the heavily contaminated zone occurring between the abandoned ponds and the O'Brian Ditch ranged from 1020 to 4250 ppm in 1956; available analyses indicate chlorides have decreased slightly in this same area to a range of 850 to 3075 ppm in 1964. Chloride concentrations in the contaminated zone lying northwest of O'Brian Ditch have remained essentially at the same level of concentration since 1956; chlorides in this locality range from 347 to 1890 ppm in 1964. The relatively low chloride of waters from several observation wells located near O'Brian and Burlington Ditches is largely due to dilution from seepage in these ditches. Chloride concentrations in the vicinity of Henderson have increased steadily since 1955. Water from a well located in Section 34, T. 1 S., R. 67 W. (1-67-34dad) had a chloride concentration of 97 ppm in 1955. The chloride concentration of water from a nearby well (1-67-34daad) was 137 ppm in 1964.

A substantial decrease in chloride concentration in the aquifer has occurred in the vicinity of the Pond F. Chlorides in water from observation well 2-67-26baad decreased from about 3080 ppm in 1955 to 766 ppm in 1964. This decrease resulted from recharge water being introduced into the aquifer by filling abandoned ponds C, D, and E, with about 400 million gallons of fresh water reportedly some time during a two-year period between 1957 and 1959. However, chloride concentrations in the vicinity of ponds C, D, and E were as great as 4205 ppm in 1962, indicating this fresh water in this locality was displaced by the inflow of contaminated ground water from the southeast. As shown in Figure 5, a chloride concentration of 2220 ppm in a water sample taken recently from an observation well (3-67-2acbc), located near the north shore of Lake Ladora, indicates the possibility



R 68 W
WELD CO.
ADAMS CO.
R 67 W
R 66 W
T 1 S
T 2 S
T 3 S
Big Dry Creek
Brighton
Beebe Seep
Barr Lake
River
Platte
South
SCALE IN MILES
DECEMBER 1964
East Lake
Henderson
Burlington
O'Brian
Third Creek
Second Creek
First Creek
Fulton Ditch
O'Brian Ditch
Thornton
Irondale
Clear Creek
Adams City
Derby
ROCKY MOUNTAIN ARSENAL
Upper Derby Lake
Ladora Lake
Lower Derby Lake
Commerce City
Sand Creek
DENVER
Aurora
LEGEND
> 200 ppm
100-200 ppm
< 100 ppm
Boundary of contaminated area in 1964
Boundary of contaminated area in 1955
Surveillance well
SOUTH PLATTE RIVER BASIN PROJECT
CHLORIDE CONCENTRATIONS IN THE VALLEY-FILL AQUIFER
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO.

Figure 5

property because of the low permeability of aquifer in the heavily contaminated parts of this area. A pit excavated recently in abandoned Pond A to a depth of three feet did not reveal shallow sludge accumulations.

Several continuous cores of the interval between the pond bottom and the base of the aquifer are needed in each abandoned holding pond to determine whether sludge deposits occur at deeper depths. Pumping tests should be conducted on several wells located in the thinner and probably less permeable areas of the contaminated zone on the arsenal. Results of these tests could be used to determine rates of ground-water movement in the heavily contaminated area.

The effect of the contaminated ground water on the quality of water in the South Platte River was evaluated. As the contaminated water moves downgradient in a northwesterly direction, the chloride concentration is reduced considerably by seepage from Burlington, O'Brian and Fulton ditches and ditch water applied on irrigated farms. The contaminated water continues to move downgradient until it is diluted further by the larger main body of ground-water flow beneath the flood plain of the South Platte River. This diluted water continues to move downvalley and discharges as ground-water return flow into the River in the vicinity of Henderson. Records of chemical analyses of South Platte River water at Henderson and at sampling stations located upstream (2) (9) (10) (11) (12) (13) (39) do not indicate the salt load contributed to the River by ground-water return flow originating from contamination on the Arsenal. However, considering the great amount of dilution in the aquifer occurring from ditch water seepage and ground-water inflow prior to discharging into the River, it is unlikely that salts originating in the contaminated zone are causing significant increases in the salinity of the River water.

Excessive chloride concentrations have been found in water samples collected from three deep wells screened in the bedrock aquifers. It is concluded that since these wells are located within the boundary of the contaminated zone, saline water has probably entered these wells through openings in the casing or through the annulus between the casing and hole. Pertinent information on these deep wells is shown in the following tabulation:

Owner	Location (T-R-Sec.)	Well Depth (ft)	Chloride (ppm)	Sampling Date
L. Baughman	2-67-9ddc	205	222	10/30/59
E. Tiedeman	2-67-14ccdb	450	385	3/8/56
Rocky Mountain Arsenal	2-67-22acdc	178	290	5/13/64

Contamination of the bedrock aquifers probably occurs only in the immediate vicinity of these defective wells. Widespread contamination of the bedrock aquifers from these defective wells is unlikely owing to the very slow rate of movement of ground water in the bedrock aquifers. However, the number of defective deep wells possibly affected by saline contamination at the present time is unknown. Records of the Geological Survey (3) and the State Engineer of Colorado show 61 deep wells are located in and near the boundary of the contaminated zone of the shallow valley-fill aquifer; relatively few of these deep water wells have been sampled since 1959.

Some shallow wells located outside of the contaminated zone yield water having chloride concentrations in excess of 200 ppm. As shown in Figure 5, most of these wells are located in the vicinity of Second Creek and in the locality southeast of Brighton. Pertinent information relating to these wells is shown in Table V. These wells yield calcium sulfate or sodium sulfate type waters. Well records of the Geological Survey (3) show gypsum (hydrous calcium sulfate) fragments occur in the silty bedrock materials near the base of the valley-fill deposits. As shown in Table V, the depth of most of the shallow wells is below the base of the valley-fill deposits, indicating the water produced is derived from both formations. The relatively high sulfate and chloride concentrations in these waters is attributed to effects of soluble gypsum and small amounts of associated salts. Waters produced from nearby wells that are screened only in the valley-fill deposits contain considerably lower concentrations of chloride and sulfate.

