# Geology and Ground-Water Resources of the Kaycee Irrigation Project Johnson County Wyoming

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1360-E

*Prepared as part of the program of the Department of the Interior for development of the Missouri River basin*

# Geology and Ground-Water Resources of the Kaycee Irrigation Project Johnson County Wyoming

*By* F. A. KOHOUT

*With a section on*

CHEMICAL QUALITY OF THE GROUND WATER

*By* F. H. RAINWATER

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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# GEOLOGY AND GROUND-WATER RESOURCES OF THE KAYCEE IRRIGATION PROJECT, JOHNSON COUNTY WYOMING

By F. A. Kohout

ABSTRACT

The area described in this report is in Johnson County, Wyo., in the lower valley of the Middle Fork of the Powder River and the upper valley of the main stem of the Powder River. The western edge of the area is the base of the eastern slope of the Bighorn Mountains; the eastern edge lies in the Great Plains.

Bedrock cropping out in the area ranges in age from Pennsylvanian to Eocene. Several prominent folds trend northwest, parallel to the Bighorn Mountains. The Tensleep, Lance, Fort Union, and Wasatch formations, which underlie the area, are potential sources of ground-water supply. Ground water from other bedrock formations in the area, however, is generally considered by local residents to be highly mineralized and undesirable for domestic use.

Stream-terrace deposits in the report area are narrow near the mountains but widen eastward toward the plains. The lower terrace deposits contain ground water, but the water generally is not suitable for domestic use. The higher terrace deposits probably do not contain much ground water.

At the present time, irrigation in the area is confined to the alluvial flats and to the stream terraces that are less than 80 feet above the river. The U. S. Bureau of Reclamation has proposed that a reservoir be built about 12 miles west of Kaycee and that the Sahara Canal be extended in order to supply water for irrigating 10,400 acres of additional land and to provide supplemental water for the 6,400 acres of land now being irrigated. Seepage of irrigation water has been an important factor in the waterlogging of about one-fourth of the presently irrigated land in the area, and similar waterlogging and loss of valuable and productive land may result from the extension of irrigation unless appropriate preventive measures are taken.

The results of chemical analyses of water samples collected during the investigation will serve as a basis for determining future changes in the quality of the ground water. The discussion of criteria used to evaluate the quality of water for domestic supply and irrigation is applicable to any water that may be considered for use in the area.

## INTRODUCTION

### LOCATION AND EXTENT OF AREA

The area studied for this report is in Johnson County, Wyo., and extends eastward from the foot of the Bighorn Mountains for 23 miles along the valley of the Middle Fork of the Powder River and 27 miles along the valley of the main stem of the Powder River to a point about 15 miles downstream from the town of Sussex (fig. 46). The project derives its name from the town of Kaycee, which is on the Middle Fork of the Powder River about 4 miles upstream from the confluence of the North Fork and the Middle Fork and about 15 miles east of the Bighorn Mountains. The length of the area is about 50 miles, and the width ranges from 3 to 8 miles. The geology of about 320 square miles was mapped as a part of the study.

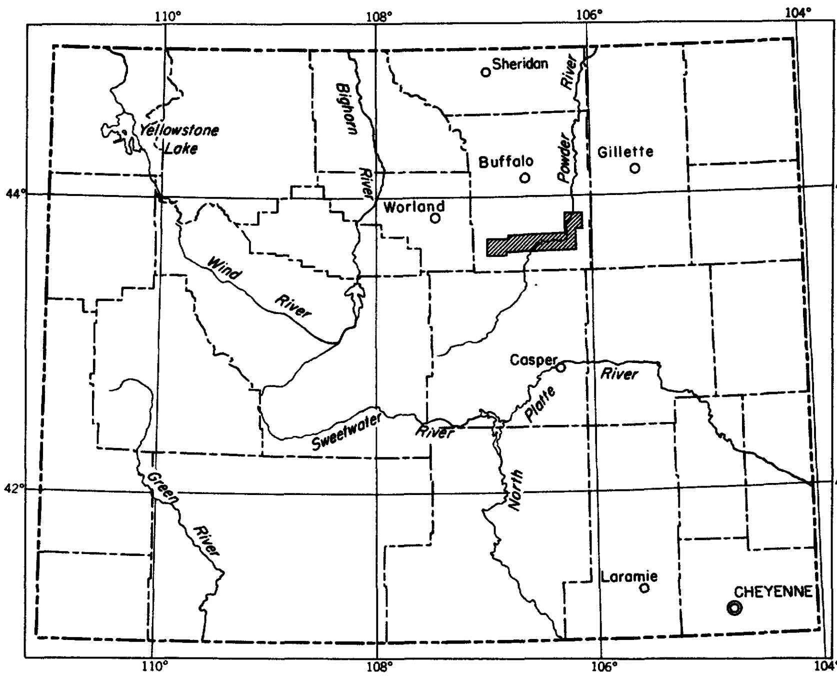


Figure 46. —Map of Wyoming showing area described in this report.

## SCOPE OF INVESTIGATION

The study upon which this report is based is one of several being made in connection with the program for the development of the Missouri River basin. The investigation included a study of the geology in relation to the occurrence of ground water in the area proposed for irrigation development. The surficial geology was plotted on areal photographs and later transferred to a base map having a scale of 2,000 feet to the inch. An inventory was made of 88 wells and springs in the area. The altitude of the wells was determined by instrumental leveling and all other pertinent data were recorded (see table 1). The depth to water in selected wells was measured monthly during the investigation period (see table 2).

The fieldwork upon which this report is based was performed by the writer between July 6 and October 16, 1950. F. C. Koopman assisted in the field for about 6 weeks. The work was done under the immediate supervision of F. A. Swenson, district geologist for Montana and northern Wyoming, and under the general supervision of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin.

The quality-of-water study was conducted under the general direction of S. K. Love, chief of the Quality of Water Branch, and P. C. Benedict, regional engineer in charge of quality-of-water investigations in the Missouri River basin. Samples of water for chemical analysis were collected from 14 wells, 3 streams, and 3 drainage ditches.

## PREVIOUS INVESTIGATIONS

The geology of the eastern part of the Kaycee project area was described by Wegemann (1912 a, b), and the geology and ground-water conditions in the immediate vicinity of Kaycee were described by Warner.[1] The proceedings of a field trip conducted by the Wyoming Geological Association (1949) through this section of Wyoming have been published as a guidebook. The book is a valuable contribution to the literature on the general geology of the region. A detailed geologic map of the area between Kaycee and Barnum, north of the Middle Fork of the Powder River, was made by Carlson.[2] Love and Weitz (1951) also compiled a geologic map of the Powder River basin. These and other papers on the general regional geology of the area are referred to in this report.

## PERSONNEL AND ACKNOWLEDGMENTS

The writer is indebted to many persons who have contributed information and assistance in the field and in the preparation and

[1]Warner, D. A., 1947, Geology and ground-water resources of the Kaycee area, Wyoming. Unpublished report in files of U. S. Geological Survey, Washington, D. C., and Wyoming State Engineer, Cheyenne, Wyo.

[2]Carlson, C. E., 1949, Areal geology and stratigraphy of the Red Fork Powder River area, Johnson County, Wyo. Unpublished thesis for Master of Arts degree, Univ. of Wyoming.

## Table 1.—*Record of wells and springs*

[Well number: See text for explanation of well-numbering system.
Type of well: B, bored; DD, dug and drilled; Dn, driven; Dr, drilled; Du, dug; Sp, spring.
Depth of well: Measured depths are given in feet and tenths of feet; reported depths are given in feet.
Type of casing: C, concrete, brick, tile pipe, or rock; N, none; P, pipe (iron or steel); W, wood.
Geologic source: Cm, Madison limestone; Ct, Tensleep sandstone; G, Quaternary gravel; Js, Sundance formation; Kc, Cody shale; Kfh, Fox Hills formation; Kl, Lance formation; Kmvp, Parkman sandstone member of the Mesaverde formation; Kmr, Mowry shale; Tfu, Fort Union formation; Tw, Wasatch formation.
Method of lift: B, bucket; C, centrifugal; Cy, cylinder; J, jet pump; N, none; P, pitcher pump; T, turbine.
Type of power: E, electric; F, natural flow; G, gas or gasoline engine; H, hand operated; W, wind.
Use of water: D, domestic; I, irrigation; In, industrial; N, none; O, observation of water-level fluctuations; P, public supply; S, stock.
Measuring-point description: Bp, base of pump; Ls, land surface; Tca, top of casing; Tpl, top of platform.
Depth to water level: Measured depths are given in feet and tenths of feet below measuring point; reported depths are given in feet below land surface.
Remarks: Ca, sample collected for chemical analysis; F, natural flow (numeral denotes gallons per minute; Tr, trickle)]

| Well no. | Owner or tenant | Date of completion | Type of well | Depth of well below measuring point (feet) | Diameter of well (inches) | Type of casing | Geologic source | Type of lift | Kind of power | Use of water | Measuring point | | | Depth to water level (feet) | Date of measurement (1950) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Description | Height above land surface (feet) | Altitude above mean sea level (feet) | | | |
| 42-84-10da | Don Taylor | | Sp | | | N | Ct | N | F | D | Ls | | | | | |
| 43-78- 5da | Roy Garrett | | Dr | 121 | 6 | P | Tw | N | F | D,S | Ls | | | | | F-Tr |
| 6ca | Emil Mieke | | Dr | 160 | 4 | P | Tw | Cy | H | D | Ls | | | | | |
| 7dc | Mr. Patrick | | Du | 11.2 | 24 | P | G | C | G | S,O | Tca | 0.5 | 4,362.31 | 8.15 | July 18 | |
| 18ba | ......do | 1946 | Dr | 259 | 4 | P | Tfu(?) | N | F | D,S | Ls | | | | | F-1 |
| 79- 1ac | Arthur Mieke | 1943 | Dr | 200 | 8 | P | Tw | Cy | W | D,S | Bp | 2.6 | 4,431.70 | 11.04 | July 14 | |
| 1ba | Harold Mieke | 1946 | Dr | 175 | 6 | P | Tw | Cy | W | D | Ls | | | 50 | Nov. 30 | |
| 1da1 | Reynolds and Decourcey. | | Du | 20.8 | 48 | P | G | Cy | G | S,O | Tpl | .6 | 4,465.95 | 11.19 | July 17 | |
| 1da2 | ......do | | Dr | 200+ | 6 | P | Tw | Cy | W | D,S | Tca | 1.3 | 4,470.39 | 68.77 | 17 | |
| 2aa | ......do | | Dr | ? | 5 | P | | Cy | W | S | | | | | | |
| 2cc | Orange Taylor | | Dr | 434 | 5 | P | | Cy | W | S | Ls | | | 84 | | |
| 2dd | Sussex School | 1950 | Dr | 270 | 4 | P | Tw | Cy | H | D | Ls | | | 68 | | Ca |
| 7cc | J. Indrart | | Dr | 175 | 6 | P | | Cy | W | S | Tca | 1.3 | 4,518.26 | 33.30 | July 12 | |
| | | | | | | | | | | | | | | 34.34 | Aug. 7 | |
| | | | | | | | | | | | | | | 34.16 | Sept. 11 | |
| 8ca | Earl Carter | | Dr | 273 | 5 | P | | Cy | W | S | Tca | 1.3 | 4,520.91 | 104.95 | July 12 | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9cc | George Raitt........ | ........... | Dr | 185 | 4 | P | ............ | Cy | W | D,S | Ls | .......... | ............ | 32 | ........... | |
| 9da1 | Arley Taylor........ | ........... | Dr | 160 | 5 | P | Tw | Cy | E | D | Ls | .......... | ............ | 40 | ........... | |
| 9da2 | ......do................ | ........... | Dr | 85 | 5 | P | Tw | Cy | W | S | Ls | .......... | ............ | 40 | ........... | |
| 9da3 | ......do................ | ........... | Dr | 137 | 6 | P | Tw | Cy | W | S | Ls | .......... | ............ | 40 | ........... | |
| 11aa | Rex Yeigh........... | 1945 | Dr | 145 | 6 | P | ............ | Cy | W | D,S | Ls | .......... | ............ | 40 | ........... | |
| 11ba | Bill Taylor........... | ........... | Dr | 150 | 5 | P | Tw | Cy | W | D,S | Ls | .......... | ............ | .......... | ........... | |
| 11bc1 | Orange Taylor....... | ........... | Dr | 180 | 5 | P | Tw | Cy | W | D,S | Ls | .......... | ............ | 60 | ........... | |
| 11bc2 | ......do................ | ........... | Dr | 300 | 6 | P | ............ | Cy | E | S | Ls | .......... | ............ | 40 | ........... | |
| 11cb | Bob Taylor.......... | ........... | Du | 17.9 | 48 | P | G | Cy | W | S,O | Tpl | .5 | 4,449.08 | 4.44 | July 17 | |
| 11dd1 | ......do................ | ........... | B | 12.5 | 6 | P | G | Cy | W | S,O | Bp | .5 | 4,430.30 | 5.44 | 18 | Ca |
| 11dd2 | ......do................ | ........... | Dr | .......... | 6 | P | ............ | N | N | N | Tca | .0 | 4,432.02 | 20.90 | 18 | |
| 12cc | Jim Andy............. | 1950 | Dr | 200 | 5 | P | ............ | Cy | G | D,S | Ls | .......... | ............ | 30 | ........... | |
| 12da | Roy Chamberlain... | ........... | Dr | 150 | 4 | P | ............ | Cy | H | D | Ls | .......... | ............ | .......... | ........... | |
| 12dc1 | Pete Mieke........... | 1950 | Dr | 140 | 6 | P | ............ | Cy | W | D,S | Ls | .......... | ............ | 30 | ........... | |
| 12dc2 | ......do................ | ........... | Du | 16 | 36 | W | G | Cy | G | S,O | Tpl | .3 | 4,426.37 | 9.80 | July 18 | |
| 13ab | Mr. Fitspatrick...... | ........... | Dr | 112 | 6 | P | ............ | Cy | W | D | Ls | .......... | ............ | 30 | ........... | |
| 13ac | Alvin Lohse.......... | ........... | Du | 11.0 | 24 | W | G | Cy | H | O | Bp | .0 | 4,375.23 | 8.95 | July 18 | |
| 13bc | Mr. Spellman....... | ........... | Dr | 118 | 6 | P | ............ | Cy | W | D | Ls | .......... | ............ | 30 | ........... | |
| 13db | B. E. Turk........... | ........... | Dr | 100 | 4 | P | Tfu(?) | Cy | W | D,S | Ls | .......... | ............ | 10 | ........... | |
| 14aa | Bob Taylor........... | 1945 | Dr | 125 | 6 | P | ............ | Cy | H | S | Ls | .......... | ............ | 30 | ........... | |
| 14bb | J. M. Miller......... | 1943 | Dr | 96 | 6 | P | ............ | Cy | W | D,S | Ls | .......... | ............ | 50 | ........... | |
| 15ac1 | Ernest Vest........... | 1930 | Dr | 160 | 5 | P | ............ | Cy | W | S | Ls | .......... | ............ | 5 | ........... | |
| 15ac2 | ......do................ | 1950 | Dr | 200 | 4 | P | ............ | N | F | D | Ls | .......... | ............ | .......... | ........... | F-1 |
| 17ac | Kenneth Mathews.. | ........... | Dr | 120 | 5 | P | ............ | Cy | H | D,S | Ls | .......... | ............ | 60 | ........... | |
| 17bb | Earl Carter........... | ........... | Dr | 105 | 4 | P | ............ | Cy | H | D | Ls | .......... | ............ | 35 | ........... | |
| 18cd | H. R. Gibbs......... | 1915 | Dr | 144 | 4 | P | ............ | C | E | D | Ls | .......... | ............ | 20 | ........... | |
| 80-11db | Charles Mayor...... | 1950 | Dr | 205 | 4 | P | ............ | Cy | W | S | Ls | .......... | ............ | 60 | ........... | |
| 13ad | J. Indrart............. | ........... | Dr | 160 | 4 | P | ............ | Cy | W | D | Ls | .......... | ............ | 130 | ........... | |
| 13ca | L. A. Shabot........ | ........... | Dr | 160 | 5 | P | ............ | Cy | H | D | Ls | .......... | ............ | ? | ........... | |
| 14cc | Charles Mayor....... | ........... | Dr | 200 | 5 | P | Tfu | J | E | D | Ls | .......... | ............ | 40 | ........... | |
| 20cc1 | Joe Kos................. | ........... | Dr | 140 | 4 | P | Kl,Kfh(?) | Cy | G | D | Ls | .......... | ............ | 17 | ........... | Ca |

11946.

