# GROUND WATER

# OPEN FILE REPORT

## EVALUATION OF THE COW VALLEY CRITICAL GROUND WATER AREA MALHEUR COUNTY, OREGON

By

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Open File Report 88-01

STATE OF OREGON

WATER RESOURCES DEPARTMENT

GEOLOGY/HYDROLOGY SECTION

RESOURCE MANAGEMENT DIVISION

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## INTRODUCTION

In 1959, Cow Valley became the first Critical Ground Water Area (CGWA) established under Oregon Ground Water Statutes. The CGWA boundary encompasses the irrigated valley floor of a small upland drainage basin, in northern Malheur County, Oregon. Ground water development started in 1949. Decline of ground water levels, well interference, and consequent overdraft of the available ground water supply prompted initiation of the CGWA process. Current ground water right certificates permit irrigation of slightly less than 1800 acres from twelve wells. At present, water levels are rising in response to a reduction in pumpage and several consecutive years of above average precipitation.

The CGWA order states that an annual evaluation of the ground water supply in Cow Valley be completed to evaluate the control provisions of the order. This study is prompted by that requirement.

## PREVIOUS STUDIES

In cooperation with the State Engineers Office (now Oregon Water Resources Department - OWRD), the U.S. Geological Survey completed a ground water study of the Cow Valley area (Brown and Newcomb, 1962). Several investigators studied the geology of the region (Wolff, 1959, 1965; Foxworthy, 1961; and Wagner and others, 1963). Evaluations of the Cow Valley ground water situation were completed by several individuals of the State Engineers Office or OWRD (Sceva, 1961, 1962; Bartholomew, 1979; and Grainey, 1985).

## LOCATION

The Cow Valley CGWA is located in the northern part of Malheur County in eastern Oregon. The valley lies on either side of State Highway 26, approximately 30 miles northwest of Vale. Nearby communities include Brogan and Ironside, which lie respectively east and west of Cow Valley (Figure 1).

The Cow Creek drainage basin referred to in this repot lies up valley from an abandoned earth dam (Pence dam) in Township 15 South, Range 41 East, in the northwest quarter of Section 3 (Figure 1). This 70 square mile basin is drained by the upper reaches of Cow Creek which exits Cow Valley through a gap in the abandoned dam. Cow Creek is an intermittent tributary of Willow Creek which is tributary to the Malheur River.

## WELL DESIGNATION

Designations of wells mentioned in this report are based on the official system for rectangular subdivision of public lands, referenced to the Willamette baseline and meridian. The well number indicates the location of wells by township, range, section, and sequence number (Figure 2). The first numeral indicates the township; the second, the range; the third, the section; and the fourth, a sequence number indicating one or more wells in the same subdivision. The letters following the section number locate the well within the section. The first letter denotes the quarter section (160 acres); the second, the quarter-quarter section (40 acres); and the third, the

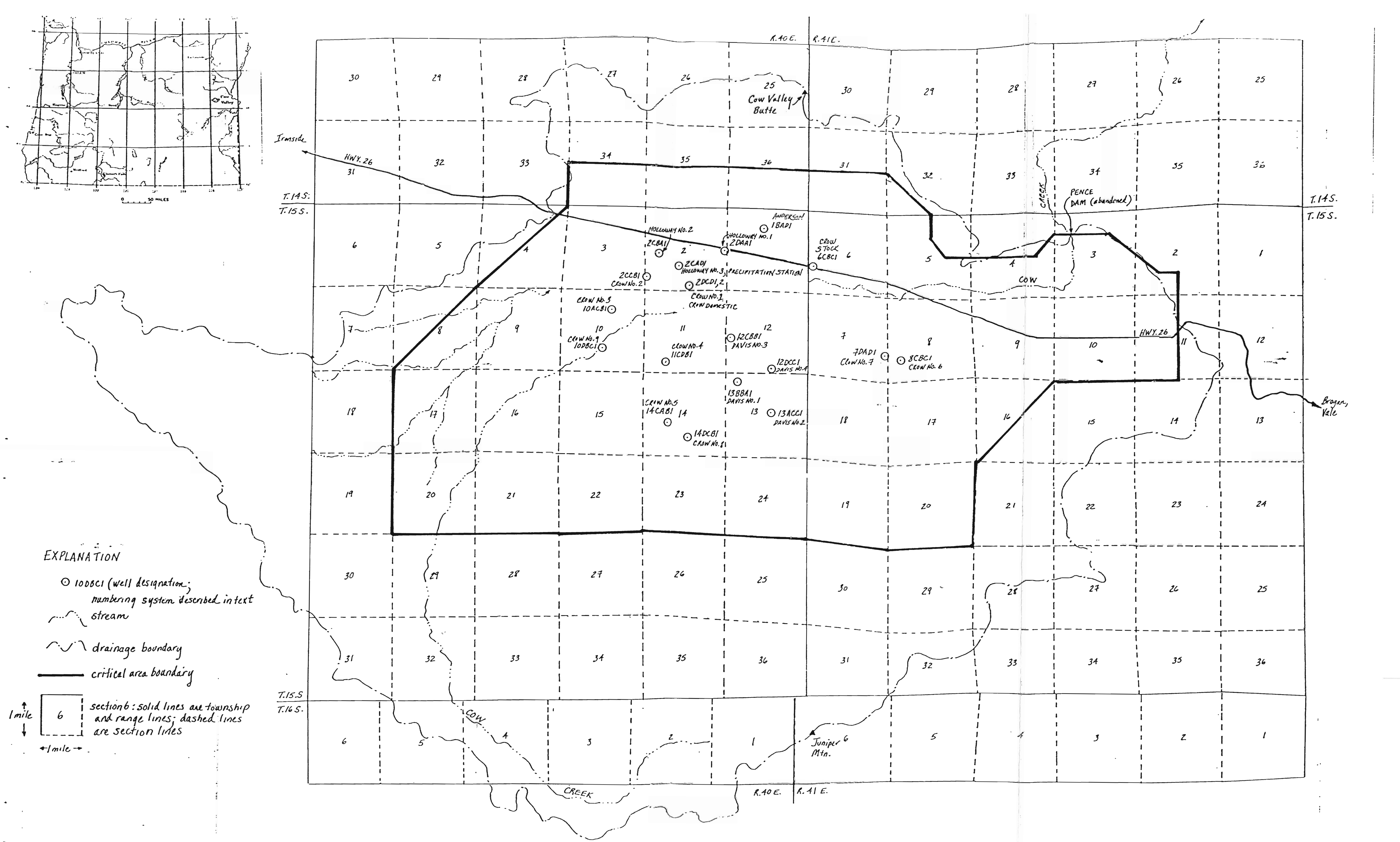



Figure 1. Map of the Upper Cow Valley drainage basin showing representative wells and the location of the Cow Valley Critical Ground Water Area, Malheur County, Oregon.

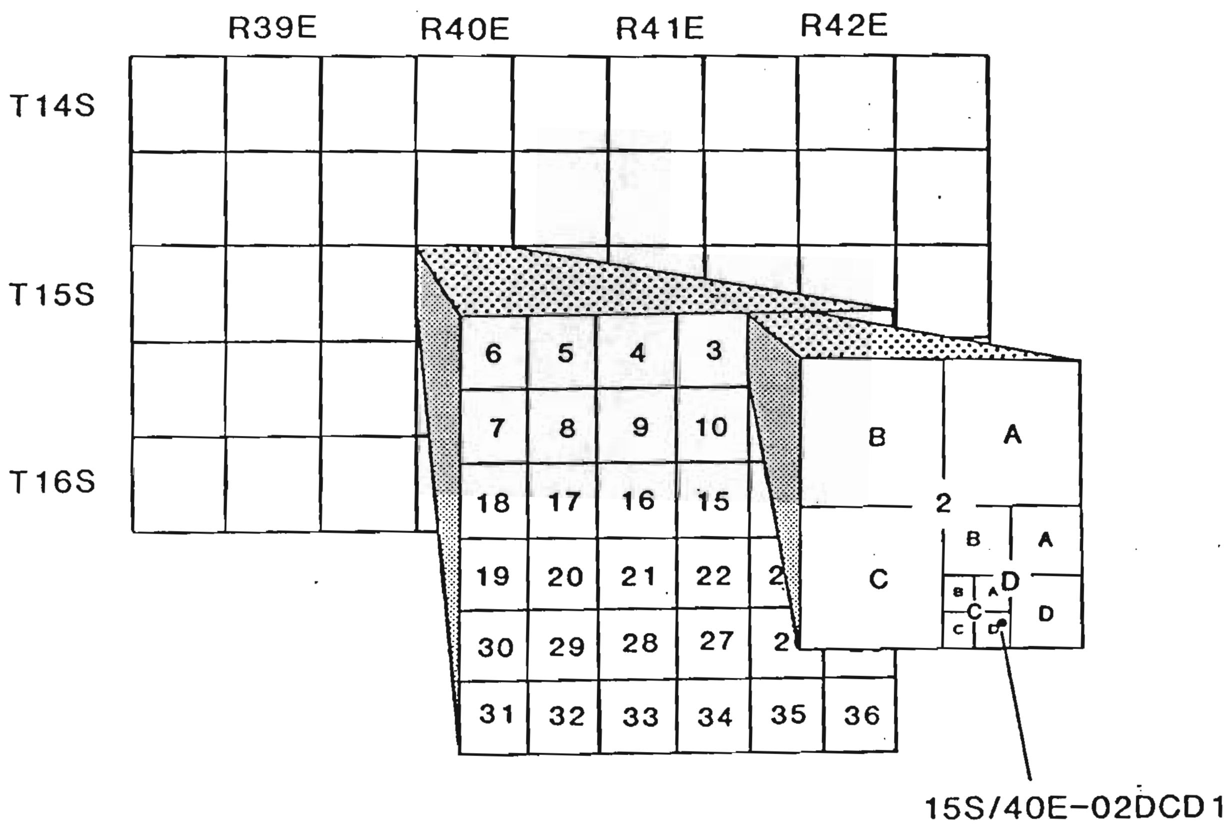



Figure 2. Well numbering system.

quarter-quarter-quarter section (10 acres). For example, well number 15S/40E-02DCD1 is in Township 15 South, Range 40 East, in the southeast quarter of the southwest quarter, of the southeast quarter of Section 2.

## PHYSIOGRAPHY

Landforms in Cow Valley and the surrounding area are somewhat controlled by rock type and structure. Block faulting created east-west trending depressions that now contain the major drainages. Cow Valley is an east-west trending basin formed by block faulting, with a normal fault on the south side of the valley (Brown and Newcomb, 1962; Wolff, 1959, 1965). The south side of the fault is upthrown. Other similar features occur in the area, trending east, or northwest (Wolff; 1959, 1965).

Cow Valley Butte is a roughly circular feature that formed when granitic rocks intruded older metamorphosed marine sediments. The lower slopes of Cow Valley Butte are covered by colluvium eroded from the upper slopes of Cow Valley Butte. These sediments form coalescing alluvial fans (bahadas) which grade into pediments closer to the hills. Cow Valley Butte rises to over 5400 feet, approximately 1500 feet above the floor of Cow Valley.

There are more than 2500 feet of relief between Cow Valley and the Juniper Mountain area to the south. The Juniper Mountain area contains metamorphosed marine sediments that represent the southernmost exposure of the Blue Mountains uplift (Wagner and others, 1963). Cow Valley Butte and Juniper Mountain respectively form the northern and southern boundaries of the Cow Valley drainage basin.