Current Disposal Practices of Rocky Mountain Arsenal

Since 1957, all industrial wastes have been conveyed to Pond F by pipeline or by tank truck. The 96-acre asphalt-lined reservoir has a capacity of 240 million gallons. Liquids have been removed from the pond by evaporation and by injection into a deep underground disposal well. Records of amounts of liquid wastes discharged to and removed from Pond F during the period of February 1961 through May 1964 are summarized in the following tabulation:

Pond spill point elevation, feet			5,200.00
Fluid Elevation, ft., Feb. 1, 1961			5,198.78
Fluid Elevation, ft., May 28, 1964			5,197.33
Fluid level decline, ft.			1.45
Net decrease in pond fluid, gallons		45,000,000	
Input of plant wastes, gallons		247,000,000	
Measured precipitation, gallons		67,100,000	
Evaporation, gallons		259,100,000	
Injected in disposal well, gallons		100,000,000	
Total output		359,100,000	

Records of precipitation and evaporation from the U.S. Weather Bureau were used to evaluate the reported information on Pond F during this period. Because quantities of precipitation and evaporation are only approximate, the monitoring of input and output from Pond F would only reveal large amounts of leakage which did not occur in this case.

Four observation wells, located near the north shore of the Pond F, are monitored for the purpose of detecting leakage from the reservoir. Water level measurements taken in 1962 and 1964 do not reveal rises in the water table that can be related to leakage from the pond. Water samples are currently obtained from these observation wells on a weekly basis for chloride determination. Chlorides in water from Well No. 118 (2-67-26bada) have increased sharply in recent months. In samples collected from this well during the months of March through May 1964, chlorides ranged from 520 to 790 ppm; during June through November 1964, chlorides ranged from 1160 to 1640 ppm. Chloride concentrations in samples from nearby observation wells No. 3A (2-67-26baad), No. 72 (2-67-23cddc) and No. 62 (2-67-26bbad) have remained essentially constant during 1964.

TABLE V

INFORMATION ON SELECTED WELLS

Well Location (T-R-Sec.)	Well Depth (ft)	Depth to Bedrock (ft)	Use of Well a/	Sampling Date	Specific Con-ductance	Calcium (ppm)	Sodium (ppm)	Bicar-bonate (ppm)	Sul-fate (ppm)	Chlo-ride (ppm)	Total Dissolved Solids (ppm)
1-66-17ddcd	38	32	S	11/23/64	3700	248	390	593	1070	295	2720
1-66-17ddcc	35	32	L.I.	11/23/64	2600	144	332	549	636	202	1770
1-66-21ccc	50	10	D	11/9/64	2570	224	250	303	793	204	1950
1-66-21dca	40	35	D	5/20/63	--	--	--	--	--	248	--
1-66-29dada	30	20	D,S	11/24/64	2440	196	235	503	330	245	1610
1-66-31acad	50	15	D	11/18/64	5510	284	940	354	1930	375	4490
2-66-17baba	30	20	N,O	11/18/64	6090	521	850	471	2480	402	4980
2-66-20adad	19	19	N,O	11/17/64	4780	461	375	329	1200	210	4530

a/ D - Domestic; L.I. - Lawn Irrigation; N - Not used; O - Observation purposes; S - Stock.

In view of the previous contamination, data collected by the Arsenal to date from the observation wells near Pond F would not reveal small amounts of leakage. The water-bearing formation underlying the vicinity of the pond should be completely displaced by water having a chloride concentration of about 100 ppm. Displacement could be accomplished by introducing low chloride water into the aquifer by water spreading in the locality south and east of the pond. This would then permit detection of significant changes in chloride concentrations in the aquifer in the vicinity of the pond. The well monitoring program should also include the utilization of other existing observation wells located near the perimeter of Pond F in order to determine whether increases in chlorides would be due to pond leakage or inflow of older contaminated water.

From March 1962 through September 1963, about 100 million gallons of filtered liquid from Pond F were injected into a deep disposal well located immediately northeast of the pond in Section 26. Throughout this period, well head injection pressures were reported to vary from 425 to 630 pounds per square inch (psi) at injection rates of about 200 gpm. The well and two piston-type injection pumps were designed to inject fluids at well head pressures of up to 2000 psi.

During the period of November 1963 to November 1964, only small amounts of wastes were injected into the disposal well, reportedly because of the relatively high costs of filtering the concentrated pond liquids and operating the high-capacity piston-type injection pumps. Pond F was modified in November 1964 by constructing an earthen embankment across a portion of the reservoir, separating "fresh" industrial wastes from the older concentrated pond liquids. Currently, filtered "fresh" industrial wastes are injected into the disposal well at a rate of about 50 gpm at a well head pressure of about 60 psi. The Arsenal plans to install a larger centrifugal pump capable of injecting at rates of about 200 gpm. Approximately 145 gpm of industrial wastes are currently discharged into Pond F.

The possibility of contaminating the fresh water sands from the disposal of wastes in the injection well is remote. The pond fluid is injected in highly fractured Pre-Cambrian granites occurring between the depths of 11,975 and 12,045 feet below the ground surface (39) (40). The well is cased and cemented to a depth of 11,171 feet below the surface. In addition, a larger diameter casing is set and cemented to a depth of 2000 feet in order to assure protection of the fresh water-bearing formations that occur above 1430 feet. Electrical logs and descriptions of the drill cuttings from the hole show the interval between 1430 and 11,950 feet below the land surface is composed largely of great thicknesses of shale, siltstone, hard sandstone and dense limestone.

Well Monitoring Programs

Since 1959 the Colorado State Department of Public Health and Tri-County Health Department have maintained a well-monitoring program for the purpose of keeping currently informed on direction and rate of movement of the contaminated water. Water samples are currently obtained every seven months from 25 surveillance wells. Locations of the surveillance wells are shown in Figure 5 and recent chemical analyses of waters from these wells are shown in Appendix B. Many additional water samples have been collected from private wells in the area by the Tri-County Health Department. The Rocky Mountain Arsenal currently collects water samples for chloride determination from 7 observation wells on a weekly basis and from an additional 7 wells on a monthly basis, and periodically obtains water samples from numerous observation wells and private wells in the area. Reports of chemical analyses are made available to all agencies concerned with the contamination problem. Well owners are notified by the Tri-County Health Department when chloride concentrations exceed 200 ppm. However, in each instance, it should be determined whether excessive chlorides in well waters are due to movements of contaminated water, or due to natural causes such as effects of soluble evaporite materials occurring in the water-bearing formation.