Table 1.—*Record of wells and springs*—Continued

| Well no. | Owner or tenant | Date of completion | Type of well | Depth of well below measuring point (feet) | Diameter of well (inches) | Type of casing | Geologic source | Type of lift | Kind of power | Use of water | Measuring point: Description | Measuring point: Height above land surface (feet) | Measuring point: Altitude above mean sea level (feet) | Depth to water level (feet) | Date of measurement (1950) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-80-20cc2 | Joe Kos | ...... | Du | 16.0 | 24 | P | G | Cy | H | S,O | Tca | 4.0 | 4,501.74 | 11.94 | Sept. 12 | Ca |
| 22bd | Roland Streeter | 1947 | Dr | 410 | 5 | P | Tfu | Cy | H | D | Ls | ...... | ...... | 14 | ...... | |
| 81- 5ab | ...... | ...... | Dr | ? | 5 | P | ...... | Cy | W | S | ...... | ...... | ...... | ? | ...... | |
| 6cd | Snook and Eldridge | ...... | B | 48.3 | 48 | W | Kc | N | N | O | Tpl | 2.2 | 4,709.51 | 38.78 | July 10 | |
| 7dc | Oscar Rissler | ...... | B | 14 | 6 | P | G | Cy | H | N | Ls | ...... | ...... | ? | ...... | |
| 10ca | Walter Elm | ...... | Dr | 400 | 4 | P | Kmvp | Cy | G | S | Tca | 1.1 | 4,579.76 | 10.37 | July 10 | Ca |
| 13bb | Beebe Ranch | ...... | Dr | 400 | 6 | P | Kl | Cy | W | D,S | Tca | .3 | 4,605.94 | 73.80 | 10 | |
| 82-11da | Howard Thompson | ...... | Du | 15.7 | 60 | C | G | Cy | H | D,O | Tpl | 1.0 | 4,680.45 | 13.23 | 12 | |
| 12aa | Joe Barber | ...... | Du | 24.4 | 36 | P | G | Cy | H | O | Tpl | .0 | 4,666.69 | 23.11 | 10 | Ca |
| 12ac | G. F. Skiles | ...... | Du | 12.5 | 36 | C | G | Cy | H | D,O | Tpl | .5 | 4,653.08 | 10.54 | 13 | |
| 12ad1 | Joe Colosimo | ...... | Du | 18.2 | 16 | C | G | Cy | H | D,O | Tpl | .2 | 4,649.58 | 8.21 | 11 | |
| 12ad2 | Rolley Gosney | ...... | Du | 13.1 | 60 | N | G | Cy | H | D,S,O | Tpl | .0 | 4,651.62 | 11.02 | 11 | |
| 12ad3 | Gordon Christenson | ...... | Du | 11.3 | 24 | W | G | Cy | H | D,S,O | Tpl | .8 | 4,648.68 | 7.74 | 13 | |
| 12ad4 | H. J. Bunning | ...... | Du | 18.6 | 48 | P | G | C | E | D,O | Tca | 1.6 | 4,648.07 | 5.88 | 12 | |
| 12ad5 | City of Kaycee | 1950 | Du | 17.2 | 60 | C | G | T | E | P | Tpl | 3.3 | 4,650.32 | 8.99 | Aug. 7 | Ca |
| | | | | | | | | | | | | | | 8.55 | Sept. 11 | |
| 12da | Joe Rissler | ...... | Du | 15 | 36 | C | G | P | ...... | N | Ls | ...... | ...... | 5 | ...... | |
| 15bc | Keith Coates | ...... | Dr | 1,925 | ...... | N | Cm(?) | N | F | N | Ls | ...... | ...... | ...... | ...... | Ca;F-500 |
| 19ba | E. F. Keith | ...... | Sp | ...... | ...... | N | Kmr | N | F | N | Ls | ...... | ...... | ...... | ...... | F-3 |
| 21db | A. F. Haines | ...... | Dr | 360 | 4 | P | ...... | N | F | D,S | Ls | ...... | ...... | ...... | ...... | F-1 |
| 29ac | E. F. Keith | ...... | Du | 17.8 | 54 | C | G | Cy | H | S,O | Bp | .6 | 4,778.90 | 15.54 | July 12 | Ca |
| 29db | ......do | ...... | Du | 9.5 | 72 | C | G | Cy | H | S,O | Bp | .6 | 4,771.17 | 8.02 | 12 | |
| 31ab | ......do | ...... | Du | 13.0 | 48 | C | G | Cy | H | O | Tpl | .0 | 4,794.91 | 8.15 | 11 | |
| 83-31bc | Wolcott Bros | ...... | Dr | 365 | 4 | P | Js | N | F | S | Ls | ...... | ...... | ...... | ...... | Ca;F-Tr |
| 33bc | Cliff Hansen | 1950 | B | 30 | 4 | P | G | Cy | H | O | Tca | 1.0 | 4,915.20 | 5.70 | July 10 | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33db | ......do | 1950 | B | 28.0 | 3 | P | G | N | N | N | Tca | .0 | 4,900.40 | 4.65 | Aug. 7 | |
| | | | | | | | | | | | | | | 4.56 | Sept. 9 | |
| 84-24cd | Mrs. McCarthy | | Dr | 405 | 4 | P | | Cy | W | S | Ls | | | 20 | | |
| 34ca | E. O. Taylor | | Sp | | | | Ct | N | F | D | Ls | | | | | F-10 |
| 35cc | Mrs. McCarthy | | Dr | 740 | 4 | P | Ct | N | F | D,S | Ls | | | | | Ca;F-10 |
| 44-78- 5ab | Mrs. Etta Floyd | | Dr | ? | ? | P | | N | F | S | Ls | | | | | F-1 |
| 7ad | D. F. Skiles | | Dr | 90 | 5 | P | Tw | Cy | W | D | Ls | | | 60 | | |
| 7cb | ......do | 1939 | Dr | 123 | 7 | P | Tw | Cy | W | S | Ls | | | 40 | | |
| 8ac | ......do | | Du | 22.6 | 60 | N | G | Cy | H | O | Tpl | .0 | 4,297.65 | 17.62 | July 17 | |
| 8bc | ......do | | Dr | 90 | 4 | P | Tw | Cy | H | S | Ls | | | 25 | | |
| 17dd1 | Roy Hutton | | Dr | 80 | 4 | P | | Cy | H | D | Tca | .3 | | 21.23 | July 17 | |
| 17dd2 | ......do | 1950 | Dr | 240 | 4 | P | | N | F | S | Ls | | | | | F-Tr |
| 30dd | | | B | 62.0 | 12 | W | | N | N | O | Tca | .0 | 4,369.19 | 61.95 | July 6 | |
| 45-78-14cd1 | Fermin Reculusa | | Dr | 70.3 | 12 | P | Tw | Cy | W | D,S | Bp | .9 | 4,244.95 | 10.78 | 14 | Ca |
| | | | | | | | | | | | | | | 10.89 | Aug. 7 | |
| | | | | | | | | | | | | | | 10.59 | Sept. 11 | |
| 14cd2 | ......do | | Dr | 400+ | 4 | P | Tfu(?) | N | F | D,S | Ls | | | | | F-2 |
| 26bd | John Streeter | 1946 | Dr | 460 | 4 | P | Tfu(?) | N | F | I,S | Ls | | | | | F-25 |
| 33ad1 | Homer Payseno | | Du | 21.5 | 48 | C | G | Cy | W | S,O | Tpl | .3 | 4,275.04 | 18.68 | July 13 | Ca |
| 33ad2 | ......do | | Dr | 71.0 | 7 | P | Tw | B | H | D | Tca | 2.3 | 4,277.04 | 26.43 | 13 | |
| 34ba1 | John Streeter | | Dr | 473 | 5 | P | Tfu(?) | N | F | S | Ls | | | | | Ca;F-12 |
| 34ba2 | ......do | 1948 | Dr | 463 | 4 | P | Tfu(?) | N | F | D | Ls | | | | | F-6 |

Table 2.—*Water-level measurements in observation wells*

[In feet below land surface]

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| **43-78-7dc** | | | | | |
| July 18, 1950 | 7.65 | Sept. 11, 1950 | 8.62 | Oct. 16, 1950 | 8.00 |
| Aug. 7 | 8.15 | | | | |
| **43-79-1da1** | | | | | |
| July 17, 1950 | 10.59 | Sept. 11, 1950 | 11.43 | Oct. 16, 1950 | 11.42 |
| Aug. 7 | 10.64 | | | | |
| **43-79-11cb** | | | | | |
| July 17, 1950 | 3.94 | May 30, 1951 | 4.22 | Nov. 30, 1951 | 6.17 |
| Aug. 7 | 3.60 | July 9 | 3.47 | Dec. 20 | 5.89 |
| Sept. 11 | 4.52 | Aug. (?) | 3.97 | Jan. 24, 1952 | 6.60 |
| Oct. 16 | 5.35 | Sept. (?) | 4.66 | Feb. 22 | 6.90 |
| Apr. 20, 1951 | 7.47 | Oct. 22 | 5.53 | Mar. 10 | 6.60 |
| **43-79-11dd1** | | | | | |
| July 18, 1950 | 4.94 | May 30, 1951 | 6.46 | Dec. 20, 1951 | 8.59 |
| Aug. 7 | 5.70 | July 9 | 6.18 | Jan. 24, 1952 | 9.20 |
| Sept. 11 | 6.61 | Sept. (?) | 8.40 | Feb. 22 | 8.82 |
| Oct. 16 | 6.60 | Oct. 22 | 8.34 | Mar. 10 | 8.83 |
| Apr. 20, 1951 | 7.82 | Nov. 30 | 8.50 | | |
| **43-79-12dc2** | | | | | |
| July 18, 1950 | 9.50 | Sept. 11, 1950 | 9.22 | Oct. 16, 1950 | 9.83 |
| Aug. 7 | 9.44 | | | | |
| **43-79-13ac** | | | | | |
| July 18, 1950 | 8.95 | May 30, 1951 | 8.76 | Nov. 30, 1951 | 9.40 |
| Aug. 7 | 9.55 | July 9 | 9.21 | Dec. 20 | 9.30 |
| Sept. 11 | 8.78 | Aug. (?) | 8.77 | Jan. 24, 1952 | 8.31 |
| Oct. 16 | 9.68 | Sept. (?) | 8.69 | Feb. 22 | 8.17 |
| Apr. 20, 1951 | 8.87 | Oct. 22 | 9.80 | Mar. 10 | 8.33 |
| **43-80-20cc2** | | | | | |
| Sept. 12, 1950 | 7.94 | Aug. (?) 1951 | 7.94 | Dec. 20, 1951 | 9.90 |
| Oct. 16 | 8.71 | Sept. (?) | 8.83 | Jan. 24, 1952 | 9.97 |
| Apr. 20, 1951 | 10.22 | Oct. 22, | 9.30 | Feb. 22 | 9.96 |
| May 30 | 7.94 | Nov. 30 | 9.73 | Mar. 10 | 9.96 |
| July 9 | 7.82 | | | | |
| **43-81-6cd** | | | | | |
| July 10, 1950 | 36.58 | Sept. 11, 1950 | 37.84 | Oct. 16, 1950 | 37.80 |
| Aug. 7 | 37.83 | | | | |
| **43-82-11da** | | | | | |
| July 12, 1950 | 12.23 | Sept. 11, 1950 | 12.77 | Oct. 16, 1950 | 12.55 |
| Aug. 7 | 12.33 | | | | |

Table 2.—*Water-level measurements in observation wells*—Continued

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| | | 43-82-12aa | | | |
| July 10, 1950 | 23.11 | Sept. 11, 1950 | 22.61 | Oct. 16, 1950 | 22.68 |
| Aug. 7 | 23.10 | | | | |
| | | 43-82-12ac | | | |
| July 13, 1950 | 10.04 | Sept. 11, 1950 | 10.84 | Oct. 16, 1950 | 10.17 |
| Aug. 7 | 10.50 | | | | |
| | | 43-82-12ad1 | | | |
| July 11, 1950 | 8.01 | Sept. 11, 1950 | 8.62 | Oct. 16, 1950 | 8.15 |
| Aug. 7 | 8.54 | | | | |
| | | 43-82-12ad2 | | | |
| July 11, 1950 | 11.02 | Aug.(?) 1951 | 11.21 | Dec. 20, 1951 | 11.28 |
| Apr. 18, 1951 | 11.18 | Sept.(?) | 11.34 | Jan. 24, 1952 | 10.97 |
| May 30 | 11.02 | Oct. 22, | 11.53 | Feb. 22 | 10.77 |
| July 9 | 10.91 | Nov. 30 | 11.53 | Mar. 10 | 10.70 |
| | | 43-82-12ad3 | | | |
| July 13, 1950 | 6.94 | Sept. 11, 1950 | 7.47 | Oct. 16, 1950 | 7.68 |
| Aug. 7 | 7.96 | | | | |
| | | 43-82-12ad4 | | | |
| July 12, 1950 | 4.28 | May 30, 1951 | 4.97 | Nov. 30, 1951 | 6.21 |
| Aug. 7 | 4.74 | July 9 | 5.21 | Dec. 20 | 5.00 |
| Sept. 11 | 4.79 | Aug.(?) | 6.15 | Jan. 24, 1952 | 5.70 |
| Oct. 11 | 5.56 | Sept.(?) | 6.50 | Feb. 22 | 4.81 |
| Apr. 18, 1951 | 4.80 | Oct. 22 | 6.39 | Mar. 10 | 4.92 |
| | | 43-82-29ac | | | |
| July 12, 1950 | 14.94 | May 30, 1951 | 14.95 | Nov. 30, 1951 | 14.93 |
| Aug. 7 | 14.61 | July 12 | 15.43 | Dec. 20 | 14.92 |
| Sept. 9 | 13.86 | Aug.(?) | 15.19 | Jan. 24, 1952 | 14.88 |
| Oct. 16 | 14.36 | Sept.(?) | 14.42 | Feb. 22 | 14.93 |
| Apr. 18, 1951 | 14.79 | Oct. 22 | 14.61 | Mar. 10 | 15.20 |
| | | 43-82-29db | | | |
| July 12, 1950 | 7.42 | Sept. 9, 1950 | 8.13 | Oct. 16, 1950 | 7.60 |
| Aug. 7 | 6.87 | | | | |
| | | 43-82-31ab | | | |
| July 11, 1950 | 8.15 | Sept. 9, 1950 | 8.19 | Oct. 16, 1950 | 8.12 |
| | | 43-83-33bc | | | |
| July 10, 1950 | 4.70 | Sept. 9, 1950 | 6.75 | Oct. 16, 1950 | 6.76 |
| Aug. 7 | 2.80 | | | | |

Table 2.—*Water-level measurements in observation wells*—Continued

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| | | 44-78-8ac | | | |
| July 17, 1950<br>Aug. 7 | 17.62<br>18.02 | Sept. 11, 1950 | 18.40 | Oct. 16, 1950 | 18.09 |
| | | 44-78-30dd | | | |
| July 6, 1950<br>Aug. 7 | 61.95<br>Dry | Sept. 11, 1950 | Dry | Oct. 16, 1950 | Dry |
| | | 45-78-33ad1 | | | |
| July 13, 1950<br>Aug. 7 | 18.38<br>19.01 | Sept. 11, 1950 | 19.20 | Oct. 16, 1950 | 19.37 |

review of this report. Joseph Barber provided information regarding the history of irrigation in the Kaycee vicinity. E. O. Taylor loaned a plot map showing the accurate location of section corners. Several persons helped by loaning books on the history of the area. Others, including many ranchers, provided information that aided materially in the collection of data for this report.