Cow Valley proper lies in the northern portion of the drainage basin and is approximately nine miles long (east-west) and four miles wide (north-south). The only natural discharge point from Cow Valley is at Pence Dam at approximately 3845 feet in elevation. The valley floor where the wells are located averages 3900 feet in elevation.

Cow Valley is drained by the upper reaches of Cow Creek (Figure 1). The creek has seldom flowed entirely through the valley; apparently only during periods of unusually high runoff (Brown and Newcomb, 1962). Physical evidence of a channel south of the highway has been obliterated in part by farming activities. Apparently, flow from upper Cow Creek commonly disappears into the ground near the area of the northeast quarter of Section 20, Township 15 South, Range 40 East. North of the highway, the Cow Creek channel runs generally east then northward to exit the valley through a gap at Pence Dam. Other small intermittent stream channels form on the slopes of Cow Valley Butte and Juniper Mountain. These streams are tributary to Cow Creek. They seldom carry enough water to reach the valley floor and/or the channel of Cow Creek.

## CLIMATE

Hot, dry summers and moderately cold winters characterize the northern Malheur county climate. The weather is affected by elevation, with more precipitation falling in the uplands than in low lying areas. No official climate station exists in Cow Valley. However, the local watermaster collects precipitation data from a storage gage established there in the summer of 1963. The gage site is located near one of the Cow Valley observation wells (Holloway No. 3, at 3911 feet in elevation) in the west end of the valley (Figure 1). Mean annual precipitation equals 11.40 inches per calendar year over the period of record (1964 to 1986). Annual precipitation ranges from 5.36 inches in 1966 to 19.05 inches in 1978 for this same period (Figure 3).

A climate station exists at Ironside approximately 11 miles west of the storage gage in Cow Valley. This station lies at 1915 feet in elevation situated in the rise of foothills surrounding the valley floor. The valley floor at Ironside averages about 3800 feet in elevation (about 100 feet lower than the valley floor of Cow Valley). The Ironside station was established in 1909, but the precipitation record is incomplete. Records were kept from 1909 to 1915 and then from 1956 to the present. Some monthly data was interpolated from nearby stations for the period 1957 to 1986.

During water years (WY) 1957 to 1986, precipitation averaged 11.84 inches per water year (WY 1957 is the precipitation measure from OCtober 1, 1956 to September 30, 1957). Precipitation data ranges from 6.55 inches in WY 1977 to 18.01 inches in WY 1982 (Figure 4a). The greatest monthly precipitation occurs during the months of December and January (Figure 4b). Cumulative departure from the WY average for 1957 to 1986 is shown in Figure 4c. Below average periods of precipitation are indicated by a decrease in slope (from left to right) and conversely above average periods of precipitation are shown by a rise in slope.

The nearest climate station with a long term record exists at Vale about 30 miles southeast of Cow Valley. At 2242 feet in elevation, the Vale station is more than 1600 feet lower than Cow Valley and has a different geographic setting. The climate record at Vale begins in 1891; however, the precipitation record is incomplete during 1915 to 1920. A relatively complete WY record exists from 1921 to 1986. During this period, the WY average equals 9.17 inches. WY precipitation totals range from 4.73 inches in 1939 to 15.68 inches in 1983 (Figure 5a). The highest monthly precipitation occurs during December and January (Figure 5b). The cumulative departure from the long term average is shown in Figure 5c. Climatic data from the Vale station was used to characterize the Cow Valley climate in the past because of the lack of other nearby climate stations.

Currently, the Ironside climate station has the most representative existing climate data for the Cow Valley area. However, the short period of record (1957 to 1986) precludes any strong reliance on a calculated long term average of the available precipitation data. The same is true for the Cow Valley record. The storage gage measurements are valuable data but the annual total is represented by only two yearly measurements. The margin for error in measurement is great. A further caution in evaluating precipitation data is the tendency to extrapolate point data (a single precipitation collection point) over the entire basin.

A comparison of Ironside and Cow Valley data indicates a calendar year average of 12.12 inches and 11.40 inches respectively for the same period of record (1964 to 1986). These figures may indicate that the Cow Valley basin receives a slightly smaller amount of precipitation than the nearby Ironside basin. The Vale average for this period is 10.18 inches. The Vale and Ironside data indicate that this period between 1964 to 1986 may be generally wetter than

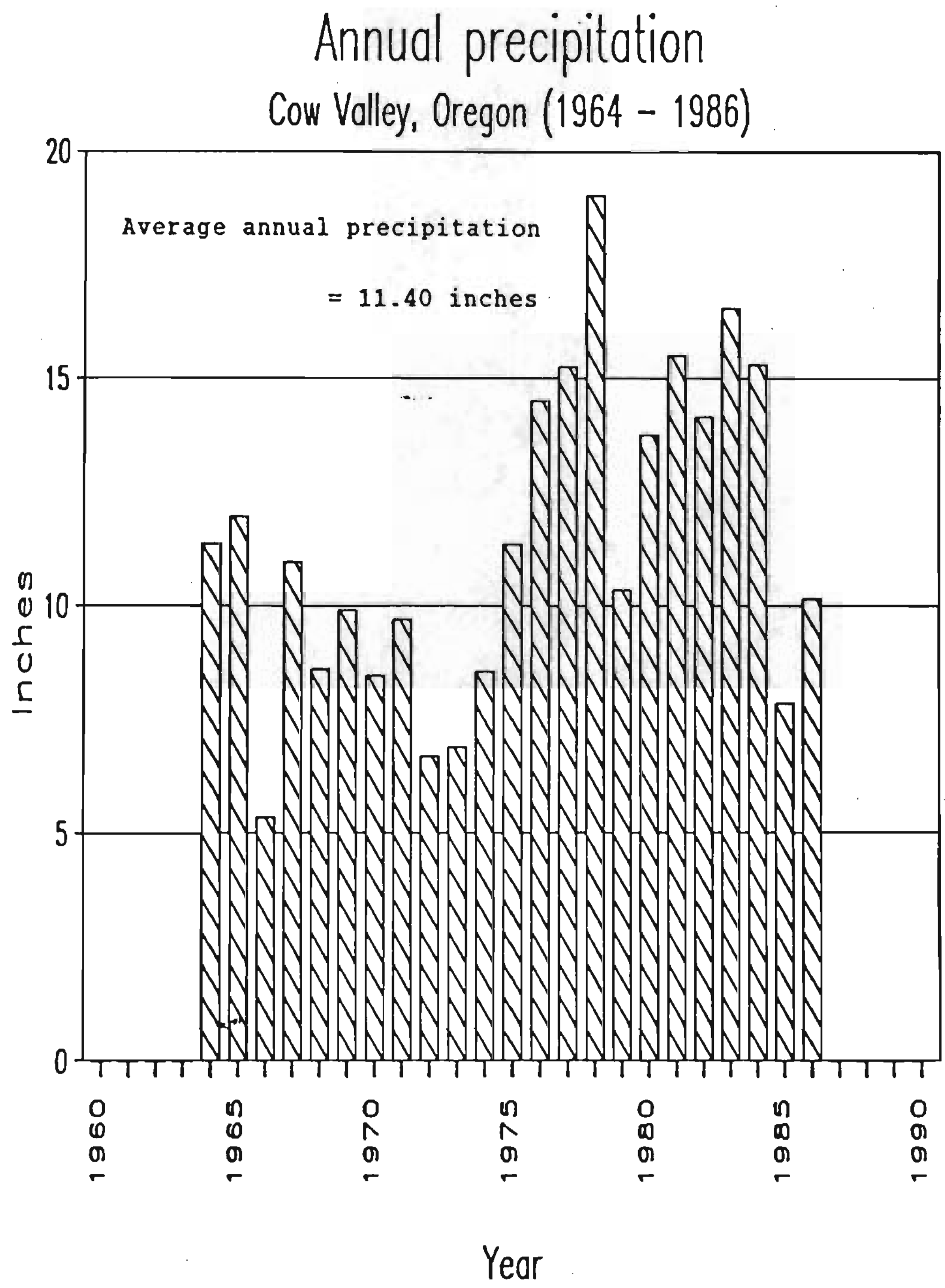
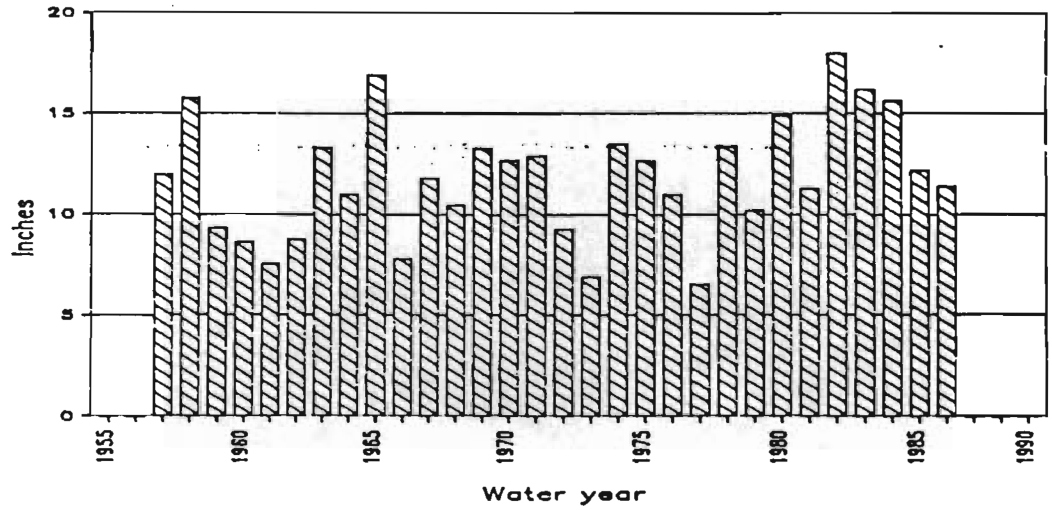
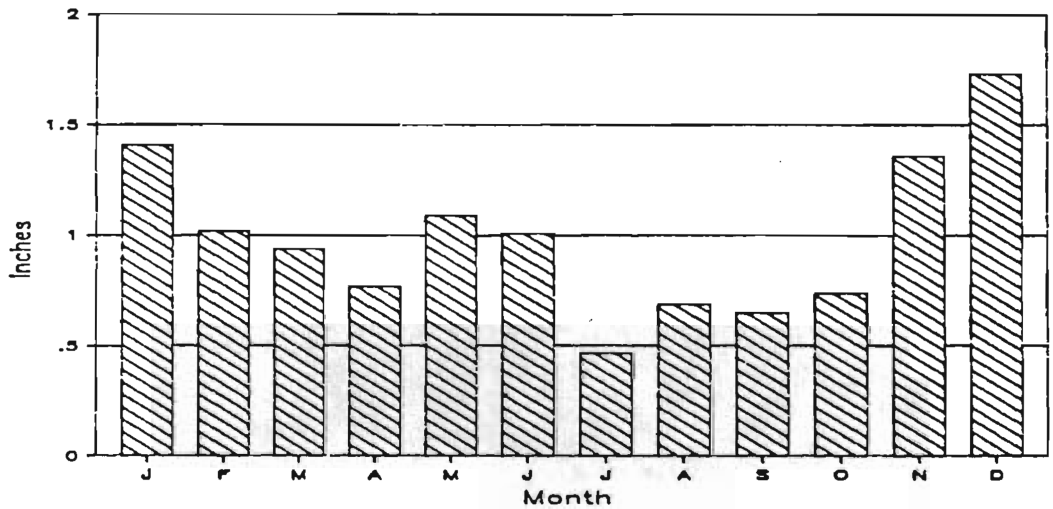