The well-monitoring programs of the Tri-County Health Department and Colorado State Department of Public Health, and the Rocky Mountain Arsenal provide adequate information on changes in chemical quality in most areas lying north of the contaminated zone. However, additional sampling wells are needed along and immediately outside of the east and west edges of the contaminated zone, in order to determine, more closely, the extent of contamination.

Records of the State Engineer of Colorado and the Geological Survey show 61 deep wells are located in and near the present boundary of the contaminated zone of the valley-fill aquifer. Water samples should be obtained periodically from all these wells for chemical analyses in order to detect possible leakage resulting from defective casings or improper cementing.

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APPENDIXES

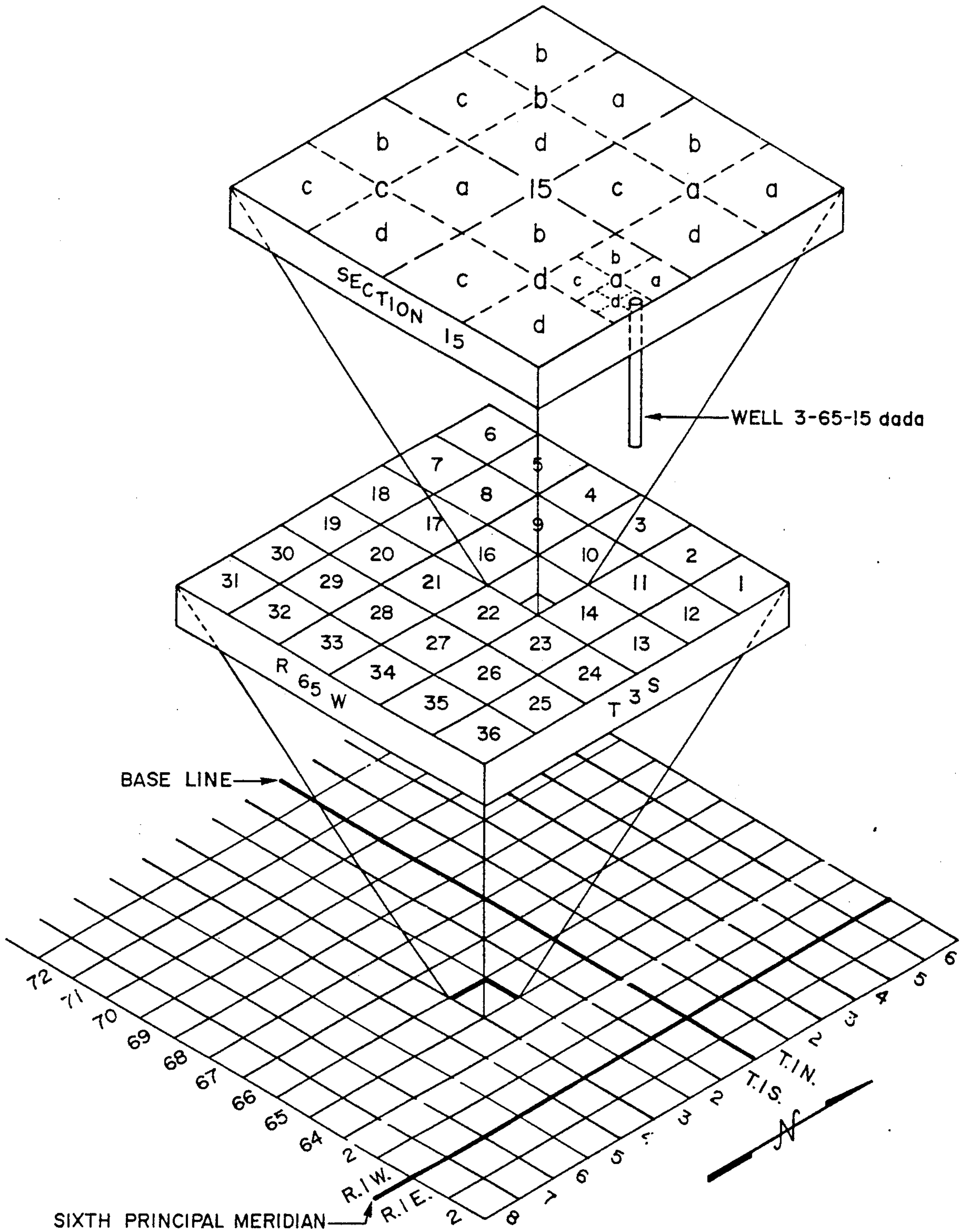
APPENDIX A

SYSTEM OF NUMBERING WELLS AND SAMPLING POINTS

Locations of wells and some sampling points are described by using a numbering system based on the U.S. Bureau of Land Management's system of land subdivision. A graphical illustration of this method of site location is shown on the following page. All ranges and townships in the report area lie within the southwest quadrant formed by the intersection of the base line and the sixth principal meridian. The township in which a well or sampling point is located is indicated by the first numeral of the location number, the range by the second numeral and the section by the third numeral. Lower case letters following the section number indicate the position of the site within the section. The first letter denotes the quarter section, the second letter the quarter-quarter section, the third letter the quarter-quarter-quarter section, and the fourth letter the quarter-quarter-quarter-quarter section. The letters a, b, c, and d are assigned in a counter-clockwise direction, beginning in the northeast quarter of the section. For example, 3-65-15dada indicates the site is in the northeast quarter of the southeast quarter of the northeast quarter of the southeast quarter of Section 15, Township 3 South, Range 65 West.