## WELL-NUMBERING SYSTEM

The location of the wells described in this report is shown on plate 22. The wells are numbered according to their location within the Bureau of Land Management's system of land subdivision. The well number shows the location of the well by township, range, section, and position within the section. The first numeral indicates the township; the second, the range; and the third, the section in which the well is situated. The lowercase letters following the section number locate the well within the section. The first letter denotes the quarter section, and the second, the quarter-quarter section. These subdivisions of the section are lettered a, b, c, and d and are assigned in a counterclockwise direction, beginning in the northeast quarter of the section or quarter section. If more than one well is located in the same 40-acre tract, they are distinguished by consecutive numbers, beginning with 1, following the lowercase letters. This system of numbering wells is illustrated in figure 47.

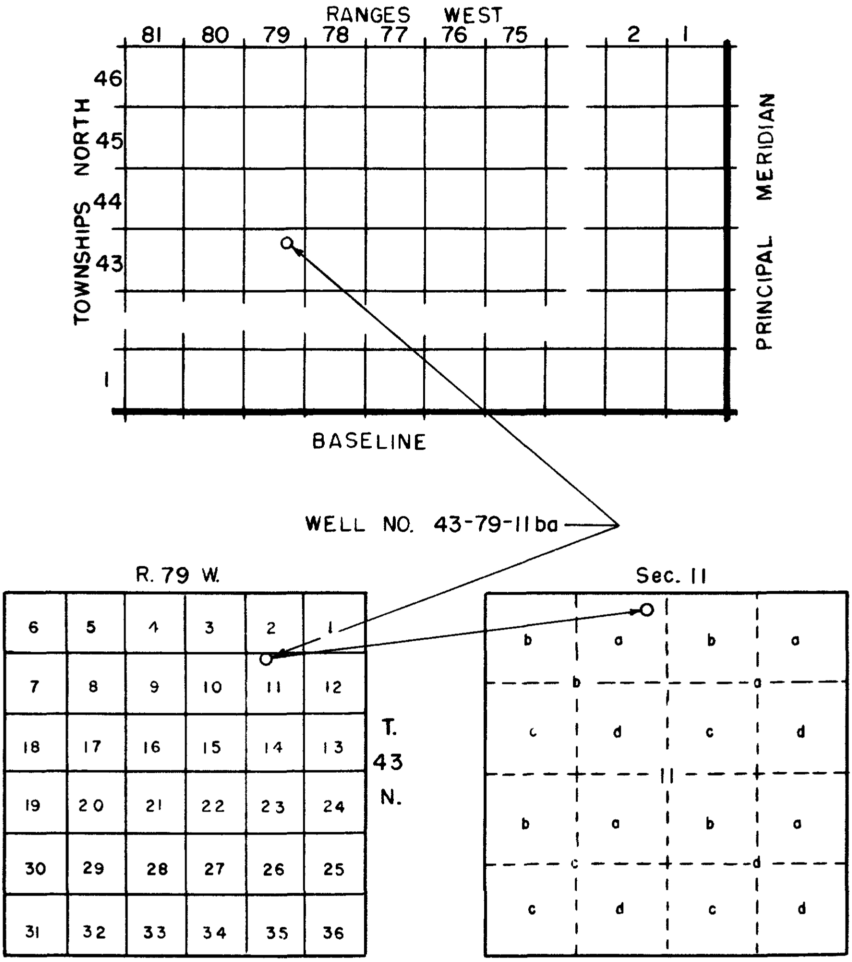


Figure 47. —Well-numbering system.

## GEOGRAPHY

### HISTORY

The territory along the eastern front of the Bighorn Mountains was a favorite hunting area for many Indian tribes. During the large influx of white settlers between 1850 and 1865, the tribes banded together and made a determined stand to protect their hunting grounds. In 1865 an expedition known officially as the Powder River Indian Expedition set out from Fort Laramie under the command of General P. E. Connor. The expedition traveled northward and crossed the Powder River on the Bozeman Trail (a famous old traders' road made in 1864 by J. M. Bozeman) in the vicinity of Pumpkin Buttes, which are four prominent buttes east of the report area that were used as a landmark by the early settlers.

The town of Kaycee was founded in 1887 on the old KC ranch and for many years was referred to as "KC."

After the Indians had been subdued and placed on reservations, the cattle industry thrived and the cattlemen's word became the semiofficial law of Wyoming. The careless application of a branding iron had been a pardonable sin when cattle herds were large and numerous, but the severe winter of 1886–87 took such a heavy toll that cattle thieves became a real menace to the stock-raising industry. At the regular annual meeting of the Wyoming Stock Growers' Association on April 6, 1892, drastic action was decided upon, and a party of 60 men set out to track down and kill 75 known cattle thieves operating out of Buffalo. After a skirmish at the KC ranch in which two of the thieves were killed, the group continued north to the TA ranch. Three days of savage fighting ensued and on April 12, at the request of Governor Barber, President Benjamin Harrison called out Federal troops, who quelled the uprising, or so-called Johnson County invasion.

## CLIMATE

The climate of the Kaycee irrigation project area, which is affected to a great extent by the Bighorn Mountains, is semiarid and is characterized by a generally low relative humidity and a potentially high rate of evaporation. Generally, the winters are long. Summer days are warm and the nights are cool. The mean temperature ranges from 20.1°F in January to 69.2°F in July. The annual average temperature is 44.1°F. The average date of the last killing frost is May 16, and that of the first killing frost is September 22. Thus, the average frost-free growing season is 122 days.

The U. S. Weather Bureau has maintained a continuous weather record since 1941 at Kaycee, the only weather station within a radius of 50 miles. During the first 10 years of record the average annual precipitation was 12.11 inches, but the precipitation ranged from a high of 17.79 inches in 1941 to a low of 9.00 inches in 1949. (See fig. 48.) The middle and eastern parts of the area receive less moisture than the western mountainous part.

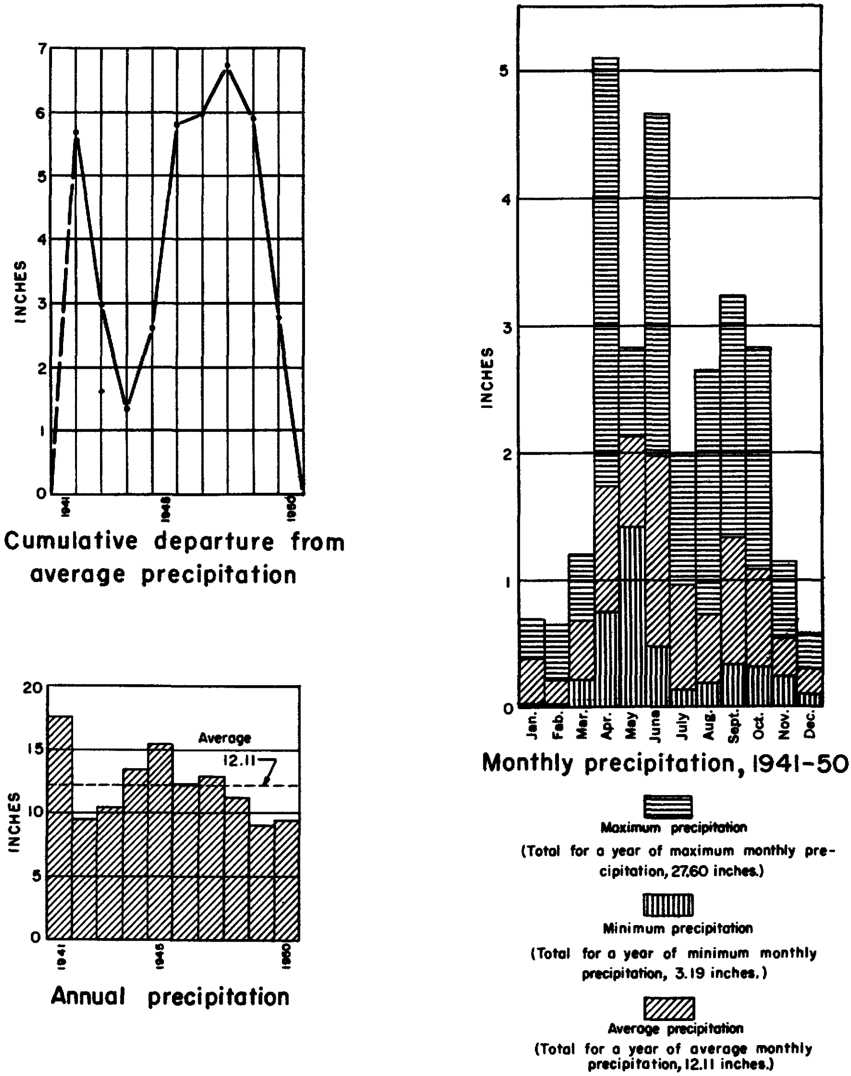


Figure 48. —Record of precipitation at Kaycee.

Although precipitation often occurs during the summer in the form of widely scattered rain and hail storms, the heaviest precipitation generally falls in April, May, June, September, and October. Total average precipitation for these 5 months is 8.30 inches and that of the other 7 months only 3.81 inches. However, precipitation from month to month is variable and several excessively dry months may be followed by greater-than-average precipitation. Conversely, a period of above-average rainfall may be followed by a period of near-drought conditions. These facts, of course, cannot be indicated in the annual rainfall totals. (See table 3.) If the driest months during the record period of 1941–50 had appeared in any single year, the total annual precipitation at Kaycee would have been only 3.19 inches, but if the wettest months in this period had appeared in any single year, the total would have been 27.60 inches. (See fig. 48.)

Table 3.—*Precipitation record, in inches, for the driest and wettest years and monthly average during the period 1941–50 at Kaycee, Wyo.*

| Month | Driest year (1949) | Wettest year (1941) | Average for period |
|---|---|---|---|
| January | 0.70 | 0.28 | 0.39 |
| February | .05 | .01 | .21 |
| March | .22 | 1.21 | .69 |
| April | .77 | 5.10 | 1.74 |
| May | 2.01 | 1.73 | 2.13 |
| June | 1.58 | 1.49 | 2.02 |
| July | .59 | 1.99 | .96 |
| August | .77 | 2.66 | .73 |
| September | .72 | 1.14 | 1.32 |
| October | 1.03 | 1.48 | 1.09 |
| November | .28 | .37 | .53 |
| December | .28 | .33 | .30 |
| Total | 9.00 | 17.79 | 12.11 |

The cumulative departure from normal precipitation at Kaycee is also shown in figure 48. The periods of above-average rainfall are indicated by a rising line, and the periods of below-average precipitation, by a declining line. A dry cycle of 2 years' duration occurred during 1942 and 1943. This was followed by a 4-year wet cycle from 1944 through 1947. The area again received below-average precipitation from 1948 through 1950.

## AGRICULTURE AND INDUSTRY

The early settlers were attracted to the region by the extensive grazing areas in the mountains and protected lowlands for the wintering of livestock. Large tracts of natural grasses that remain green during the summer months, perennial streams for watering stock, and stands of pine trees for shade combine to make the mountainous areas ideally suited for summer grazing. The common practice of ranchers is to drive their herds of cattle and sheep to the higher grazing areas in the spring and return them to the valleys in the fall. This migration represents a journey of from 50 to 60 miles for the herds from ranches in the region north of Sussex. Cattle raising remains the chief industry in the Kaycee area.

The crops grown in the area are used principally for feeding stock during the winter. More irrigated land is used for raising alfalfa than for any other crop. Two cuttings are made each year. The greater part of the alfalfa is stacked in the field and fed from the stacks to the livestock. Wheat, oats, corn, and barley are raised to supplement the alfalfa and hay. Generally the meadows adjacent to the river are not cultivated because the natural stand of blue timothy makes excellent hay. These meadows are subirrigated or are partly irrigated. The blue timothy is perennial but subirrigated alfalfa dies out quickly, possibly because of the high salt content of the ground water. There is very little dryland farming in the Kaycee area.

No manufacturing plants are situated in the project area, and business is confined to supplying the needs of the ranchers. In 1948 and subsequent years, explorative investigations have been carried on in the "oil field" area near Sussex and to some extent in adjacent areas. Equipment for this work is brought into the area in company trucks. Some workable bentonite deposits are present in the area west of Kaycee, but poor transportation facilities have prevented development of this resource.

## DRAINAGE

The Middle Fork of the Powder River enters the project area about 18 miles southwest of Kaycee. It flows northeastward and is joined by Beaver Creek about 11 miles southwest of Kaycee and by the Red Fork about 8 miles southwest of Kaycee. From Kaycee, it flows eastward about 5 miles to its confluence with the North Fork. About 3 miles farther east it is joined by the South Fork, and downstream from this confluence the combined flow is known as the Powder River. About 2 miles west of Sussex it is joined by Salt Creek, and about 2 miles northeast of Sussex the Powder River veers northward for a distance of about 7 miles, then northeastward for another 7 miles to the point where it leaves the project area. (See pl. 23.)

The Middle Fork of the Powder River is a rushing mountain stream. In some places its course is determined by the geologic structure. For example, at one place in the western part of the area it flows around the ends of plunging, interfingering anticlines. It breaches the southern end of the Kaycee dome, flows along the axis for a couple of miles, then resumes its general eastward course. As the stream flows out onto the plains east of Kaycee it changes character and meanders over its sandy bed.

Records of the combined flow of the Middle and North Forks of the Powder River at the gaging station about 100 yards below the intake of the Sahara Canal (sec. 13, T. 43 N., R. 81 W.), 6 miles east of Kaycee, date back to October 23, 1933, but only since October 1940 have continuous records been maintained. (See table 4.) The drainage area comprises 980 square miles. The maximum daily discharge during the period of record (1933–47) was 5,230 cfs on August 11, 1941 (gage height, 12.57 feet). In 1938 no measurable flow was recorded from July 14–16, from August 1–11, and on August 14, probably because all the water was being diverted into the Sahara Canal.

The Middle Fork of the Powder River reaches its highest stage during April, May, and June as a result of the runoff from melting snow and spring rain. The river reaches its lowest stage during the summer when water is diverted from the river into the Sahara Canal for irrigation. During the early part of the growing season, May and June, the river furnishes sufficient water for irrigation purposes, but during July and August the demand for water often exceeds the supply. In dry years, this lack of water has frequently resulted in serious crop damage and loss.

## IRRIGATION

Irrigation in the upper Powder River valley began in the 1890's. An influx of settlers during this period made the acquisition of water rights a necessity. Construction of the Sahara Canal was started in 1900. It has since been lengthened to about 15 miles and now supplies irrigation water to numerous ranches. The Sahara Canal is the only collectively owned irrigation system in the area. Construction and maintenance costs are being repaid by an assessed price per acre-foot of water used.

A stone and timber dam across the Powder River diverts the water into the Sahara Canal. This dam is high enough to divert the entire flow of the river during July, August, and September. The Sahara Canal flows for 2 miles from its intake on the south side of the Powder River and then crosses the river by means of an elevated flume a short distance upstream from the confluence of the South and Middle Forks of the Powder River. The Sahara Canal ends at Fourmile Creek in the northeast corner of sec. 2, T. 43 N., R. 79 W.