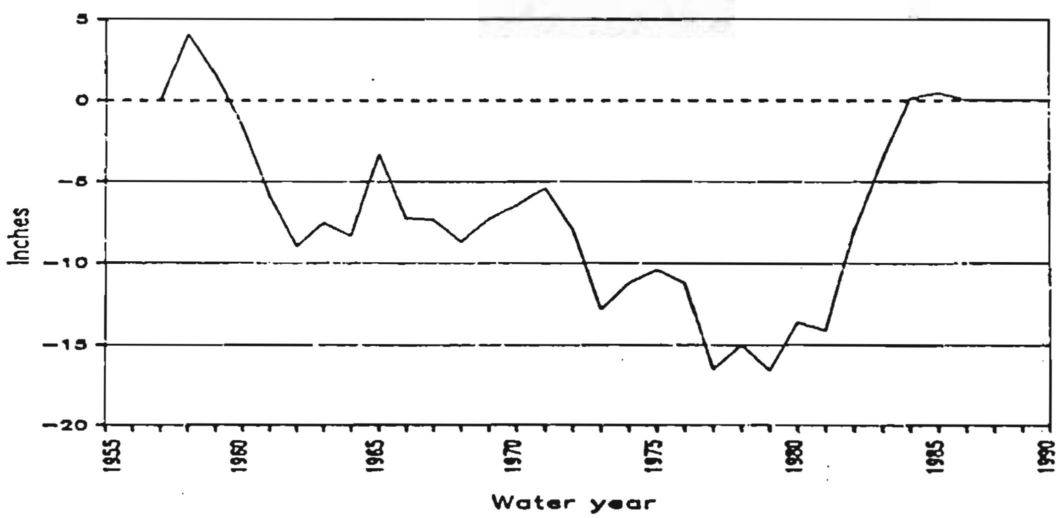

Figure 3. Annual precipitation at Cow Valley, Oregon (1964 - 1986).




4a. Water year precipitation.

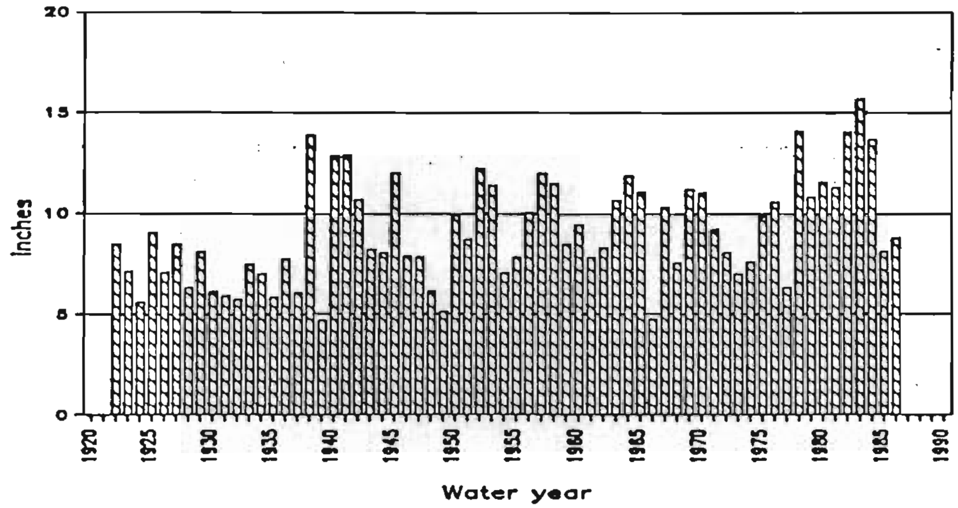



4b. Average monthly precipitation.

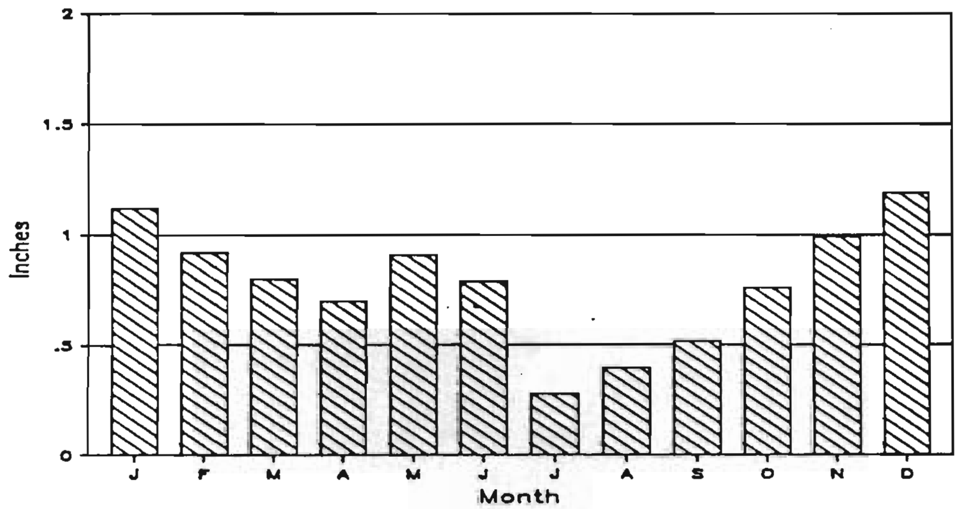



4c. Cumulative departure.

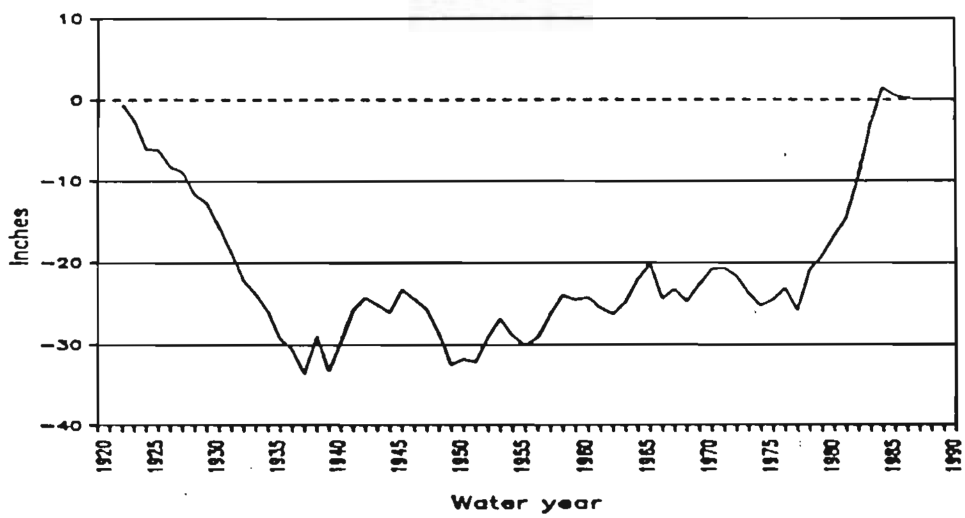
Figure 4. Precipitation data at Ironside, Oregon (1957 - 1986).




5a. Water year precipitation.




5b. Average monthly precipitation.




5c. Cumulative departure.

Figure 5. Precipitation data at Vale, Oregon (1922 - 1986).

the long term average. For this study, the Ironside data has been assumed to be more useful than the Vale and Cow Valley data to characterize the Cow Valley basin climate.

In addition to precipitation data, temperature data exist for the period from 1956 to 1986 at the Ironside station. January temperatures average 23 degrees Farenheit (F) and July temperatures average 70 degrees for this period of record. The number of frost free days average 111 days per year from 1956 to 1986.

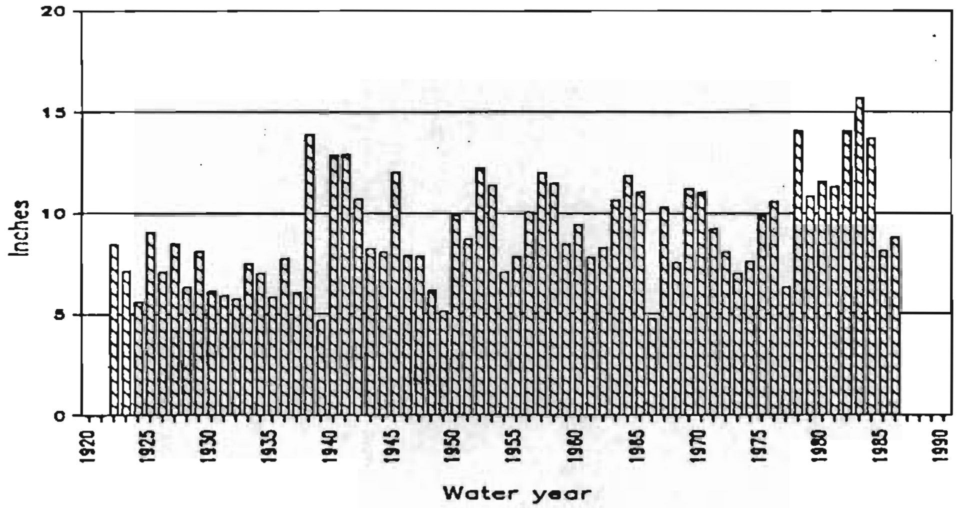
## GEOLOGIC HISTORY

Geologic mapping of the Cow Valley area forms part of some unpublished graduate work (Wolff; 1959, 1965). Other workers studied Jurassic exposures in the Juniper Mountain area (Wagner and Brooks, 1963). Reconnaissance mapping of the Cow Valley area is included in a ground water study (Brown and Newcomb, 1962) and a geologic research paper (Foxworthy, 1961). A generalized stratigraphic column displays the geologic units in the regional area (Figure 6). Figure 7 shows representative logs of wells in the Cow Valley area.

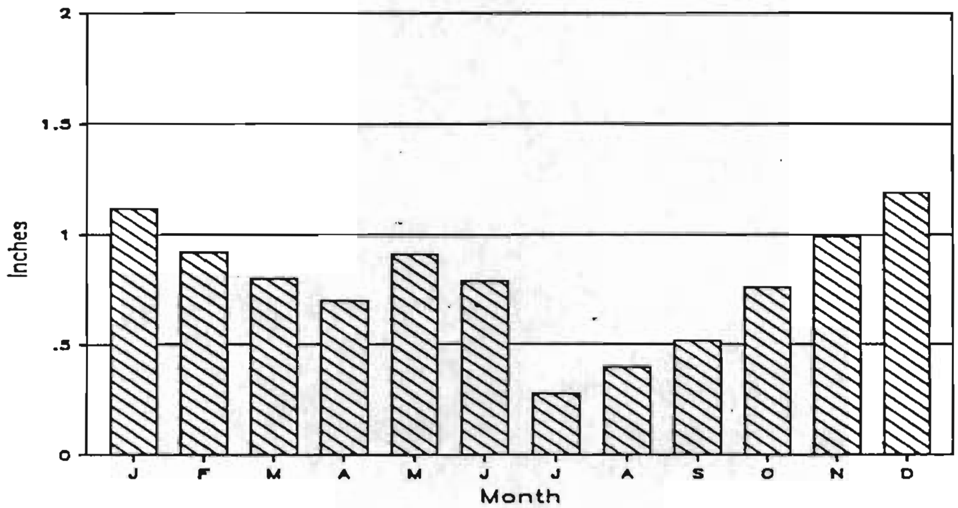
Jurassic exposures in the Juniper Mountain area, along the flanks of Cow Valley Butte and along Brogan Hill Summit form the oldest rocks found in the area. These rocks consist of metamorphosed marine sediments such as shales, sandstones, limestones, and conglomerates. These Jurassic exposures represent the southernmost extent of pre-Tertiary rocks associated with the Blue Mountains uplift in eastern Oregon (Wolff; 1959, 1965). The Blue Mountains uplift began early in Mesozoic time and continued throughout most of the era. Sediment deposition and deformation occurred concurrently. A well penetrates more than 750 feet of these sediments in the west end of Cow Valley (Crow No. 9).