APPENDIX A

SYSTEM OF NUMBERING WELLS & SAMPLING POINTS



APPENDIX B

Chemical Analysis of Water
(Results in Parts per Million)

Location (T-R-Sec)	Owner	Use of Water a/	Well Depth (ft.)	Sampling Date	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium (Na)	Sulfate (SO_4)	Chloride (Cl)	Bicarbonate (HCO_3)	Fluoride	Total Phosphate (PO_4)	Nitrate (NO_3)	ABS	Total Dissolved Solids	Total Alkalinity as $CaCO_3$	Hardness as $CaCO_3$	Conductance Micromhos/cm	pH	Analyst b/	Remarks c/
1-66-6cbdd	Brighton #8	P.S.	35	11/9/64	0.11	0.0	136	155	308	120	346	--	--	62.9	0.1	1060	284	476	1580	7.1	P	
1-66-6dacd	Brighton #6	P.S.	50	6/3/64	--	--	--	--	--	124	--	--	--	72	0.0	--	--	--	--	--	C	
1-66-6dbbc	Brighton #10	P.S.	42	6/3/64	--	--	--	--	--	125	--	--	--	69	0.0	--	--	--	--	--	C	
1-66-7abac	Brighton #4	P.S.	33	6/3/64	--	--	--	--	--	144	--	--	--	55	0.1	--	--	--	--	--	C	
1-66-7abb	Brighton #1, 2, 3	P.S.	40,50,40	11/5/43	--	--	138	134	332	91	--	--	--	32	--	999	--	--	--	7.9	U	Composite Sample
1-66-7abb	Brighton #1, 2, 3	P.S.	40,50,40	11/9/64	0.19	0.0	146	145	302	132	346	--	--	62.9	0.1	1060	284	516	1590	7.2	P	Composite Sample
1-66-7bcbd	Brighton #13	P.S.	65	6/3/64	--	--	--	--	--	125	--	--	--	62	0.0	--	--	--	--	--	C	
1-66-7cabc	Brighton #12	P.S.	66	6/3/64	--	--	--	--	--	113	--	--	--	71	0.0	--	--	--	--	--	C	
1-66-7dbcb	Brighton #7	P.S.	55	11/9/64	0.11	0.0	144	145	300	129	371	--	--	62.9	0.1	1110	304	516	1600	7.3	P	I
1-66-7dccb	Brighton #11	P.S.	62	11/9/64	0.16	0.0	150	140	296	138	356	--	--	64.7	0.1	1090	292	520	1590	7.4	P	II
1-66-17cbdc	L. Darras	I	28	11/23/64	0.21	0.0	115	113	268	128	329	--	--	82.9	0.2	976	270	472	1140	7.8	P	
1-66-17dddd	S. Kuster	S	38	11/23/64	0.19	0.0	248	390	1070	295	593	--	--	43.2	0.1	2720	486	1040	3700	7.8	P	
1-66-17ddcc	S. Kuster	L.I.	35	11/23/64	1.46	0.0	144	332	636	202	549	--	--	44.7	0.2	1770	450	600	2600	7.8	P	
1-66-18dcdd	B. Wagner	S	35	8/12/64	0.2	0.0	173	130	226	105	200	1.1	0.0	35	0.09	724	164	277	1100	--	C	XXV
1-66-20dccd	V. Amdahl	L.I.	20	1-6-64	0.05	0.0	336	160	230	142	400	1.3	0.0	34	0.08	1050	328	463	1470	--	C	VI
1-66-21cad	Barr Lake Inn	D	50	11/9/64	0.11	0.0	224	250	793	204	303	--	--	89.5	0.3	1950	248	787	2570	7.1	P	
1-66-29dada	E. Mowery	D	30	11/24/64	0.04	1.25	196	235	330	245	503	--	--	2.6	0.1	1610	412	710	2440	7.6	P	
1-66-29dddd	E. Mowery	I	30	7/12/64	--	--	--	--	--	87	--	--	--	--	--	--	--	--	--	--	P	
1-66-30aaab	G. Hoffman	D	50	8/12/64	0.08	0.0	205	140	313	120	224	1.2	0.0	7	0.0	854	184	352	1285	--	C	VII
1-66-30bbab	H. Shreeve	S, L.I.	20	1/6/64	0.05	0.0	344	124	230	107	356	0.65	--	25	0.0	897	292	443	1262	--	C	IV
1-66-31acad	E. Potter	D	50	11/18/64	--	--	284	940	1930	375	354	--	--	11.4	0.3	4490	290	1240	5510	7.3	P	XXIV
1-67-22dddd	W. Kemp	D,S	60	8/11/64	0.05	0.0	252	150	362	92	210	1.3	0.5	41	0.1	943	172	455	1378	--	C	XVI
1-67-24aaad	G. Okubo	D	30	8/12/64	0.08	0.0	343	125	275	117	356	0.8	0.0	40.5	0.09	934	292	475	1370	--	C	XXVI
1-67-24cccc	J. Tochihara	D	50	1/6/64	0.15	0.0	440	124	265	120	420	0.55	--	35	0.0	1024	344	557	1431	--	C	III
1-67-25abbb	L. Ehlen	S	33	8/11/64	0.05	0.0	327	150	358	90	190	0.7	0.0	41.5	0.1	1043	156	475	1545	--	C	V
1-67-34abdc	F. Nyholt	D	12	8/11/64	0.05	0.0	347	180	489	118	303	1.6	0.0	16	0.1	1165	248	475	1645	--	C	XVIII
1-67-34daab	R. Miller	D	18	1/6/64	0.15	0.0	400	125	282	137	361	0.8	--	76	0.05	1062	296	557	1470	--	C	XIX
1-67-36adcd	J. Erger	D	20	1/6/64	0.05	0.0	420	158	299	158	454	0.6	--	00.0	0.18	1101	372	549	1555	--	C	XXIII
1-67-36cbcc	C. Shaw	D	38	8/11/64	0.08	0.0	233	114	236	129	210	1.1	0.0	78.0	0.2	316	172	408	1250	--	C	VIII
1-67-36ddcd	H. Manley	S	40	8/11/64	0.0	0.0	252	93	191	97	298	0.7	0.0	29	0.07	719	244	360	1089	--	C	XXII
2-66-5caa	E. Kallsen	S	42	11/23/64	1.23	0.0	62	125	162	30	356	--	--	51	0.1	664	292	230	1020	7.8	P	