Several ranchers west of Kaycee own and operate their own irrigation systems. Small dams are constructed across the Middle and Red Forks of the Powder River to divert the water. These small diversion dams are quite effective, as some ranchers

Table 4.—*Discharge, in acre-feet, of the combined flow of the Middle and North Forks of the Powder River at gaging station 6 miles east of Kaycee*

| Water year | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1933-34 | [1]2,070 | 7,030 | [2]2,020 | ........ | ........ | [3]2,630 | 10,100 | 1,140 | 3,630 | 1,490 | ........ | ........ | ........ |
| 1934-35 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 1935-36 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 1936-37 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 1937-38 | ........ | ........ | ........ | ........ | ........ | ........ | [4]13,030 | 27,900 | 9,830 | 2,570 | 25 | 1,220 | ........ |
| 1938-39 | 3,170 | 4,400 | 4,600 | 4,580 | 3,480 | 6,640 | 9,530 | 14,130 | 9,110 | 463 | 7.3 | 6.0 | 60,120 |
| 1939-40 | 2,600 | 4,030 | 4,250 | 3,100 | 4,290 | 4,870 | 8,970 | 14,420 | 2,360 | ........ | ........ | ........ | ........ |
| 1940-41 | 6,980 | 5,550 | 4,740 | 4,300 | 4,360 | 6,310 | 15,280 | 56,140 | 7,310 | 7,600 | 18,160 | 7,150 | 143,900 |
| 1941-42 | 7,780 | 7,520 | 6,120 | 5,060 | 5,530 | 8,360 | 26,720 | 28,640 | 5,960 | 52 | 1,480 | 2,940 | 106,200 |
| 1942-43 | 5,650 | 5,470 | 4,600 | 4,560 | 5,340 | 8,050 | 23,670 | 24,290 | 25,560 | 2,680 | 537 | 2,820 | 113,200 |
| 1943-44 | 5,320 | 5,840 | 5,840 | 5,330 | 5,150 | 6,930 | 10,480 | 61,530 | 37,420 | 10,390 | 909 | 2,550 | 157,700 |
| 1944-45 | 5,760 | 6,370 | 5,780 | 6,070 | 5,960 | 8,220 | 9,210 | 28,300 | 23,300 | 8,870 | 2,590 | 5,140 | 115,600 |
| 1945-46 | 7,280 | 7,290 | 5,880 | 6,070 | 5,600 | 7,660 | 27,560 | 27,040 | 14,380 | 5,320 | 824 | 4,150 | 119,100 |
| 1946-47 | 6,600 | 6,780 | 6,040 | 4,320 | 6,410 | 11,380 | 11,830 | 61,560 | 22,950 | 8,210 | 1,270 | 3,340 | 150,700 |
| 1947-48 | 6,530 | 6,690 | 6,510 | 6,290 | 9,590 | 10,460 | 9,420 | 26,400 | 10,560 | 3,110 | 1,340 | 1,410 | 98,310 |
| 1948-49 | 6,100 | 6,140 | 5,780 | 4,990 | 7,100 | 11,590 | 10,570 | 23,020 | 13,950 | 954 | 89 | 1,320 | 91,600 |

[1]Oct. 23-31.
[2]Dec. 1-10.
[3]Mar. 18-31.
[4]Apr. 9-30.

irrigate as much as 800 acres. However, in the spring when the mountain snow melts and precipitation is greatest, many of these dams are washed out by high water.

In the valley west of "the red wall",[3] water for irrigation is supplied from reservoirs that are formed by damming perennial mountain creeks. In the Powder River valley north of Sussex, irrigation reservoirs are formed by damming "intermittent" streams, which contribute water to the Powder River during the spring thaws and periods of heavy precipitation.

The proposed Kaycee irrigation project is to be Government sponsored. It has been designed to supply supplemental water to 6,400 acres of land now being irrigated and to furnish water for the irrigation of an additional 10,400 acres of presently nonirrigated land. (See pl. 23.) The project is to include the construction of a dam across the Middle Fork of the Powder River (sec. 33, T. 43 N., R. 83 W.), so that water from the spring thaws can be stored for release during the irrigation season; also the lengthening of the Sahara Canal, so that land west of the Powder River in Tps. 44 and 45 N., R. 78 W., can be irrigated.

## TRANSPORTATION

U. S. Highway 87 is a north-south paved road that passes through Kaycee. State Highway 21A is paved eastward from Kaycee to a point 2 miles north of Sussex; at this point the highway divides, one unpaved branch going north and the other, southeast. The road from Kaycee to Mayoworth, 12 miles northwest of Kaycee, is paved, but the road from Kaycee to Barnum, 24 miles west of Kaycee, is graded.

The nearest railroad is the Chicago, Burlington and Quincy, which operates between Billings, Mont., and Denver, Colo., and passes through Casper, 76 miles south of Kaycee. Cattle are either shipped by truck from Kaycee or driven south along the valley west of "the red wall" to the nearest railroad siding. Several bus and truck lines are routed through Kaycee over U. S. Highway 87. An emergency landing field is located at Sussex, but the area has no regular air service.

## TOPOGRAPHY

That part of the Kaycee irrigation project area east of Kaycee lies in the High Plains subdivision of the Great Plains; the area to

[3]Local name applied to a conspicuous cliff near Barnum. The cliff has formed in resistant strata of the Chugwater formation.

the west of Kaycee is in the Middle Rocky Mountains province. The Kaycee irrigation project area can be divided, west to east, into four topographic belts: (1) the Bighorn Mountains, (2) the mountain foothills and valleys, (3) the cuestas and plains, and (4) the rolling plains.

The Bighorn Mountains rise sharply to a height of about 8,000 feet (in the drainage basin of the Powder River), and the western end of the Kaycee irrigation project area includes a small part of their eastern flank, which is formed by the dip slope of the Tensleep sandstone and rocks of Permian age. Numerous streams have eroded canyons, which are as much as 400 feet deep, in the dip slope. Pine trees, greasewood, and abundant grass cover the areas between the canyons.

The division between the main range and the foothills is marked by a long, northwest-trending valley west of "the red wall." West of this valley, the elevation of the land surface increases rapidly; east of the valley, the rugged foothills are in high relief, but the total increase in elevation is not great. The maximum relief of the foothill belt is about 800 feet; that of the area as a whole is 1,500 feet.

The foothill belt consists of a series of hills and intervening valleys that coincide, in general, with the anticlines and synclines of the underlying geologic structure. The vegetative cover of the foothills changes, according to the type of bedrock exposed, from pine trees to sagebrush, from sagebrush to grass, and from grass to no vegetation at all.

About a mile west of Kaycee the foothill belt is abruptly replaced by the much less rugged terrain of the plains section. Numerous cuestas, or hogbacks, are present in this area. Cuestas are formed by the differential erosion of sandstone and shale strata; erosion of the former produces ridges, and erosion of the latter produces valleys. Most conspicuous among the cuestas is one formed, in part, by the Fort Union formation. It is covered with pine trees and is often referred to as the "great pine ridge."

In the vicinity of Sussex the cuestas and plains give place to the rolling plains. The valley of the Powder River broadens considerably and the river terraces widen and become more extensive. As the gradient decreases, the river gradually becomes sluggish and sediment-laden. The underlying bedrock in this area is the virtually flat lying Wasatch formation of Eocene age. The soft sandstone and shale of this formation produce typical badlands in which buttes and mesas are common. The Pumpkin Buttes, about 20 miles east of Sussex, are about 1,000 feet higher than the surrounding land surface. One isolated gravel-topped terrace in sec. 9, T. 44 N., R. 78 W., now stands as a butte. The vegetation in this part of the Kaycee irrigation project area is xerophytic and consists mainly of grasses, sagebrush, pricklypear, and tumbleweed. The lower river terraces, however, support an abundant growth of cottonwood trees and natural blue timothy grass.

In summary, the area included in the Kaycee irrigation project contains the physical features of both the mountains and the plains. The Powder River changes from a typical rushing mountain stream in the western section of the area to a sluggish, meandering, sediment-laden stream in the eastern plains section. In the mountainous regions the river valley is narrow—in no place more than a quarter of a mile wide—but as the river flows through the flat plains section its valley widens to as much as 3 miles and is bordered by broad terraces.

## GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The rocks exposed in the Kaycee irrigation project area range in age from Pennsylvanian to Recent. (See pl. 22 and chart 1.) Except along the axes of the anticlinal folds in the foothill region, exposures of the older rocks are confined to the western end of the area, on the eastern flank of the Bighorn Mountains; the younger rocks crop out in the eastern part of the area. The youngest consolidated rock in the area is the Wasatch formation of Eocene age. The unconsolidated sediments are stream-terrace deposits of Pleistocene age and alluvium and colluvium of Recent age.

Stream-terrace deposits border the Powder River and its major tributaries. Many of the terraces, the highest of which is 235 feet above the river, are overlain by a wedge-shaped mantle of colluvium, or slope wash, derived from the adjacent valley walls. Recent alluvium, which is sometimes flooded during periods of high water, is present along most of the streams in the area. The thickness, lithology, and water-bearing properties of the formations exposed in the project area are given in chart 1.

Local residents report that the water obtained from wells drilled into bedrock generally is soft and fairly high in mineral content; the water derived from the terrace gravel or alluvial deposits is hard; and the water from the Tensleep, Lance, Fort Union, and Wasatch formations is satisfactory for both domestic and stock supplies.

Some wells yield only small quantities of water; others yield as much as 500 gpm. Well 45–78–26bd, which is believed to derive much of its supply from the Fort Union formation, yields about 25 gpm, which is used to irrigate hay fields.

## PENNSYLVANIAN SYSTEM, TENSLEEP SANDSTONE

The Tensleep sandstone is exposed at the western extremity of the area where its dip slope forms part of the eastern slope of the Bighorn Mountains. The main outcrops are along the sides and bottoms of the deep canyons that have been eroded into the dip slope.

The Tensleep sandstone is about 400 feet thick in this area and consists of light-gray and white to pinkish-white crossbedded fine- to medium-grained sandstone, which in places is porous and friable. The less indurated beds are the more permeable. Moderate-to-large supplies of water are available to wells penetrating an adequate thickness of saturated material. The Tensleep sandstone is recharged by the direct percolation of precipitation and by seepage into the formation from creeks incised into the dip slope. Flowing wells possibly could be obtained by drilling into the Tensleep in the valley west of "the red wall" and in other topographically favorable locations. Local residents report the water to be moderately hard but of excellent quality for domestic use. The chemical analysis of a sample of water from well 43–84–35cc, which was drilled into the Tensleep sandstone, is given in table 6.

## PERMIAN SYSTEM

Overlying the Tensleep sandstone are rocks of Permian age, the dip slope of which forms the lower flanks of the Bighorn Mountains. These rocks consist of two buff to light-brown mottled limestone layers that are separated by a maroon to rust-colored clay layer. Highly distorted fossils and some crinoid stems are present in these beds. These rocks are about 30–40 feet thick and are overlain by the red beds of the Chugwater formation. The lower beds of this sequence were identified primarily by the gray-to-black concretionary chert contained in the limestone. Data pertaining to the water-bearing properties are not available.

## TRIASSIC SYSTEM, CHUGWATER FORMATION

The Chugwater formation is exposed in the western part of the report area in a belt 2–3 miles wide along the foot of the Bighorn

Mountains. It is exposed also on the crests of the Freeman and Red Fork anticlines. The upper and middle parts of this formation form, respectively, "the red wall" and the valley west of "the red wall." The lower part of the formation is somewhat more resistant and mantles the lower slopes of the Bighorn range. The Chugwater formation in this area is about 1,000 feet thick.

The upper part of the Chugwater formation is bright-red to reddish-brown massive fine- to medium-grained sandstone; the middle part is soft red shale or siltstone; and the lower part of the formation is red siltstone and gypsum. Beds of the alabaster variety of gypsum, some as much as 2 feet thick, are present in the lower part of the Chugwater formation.

In some places the sandstone member of the Chugwater formation contains a small amount of water, which probably is too highly mineralized to be suitable for human consumption, although it may be potable for stock.

## JURASSIC SYSTEM

### SUNDANCE FORMATION

Overlying the Chugwater formation is the Sundance formation, which crops out a short distance east of "the red wall" in a belt one-fourth to three-fourths of a mile wide. It is exposed also on the flanks of the Freeman and Red Fork anticlines. The Sundance formation in the report area has an average thickness of about 260 feet.

The upper part of the Sundance formation is light-gray to greenish-gray glauconitic shale containing a hard brown limestone layer at the top. The lower part of the formation is slabby sandstone interbedded with shale and contains yellow sandstone at the base. The Sundance formation was deposited in a marine environment, and it is characterized by a high content of glauconite and by an abundance of fossil remains of the belemnite ***Pachyteuthis*** throughout the formation.

Recharge to the Sundance formation is by the infiltration of precipitation and by seepage from the overlying alluvial deposits. Small-to-moderate supplies of water of poor quality are available to wells that penetrate the sandstone layers of the formation. Wells penetrating this formation flow where structural and topographic conditions are favorable. The chemical analysis of water obtained from well 43–83–31bc, which is 365 feet deep and penetrates the Sundance formation, is given in table 6.

#### MORRISON FORMATION

The Morrison formation, which overlies the Sundance formation, crops out in a northwest-trending belt about 1 mile west of the junction of the Middle Fork of the Powder River and Beaver Creek. It crops out also along the crest of the Middle Fork and Kaycee domes and on the flanks of both the Freeman and Red Fork anticlines. The outcrop ranges in width from a mile in sec. 20, T. 42 N., R. 83 W., to less than 100 feet on the west side of the Red Fork anticline. Although the stratigraphic thickness of the Morrison formation is about 200 feet, the stress of folding in the Red Fork anticline has been great enough to squeeze the incompetent sediments to about half their original thickness.

The Morrison formation is of continental origin and contains many dinosaur bones, gastroliths, and other reptilian remains. It is composed of poorly cemented lenticular beds of fine- to medium-grained sandstone and shale and is characterized by streaks grading from light and medium gray to purple, red, brown, and white. The lower part of the formation contains lenses of massive crossbedded white sandstone as much as 20 feet thick.

Small-to-moderate supplies of water probably are available to wells penetrating saturated beds where recharge is adequate. A well drilled on the Kaycee dome encountered salt water in the Morrison formation. No wells in the project area derive water from this formation.

## CRETACEOUS SYSTEM

### LOWER CRETACEOUS SERIES

#### CLOVERLY FORMATION

The Cloverly formation, which rests on the Morrison formation, is about 30 feet thick in the Kaycee irrigation project area. Because of its resistance to erosion, it is well exposed along the flanks of all the anticlines and domes in the area. The largest outcrops are at the crest of the Kaycee dome, on the eastern flank of the Red Fork anticline, along the axes of the Freeman anticline and syncline, and on the flanks of the Middle Fork dome and syncline.

The Cloverly formation consists of massive, ledge-forming white to light-cream medium-grained friable sandstone that weathers to light brown or pink. It is composed chiefly of clean quartz sand but contains some feldspar and some thin lenses of smallpebble conglomerate. The sandstone is poorly cemented, and in places where the soft underlying Morrison formation has been eroded from beneath it, large blocks have collapsed.

Small-to-moderate amounts of water probably can be obtained from the Cloverly formation where adequate recharge is available. Where the competent sandstone of the formation has been fractured during diastrophism, the joints thus produced probably would provide ample space for the flow of water into wells penetrating the formation. No wells in the Kaycee area, however, obtain water from the Cloverly formation, and no information pertaining to the probable yield of the formation or the mineral properties of the water is available.

### THERMOPOLIS SHALE

In the report area the Thermopolis shale, which overlies the Cloverly formation, forms a more or less continuous belt around all the structures of the area. The outcrops range in width from half a mile along the flanks of the anticlines to as much as 2 miles in the synclinal valleys.

The Thermopolis shale generally is divided into three parts: the lower part consists of soft thin-bedded black shale that weathers dark brownish gray. The middle part is the Muddy sandstone member, which lies about 40 feet below the top of the formation. It is a well-indurated drab buff to brown medium-grained sandstone 5–30 feet thick. The Muddy sandstone member is well known to petroleum geologists as a marker bed. It resembles the Cloverly formation but can be identified by its drab color and the grains of black minerals present in it. In many places the Muddy sandstone member forms conspicuous ledges and is an excellent guide horizon for working out structural relationships. The third, or upper, part of the Thermopolis shale consists of dark-gray shale and lenticular beds of bentonite.