In late Mesozoic time, Cow Valley Butte formed as a result of emplacement of a granitic intrusive. Indirect evidence correlates the age of the butte with that of the Wallowa and Idaho Batholiths (Wolff, 1965). Uplift and erosion continued and a hiatus in sediment deposition lasted until Miocene time.

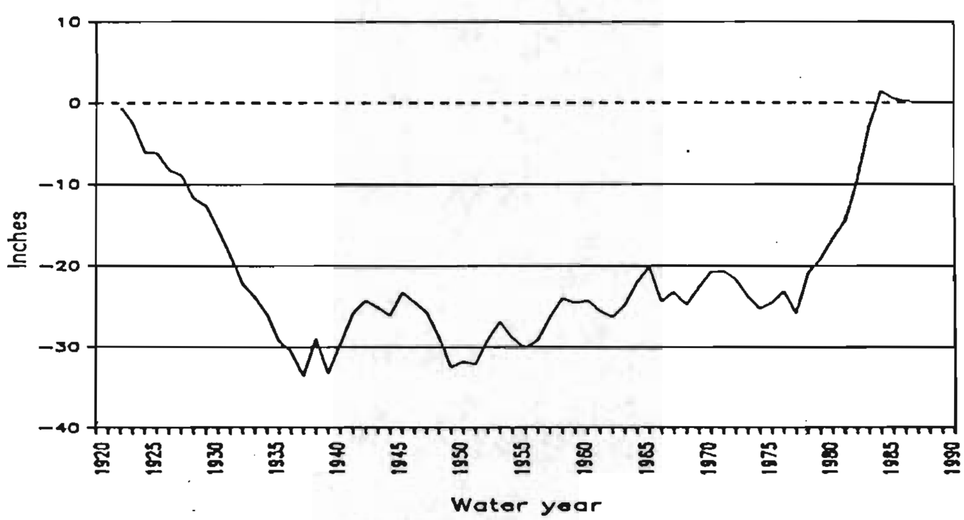
Extrusion of Columbia River basalts occurred to the north and northwest during Miocene time. Deposition of a series of other volcanic rocks occurred in the Cow Valley area. These rocks include tuffs, basalts and rhyolites. A well penetrates more than 200 feet of these rocks in Cow Valley (Holloway No. 2). These Miocene volcanic rocks unconformably overlie rocks of Jurassic age. Sometime after the volcanic rocks were deposited normal block faulting occurred along northwest trends. Mudflows and fluvial material began to fill basinal areas. Pliocene block faulting occurred in an east-west direction creating present day basins such as Cow Valley. Basin filling continued during this time. In late Pliocene to Pleistocene time, basalt flows covered portions of the regional area. During Pleistocene to Recent times streams have cut through these flows into underlying rocks partially clearing the fault block basins.




5a. Water year precipitation.




5b. Average monthly precipitation.




5c. Cumulative departure.

Figure 5. Precipitation data at Vale, Oregon (1922 - 1986).

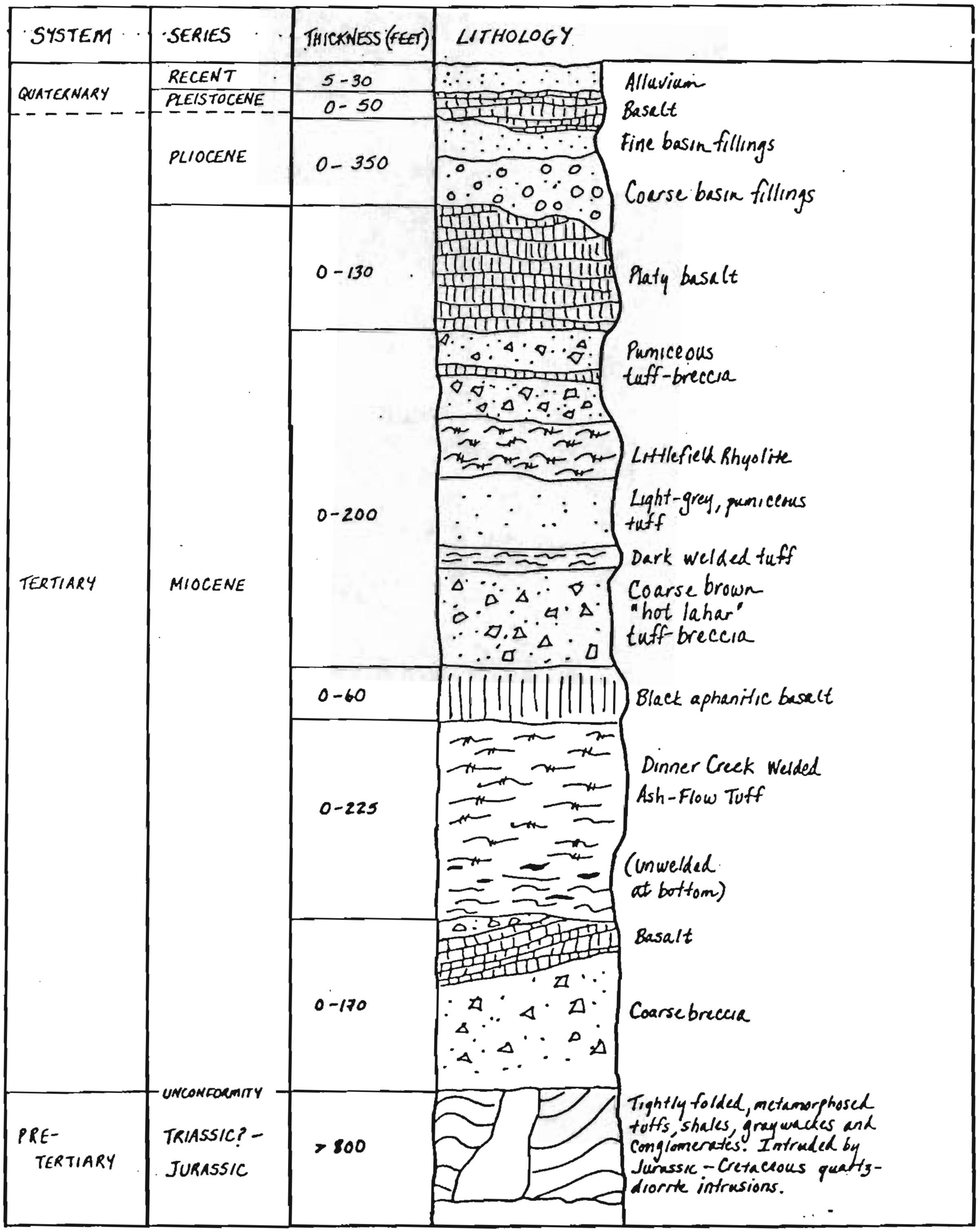
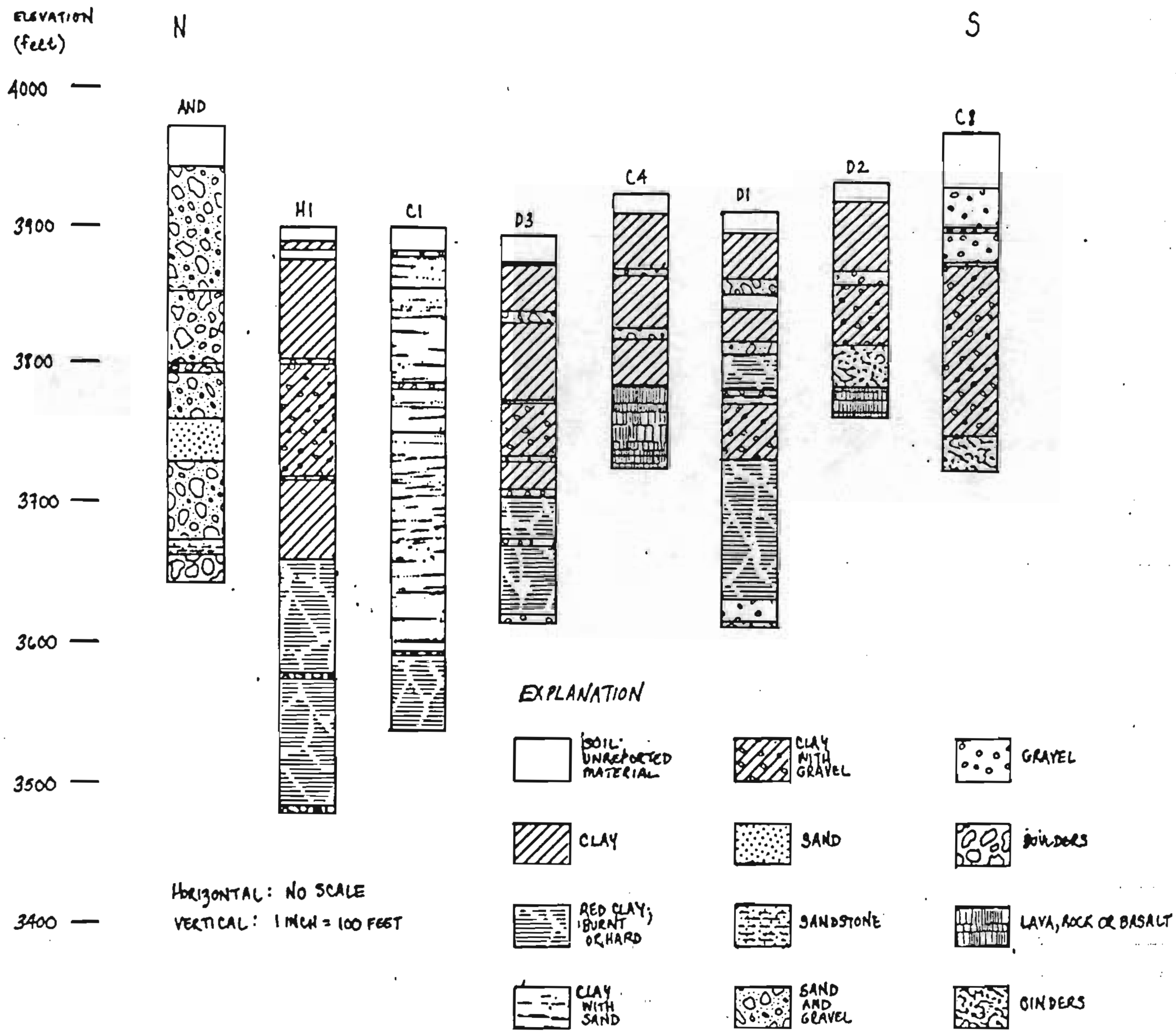



Figure 6. Generalized stratigraphic column of geologic units in regional area (after Wolff; 1959, 1965).

Figure 7. Logs of selected wells in Cow Valley.