APPENDIX B

Chemical Analysis of Water (Continued)

Location (T-R-Sec)	Owner	Use of Water a/	Well Depth (ft.)	Sampling Date	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium (Na)	Sulfate (SO_4)	Chloride (Cl)	Bicarbonate (HCO_3)	Fluoride	Total Phosphate (PO_4)	Nitrate (NO_3)	ABS	Total Dissolved Solids	Total Alkalinity as $CaCO_3$	Hardness as $CaCO_3$	Conductance Micromhos/cm	pH	Analyst b/	Remarks c/
2-66-7abbb	RMA #52	N, O	25	11/18/64	--	--	316	260	1030	155	349	--	--	10.7	0.1	2390	286	1100	2860	7.2	P	
2-66-7dcdc	S. Wawok	D	55	11/23/64	0.92	0.0	98	200	492	128	264	--	--	82.9	0.2	1280	216	408	1860	8.0	P	
2-66-17baba	RMA #53	N. C	30	11/18/64	--	--	521	850	2480	402	471	--	--	0.8	0.3	4980	386	1870	6090	7.2	P	
2-66-20adad	RMA #47	N, O	22	11/17/64	--	--	461	375	1200	210	329	--	--	0.3	0.1	4530	270	1800	4780	7.4	P	
2-66-21cddc	RMA #54	N, O	30	11/18/64	--	--	332	495	1490	142	490	--	--	3.5	0.2	3400	402	1260	3860	7.1	P	
2-66-31bdaa	RMA #20	N, O	28	11/17/64	--	--	52	100	246	46	283	--	--	0.0	0.1	560	232	234	862	7.9	P	
2-67-1bbbb	J. Salthouse	D	46	8/11/64	0.08	0.0	244	115	240	134	234	0.9	0.0	59.	0.13	845	192	396	1236	--	C	XII
2-67-3bdbd	J. Himes	S, I	32	8/12/64	0.05	0.0	232	118	232	112	249	1.0	0.0	30.	0.07	763	204	348	1064	--	C	XX
2-67-4dbdc	RMA #55	N, O	30	11/18/64	--	--	81	100	132	68	354	--	--	0.2	0.8	679	290	325	1060	7.4	P	
2-67-9hdba	RMA #56	N, O	30	11/18/64	--	--	81	85	85	78	346	--	--	0.7	1.0	578	284	284	913	7.6	P	
2-67-9daac	E. Aden	I	30	8/12/64	0.05	0.0	630	225	407	625	210	1.7	--	32.5	0.17	2009	172	939	2838	--	C	XIV
2-67-11aaba	J. Fry, Sr.	S	44	8/11/64	0.2	0.0	244	122	245	149	213	0.6	0.0	45.	0.13	890	224	420	1345	--	C	XIII
2-67-11bdad	B. Murray	I	60	8/11/64	0.05	0.0	402	175	342	310	234	1.0	0.0	30.5	0.18	1301	192	614	1972		C	XXI
2-67-11daaa	RMA #113	N, O	54	11/18/64	--	--	316	265	750	382	381	0.9	4.47	9.3	0.3	2320	312	1100	3020	7.0	P	As 0.0, COD 21
2-67-13dccc	----	---	---	11/23/64	0.32	0.0	131	140	465	125	212	--	--	12.8	0.2	1120	174	490	1590	8.4	P	First Creek
2-67-25ddab	RMA #61	N, O	12	11/17/64	--	--	106	175	410	114	290	--	--	0.09	0.1	1100	238	455	1570	7.6	P	
2-67-26baba	RMA #3A	N, O	39	11/17/64	--	--	45	690	268	766	915	--	--	0.11	0.4	2330	750	228	3860	7.8	P	
2-67-26bada	RMA #118	N, O	39	11/17/64	--	--	300	660	301	1550	939	--	--	0.2	1.1	4300	770	1600	6160	7.0	P	
2-67-26bad	RMA Pond F	--	--	10/14/64	--	--	--	--	--	--	--	--	--	29.0	--	20968	---	---	---	8.4	R	COD 6241, DO 1.2
2-67-26badc	RMA Pond F	--	--	11/17/64	--	--	112	7600	615	7280	5880	--	--	--	--	22700	4820	610	27500	8.4	P	
2-67-26bbad	RMA #62	N, O	51	11/17/64	--	--	34	540	408	350	578	9.7	9.58	0.1	0.1	1740	474	202	2790	7.6	P	As 0.01, COD 25
2-67-28aaaa	Irondale Trailer Court	P.S.	51	11/12/64	0.12	0.0	71	110	139	106	222	--	--	2.1	0.0	604	182	265	983	7.6	P	
2-67-28abb	A. Hessling	D, I	50	1/6/64	0.10	0.0	344	65	249	45	268	0.5	--	21.	0.0	717	220	424	1022	--	C	XX
2-67-29cdc	S. Adams WSD #2 (S-9)	P.S.	80	11/12/64	0.12	0.0	196	150	359	119	381	--	--	50.1	0.1	1160	312	590	1620	7.4	P	X
2-67-32adc	S. Adams WSD #2 (S-8)	P.S.	100	11/12/64	0.0	0.0	140	62	248	50	254	--	--	18.4	0.00	71	208	420	1020	7.7	P	
2-67-32adc	S. Adams WSD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	991	288	525	1430	7.6	P	

APPENDIX B

Chemical Analysis of Water (Continued)