Small amounts of water probably can be obtained from the Muddy sandstone member where recharge conditions are favorable. Very small seeps of foul-smelling water issue from the shale at some places. These probably are the result of the percolation of precipitation into shallow cracks and fissures in the weathered upper part of the exposed rock.

### MOWRY SHALE

The Mowry shale is exposed in the Freeman and Middle Fork synclines, on the flanks of the Kirtley anticline, and on the Kaycee dome. The formation forms an outcrop area of 7 square miles on the southeast side of the Powder River in T. 42 N., R. 83 W., where the Red Fork anticline plunges sharply into the subsurface. Around the Kirtley anticline and the Kaycee dome the outcrop ranges in width from one-eighth of a mile to a mile.

The Mowry shale overlies the Thermopolis shale. It is about 150 feet thick and consists of dark-gray to brownish-gray siliceous shale that weathers to silver gray, thin-bedded sandstone that forms ridges, and relatively thin beds of bentonite. The formation contains numerous well-preserved fish scales and fish bones. Only pine trees grow on the slopes mantled by this brittle shale.

Locally, the Mowry shale yields small amounts of water. Recharge is by the percolation of precipitation in localities where the formation is exposed and some disintegration from weathering has occurred. Joints and bedding-plane fissures in the formation provide space for the storage and flow of small quantities of water. For example, water flowing from a fractured zone in the shale emerges as a spring at the bottom of a hill composed of the Mowry shale (spring 43–82–19ba).

## UPPER CRETACEOUS SERIES

### FRONTIER FORMATION

In the Kaycee area the Mowry shale is overlain by the Frontier formation, which crops out on the flanks of the Kaycee dome and in the trough of the Kaycee syncline. The outcrop covers about 23 square miles and is about 4 miles wide.

Well drillers in this region divide the Frontier formation into the first, second, and third Wall Creek "sands." The first and second Wall Creek "sands" form the prominent cuestas that rise on the eastern flank of the Kaycee dome about a mile west of Kaycee. The first Wall Creek "sand" is composed of interbedded sandstone and shale that is massive and sandy at the top. It lies above the second Wall Creek "sand," which is rust-colored medium- to coarse-grained sandstone containing a 6-foot bed of black-pebble conglomerate. The pebbles are smooth and well rounded and range in diameter from an eighth of an inch to 2 inches. Below the second Wall Creek "sand" is the third Wall Creek "sand," which consists of light- to dark-gray sandy shale containing beds of bentonite in the lower part. The base of these bentonite beds forms the contact with the underlying Mowry shale.

Small-to-moderate supplies of water probably are available to wells that penetrate the Wall Creek "sands" of the Frontier formation. Recharge is by infiltration of precipitation and by seepage from the alluvial deposits of the Middle Fork of the Powder River. The possibility of obtaining water supplies from the Frontier formation in the vicinity of the town of Kaycee was investigated by Warner.[4] He stated that, although there were several springs and a flowing well within 8 miles of Kaycee, the well showed a marked decrease in yield after being pumped for only 24 hours by a 2-inch cylinder pump connected to a 1-horsepower motor.

Samples of water from two wells which are outside the report area but which derived water from the Wall Creek "sands" of the Frontier formation were collected by Warner for analysis. One sample contained 812 ppm of dissolved solids and the other, 1,090 ppm; one had a total hardness of 400 ppm and the other, 460 ppm, of which 129 and 136 ppm, respectively, were noncarbonate. Warner concluded that an adequate supply of water could not be obtained from the Wall Creek "sands" and that the water would require considerable treatment to make it satisfactory for domestic use.

## CODY SHALE

The Cody shale overlies the Frontier formation and is exposed in a wedge-shaped belt having an area of about 27 square miles and ranging in width from 2 miles at the north edge of the project area to 7 miles at the south edge. The town of Kaycee is built on terrace deposits that overlie the Cody shale about 1 mile from the contact of the Cody shale and the Frontier formation.

The Cody shale is 3,000–3,300 feet thick and is composed of medium- to dark-gray marine shale. The lower part is somewhat calcareous and contains large fossiliferous concretions at several horizons. Approximately 1,000 feet below the top of the formation is a lenticular bed of sandstone about 100 feet thick. This sandstone correlates with the Shannon sandstone member of the Steele shale, which is present in the Salt Creek oilfield and which yields both water and oil in some localities.

The larger part of the Cody shale is relatively impermeable and yields very little water. Well 43–81–6cd is the only well known to derive water from this formation. The owner reports that the well can be dipped dry with a bucket and that, although the water is unsuitable for domestic use, it is potable for stock.

[4]Warner, D. A., 1947, Geology and ground-water resources of the Kaycee area, Wyoming. Unpublished report in files of U. S. Geological Survey, Washington, D. C., and the Wyoming State Engineer, Cheyenne, Wyo.

## MESAVERDE FORMATION

Overlying the Cody shale is the Mesaverde formation, which crops out in the Kaycee area in a northwest-trending belt that crosses the Middle Fork of the Powder River 3 miles east of Kaycee. The width of the outcrop is about 1, 200 feet.

The Parkman sandstone member, which forms the base of the Mesaverde formation, is a massive, crossbedded cliff-forming yellow sandstone containing large brown concretions and ferruginous slabby sandstone layers. Pelecypod and gastropod fossils are present near the base of this member, and fossil bones occur near the top. The middle and upper parts of the Mesaverde formation are composed of carbonaceous shale and of brownish slabby sandstone that is pinkish on weathering. The upper part contains a 3-foot bed of glauconitic sandstone. The Mesaverde formation is about 600 feet thick and grades into the overlying marine Bearpaw shale.

Small-to-moderate supplies of water are available to wells penetrating the Mesaverde formation. Recharge is by percolation of precipitation and by seepage from the Middle and South Forks of the Powder River. Well 43–81–10ca penetrates the Parkman sandstone member. Data on the quality of the water in the Mesaverde formation are given in table 6.

## BEARPAW SHALE

Exposures of the Bearpaw shale in the Kaycee irrigation project area range in width from 1, 200–4, 000 feet and roughly parallel the northwest strike of the Bighorn Mountains. The thickness in the Kaycee area averages about 600 feet. The Bearpaw shale is made up of a series of more or less sandy shale and clay layers interbedded with carbonaceous shale that weathers buff and blue. The carbonaceous shale contains organic material having the appearance of seaweed. Exposures of the Bearpaw shale in the vicinity of Buffalo, Wyo., differ considerably in lithology from those in the Kaycee project area. Rocks mapped as Bearpaw shale in the Powder River region are much more sandy than the dark-gray shale exposed at Buffalo. Inasmuch as this part of the stratigraphic section of the Salt Creek oilfield differs from that of the Buffalo region and also from that exposed along the Powder River, the writer believes that the Kaycee project area lies in a transition zone between the Salt Creek and Buffalo regions.

In places where recharge is adequate, the more permeable beds of the Bearpaw shale possibly would yield small quantities of water; however, no wells in the Kaycee area derive water from this formation.

### FOX HILLS SANDSTONE

The Fox Hills sandstone, which overlies the Bearpaw shale, is about 600 feet thick in the Kaycee area and is exposed in a belt paralleling the North Fork of the Powder River and ranging in width from 1,400–2,000 feet.

The lower part of the Fox Hills sandstone consists of a massive, cliff-forming medium-grained sandstone that weathers reddish brown. Overlying this is a medium- to coarse-grained "salt and pepper" sandstone containing a 10-foot layer of carbonaceous shale near its center. The shale is lignitic in its lower part and contains the cephalopod *Baculites* and the pelecypod *Inoceramus.* The sandstone above and below the shale contains numerous borings, possibly of crabs, that have been filled with gray clay. The upper part of the Fox Hills sandstone consists of soft gray shale interbedded with several hard gray shale layers containing pelecypods. The Fox Hills sandstone is overlain by the Lance formation, the lower bed of which is the sandstone designated by petroleum geologists as the "refinery sand."

Moderate supplies of water probably are available to wells penetrating the Fox Hills sandstone. Recharge to the formation is by the infiltration of precipitation and by seepage from the alluvial deposits on the North, Middle, and South Forks of the Powder River. The "salt and pepper" member of the Fox Hills sandstone is poorly cemented and probably transmits moderate quantities of water. However, no well in the area is known to penetrate the Fox Hills sandstone, although possibly well 43–80–20cc1, situated about a quarter of a mile down dip from the outcrop of the Fox Hills sandstone, penetrates the upper beds of the formation.

### LANCE FORMATION

The Lance formation overlies the Fox Hills sandstone and is exposed in the Kaycee area in a belt about 2 miles wide that parallels the outcrops of the other bedrock formations in the area.

The Lance formation is dark or drab and is formed of brownish sandstone and gray sandy-to-carbonaceous shale. The sandstone is a highly crossbedded channel-sand deposit and contains numerous large round or irregular concretions. The carbonaceous shale is progressively more lignitic toward the top of the formation as it grades into the overlying Fort Union formation. The contact between the Fort Union and the Lance formation is shown as a dashed line because its exact location could not be determined. (See pl. 22.)

Because the sandstone of the Lance formation generally is poorly indurated and moderately permeable, wells penetrating the formation where recharge is available yield small-to-moderate supplies of water. The water is reported to be moderately mineralized but potable. Recharge to the Lance formation is by the direct percolation of precipitation and by seepage from the alluvial deposits. Considerable recharge is undoubtedly contributed by the North, South, and Middle Forks of the Powder River and by Salt Creek, which have a combined length of flow across the formation of about 12 miles. Wells 43–81–13bb and 43–80–20cc1 derive water from the Lance formation. However, as stated previously, well 43–80–20cc1 possibly obtains water from the underlying Fox Hills sandstone also.

## TERTIARY SYSTEM

### PALEOCENE SERIES, FORT UNION FORMATION

The outcrop belt of the Fort Union formation in the project area is about 1½ miles wide. North of the Powder River the outcrop belt trends southeast; south of the river it veers eastward. The regional dip is northeasterly and ranges from 20°–30°.

The contact of the Fort Union formation with the underlying Lance formation is transitional; consequently, the lower part of the Fort Union resembles the Lance. The presence of many coal beds, which are interbedded with clay, shale, and sandy shale, give an overall gray or drab color to this part of the formation. The middle part of the Fort Union formation consists of a series of massive sandstone beds, which form the "great pine ridge." The sandstone is medium grained and contains round ferruginous concretions and numerous leaf and stem impressions. It is commonly buff to brown, but in places it weathers to bright red. The upper part of the formation contains also shale and lignitic deposits, and the color reverts to the characteristic gray or drab.

The thickness of the Fort Union formation is not uniform; in the Kaycee irrigation project area its average thickness is about 2,500–3,000 feet. It is unconformably overlain by the Wasatch formation.

Moderate-to-large supplies of water possibly may be obtained from wells that penetrate an adequate thickness of saturated material in the formation. Recharge is by infiltration of precipitation and by seepage from the alluvial deposits of Salt Creek and the Middle Fork of the Powder River and from the overlying Wasatch formation. Several wells, which are thought to penetrate the Fort Union formation in T. 45 N., R. 78 W., yield as much as 25 gpm. Well 45–78–34ba1, which is 473 feet deep, probably penetrates and derives water from the Fort Union formation.

#### EOCENE SERIES, WASATCH FORMATION

The outcrops of the Wasatch formation comprise about 60 square miles in the eastern part of the Kaycee irrigation project area and two small remnants in secs. 12 and 14, T. 42 N., R. 84 W., in the western part of the area. The Wasatch formation consists of two lithologic units.

The basal unit is about 200 feet thick and is composed of lentils of friable white sandstone interbedded with layers of greenish sandy clay that weathers red upon exposure. The strata are nearly horizontal and have a banded appearance. Beds of sandstone containing pebbles of black chert and some crystalline rocks occur in the lower part of this unit and are as much as 5 feet thick. These conglomerates are exposed in secs. 8, 9, and 10, T. 43 N., R. 80 W., and occur as isolated remnants in secs. 21, 22, 28, and 29, T. 45 N., R. 78 W. Although these conglomerate beds are associated with the Middle Fork of the Powder River and presumably represent channel deposits of the ancient river during Eocene time, they probably should not be correlated with the Kingsbury conglomerate member or Moncrief member of the Wasatch of the Buffalo region.

The upper unit of the Wasatch formation consists of shale, bentonite beds that crop out as bare knobs, beds of lignite as much as 3 feet thick, thin lenticular layers of reddish-black sandstone, and massive variegated greenish-gray claystone that weathers various shades of red, the color giving the claystone a streaked appearance. Well-preserved gar-pike scales and mammal teeth were found in anthills in the area, and primate jaw bones with molars in place were collected from the unit 20 feet below the bottom of the bentonite beds that form the bare knobs.

Generally, small-to-moderate supplies of water are available to wells that penetrate the Wasatch formation. The lenticular sandstone layers, however, are fine grained and relatively impermeable—factors that tend to limit the yield. Some wells are reported to yield water that has a decided cathartic effect; other wells yield water of good quality for domestic use. Samples of water were collected from wells 43–79–2dd and 45–78–14cd1; the results of the chemical analysis of these samples are given in table 6.

## QUATERNARY SYSTEM

### PLEISTOCENE SERIES, STREAM-TERRACE DEPOSITS

Seven stream terraces, ranging from 6 to 235 feet above the river, border the flood plain of the Powder River and its major tributaries at various places within the area. The terraces are underlain by deposits of silty and sandy soil 5–40 feet thick, which in turn are underlain by unconsolidated sand and coarse gravel. The gravel contains well-rounded pebbles and cobbles of quartzite and intrusive igneous rocks, and some fragments of agate and petrified wood. From the youngest to the oldest, the terraces are designated 1, 2, 3, 4, 5, 6, and 7. A generalized description of the terrace deposits is given in table 5.

The stream terraces are very narrow in the upper reaches of the major tributaries of the Powder River. In a downstream direction the terrace deposits are progressively finer grained and the terraces are increasingly wider. In the Sussex region the terrace deposits are composed chiefly of silt and sand and the combined width of the terraces is about 3 miles. Generally, the surface of the higher terraces slopes toward the river, owing to the presence of a wedge of colluvium, or slope wash, that mantles the slope between terraces and fans out onto the lower terrace. Only terraces 1 and 2 are flat.