SURFACE WATER AND GROUND WATER DEVELOPMENT

Farmers and ranchers started irrigation in Upper Cow Valley near the turn of the century (Declaratory Decree No. 9231-E, 1977). After the spring thaw, Upper Cow Creek provides enough water to irrigate small plots of alfalfa hay and pasture. Surface water rights exist for irrigation of about 210 acres (Figure 8). Priority dates range from 1901 to 1905. Irrigators continue to use these rights.

Surface water filings for stored water existed for a lower section of Cow Creek (Section 10, 11, Township 15 South, Range 40 East) in the late 1940's. The two reservoirs that were constructed could not store water over any long period of time. Stored water infiltrated the permeable valley floor behind the dams. This infiltration presumably resulted in elevated water levels in nearby wells (Brown and Newcomb, 1962). Abandonment of the reservoirs eventually occurred. The surface water permits were cancelled in 1981.

Stock and domestic wells comprise the only ground water use in the valley prior to 1950. A dry climate prevented any major crop use of the land. The valley floor was used mainly for grazing. Drilling of the first irrigation well initiated rapid ground water development. Irrigation wells could produce more than 1000 gallons per minute (gpm) from the Cow Valley ground water reservoir. Drillers completed seventeen irrigation wells between 1949 to 1955 (Table 1) in a nine mile2 area. Ground water rights were issued for twelve of these wells. Two wells operated without ground water permits from 1955 to 1959. Three wells never pumped from the ground water reservoir.

Interest soon developed concerning the quantity of ground water available. The U.S. Geological Survey (USGS) selected two observation wells in 1950 for water level measurement in Cow Valley. In 1954, the Oregon State Engineer requested an investigation by the USGS on ground water resources in Cow Valley. In late 1959, Cow Valley became the first critical ground water area in the state. The order set forth certain control provisions and designated the critical area boundary (Figure 1).

Enforcement of the control order started during the 1960 irrigation season. Two wells previously operating without permits were shut down. Pending applications were rejected. Cow Valley was closed to further appropriation of ground water. Flowmeters were installed on all active irrigation wells. The order provided for appropriation of ground water totaling 5289.30 acre-feet per year. Rights presently exist for 5275.80 acre-feet per year. The difference relates to a change in place of use. Priority dates range from 1950 to 1954 for twelve irrigation wells (Table 2).

RECHARGE

Recharge occurs to the valley from precipitation as noted from examination of wate level data. Downward percolation of precipitation and runoff from the surrounding alluvial fans and valley floor occurs during the late fall to early spring. Geomorphic and geologic conditions indicate that precipitation may be the only source of recharge to the Cow Valley basin.

Cow Valley is situated in an upland basin that is higher in elevation than similar basins to the west, north, and east (Ironside, Willow Creek, and

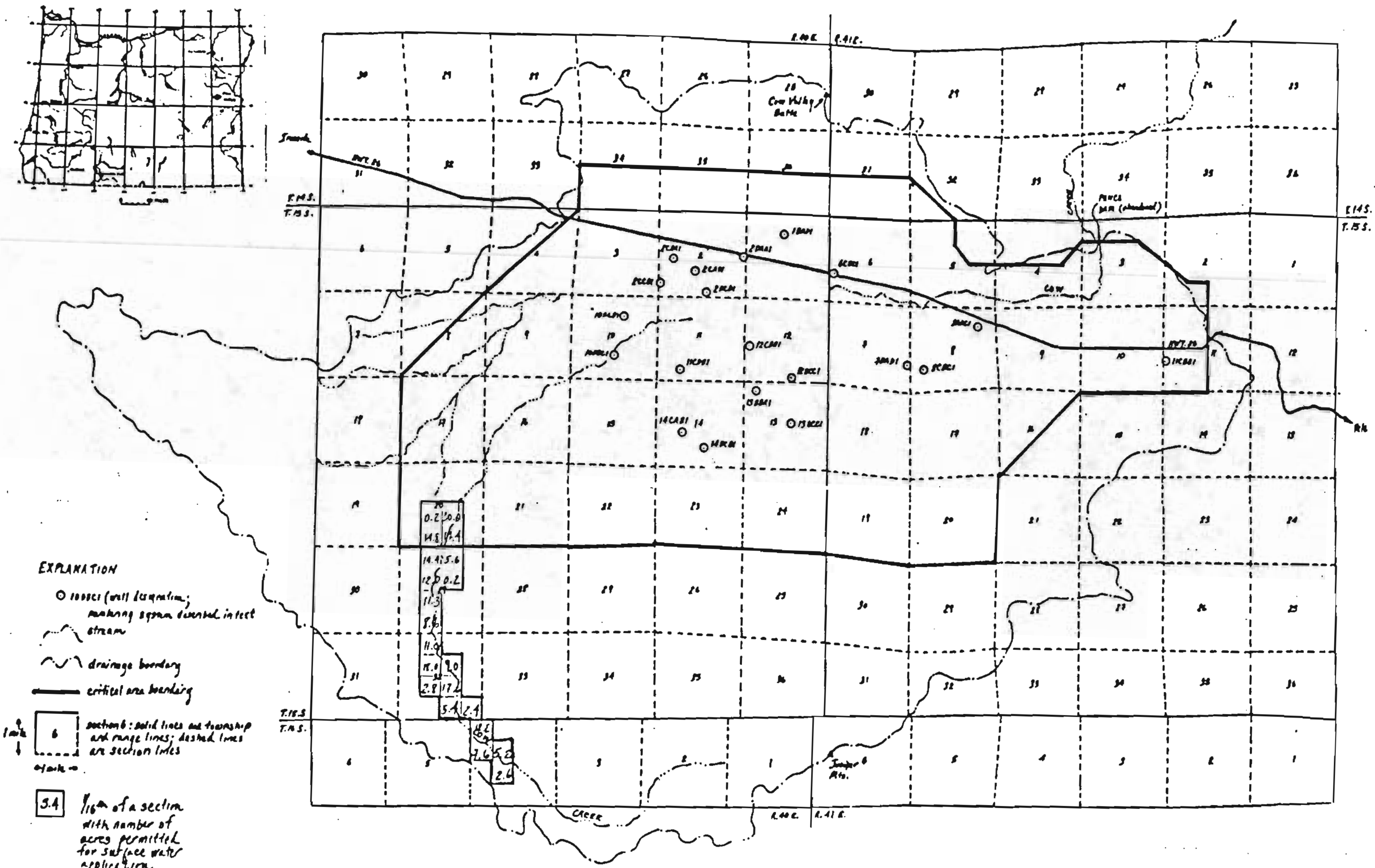



Figure 8. Map of surface water rights in the Cow Valley drainage basin.

Table 1. Records of representative wells in the Cow Valley Critical Ground Water Area

Well number: See text for description of well numbering system.
Altitude: Altitude of land surface at well head. Surveyed where accuracy is shown; otherwise interpolated from topographic maps (contour interval, 20 feet).
Well depth: Total depth drilled.
Diameter: Diameter of outermost casing visible at land surface.
Depth of casing: Depth of deepest casing in the well.
Perforated interval: Interval shown is the open interval.
Water level: Water level reported by driller.
Use of well: I = irrigation, U = unused, S = stock.
Abbreviations used in table: gpm = gallons per minute; ft = feet; in = inches; hrs = hours.

| Well number | Owner name | Other well name | Altitude (ft) | Well depth (ft) | Diameter (in) | Depth of casing (ft) | Perforated interval (ft) | Year completed | Water level (ft) | Discharge (gpm) | Drawdown (ft) | Pumping period (hrs) | Use of well |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | T. 15 S., R. 40 E. | | | | | | | |
| 01BAD1 | Anderson | AND | 3972.80 | 330 | 14 | 300 | 180-245<br>275-290 | 1953 | 90 | 1400 | 70 | -- | I |
| 02CAD1 | Holloway No. 3 | H3 | 3910.73 | 176 | 14 | 58 | none | 1952-54 | -- | 600 | 60 | -- | U |
| 02CBA1 | Holloway No. 2 | H2 | 3916.28 | 535 | 12 | 250 | 40-100 | 1952? | 40 | -- | -- | -- | I |
| 02CCB1 | Crow No. 2 | C2 | 3914.99 | 310 | 10 | 170 | 80-170 | 1949-50 | 37.5 | 251-310 | 40 | 3.25 | I |
| 02DAA1 | Holloway No. 1 | H1 | 3897.77 | 421 | 12 | 55 | none | 1949 | 19 | 1000 | 31 | 8 | I |
| 02DCD1 | Crow No. 1 | C1 | 3897.93 | 362 | 10 | 121 | 0-121 | 1949 | 17 | 1000 | 18 | -- | U |
| 02DCD2 | Crow domestic | -- | 3897.35 | 74 | 6 | 62 | none | -- | -- | -- | -- | -- | U |
| 10ACB1 | Crow No. 3 | C3 | 3922.90 | 255 | 12 | 130 | 6-130 | 1950 | 42 | 840 | 38 | -- | I |
| 10DCB1 | Crow No. 9 | C9 | 3936.30 | 1000 | 14 | 100 | 60-100 | 1952 | -- | 580 | 121 | 1 | I |
| 11CDB1 | Crow No. 4 | C4 | 3922.58 | 200 | 12 | 128 | none | 1950 | -- | -- | -- | -- | I |
| 12CBB1 | Davis No. 3 | D3 | 3893.16 | 280 | 14 | 66 | none | 1954 | -- | 1200 | 80 | -- | U |
| 12DCC1 | Davis No. 4 | D4 | 3911.56 | 100 | 14 | -- | -- | 1954 | -- | -- | -- | -- | U |
| 13ACC1 | Davis No. 2 | D2 | 3932.95 | 173 | 14 | 156 | none | 1954 | -- | 900 | 110 | -- | U |
| 13BBA1 | Davis No. 1 | D1 | 3910.26 | 300 | 14 | 162 | none | 1954 | -- | 900 | 110 | -- | U |
| 14CAB1 | Crow No. 5 | C5 | 3951.59 | 285 | 12 | 160 | none | 1950 | -- | -- | -- | -- | I |
| 14DCB1 | Crow No. 8 | C8 | 3969.40 | 248 | 14 | 157.5 | none | 1951 | -- | -- | -- | -- | I |
| | | | | | | T. 15 S., R. 41 E. | | | | | | | |
| 06CBC1 | Crow Stock | -- | 3900 | 48 | 6 | 23 | none | 1957 | 32 | 10 | 4 | 1 | S |
| 08CBC1 | Crow No. 6 | C6 | 3919.51 | 338 | 12 | 150 | none | 1951 | 46 | 1225 | 105 | 1.25 | I |
| 07DAD1 | Crow No. 7 | C7 | 3923.25 | 360 | 12 | 100 | none | 1951 | -- | -- | -- | -- | I |