Location (T-R-Sec)	Owner	Use of Water a/	Well Depth (ft)	Sampling Date	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium (Na)	Sulfate (SO_4)	Chloride (Cl)	Bicarbonate (HCO_3)	Fluoride	Total Phosphate (PO_4)	Nitrate (NO_3)	ABS	Total Dis-solved Solids	Total Alka-linity as $CaCO_3$	Hardness as $CaCO_3$	Conductance Micromhos/cm	pH	Analyst b/	Remarks c/
2-68-25daaa	Thornton #5	P. S.	26	11/16/64	0.3	0.0	164	98	227	56	224	--	--	0.3	0.2	643	184	252	983	7.2	P	
2-68-36aada	Thornton #12	P. S.	29	11/16/64	0.14	0.17	125	165	334	178	268	--	--	0.3	0.1	1040	220	388	1570	7.6	P	
2-68-36aadd	Thornton #15	P. S.	29	11/16/64	0.13	0.02	114	170	353	180	261	--	--	0.3	0.1	1040	214	374	1560	7.8	P	
2-68-36bdaa	N. Washington WSD #1	P. S.	18	11/9/64	0.0	0.13	126	115	246	52	381	--	--	40.4	0.0	848	312	400	1250	7.2	P	325' gallery
2-68-36bdad	N. Washington WSD #2	P. S.	25	11/9/64	0.0	0.08	89	155	366	19	322	--	--	29.8	0.1	939	264	250	1330	7.4	P	925' gallery
2-68-36dcbc	N. W. Water Corp	P. S.	30	11/9/64	0.23	1.00	69	95	246	20	210	--	--	7.1	0.5	636	172	268	940	7.0	P	
3-67-1dddd	RMA #10	N, O	77	11/17/64	--	--	83	91	272	49	306	--	--	0.3	0.0	600	251	275	913	7.8	P	
3-67-2acbc	RMA #109	N, O	30	11/17/64	--	--	116	1820	884	2020	165	0.8	2.04	0.5	0.3	6370	135	430	9560	7.5	P	As 0.0, COD 131
3-67-2cab	RMA -Lake Ladora	--	--	11/17/64	--	--	116	100	307	116	161	--	--	0.0	0.0	790	132	380	1240	8.4	P	
3-67-5abcd	S. Adams WSD #2 (S-7)	P.S.	80	11/12/64	0.05	0.0	188	160	374	123	364	--	--	50.1	0.1	1190	302	560	1670	7.4	P	IX
3-67-5dddd	S. Adams WSD #2 (S-5)	P.S.	80	11/12/64	0.10	0.0	160	150	341	92	342	--	--	23.6	0.9	1010	280	470	1430	7.4	P	
3-67-5dddd	S. Adams WSD #3 (S-6)	P.S.	80	11/12/64	0.14	0.0	168	145	355	103	361	--	--	30.7	0.9	1080	296	505	1540	7.4	P	
3-67-6ab	R. E. Murfine	--	32	11/5/43	--	--	178	63	433	102	--	--	--	48.	--	1107	--	--	--	7.9	U	
3-67-6ccdc	S. Adams WSD #2 (S-2)	P.S.	43	11/12/64	0.02	0.0	150	155	300	123	376	--	--	20.2	0.9	1020	308	465	1570	7.2	P	
3-67-6ccdc	S. Adams WSD #3 (S-3)	P.S.	45	11/12/64	0.07	0.08	144	160	304	141	388	--	--	7.3	1.0	1040	318	445	1570	7.2	P	
3-67-7acaa	Town & Country #2	P.S.	22	11/24/64	7.64	1.91	188	100	533	142	224	--	--	0.2	0.1	1510	184	600	1930	6.6	P	Phenol 0.0 Oil 2.0
3-67-7addd	Town & Country #1	P.S.	42	11/24/64	0.01	1.16	176	175	453	148	522	--	--	5.9	0.6	1220	428	570	1760	7.8	P	Phenol 0.0, Oil 2.0 XI

a/ D - Domestic; I - Irrigation; L.I. - Lawn Irrigation; N - Not used; O - Observation purposes; P.S. - Public Supply; S - Stock.

b/ C - Colorado State Department of Public Health; P - U. S. Public Health Service; R - U. S. Army Rocky Mountain Arsenal; U - Colorado State University

c/ Roman Numeral designates surveillance well monitored by Tri-County Health Department.