The terrace deposits underlying the irrigated terraces are water bearing. The main source of recharge to this reservoir is the percolation of irrigation water; some recharge, however, is received by infiltration of water precipitated on the area and by seepage from perennial streams. The water level under the irrigated terraces fluctuates considerably from season to season. Wells that penetrate the gravel underlying these irrigated terraces yield a perennial supply of water, but, generally, it is not suitable for domestic use. The presence of a permanent body of ground water in the terrace deposits beneath the higher nonirrigated terraces is somewhat doubtful. Precipitation, which averages 12.11 inches per year, is the main source of recharge to these higher terrace deposits. The fine clay and silt of the colluvial deposits that mantle a large part of the higher terrace deposits is relatively impermeable; consequently, much of the precipitation escapes as runoff and little reaches the underground

Table 5.—*Generalized description of stream-terrace deposits along the Powder River and its major tributaries near Kaycee, Wyo.*

[See pl. 22 for location of terrace remnants]

| Terrace | Height above river level (feet) | Thickness of gravel (feet) | Availability of ground water | Location of largest remnants | Remarks |
|---|---|---|---|---|---|
| 1 | 6-12 | 5 or less | Adequate supplies for domestic and stock wells 4-12 feet deep. | Remnants along larger streams; virtually absent near mountains. | Recharged by precipitation, irrigation, and river inflow. Water quality is poor. Irrigated from several diversion canals west of Kaycee. |
| 2 | 15-25 | 5-10 | Adequate supplies for domestic and stock wells 8-20 feet deep. | Along Powder River. Largest remnants lie east of Kaycee. | Recharged by precipitation and irrigation. Irrigated from Sahara Canal. |
| 3 | 30-50 | 4-15 | Adequate supplies for domestic and stock wells 2-20 feet deep where recharge is available. | Largest remnants around and north of Sussex and in secs. 29 and 30, T. 43 N., R. 82 W. | Recharged by precipitation and irrigation. Water quality is generally poor. Irrigated from Sahara Canal, diversion canals west of Kaycee, and irrigation reservoir in sec. 8, T. 44 N., R. 78 W. |
| 4 | 60-80 | 10-20 | Small-to-moderate supplies for domestic and stock wells 15-25 feet deep where recharge available. | Largest remnants 1 mile east of Kaycee and 2 miles north of Sussex. | Recharged by precipitation and irrigation. Irrigated from Sahara Canal in sec. 1, T. 43 N., R. 79 W. |
| 5 | 90-110 | 10-20 | Water supply doubtful because of dissected condition of terraces. | Largest remnant is 2 miles northwest of Sussex. | Recharged by precipitation. Not irrigated. |
| 6 | 120-150 | 4-30 | Water supply doubtful but largest remnants may yield water. | Largest remnants along North Fork and Middle Fork, in vicinity of Middle Fork reservoir site. | Do. |
| 7 | 215-235 | 15-25 | Water supply doubtful. | Only one remnant; comprises about 50 acres in sec. 9, T. 44 N., R. 78 W. | Recharged by precipitation. Not irrigated. Forms gravel-capped butte. |

reservoir. No wells in the area derive water from the higher terrace deposits.

## RECENT SERIES

### COLLUVIUM

The colluvial deposits range in thickness from about 60 feet to a featheredge and consist of clay, silt, and sand derived from the formation with which they are associated. The most extensive deposits are on the west side of the Powder River, downstream from Sussex. These deposits are relatively impermeable because the fine-grained silty and clayey sediments settle and form compact layers. No wells derive water from the colluvial deposits in the report area, although in some places a little water may be available. It is probable, however, that the water would not be of usable quality.

In the valley west of "the red wall" and along a tributary of Salt Creek in sec. 29, T. 43 N., R. 79 W., the colluvium is intermingled with alluvium. The deposits in the valley west of "the red wall" are derived from the Chugwater formation; the soil formed on them is bright red. Where recharged by seepage from irrigation, these mixed deposits probably would yield small quantities of highly mineralized water.

The combined area of the colluvium and the colluvial and alluvial deposits, undifferentiated, is about 7 square miles.

### ALLUVIUM

Alluvial deposits in the project area are of Recent age and are present only beneath the flood plains of the principal stream valleys. The width of the alluvium ranges from a few feet in the mountainous regions to as much as a mile in the eastern part of the area.

The alluvial deposits consist chiefly of gravel and other materials derived from erosion of the drainage area of the streams. In the eastern part of the area, the decreased gradient results in an increased deposition of silt and sand.

The surface of the alluvium is less than 5 feet above the surface of the river and frequently is submerged during periods of high water. Generally, the water table is no more than 4 feet below the surface of the alluvium. Willows, brush, and weeds grow abundantly on the alluvium. Recharge to the ground-water reservoir is by seepage from the stream and, where adjacent terraces are irrigated, by underdrainage from the terrace deposits.

The alluvium is the source of the public water supply of Kaycee. Before the construction of the Kaycee water-supply system, the residents of Kaycee and most of the ranchers hauled their water from the municipal supply at Buffalo, 50 miles to the north. Warner[5] reports that a water supply for Kaycee was developed by installing collection galleries about 20 feet from the edge of the river to intercept underflow from the Middle Fork of the Powder River. At first fine sand and silt blocked the perforations of the casing, but this was corrected and the town now has an ample water supply.

## STRUCTURE

The Kaycee irrigation project area lies at the western edge of a large structural basin bordered by the Black Hills on the east, the Casper Mountains and the Hartville uplift on the south and southeast, and the Bighorn Mountains on the west. Wegemann (1917) states: "The Bighorn Mountains are flanked on the southeast by several anticlines, arches of strata that rise like a series of waves, each higher than the last, toward the major arch that forms the mountains themselves." Five asymmetrical anticlines in the area have been mapped. In general, the axes of the anticlines parallel the northwest-trending axis of the Bighorn Mountains. The Freeman, Red Fork, and Kirtley anticlines and the Kaycee dome were so named by previous investigators. The dome that interfingers with the Freeman syncline is referred to in this report as the Middle Fork dome. The Freeman and Red Fork anticlines and the Middle Fork dome interfinger in complex fashion with their adjacent synclines. The Middle Fork syncline joins the Freeman syncline in sec. 19, T. 43 N., R. 83 W., and the Freeman syncline and the Red Fork syncline are joined in sec. 34, T. 43 N., R. 83 W. (See pl. 22.) The axis of the Freeman syncline pitches southeast and northwest from an arch that connects the Freeman anticline and the Middle Fork dome (sec. 28, T. 43 N., R. 83 W.).

Two northwest-striking faults intersect the north-trending axis of the Kaycee dome. The displacement of the larger, northeastern, fault is about 500 feet; that of the southwestern fault, 300–400 feet. Between these two faults and parallel to them is a much shorter fault having less displacement. (See fig. 49.) Four other

[5] Warner, D. A., 1947, Geology and ground-water resources of the Kaycee area, Wyoming. Unpublished report in files of U. S. Geological Survey, Washington, D. C., and the Wyoming State Engineer, Cheyenne, Wyo.

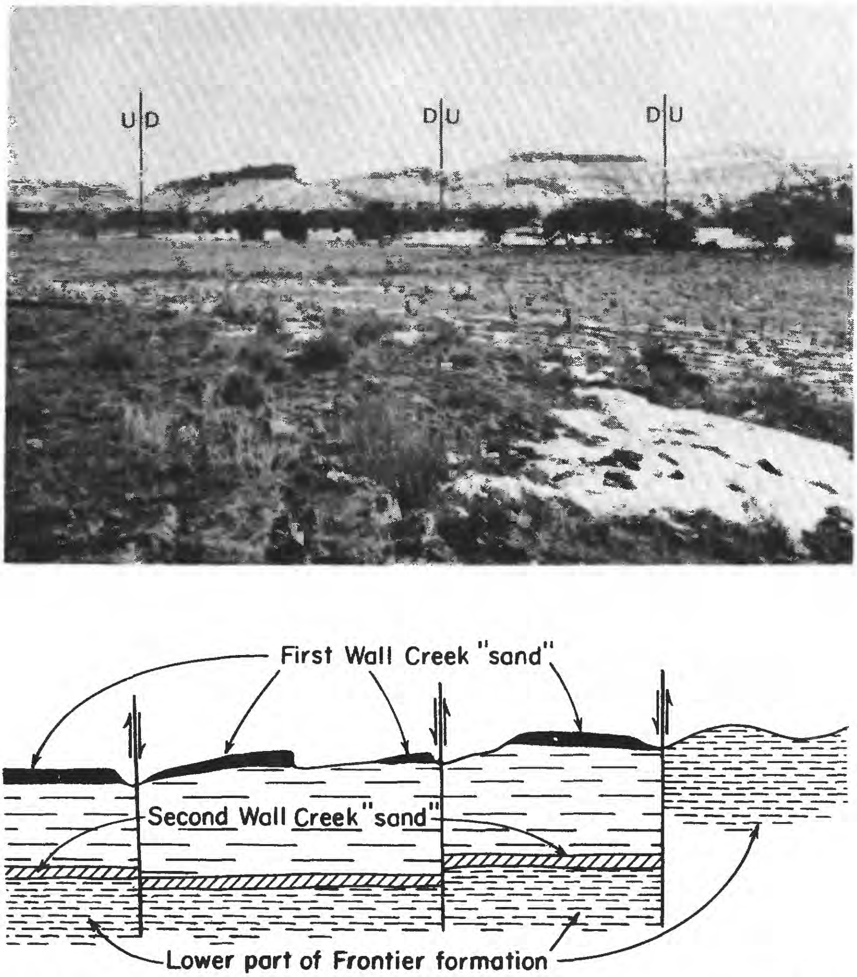


Figure 49. —Faults in the Kaycee dome in sec. 14, T. 43 N., R. 82 W. View southeast across the Powder River from the Barnum road. The dark ledge-forming member is the upper Wall Creek sandstone member of the Frontier formation (first Wall Creek "sand" of drillers). The snow-covered strata at right are shale beds of the lower part of the Frontier formation. *D* (down) and *U* (up) indicate the relative movement along the faults.

faults in the Kaycee dome area were mapped; also, a small strike fault was mapped in sec. 33, T. 43 N., R. 79 W. (See fig. 50.) A fault at the southern end of Middle Fork dome in sec. 9, T. 42 N., R. 83 W., appears to be a vertical north-trending fault that is hinged at its northern end.

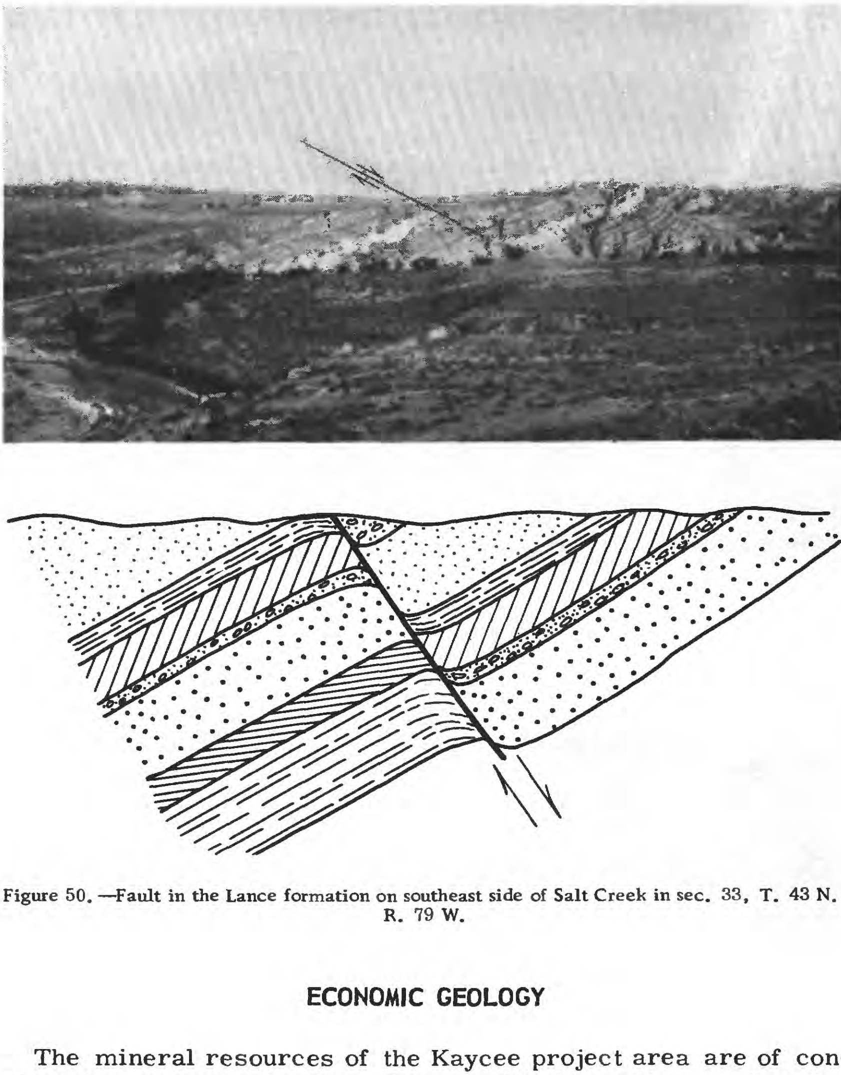

Figure 50.—Fault in the Lance formation on southeast side of Salt Creek in sec. 33, T. 43 N., R. 79 W.

## ECONOMIC GEOLOGY

The mineral resources of the Kaycee project area are of considerable importance. The Sussex oilfield, which is 7 miles southeast of Sussex, is one of the largest in Wyoming. Its development began in 1948; at present (1951), the area between Sussex and Kaycee is being investigated preparatory to extending the field westward. In 1950 an unsuccessful oil-test well was drilled about 6 miles northwest of Kaycee near the Mayoworth road. Earlier, several unsuccessful oil-test wells were drilled on the Kaycee dome. One of these, well 43–82–15bc, which is believed to enter the Madison limestone of Mississippian age, was plugged after water was encountered. The water emerged later as a spring in the alluvial bottom of the Middle Fork. The flow is about 500 gpm; the water is warm (82°F) and highly mineralized. (See table 6.)

Beds of bentonite, as much as 10 feet thick, are present at the base of the Frontier formation and in the lower and upper members of the Thermopolis shale. Bentonite has been mined in several places in the area and these are indicated on the geologic map (pl. 22).

Gravel deposits crop out in numerous places at the edge of stream terraces. The overburden has been stripped from a large gravel deposit in the southeast quarter of sec. 18, T. 43 N., R. 80 W., and the gravel is used in the construction of roads.

The Fort Union and Wasatch formations contain thin seams of lignite. The Babion coal mine in sec. 6, T. 43 N., R. 82 W., has been abandoned. At present (1951) the mining of lignite is limited to "gopher holing" by individual ranchers.

A gold-bearing zone was reported to have been penetrated by an oil-test well drilled in sec. 3, T. 43 N., R. 82 W.

## GROUND WATER

### RECHARGE

The source and rate of ground-water recharge differ widely within the Kaycee irrigation project area. In irrigated areas, the principal source of ground-water recharge is the infiltration of irrigation water. Because of the shortage of surface water during the summer months, the amount of irrigation water applied to the cultivated land probably does not exceed a total of 2 acre-feet per acre. About 1,600 acres of irrigated land north of Sussex is waterlogged, which indicates that much of the irrigation water is reaching the underground reservoir. Precipitation, which averages 12.11 inches per year at Kaycee, is of secondary importance as a source of recharge in areas where irrigation water is applied to the land.

In nonirrigated areas, the ground-water reservoirs are recharged almost entirely by the infiltration of rain and melting snow. Seepage from surface streams and underflow from outside the area also are sources of some recharge.

### DISCHARGE

Ground water is discharged from the Kaycee irrigation project area as underflow, by seepage into the Powder River and its tributaries and into drainage ditches, by small springs issuing from the edges of irrigated stream terraces and along the sides of creeks, by evaporation where the water table is near the land surface, by transpiration of phreatophytes, and by pumping from wells. During July and August the entire flow of the Middle Fork of the Powder River is diverted into the Sahara Canal, but a few miles downstream from the diversion the river is again a flowing stream because of ground-water discharge. Discharge by pumping from shallow wells is small because the water generally is of poor quality and not suitable for domestic use. The amount of water obtained from wells penetrating bedrock ranges from a pumpage of several hundred gallons per day to a flow of 500 gpm (well 43–82–15bc).

## MOVEMENT

### UNCONFINED WATER

Free, or unconfined, water moves along the path of least resistance from a point of higher head to a point of lower head. The direction of ground-water movement coincides with the maximum slope of the water table. Ground water in the terrace deposits and in the alluvium generally moves in a downstream direction toward a flowing stream. The average gradient of the water table in the project area is about 1 foot in 1,000 feet.

### CONFINED WATER

The piezometric surface of an artesian aquifer is an imaginary surface that everywhere coincides with the pressure head of the water in the aquifer. It slopes from the catchment area of the aquifer through all points to which the water will rise in wells tapping the aquifer. Where the altitude of the land surface is less than the altitude of the piezometric surface of an aquifer, wells penetrating the aquifer will flow. The shape and slope of the piezometric surface depend upon the quantity and location of the recharge and discharge, and on the structure and hydrologic properties of the aquifer. Water in the artesian aquifers moves in a direction that coincides with the maximum slope of the piezometric surface.