Table 2. Record of ground water rights in the Cow Valley Critical Ground Water Area

| Owner of Record | Application/ Transfer Number | Permit Number | Certi- ficate Number | Source | Other Well Name | Priority | Use (acres) | Amount (cfs) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Rankin Crow | U-373 | U-349 | 23628 | Well 2 | C2 | 9/18/50 | 40.5 | .51 | |
| Rankin Crow | U-390 | U-359 | 23631 | Well 5 | C5 | 9/20/50 | 194.1 | 2.40 | |
| Rankin Crow | U-421 | U-391 | 23632 | Well 6&7 | C6,C7 | 5/10/51 | 474.6 | 3.00<br>3.00 | Well 6<br>Well 7 |
| Rankin Crow | U-422 | U-392 | 23633 | Well 5 | C5 | 5/10/51 | 130.4 | 1.81 | |
| Rankin Crow | U-434 | U-406 | 23634 | Well 8 | C8 | 8/21/51 | 40.9<br>130.4 | 2.14 | Primary<br>Supplemental |
| Rankin Crow | U-531 | U-490 | 23635 | Well 9 | C9 | 2/ 2/53 | 48.0 | .60 | |
| Altha Anderson | U-686 | U-629 | 26522 | Locey Well | AND | 3/30/54 | 156.9 | 1.96 | |
| Burton Haverfield | T-2376 (U-305) | | 44316 | Well 1 | C1 | 2/14/50 | 189.0 | 2.36 | |
| Burton Haverfield | T-2378 (U-374) | | 46078 | Well 3 | C3 | 9/18/50 | 164.2 | 2.05 | |
| Cow Valley Ranches | T-2651 (U-531) | | 44208 | Well 9 | C9 | 2/ 2/53 | 48.0 | .60 | |
| Cow Valley Ranches | T-2671 (U-389) | | 44207 | Well 4 | C4 | 2/ 5/51 | 132.0 | 1.70 | |
| Norman Christensen | T-3072 (U-443) | | 47837 | Well 1&2 | H1,H2 | 11/ 5/51 | 188.0 | 2.35 | |
| Gary Heisey | T-3413 (U-390)<br>(U-422)<br>(U-434) | | *—*<br>*—*<br>*—* | Well 5<br>Well 5<br>Well 8 | C5<br>C5<br>C8 | 9/20/50<br>5/10/51<br>8/21/51 | 194.1<br>130.4<br>40.9<br>130.4 | 2.40<br>1.81<br>2.14 | <br><br>Primary<br>Supplemental |

*—*: Proofs not yet signed

Brogan, respectively). In addition, water level elevations from observation well data in these basins are considerably lower than water level elevations in Cow Valley.

Relatively impermeable rocks are exposed on the valley margins and underlie the valley floor at depth. The valley itself is fault bounded. This creates a situation in which permeable valley fill material is juxtaposed with relatively impermeable rocks on all sides.

All of these factors serve to indicate that Cow Valley may be hydrologically isolated from surrounding areas. In other words, it is likely that little movement of ground water occurs from outside the basin into Cow Valley because of its geographic and geologic characteristics.

The greatest recharge potential occurs in the southwestern part of the valley where Cow Creek and its tributaries carry runoff from the slopes of the Juniper Mtn. area. This runoff in large part recharges the Cow Valley aquifer where surface flow disappears into the valley alluvium. Water table elevations in the southwestern part of the valley are higher than those elsewhere in the valley.

The most effective recharge to the aquifer system likely occurs during the months of November through February; March precipitation may also be occasionally significant (Figure 4). The availability of precipitation for recharge is strongly reduced during the months of March through October due to potential evapotranspiration. Potential evapotranspiration figures calculated for a basin just north of Cow Valley were subtracted from average monthly Ironside precipitation values. These calculated values provide an indication of the precipitation months most likely to contribute recharge to the Cow Valley aquifer system (Figure 9).

The months of May and June are significant precipitation months (Figure 4). However, evapotranspiration figures (noted above) indicate that little of this precipitation reaches the water table. Instead, this precipitation is heavily utilized at or near the surface by crops and other vegetation. May and June precipitation in the Cow Valley basin is important in that this precipitation reduces the annual amount of ground water used for irrigation.

## GROUND WATER OCCURRENCE

Ground water occurs in sand and gravel lenses in Pliocene basin fill and in porous zones in older Miocene volcanic rocks. The underlying Jurassic sediments are relatively impervious to ground water movement (Brown and Newcomb, 1962). One well penetrates more than 750 feet of Jurassic sediments. No head change and little water production was noted from this interval (Crow No. 9). All other wells penetrate sand and gravel lenses and/or porous zones in volcanic rock materials to obtain ground water.

Ground water in the basin sediments and underlying volcanic rocks appears hydraulically connected. Several factors support this conclusion. Water level fluctuations generally correspond from well to well. Pumping from one zone affects wells open to a second zone (Brown and Newcomb, 1962). Also, water chemistry data show remarkable similarity (excluding the deeper well that penetrates Jurassic sediments).

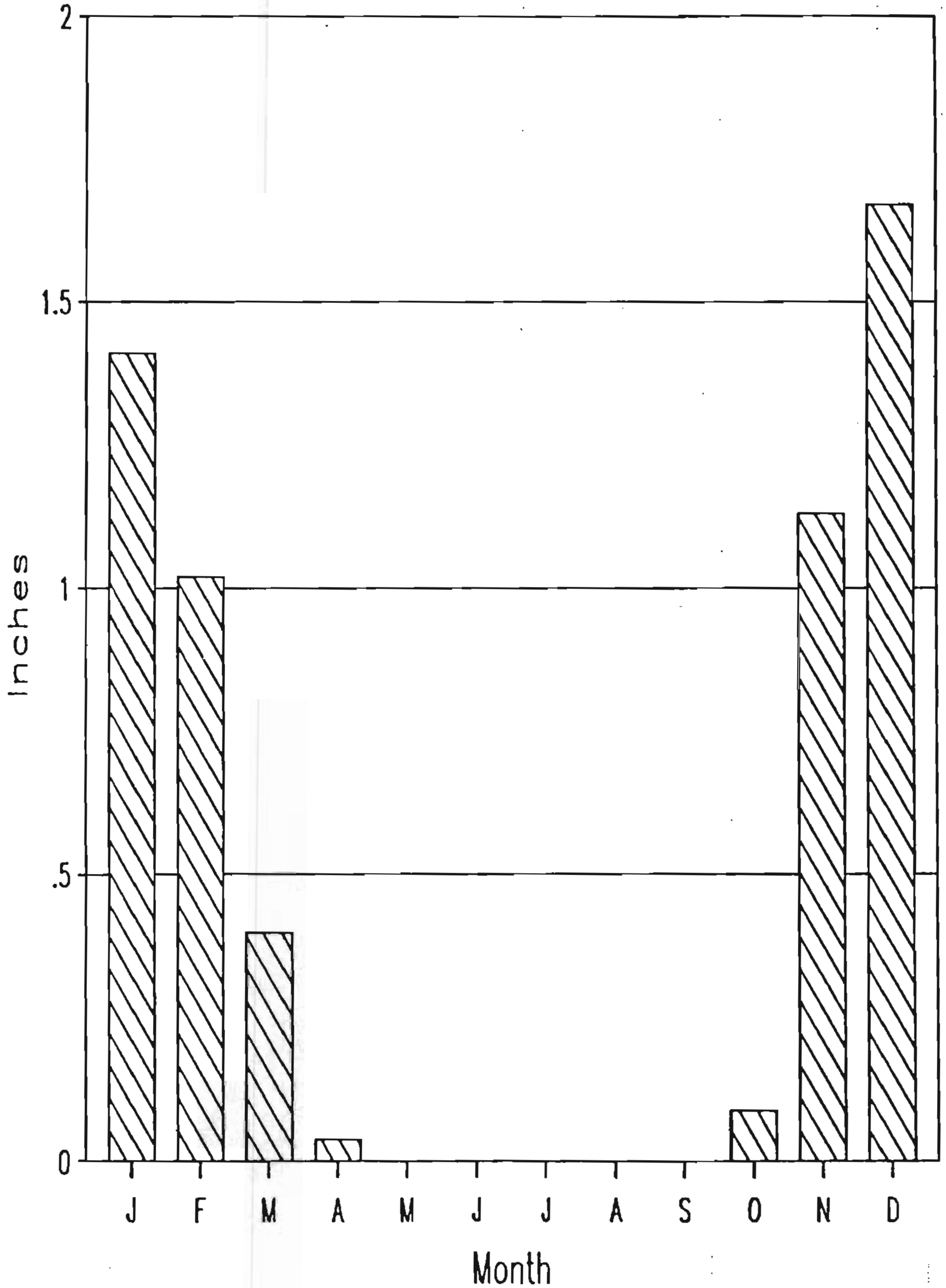



Figure 9. Calculated average monthly precipitation minus potential evapotranspiration, Ironside, Oregon (1957 - 1986).

The Cow Valley ground water reservoir resembles an unconfined system. The water table surface responds directly to precipitation and pumpage from irrigation wells. During periods of drought and/or heavy pumpage the water table has dropped up to 3.5 feet in one year (1973). The water table also responds rapidly to reduced pumpage and/or greater than normal precipitation. In 1983, the water table rose an average of 4.5 feet, partly in response to precipitation that was more than 150 percent of normal.

Aquifer test data reported by Brown and Newcomb (1962) indicate locally confined conditions (storage coefficients of $1.4 \times 10^{-3}$ and $2.4 \times 10^{-3}$). However, it was believed that longer term tests (greater than 20 hours) would demonstrate storage coefficients more indicative of an unconfined system. Longer term tests would also more clearly show possible drawdown effects on nearby wells.

The surface area of the aquifer is approximately 15 miles$^2$. The volume of water drained from the aquifer associated with one foot of head change per year can be calculated.

Equation 1: $Q = SA (\Delta h)$

- Q = Volume of water drained from the aquifer due to a 1 foot head change in one year
- S = Storage coefficient = $2.4 \times 10^{-3}$
- A = Surface area of the aquifer = 15 miles $^2 = 4.18 \times 10^8$ ft$^2$
- $\Delta$h = Hypothetical change in head in one year = 1 foot

Q = $1.0 \times 10^6$ ft$^3$ = 23 acre-feet

This volume of ground water (23 acre-feet) is relatively insignificant in comparison to the 1000's of acre-feet of water withdrawn from the aquifer each year and does not explain the measured decline of water levels in wells. It is likely that the storage coefficient is much larger. A range of storage coefficients have been calculated for unconfined aquifers. These values range from 0.2 to 0.30. The estimated volume of ground water removed from storage given one foot to head loss ('Q') would then range from 190 to 2880 acre-feet. A long term aquifer test is necessary in order to better estimate various aquifer characteristics.

## GROUND WATER LEVELS

Some amount of water level record exists for seventeen wells in the Cow Valley area. All of the wells respond in a similar fashion to stresses applied to the aquifer system. However, the wells nearer the southwest end of the valley respond more quickly to recharge from infiltration of precipitation and runoff.

The water level record for each well usually includes at least one spring and one fall measurement for each year. However, the frequency and timeliness of water level data collection could be improved to assist analysis of the data. Good water level data is necessary in order to determine its relationship to pumpage and precipitation. A continuous water level recorder was set up at the Davis No. 3 well (15S/40E-12CBB1) in January 1986 to record the annual cycle of water level change.

The water table is highest in the spring of each year. From April to September ground water is pumped from the aquifer. A cone of depression develops around each pumping well as water moves toward the well. Consequently the water table is lowered and ground water is removed from storage. When the wells are shut off the water table around the well recovers as water fills the cone of depression. However, the water table measured in the fall is still below the highest level of the water table was measured in the previous spring. Recharge to the aquifer occurs during the late fall through the spring of the following year as a result of infiltration of precipitation and runoff. An end result of recharge is to resupply the ground water removed from storage.

The change in elevation of the water table (or the change in depth to water in a well) may be compared from one spring to the next. If the water table is higher in the spring following a season of pumping, then recharge has been greater than discharge (ground water pumpage plus natural discharge). Conversely, if the water table is lower in the spring following a season of pumping, then the change can be attributed to discharge that has been greater than recharge. In effect, ground water lost from storage has not been entirely replenished. Recharge and discharge should be somewhat equal when the water table from one spring to the next shows little or no change. In other words, ground water removed from storage has been fully replenished.