APPENDIX C

CHLORIDE CONCENTRATION OF WATER FROM WELLS SHOWN IN FIGURE 5

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
1-66-6cba	Kuner-Empson	C,P	30	8/12/63	130	C
1-66-6cbdd	Brighton #8	P.S.	35	11/9/64	120	P
1-66-6dacd	Brighton #6	P.S.	50	6/3/64	124	C
1-66-6dbbc	Brighton #10	P.S.	42	6/3/64	125	C
1-66-7abac	Brighton #4	P.S.	33	6/3/64	144	C
1-66-7abb	Brighton #1, 2,3	P.S.	40,50 40	11/9/64	132[c]	P
1-66-7bcbd	Brighton #13	P.S.	65	6/3/64	125	C
1-66-7cabc	Brighton #12	P.S.	66	6/3/64	113	C
1-66-7dbcb	Brighton #7	P.S.	55	11/9/64	129	P
1-66-7dccb	Brighton #11	P.S.	62	11/9/64	138	P
1-66-17cbdc	L. Darras	I	28	11/23/64	128	P
1-66-17ddcd	S. Kuster	S	38	11/23/64	295	P
1-66-17ddcc	S. Kuster	L.I.	35	11/23/64	202	P
1-66-18cdcc	A. Hattendorf	D	40	4/5/62	106	G
1-66-18dcdd	B. Wagner	S	35	8/12/64	105	C
1-66-20dccd	V. Amdahl	L.I.	20	1/6/64	142	C
1-66-21cad	Barr Lake Inn	D	50	11/9/64	204	P
1-66-21cbc	J. Candelarie	D	60	5/15/63	184	C
1-66-21dcb	M. Espinosa	D	40	5/20/63	248	C
1-66-28ccb	W. Pollard	D	40	2/3/64	79	C
1-66-29cac	---	I,S	45	4/5/62	119	G
1-66-29dada	E. Mowery	D	30	11/24/64	245	P
1-66-29dddd	E. Mowery	I	30	7/12/64	87	P
1-66-30aaab	G. Hoffman	D	50	8/12/64	120	C
1-66-30bbab	H. Shreeve	S,L.I.	20	1/6/64	107	C
2-67-29cdc	So. Adams WSD No. 2(S-9)	P.S.	80	11/12/64	119	P
2-67-30cbd	Kinney	H	30	7/31/63	118	C
2-67-31aabb	Sausd	--	--	8/7/63	114	C
2-67-31aadc	I. Haberhorn	--	--	3/4/64	119	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-32aad	S. Adams WSD #2(S-8)	P.S.	100	8/12/64	50	P
2-67-32aad	S. Adams WSD #3	P.S.	93	8/12/64	97	P
2-67-35abaa	RMA #5	N,O	55	5/20/64	1930	R
2-67-35bca	RMA	N,O	45	12/8/59	3117	R
2-67-35cca	RMA	N,O	48	12/8/59	125	R
2-67-36bdc	RMA #40	N,O	42	2/16/60	2278	R
2-67-36cbdd	RMA #7	N,O	36	6/14/62	1518	R
2-67-36ccdd	RMA #81A	N,O	31	6/14/62	382	R
2-68-25daaa	Thornton #5	P.S.	26	11/16/64	56	P
2-68-36aada	Thornton #12	P.S.	29	11/16/64	178	P
2-68-36aadd	Thornton #15	P.S.	29	11/16/64	180	P
2-68-36bdaa	N. Wash WSD #1 Gallery	P.S.	18	11/9/64	52	P
2-68-36bdad	N. Wash. WSD #2 Gallery	P.S.	25	11/9/64	19	P
2-68-36dcbc	NW Water Corp	P.S.	30	11/9/64	20	P
3-66-4bccb	H. Hendler	I	18	1/1/55	52	G
3-66-5ccd	--	N	20	7/28/64	86	P
3-66-6cccb	RMA	N	46	10/4/55	228	G
3-66-8daaa	RMA	N	15	10/4/55	39	G
1-66-31acad	E. Potter	D	50	11/18/64	375	P
1-66-32aadd	M. Dahlinger	S	16	4/5/62	85	G
1-66-32cdaa	G. Reasoner	N	19	2/4/60	188	R
1-67-1abbb	E. Getz	D	30	4/18/63	98	C
1-67-12abba	R. Pfeif	D	30	4/18/63	115	C
1-67-13aaa	M. Tesbero	D	42	6/18/63	95	C
1-67-13acdd	G. Quick	D	35	4/5/62	116	G
1-67-22dddd	W. Kemp	D,S	60	8/11/64	92	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
1-67-24aaad	G. Okubo	D	30	8/12/64	117	C
1-67-24cccc	J. Tochihara	D	50	1/6/64	120	C
1-67-25abbb	L. Ehlen	S	33	8/11/64	90	C
1-67-34abdc	F. Nyholt	D	12	8/11/64	118	C
1-67-34daab	R. Miller	D	18	1/1/64	137	C
1-67-34ddcd	A. Adams	I	10	6/10/63	117	C
1-67-35abd	W. Johnston	D	--	6/24/64	93	C
1-67-35bddd	C. Griffith	I	40	7/15/63	90	C
1-67-35dcbb	J. Carlson	--	32	4/18/63	87	C
1-67-36adcd	J. Erger	I	20	1/6/64	158	C
1-67-36cbcc	C. Shaw	D	33	8/11/64	129	C
1-67-36ddcb	H. Manley	I	30	8/11/64	97	C
2-66-4baa	E. Dahlinger	S	20	2/1/60	43	R
2-66-5caa	E. Kallsen	S	42	11/23/64	30	P
2-66-7abbb	RMA #52	N,O	25	11/18/64	155	P
2-66-7dcdc	S. Wawok	D	55	11/23/64	128	P
2-66-8cbb	W. Longaker	N	50	8/11/64	47	P
2-66-17baba	RMA #53	N,O	30	11/18/64	402	P
2-66-19ccdc	RMA	N	15	3/13/56	139	G
2-66-20addc	RMA #47	N,O	22	11/17/64	210	P
2-66-21cddc	RMA #54	N,O	30	11/18/64	142	P
2-66-31bdda	RMA #20	N,O	28	11/17/64	46	P
2-66-31dacd	RMA	--	41	10/3/55	43	G
2-66-32dcdd	RMA	--	49	10/3/55	50	G
2-67-1adbb	G. Squires	I	34	7/16/63	115	C
2-67-1bbbb	J. Salthouse	D	46	8/11/64	134	C
2-67-1bb	R. Weaver	--	44	6/24/63	112	C
2-67-1bdbb	G. Squires	I	40	7/16/63	123	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-2caca	R. Brakes	I	40	6/10/63	119	C
2-67-2cdd	C. Erger	I	40	7/9/63	94	C
2-67-3bdbd	J. Himes	S,I	32	8/12/64	112	C
2-67-3cccd	G. Furguson	I	11	1/23/62	506	R
2-67-3dbda	M&G Feedlot	S	60	4/23/63	145	C
2-67-3ddc	H. Penrod	I	--	7/30/63	306	C
2-67-4dbdc	RMA #55	N,O	30	11/18/64	68	P
2-67-5dddd	T. Abbott	--	--	2/10/64	125	C
2-67-9abac	RMA #57	N,O	29	1/30/62	81	R
2-67-9bdba	RMA #56	N,O	30	11/18/64	78	P
2-67-9ccdd	H. Thomas	--	10	1/23/62	78	R
2-67-9daac	E. Aden	I	30	8/12/64	625	C
2-67-10bddc	W. Myers	I	47	12/14/61	310	R
2-67-10addd	R. Humphreys	I	49	1/29/62	215	R
2-67-11aaba	J. Fry, Sr.	S	44	8/11/64	149	C
2-67-11baca	B. Murray	I	50	11/4/64	288	R
2-67-11bdad	B. Murray	I	60	8/11/64	310	C
2-67-11daaa	RMA #113	N,O	54	11/18/64	382	P
2-67-11dcaa	P. Erger	I	50	5/27/64	990	R
2-67-12cadb	RMA #112	N	50	8/18/61	191	R
2-67-12cbba	DM&H Cattle Company	S	45	1/22/62	399	R
2-67-12ccaa	T. Bollers	D	50	10/20/64	500	R
2-67-13abcb	RMA #111	N,O	46	8/18/61	435	R
2-67-13bddd	RMA #77	N,O	40	5/17/62	328	R
2-67-13cad	J. Stohr	N	41	12/14/60	380	R
2-67-14bddc	RMA #95	N,O	36	10/20/61	618	R
2-67-14cab	RMA #58	N,O	32	12/18/61	786	R
2-67-15abca	RMA #87	N,O	58	4/25/63	111	R
2-67-15bacc	RMA #89	N,O	40	4/25/63	379	R
2-67-15badd	RMA #88	N,O	43	1/17/63	347	R
2-67-15bcba	RMA #90	N,O	35	4/25/63	580	R
2-67-15dcbc	D. Heinz	I	42	7/30/63	347	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-16acda	RMA #92	N,O	40	4/25/63	138	R
2-67-16adac	RMA #91	N,O	32	4/25/63	860	R
2-67-16ccaa	P. Latorria	D	50	1/9/64	104	C
2-67-16cccc	D. Latorria	--	50	12/17/63	86	C
2-67-16dbbb	J. Priola	I	50	1/23/62	138	R
2-67-21addc	RMA #86	N,O	57	10/16/64	330	R
2-67-22abbb	RMA #82	N,O	40	11/12/64	165	R
2-67-22badb	RMA #83	N,O	44	11/12/64	1410	R
2-67-22bcda	RMA #85	N,O	45	11/12/64	1525	R
2-67-22bdbb	RMA #84	N,O	45	11/12/64	1016	R
2-67-22cadc	RMA #108	N,O	40	11/10/64	1850	R
2-67-22cdbc	RMA #104	N,O	55	6/5/62	2108	R
2-67-22cddd	RMA #43	N,O	27	11/10/64	2180	R
2-67-22dbad	RMA #1	N,O	40	11/10/64	1750	R
2-67-22ddba	RMA #2	N,O	49	6/5/62	1114	R
2-67-23addd	RMA #115	N,O	31	6/5/62	1999	R
2-67-23cdbb	RMA #71	N,O	63	6/5/62	1540	R
2-67-23cddc	RMA #72	N,O	61	11/10/64	400	R
2-67-23dbca	RMA #25	N,O	20	11/10/64	3075	R
2-67-24acac	RMA #78	N,O	30	12/7/60	112	R
2-67-24bbbb	RMA #60	N,O	--	6/30/64	960	R
2-67-25ddab	RMA #61	N,O	12	11/17/64	114	P
2-67-26abca	RMA #118	N,O	39	11/17/64	1550	P
2-67-26acab	RMA #73	N,O	61	6/14/62	1256	R
2-67-26baad	RMA #3A	N,O	39	11/17/64	766	P
2-67-26bbad	RMA #62	N,O	51	11/17/64	350	P
2-67-26bdcc	RMA #117	N,O	44	6/14/62	863	R
2-67-26cba	RMA #4	N,O	--	6/14/62	1648	R
2-67-26cbd	RMA #98	N,O	--	6/14/62	4205	R
2-67-27acbd	RMA #68	N,O	50	11/10/64	1780	R
2-67-27addc	RMA #67	N,O	44	4/29/64	1010	R
2-67-27bbbd	RMA #103	N,O	55	6/5/62	142	R
2-67-27bcad	RMA #99	N,O	72	11/10/64	850	R
2-67-27ddbd	RMA #100	N,O	50	6/14/62	1726	R