Bedrock formations in the report area dip generally in a northeasterly direction, but on the western limbs of the various anticlines the dip is in the opposite direction. Recharge to formations older than the Tensleep sandstone is by infiltration of precipitation that falls high on the eastern flank of the Bighorn Mountains. As these formations do not crop out on the crest of any of the anticlines in the foothill region, the ground water moving through them has no natural outlet within the report area. The abandoned oil well 43–82–15bc, which is on the axis of the Kaycee dome (the anticline farthest from the recharge area), penetrates the cavernous Madison limestone and flows at the rate of about 500 gpm from a depth of 1,925 feet. Some of the ground water in the Tensleep sandstone, which also is recharged where it is exposed on the eastern slope of the Bighorn Mountains, is discharged by springs where the formation crops out on the crest of the Red Fork anticline north of the report area. Wells penetrating the Tensleep sandstone probably would yield moderate to large quantities of water of good quality. The depth to the Tensleep sandstone is considerably greater in the synclinal areas than on the anticlines, where the strata overlying the Tensleep have been removed by erosion.

Recharge to the formations younger than the Tensleep sandstone is by precipitation and seepage from streams where the formations crop out on the east slope of the Bighorn Mountains and on the flanks of the geologic structures within the project area.

The water in all the bedrock aquifers in the project area probably is under artesian pressure, but flowing wells are present only in an area west of Kaycee, in the vicinity of Sussex, and in an area north of Sussex.

## WATERLOGGED LAND

Under the larger irrigated terraces perennial ground-water bodies have been formed by recharge from irrigation water. In part of the area, discharge was less than the recharge from irrigation, and consequently water accumulated in the underground reservoir until the water table rose close to the land surface. In some places, the capillary fringe—the zone immediately above the water table in which water is held by capillarity—intersects the land surface and evaporation of water ensues. As evaporation continues, additional water moves upward by capillarity from the zone of saturation and the minerals dissolved in the water are precipitated as a white deposit in the upper part of the soil and on the land surface. This deposit, mainly of calcium and magnesium salts, is commonly referred to as alkali.

At present about 1,600 acres of land north of Sussex is so waterlogged it will not support a healthy growth of plants. This condition exists notwithstanding a shortage of irrigation water during the summer months. Drainage ditches have been dug, but many of them are too shallow to be effective and some are clogged by quicksand and weeds.

The effect of waterlogging and consequent accumulation of alkali is particularly evident in an area on the Rex Yeigh farm, 1 mile north of Sussex. A row of cottonwood trees on this farm grades from a healthy condition in a nonwaterlogged area to a scrubby condition in a waterlogged area. (See fig. 51.) A drainage ditch 5 feet deep was dug to relieve the waterlogged condition which, however, could have been prevented if adequate facilities for drainage had been provided at the time irrigation was begun in the area.

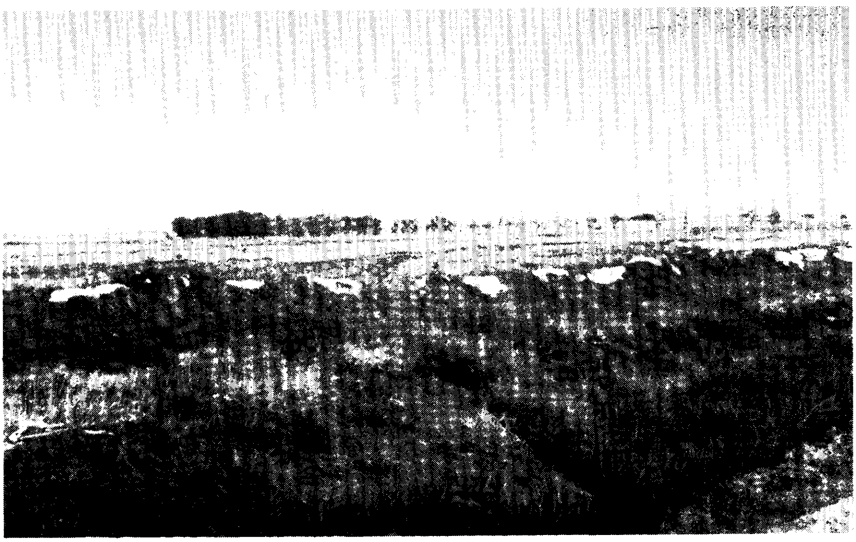

Figure 51. —Drainage ditch 1 mile north of Sussex (in foreground) and waterlogged land on Rex Yeigh farm (in background).

When the Kaycee irrigation project is completed, additional land on the west side of the Powder River north of Fourmile Creek will be irrigated. Several large meadows in this part of the area now support a subirrigated growth of blue timothy, some of which is as much as 3 feet high. The water table under this part of the area apparently is at a relatively shallow depth. It is believed that, when irrigation water is applied, recharge to the underlying terrace deposits will exceed discharge and that at least 25 percent of the irrigable land will become waterlogged unless adequate drainage facilities are installed.

Topographically, the land in this area west of the Powder River and north of Fourmile Creek is conducive to natural drainage.

Steep- to vertical-sided gullies intersect the highest terrace deposits and the overlying colluvium at intervals of less than a mile. These gullies, which were cut by intermittent streams, range in depth from a few feet to 30 feet and make excellent natural drains. When the water table under the highest terrace is raised by recharge from irrigation, springs and seeps probably will emerge along the sides of these gullies and much of the excess ground water will be drained. Although the gullies in that terrace are well developed, some of them have no direct outlet to the river, and the water draining down them will spread out on the lower terraces and percolate into the ground, thus becoming a factor in the waterlogging of the lower terraces.

## CHEMICAL QUALITY OF THE WATER

By F. H. Rainwater

Determination of the chemical quality of water in the Kaycee irrigation project is based on the samples collected during the fall of 1950. Samples of water from the alluvium of the Powder River and its tributaries, from several bedrock formations, and from surface sources were analyzed. (See fig. 52.) Analyses of these samples (see table 6) will aid in evaluating changes in water quality that may result from extension of irrigation. Analyses of surface waters in the Kaycee irrigation project have been reported by Swenson (Hembree, Swenson, and others, 1949).

Where geologic conditions are very diversified, the overall chemical quality of the water cannot be defined from a few analyses. Nevertheless, a discussion of the mineral character of the sampled water and its suitability for irrigation and domestic purposes is of interest to present and potential users.

The quantity and nature of mineral matter in water depend primarily on the type of rock and soil through which the water passes and on the length of time in contact. Figure 53 shows the wide divergence in dissolved-solids content and percentage composition of water from the bedrock aquifers. The reacting values of the various constituents, or concentrations expressed in equivalents per million, where the sum of the predominant positively charged ions (cations) was equal to the sum of the predominant negatively charged ions (anions), were used in the preparation of this illustration.

Table 6.—*Chemical analyses of water of the*

[Analytical results in parts per

| Source | Depth of well (feet) | Date of collection (1950) | Temperature (°F) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Allu** | | | | | | | | | | |
| 43-79-11dd1....... | 12.5 | 9-22 | 54 | 14 | 0.14 | 395 | 197 | 355 | 13 | 385 |
| 43-80-20cc2....... | 16.0 | 8-19 | 50 | 14 | 1.5 | 137 | 69 | 218 | 7.5 | 330 |
| 43-82-12aa......... | 24.4 | 8-19 | ........ | 13 | 7.0 | 395 | 197 | 610 | 6.8 | 565 |
| 43-82-12ad5[1]....... | 17.2 | 9-22 | 57 | 12 | .61 | 171 | 58 | 149 | 6.4 | 274 |
| 43-82-29ac......... | 17.8 | 8-19 | 47 | 14 | .24 | 305 | 146 | 895 | 4.0 | 693 |
| 45-78-33ad1....... | 21.5 | 9-22 | 55 | 13 | .15 | 403 | 137 | 495 | 8.8 | 418 |
| **Wasatch (?)** | | | | | | | | | | |
| 43-79-2dd.......... | 270 | 8-19 | 52 | 2.5 | .14 | 2.5 | 3.0 | 257 | 3.2 | 152 |
| 45-78-14cd1....... | 70.3 | 9-22 | 57 | 7.1 | .67 | 7.5 | 2.7 | 186 | 1.5 | 434 |
| **Fort Union (?)** | | | | | | | | | | |
| 45-78-34ba1....... | 473 | 9-22 | 55 | 9.7 | 0.03 | 4.0 | 0.6 | 141 | 1.1 | 238 |
| **Lance formation-Fox** | | | | | | | | | | |
| 43-80-20cc1....... | 140 | 8-19 | 51 | 13 | 2.4 | 318 | 116 | 780 | 8.0 | 436 |
| **Mesaverde** | | | | | | | | | | |
| 43-81-10ca........ | 400 | 8-19 | 51 | 7.1 | 12 | 55 | 8.9 | 692 | 2.2 | 220 |
| **Sundance** | | | | | | | | | | |
| 43-83-31bc........ | 365 | 8-19 | 56 | 1.7 | 5.0 | 111 | 18 | 1,150 | 17 | 8 |
| **Tensleep** | | | | | | | | | | |
| 43-84-35cc........ | 740 | 8-19 | 61 | 11 | 0.03 | 49 | 25 | 4.0 | 1.0 | 256 |
| **Madison** | | | | | | | | | | |
| 43-82-15bc........ | 1,925 | 8-19 | 82 | 14 | 0.16 | 430 | 129 | 1,830 | 29 | 116 |
| **Surface** | | | | | | | | | | |
| Middle Fork Powder River above Beaver Creek..... | .......... | 8-19 | 56 | 8.7 | 0.02 | 110 | 29 | 26 | | 198 |
| Beaver Creek near mouth.............. | .......... | 8-19 | 57 | 15 | .02 | 200 | 70 | 60 | | 221 |
| Red Fork near Barnum, Wyo........ | .......... | 8-19 | 58 | 9.3 | .02 | 76 | 30 | 31 | | 212 |
| Sahara Canal, 8 miles east of Kaycee............ | .......... | 8-19 | 64 | 7.8 | .02 | 142 | 55 | 164 | | 208 |
| Drainage ditch 1 miles north of Sussex............ | .......... | 8-19 | 67 | 5.6 | .02 | 438 | 197 | 699 | | 300 |
| Drainage ditch ½ mile west of Sussex........... | .......... | 9-22 | 67 | 13 | .20 | 394 | 1,130 | 1,950 | | 572 |

[1]Contains 1.43 ppm manganese. In solution at time of analysis.

*Kaycee irrigation project area, Wyoming*

million except as indicated]

| Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Noncarbonate | Percent sodium | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| vium | | | | | | | | | | | |
| 0 | 1,820 | 207 | 0.5 | 133 | 0.20 | 3,320 | 1,790 | 1,470 | 30 | 3,780 | 7.4 |
| 0 | 668 | 119 | .4 | 2.6 | .10 | 1,400 | 627 | 356 | 43 | 1,880 | 7.4 |
| 0 | 2,280 | 215 | .4 | 2.3 | .20 | 4,000 | 1,790 | 1,330 | 42 | 4,500 | 7.1 |
| 0 | 608 | 106 | .4 | .9 | .10 | 1,250 | 667 | 442 | 32 | 1,670 | 7.4 |
| 0 | 2,540 | 70 | 1.2 | 3.3 | .30 | 4,320 | 1,360 | 792 | 59 | 4,970 | 7.5 |
| 0 | 1,890 | 177 | .6 | 54 | .10 | 3,380 | 1,570 | 1,230 | 41 | 3,920 | 7.4 |
| formation | | | | | | | | | | | |
| 60 | 330 | 23 | 1.4 | 0.2 | 0.10 | 760 | 19 | 0 | 96 | 1,180 | 9.6 |
| 8 | 8.0 | 42 | 1.1 | 1.0 | .00 | 488 | 30 | 0 | 93 | 783 | 8.3 |
| formation | | | | | | | | | | | |
| 10 | 90 | 8.5 | 0.8 | 0.2 | 0.00 | 384 | 13 | 0 | 96 | 600 | 8.6 |
| Hills (?) sandstone | | | | | | | | | | | |
| 0 | 2,320 | 157 | 0.4 | 0.2 | 0.10 | 3,930 | 1,270 | 912 | 57 | 4,570 | 7.4 |
| formation | | | | | | | | | | | |
| 0 | 1,430 | 36 | 0.3 | 2.5 | 0.00 | 2,340 | 174 | 0 | 90 | 3,120 | 7.8 |
| formation | | | | | | | | | | | |
| 0 | 2,750 | 18 | 1.4 | 4.8 | 0.00 | 4,080 | 349 | 342 | 87 | 4,970 | 5.6 |
| sandstone | | | | | | | | | | | |
| 0 | 21 | 2.3 | 0.1 | 1.6 | 0.10 | 240 | 227 | 17 | 4 | 408 | 7.7 |
| limestone | | | | | | | | | | | |
| 0 | 1,500 | 2,830 | 1.6 | 2.7 | 0.30 | 6,820 | 1,600 | 1,510 | 71 | 9,970 | 6.7 |
| water | | | | | | | | | | | |
| 0 | 254 | 15 | 0.2 | 1.0 | 0.10 | 570 | 394 | 232 | 12 | 779 | 8.0 |
| 0 | 695 | 6.0 | .3 | 4.4 | .10 | 1,160 | 787 | 606 | 14 | 1,450 | 7.8 |
| 0 | 153 | 33 | .3 | .7 | .10 | 458 | 313 | 139 | 18 | 677 | 7.9 |
| 0 | 600 | 100 | .4 | 1.1 | .10 | 1,170 | 581 | 410 | 38 | 1,600 | 7.9 |
| 0 | 2,810 | 146 | .7 | 54 | .20 | 4,500 | 1,900 | 1,650 | 44 | 4,900 | 7.7 |
| 0 | 7,740 | 942 | 1.7 | 6.0 | .30 | 12,500 | 5,630 | 5,160 | 43 | 12,500 | 8.0 |

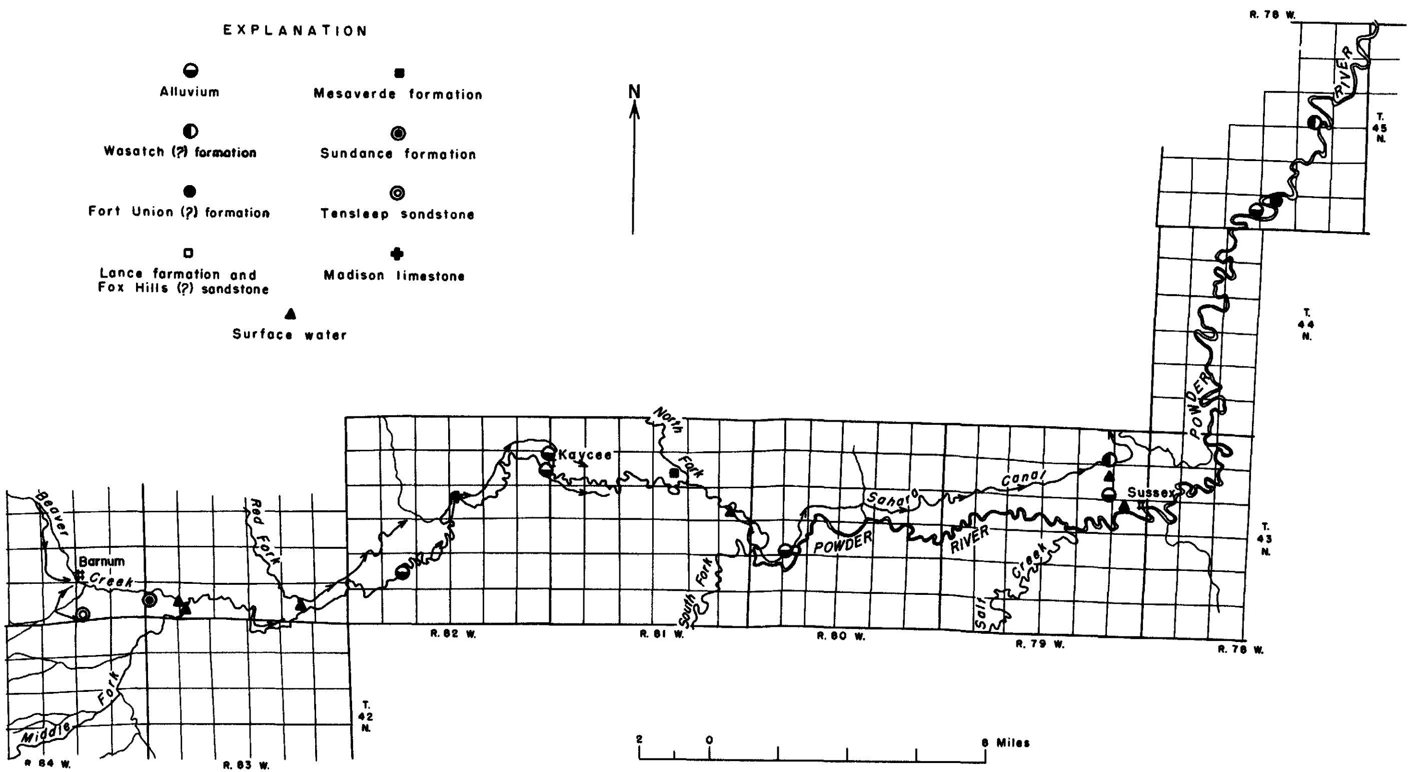


Figure 52.—Location of water-sampling points and geologic source of samples, Kaycee irrigation project, Wyoming.