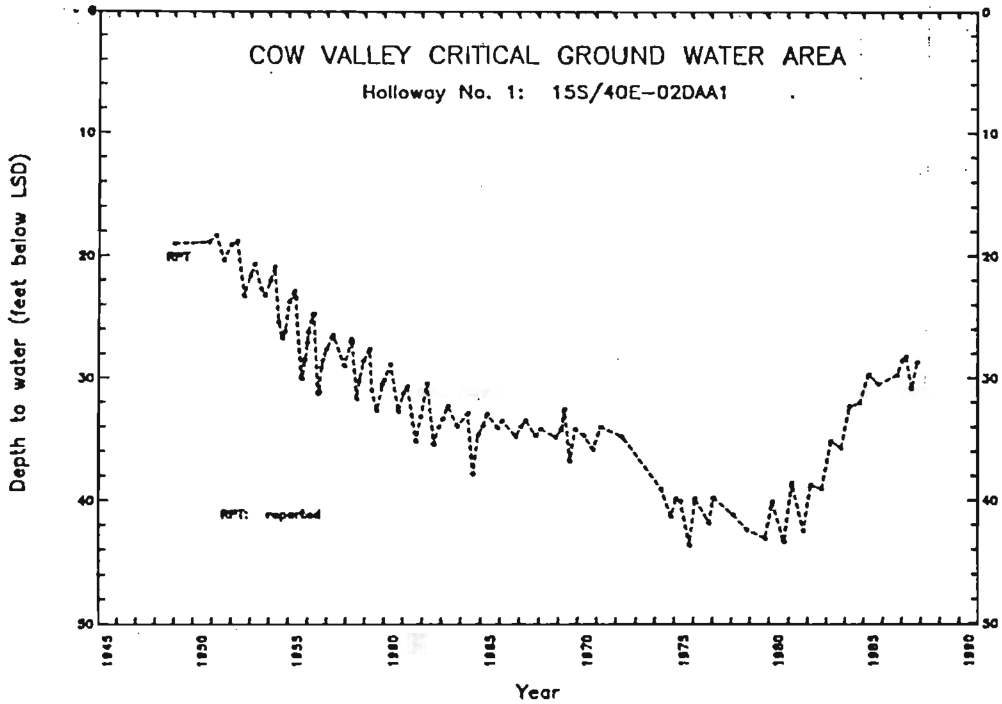
Long term water level records exist for two wells (Holloway No. 1 and Crow No. 2) that are somewhat representative of the other wells in the valley. These records indicate an average decline of about 24 feet from 1951 to 1978. This decline averages about 0.8 feet per year (Figure 10.) The water level record for most of 1978 to 1979 is incomplete. However, from the small amount of data available it is thought that water levels continued to decline through 1979. All measured wells show a continuous rise in water level from 1980 to 1986, averaging about 2.0 feet per year. Spring high water levels measured in 1986 are about 11.5 feet below the approximate pre-development levels measured in 1951. If recent high precipitation and reduced pumpage patterns continue, water levels could rise to pre-development levels by the mid-1990's.

The water table surface slopes down valley from the south and west and joins the Cow Creek channel in the northeastern part of the valley. Two computer generated water level surfaces are shown in Figure 11 and Figure 12. The Spring 1977 surface shows the water table near its lowest measured level. A Spring 1987 surface shows a water table surface 10 to 15 feet higher than the 1977 contoured water level surface.

## GROUND WATER PUMPAGE

Changes in water application methods, precipitation trends and farming economics have had an effect on ground water use in Cow Valley. These factors in combination with the control provisions of the critical ground water order have resulted in generally declining annual pumpage figures since the early 1960's (Figure 13).

Ground water withdrawal peaked in 1955. At that time, fourteen irrigation wells with open discharge lines pumped more than 6000 acre-feet of ground water. The control order went into effect in 1960. In that year, about 4700 acre-feet of ground water was withdrawn from the aquifer. Ground water



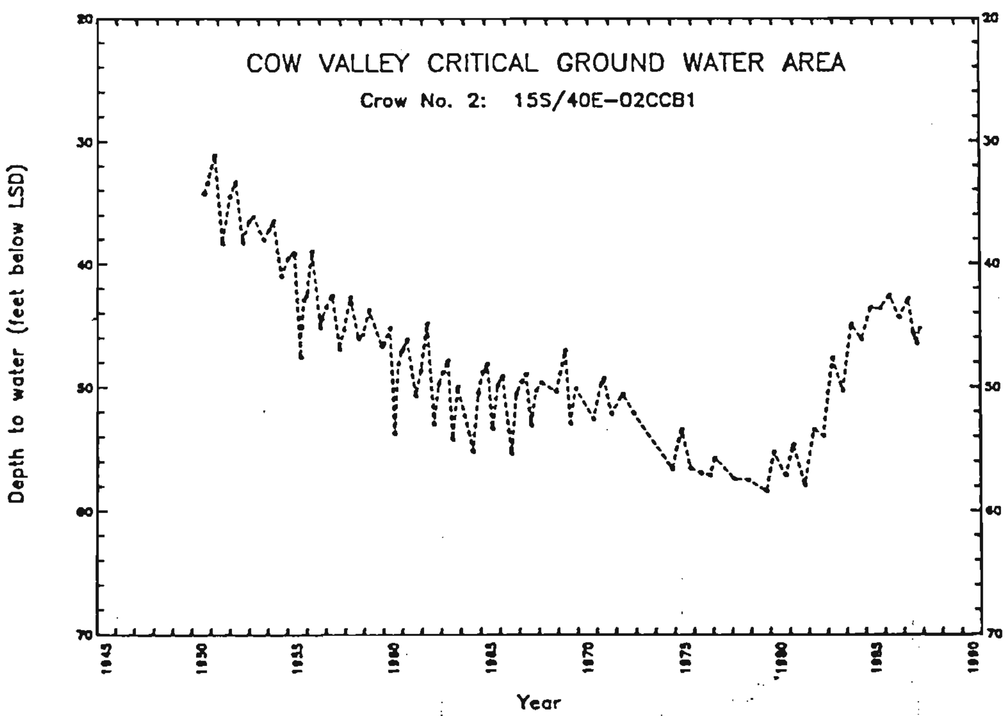




Figure 10. Long-term hydrographs for two wells in Cow Valley.

Water level surface: Spring 1977

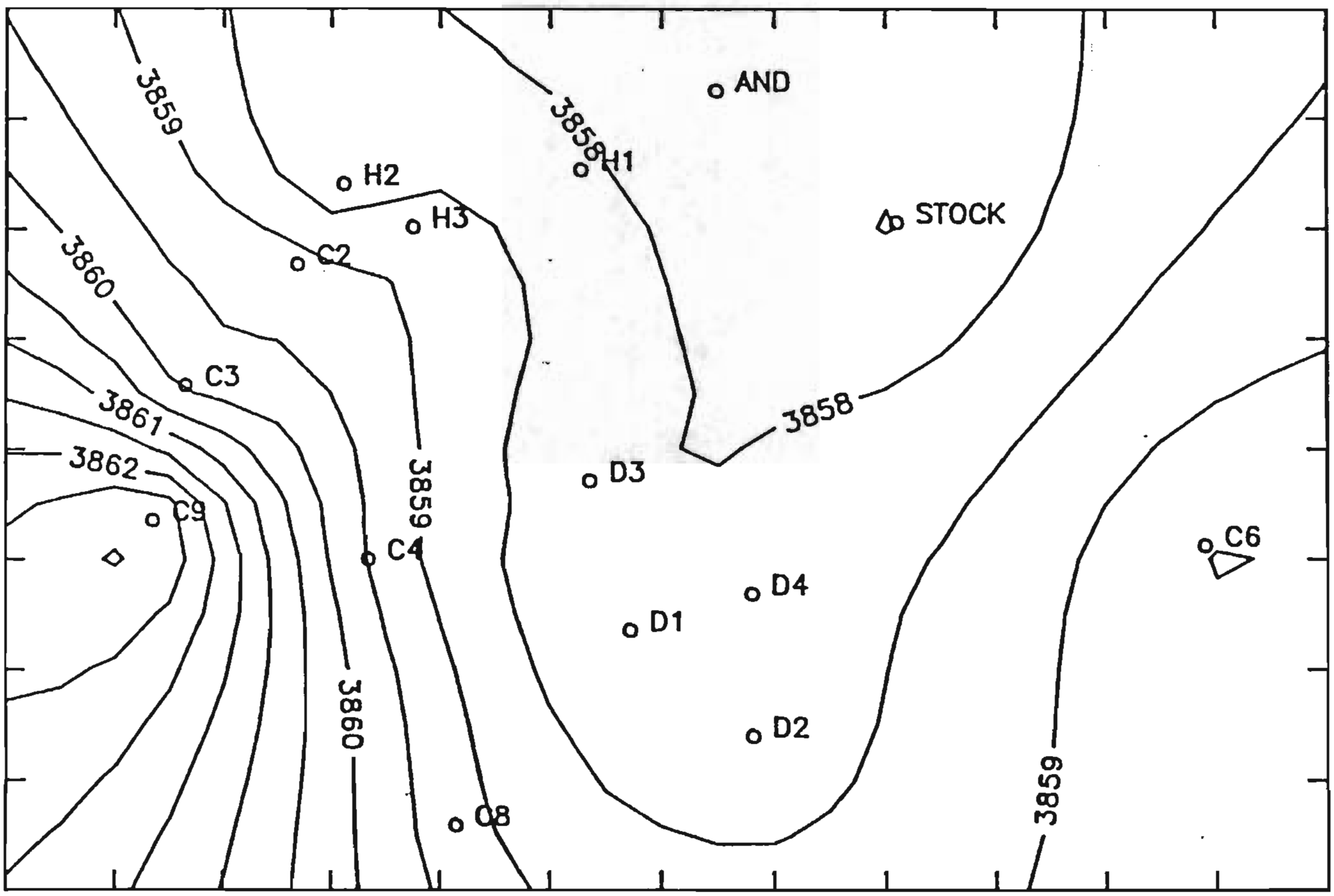



Figure 11. Water level surface; Spring 1977 (contour interval = 0.5 feet).