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-28aaaa	Irondale Trailer Ct.	D	51	11/12/64	106	P
2-67-28abb	A. Hessling	D,I	51	1/6/64	45	C
2-67-28daa	E. Ullaberri	--	50	11/17/59	42	C
3-66-9bbcc	Jeremiassen	I,S	32	10/7/55	71	G
3-66-17bdcd	B. Bollers	I	70	10/5/55	26	G
3-67-1dddd	RMA #10	N,O	77	11/17/64	49	P
3-67-2acbc	RMA #109	N,O	30	11/17/64	2020	P
3-67-5abcd	S. Adams WSD #2(S-7)	P.S.	80	11/12/64	123	P
3-67-5acd	D. Pfeif	--	65	8/6/63	105	C
3-67-5dddd	S. Adams WSD #2(S-5)	P.S.	80	11/12/64	92	P
3-67-5dddd	S. Adams WSD #3(S-6)	P.S.	80	11/12/64	103	P
3-67-6ccdc	S. Adams WSD #2(S-2)	P.S.	43	11/12/64	123	P
3-67-6ccdc	S. Adams WSD #3(S-3)	P.S.	45	11/12/64	141	P
3-67-7acaa	Town & Country #2	P.S.	22	11/24/64	142	P
3-67-7addd	Town & Country #1	P.S.	42	11/24/64	148	P
3-67-8abbc	--	--	70	4/9/63	126	C
3-67-8dccd	S. Adams WSD __(S-4)	N	80	4/63	106	C
3-67-13bbbb	F. Bostic	D	75	10/7/55	28	G
3-67-14acaa	B. Bollers	I	51	10/6/55	43	G
3-67-18bdda	Oriental Refining Co.	Ind,C	45	7/5/55	75	G
3-68-12cbab	Packaging Corp. of America	Ind	32	1/6/58	194	L

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
3-68-12cbbc	Litvak Packing Co.	Ind.	32	1/15/60	358	L
3-68-12cdca	Packaging Corp. of America	Ind.	21	6/30/58	125	L
3-68-12ccdb	Tenneco	Ind.	46	6/2/59	65	L
3-68-14abca	Denver Livestock Feeding Co.	S	18	6/26/59	270	L
3-68-14baac	Denver Livestock Feeding Co.	S	18	6/29/59	168	L

a/

C	Cooling	Ind	Industrial	S	Stock
D	Domestic	I	Irrigation	L.I.	Lawn Irrigation
P	Processing	O	Observation purposes	P.S.	Public Supply
				N	Not used

b/
- C Colorado State Department of Public Health
- G U.S. Geological Survey
- L Private Laboratory Results Reported by U.S.G.S.
- P U.S. Public Health Service
- R U.S. Army, Rocky Mountain Arsenal
- U Colorado State University

c/ Composite Sample

GPO 855-566