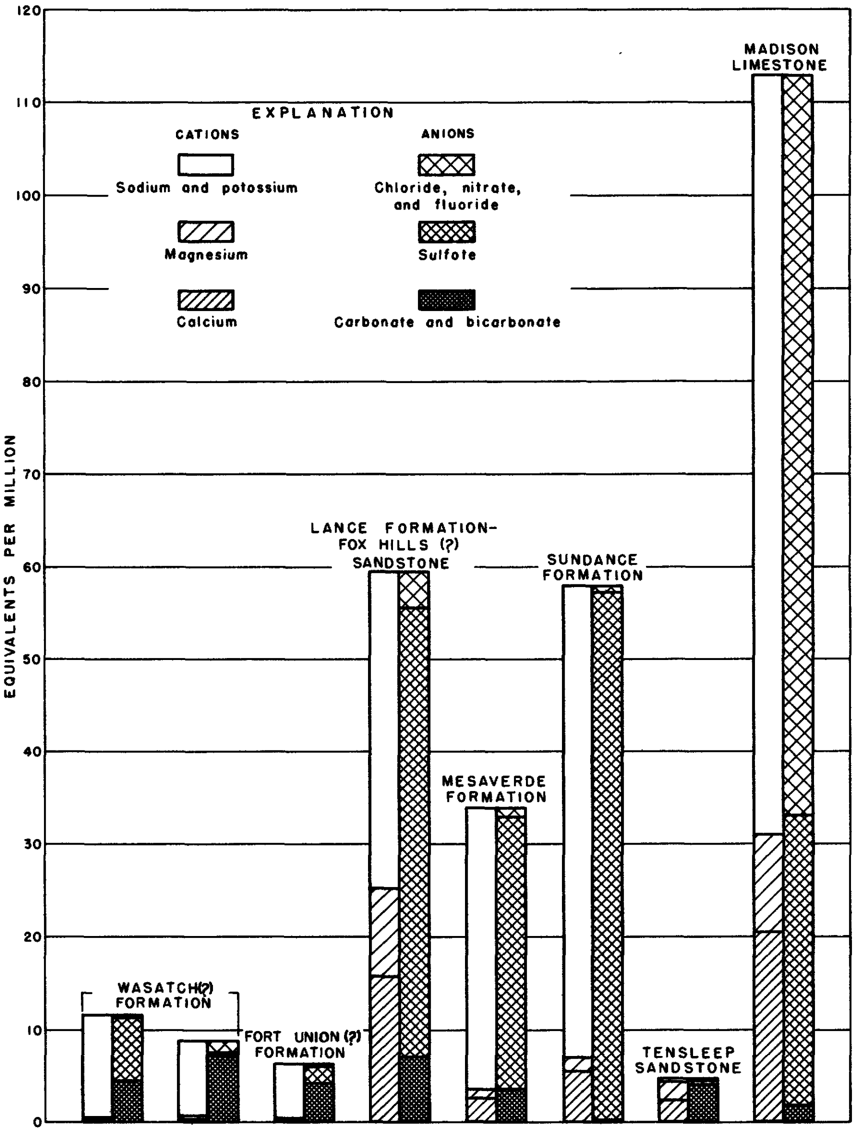


Figure 53. —Chemical quality of water from consolidated rocks, Kaycee irrigation project, Wyoming.

## SUITABILITY FOR DOMESTIC USE

The U. S. Public Health Service (1946) has established certain maximum concentration limitations for potable water to be used by interstate carriers. Although excess concentrations of other than toxic substances do not necessarily preclude the domestic use of water, these limitations are valuable for comparison.

*Recommended limits for certain constituents of drinking water*

[U. S. Public Health Service standards (1946), except as indicated. Expressed in parts per million]

| | | | |
|---|---|---|---|
| Iron and manganese | 0.3 | Fluoride | 1.5 |
| Magnesium | 125 | Nitrate | [1]44 |
| Sulfate | 250 | Dissolved solids | [2]500 |
| Chloride | 250 | | |

[1]Maxcy (1950).
[2]1,000 ppm permissible if water of better quality is not available.

High concentrations of iron and manganese are objectionable in water for domestic purposes because they stain fixtures, utensils, and fabrics. Calcium and magnesium are the principal constituents that make water hard. Hardness limits have not been specified, but if the amount exceeds 200 ppm the water is considered very hard. Water containing large quantities of magnesium in conjunction with sulfate (Epsom salts) has saline cathartic properties. Other salts of sulfate have similar physiological effects but in varying degree. Drinking water containing much more than about 500 ppm of chloride has a characteristic salty taste.

High fluoride concentration in water is known to be associated with a condition of the teeth known as mottled enamel, if the water is used for drinking by children during the period of calcification, or formation, of the teeth (Dean, 1936). However, the drinking of water that contains small quantities of fluoride during the same period has been shown to build stronger and healthier teeth (Dean, 1938). Nitrate in ground water in amounts greater than a few parts per million may indicate previous contamination by sewage or other organic matter, as it represents the final stage of oxidation in the nitrogen cycle. Cyanosis in infants ("blue baby") has resulted from drinking water that has a high nitrate content (Comly, 1945).

Water collected from wells in the alluvium of the Kaycee area is, without exception, highly mineralized and very hard. The total iron content ranges from 0.14 to 7.0 ppm. Water that has these quality characteristics is generally not acceptable for domestic use. Well 43–82–12ad5 furnishes water for the Kaycee municipal supply. Infiltration of more dilute river water into the collection galleries of the well results in a mixed water. The chemical quality of this mixed water is better than that of water from the alluvium.

## SUITABILITY FOR IRRIGATION

Certain chemical constituents of irrigation water supplement soil nutrients and are beneficial to plant growth, whereas excessive quantities of others may be detrimental to plant growth and soil structure. The more important factors that affect the quality of water for irrigation are the total amount of dissolved salts, the bicarbonate content, the boron content, and the relative proportion of sodium.

Water having a high sodium ratio adversely affects the soil texture by the chemical process of cation exchange, by which sodium replaces calcium and magnesium in the soil complex. Percent sodium is calculated by the following equation:

$$\frac{\text{epm Na} \times 100}{\Sigma \text{ epm (Ca, Mg, Na, K)}}$$

Studies in cation exchange in the soil show that dispersion of the soil particles may occur when the percent sodium in irrigation water exceeds 50. Water that has a high percent sodium may cause the soil to become relatively impermeable to the downward movement of water and, thereby, may accentuate drainage problems and bring about saline soils and crop damage.

Wilcox (1948, p. 27) presents a table (see table 7), based on field observations, that classifies water for irrigation on the basis of ionic concentration and percent sodium.

Table 7.—*Classification of water for irrigation*

| Classes of water | | Concentration | | Percent sodium |
|---|---|---|---|---|
| Rating | Grade | Electrical conductance (K x $10^6$ at 25°C)[1] | Equivalents per million | |
| 1.......... | Excellent......... | Less than 250 | Less than 2.50 | Less than 20 |
| 2.......... | Good.............. | 250-750 | 2.50-7.50 | 20-40 |
| 3.......... | Permissible....... | 750-2,000 | 7.50-20.00 | 40-60 |
| 4.......... | Doubtful.......... | 2,000-3,000 | 20.00-30.00 | 60-80 |
| 5.......... | Unsuitable........ | More than 3,000 | More than 30.00 | More than 80 |

[1]Corresponds to unit "micromhos at 25°C", reported in table 6.

The U. S. Salinity Laboratory Staff (1954) utilizes the sodium-adsorption ratio to predict the sodium, or alkali, hazard of an irrigation water, and specific conductance as an indication of the salinity hazard. (See fig. 54.)

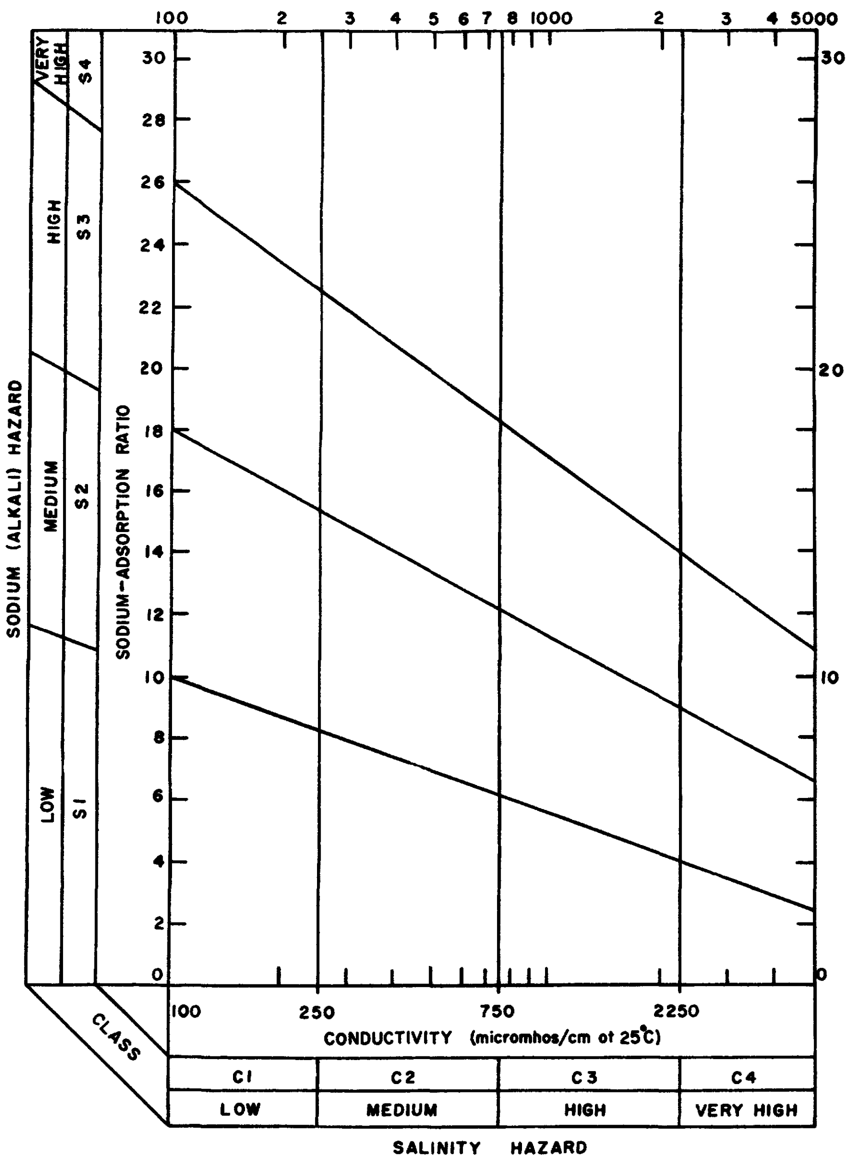


Figure 54.—Diagram for classification of water for irrigation.

$$\text{Sodium-adsorption ratio} = \frac{\text{epm Na}}{\sqrt{\frac{\text{epm Ca + Mg}}{2}}}$$

Of the 6 wells in the alluvium that were sampled, only 2 (43–80–20cc2 and 43–82–12ad5) supply water that can be classified as suitable for irrigation by Wilcox's method. The remainder fall in the unsuitable category. Wilcox's requirements pertain only to water applied to average soils according to usual irrigation practices. Investigators of water quality generally agree that factors such as soil composition, permeability, drainage, irrigation practice, and precipitation must be considered in rating water for irrigation. Water that is unsuitable according to the standards given in table 7 is used successfully in some areas of permeable, well-drained soils.

The relative amount of bicarbonate and of calcium and magnesium also affect the suitability of the water for irrigation. Eaton (1950) has shown that if the salts in a water are concentrated by evapotranspiration to the extent that sparingly soluble calcium carbonate and magnesium carbonate precipitate, the percent sodium will increase. If the amount of carbonate and bicarbonate equals or exceeds the amount of calcium and magnesium, expressed in equivalents per million, the percent sodium could increase to almost 100. Also, the pH of the water increases, and the highly alkaline water may dissolve organic matter from the soil. Such a soil is often referred to as "black alkali."

None of the samples analyzed contained boron in excess of 0.33 ppm, which is the tolerance limit for the most sensitive crops.

## CONCLUSIONS AND RECOMMENDATIONS

This investigation was made prior to the extension of irrigation in the Kaycee area to aid in evaluating the drainage and quality-of-water problems that are likely to develop because infiltrating irrigation water will increase recharge to the ground-water reservoir.

Of the bedrock formations exposed in the area, the Tensleep sandstone and the Lance, Fort Union, and Wasatch formations are the principal aquifers, and small-to-moderate supplies of water can be obtained from them in many localities. Water derived from these formations generally is reported to be usable for domestic purposes.

The unconsolidated sediments underlying both the irrigated terraces and the flood plain contain a permanent reservoir of ground water that yields moderate to large supplies of water to wells. Water from the terrace deposits is reported to be unsuitable for use, and water from the alluvium is highly mineralized, very hard, and generally not acceptable for domestic or irrigation use except where the pumping of wells induces recharge by seepage from the river. Because of poor drainage, a total of about 1,600 acres in the vicinity of Sussex is waterlogged. Much of the waterlogged area is entirely unproductive owing to the concentration of salts in the soil solution.

Much of the waterlogged land probably can be reclaimed by cleaning out and deepening the drainage ditches, which have become clogged by weeds and silt, and by the construction of relief wells in the bottoms of the ditches as an additional aid to effective drainage. Before any construction work is begun, however, a more detailed ground-water investigation should be made. A properly designed and located drain will be much more effective and much less costly than several that are improperly designed or located.

Irrigation of the terraces on the west side of the Powder River north of Fourmile Creek will also result in extensive waterlogging unless effective drainage facilities are provided. An important preliminary step to the design of such facilities should be the installation of a network of observation wells. The periodic measurement of the water level in these wells should be started at least a year before the terraces are irrigated. If, after irrigation is begun, the water level rises persistently in any part of the area, appropriate measures to prevent waterlogging should be taken immediately.

The information derived from the water-quality study will serve as a basis for future comparison to ascertain the nature and extent of changes in water quality brought about by modifications of the present hydrologic regimen in the Kaycee irrigation project. A continuous quality-of-water control study is recommended as a part of the overall plan of area development.

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