Water level surface: Spring 1987

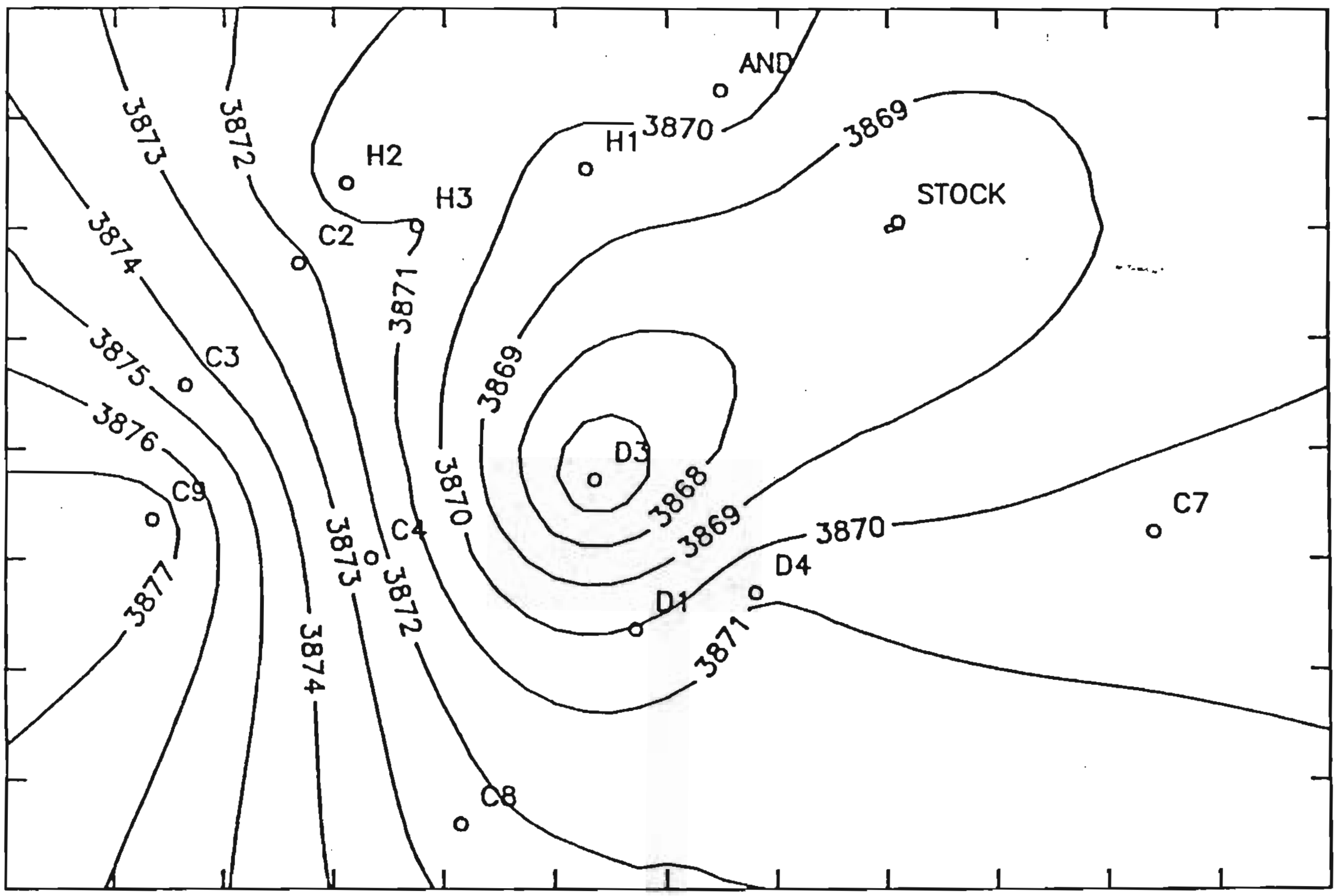



Figure 12. Water level surface; Spring 1987 (contour interval = 0.5 feet).

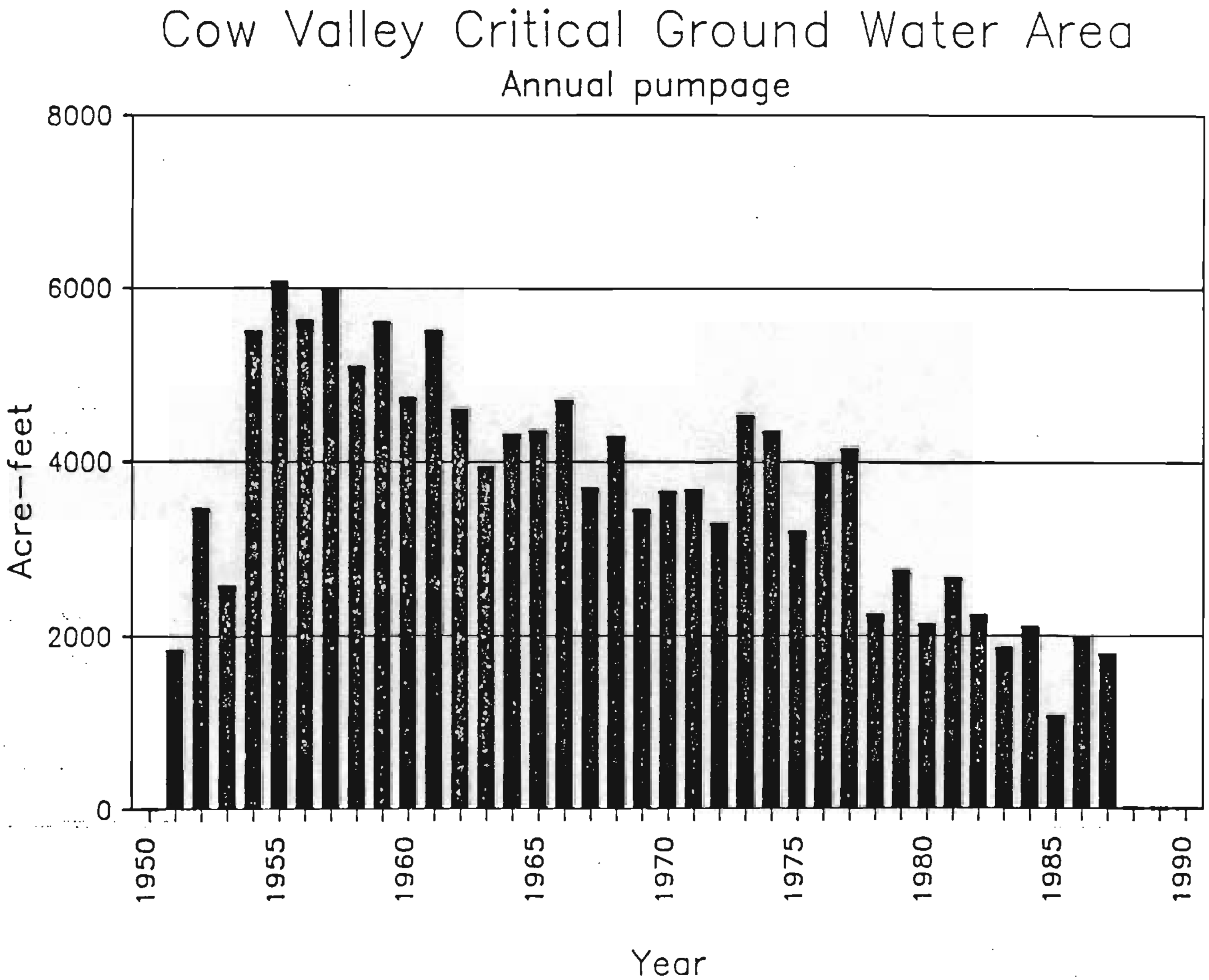



Figure 13. Annual irrigation pumpage in Cow Valley.

pumpage averaged 4000 acre-feet per year (AF/YR) during the early 1960's through the late 1970's. Towards the end of this period, open discharge lines were gradually replaced by more economical hand lines and wheel lines. From the late 1970's to 1986, ground water pumpage averaged 2100 AF/YR. Currently one center pivot is in operation. In 1985, 5 wells were in use. Nine wells operated in 1986 and seven wells were operated in 1987. Irrigation pumps at two wells have been destroyed by lightening strikes and are no longer used.

Smaller annual pumpage values during the late 1970's to 1986 can be attributed to several factors. The change from open discharge systems to more economical irrigation systems clearly has had an effect on water use. Some acreage that was formerly irrigated has been put into various conservation reserve programs. Since 1979, precipitation has been generally above the long term average (11.84 inches). To summarize, less ground water is used because of a change in application methods, a smaller amount of acreage is irrigated, and more precipitation has been available for recharge.

Electrical power consumed by irrigation pumps was used to determine annual pumpage for the period from 1951 to 1959. Flowmeter readings provided pumpage information from 1960 to 1986. Electrical power readings available until 1976 provided a cross check on the flowmeter data. Annual pumpage for each irrigation well in Cow Valley is tabulated in Table 3.

Less than 10 domestic and/or stock wells are thought to have been in operation in Cow Valley at any one time during the past and present. The wells are scattered throughout the valley. The ground water use from these wells and the consequent effect on the ground water system is thought to be neglible.

## NATURAL DISCHARGE

Natural discharge from the valley by evapotranspiration and flow from Cow Creek has not been quantified. However, in the northeast part of the valley water has been observed in Cow Creek flowing out of the valley through an abandoned earth dam. This flow was observed in February of 1987 and can be attributed to ground water. In addition, water is noted in the Cow Creek channel around the dam area on an airphoto taken in July 1979.

A reconnaissance of the Cow Creek channel was made in February 1987 and July 1987 to observe surface water and/or ground water contributions to upper Cow Creek and discharge from the valley (see Figure 1 for locational information relating to the following description).

In February water was observed in Cow Creek downstream to an area in Township 15 South, Range 40 East, Section 16CC (elevation = 4020 feet). At this point, any noticeable channel water disappeared into the subsurface and the channel bottom became relatively dry slightly further downstream. In July of the same year, water was observed in the channel approximately 300 feet upstream from the February observation point. Here, water in the channel also disappeared into the subsurface and the channel became relatively dry only 30 to 40 feet downstream.

The Cow Creek channel from Section 16, Township 15 South, Range 40 East, to where it crosses under the highway was observed to be dry in February 1987. In addition, a portion of the channel has been obliterated by farming

Table 3. Ground water pumpage in the Cow Valley Critical Ground Water area.

| Year | AND | H1 | H2 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | D1 | D2 | Annual pumpage (acre-feet) year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Well designation* | | | | | | | | | | | | | | |
| 1951 | | 214 | | 304 | 224 | 271 | 324 | 489 | | | | | | | 1826 |
| 1952 | | 114 | 207 | 350 | 196 | 344 | 222 | 632 | 911 | 308 | 167 | | | | 3451 |
| 1953 | | 77 | 139 | 234 | 91 | 259 | 155 | 537 | 406 | 345 | 264 | 57 | | | 2564 |
| 1954 | 439 | 177 | 377 | 423 | 353 | 405 | 273 | 726 | 901 | 703 | 505 | 212 | | | 5494 |
| 1955 | 376 | 249 | 527 | 342 | 185 | 417 | 318 | 694 | 936 | 560 | 491 | 218 | 312 | 433 | 6058 |
| 1956 | 269 | 132 | 248 | 445 | 254 | 406 | 335 | 617 | 747 | 548 | 580 | 171 | 402 | 457 | 5611 |
| 1957 | 91 | 133 | 296 | 511 | 199 | 444 | 359 | 713 | 956 | 656 | 719 | 174 | 294 | 435 | 5980 |
| 1958 | 396 | 115 | 348 | 433 | 234 | 414 | 306 | 661 | 577 | 426 | 542 | 228 | 230 | 170 | 5080 |
| 1959 | 264 | 135 | 419 | 413 | 272 | 419 | 339 | 602 | 788 | 753 | 561 | 155 | 252 | 216 | 5588 |
| 1960 | 418 | 165 | 419 | 446 | 236 | 398 | 309 | 576 | 662 | 402 | 533 | 159 | | | 4723 |
| 1961 | 399 | 154 | 428 | 500 | 120 | 501 | 372 | 582 | 1194 | 513 | 579 | 153 | | | 5495 |
| 1962 | 209 | 96 | 235 | 482 | 122 | 499 | 309 | 589 | 1123 | 299 | 508 | 121 | | | 4592 |
| 1963 | 0 | 117 | 441 | 384 | 100 | 427 | 239 | 585 | 848 | 258 | 480 | 62 | | | 3941 |
| 1964 | 231 | 128 | 378 | 466 | 112 | 474 | 281 | 425 | 1053 | 301 | 404 | 49 | | | 4302 |
| 1965 | 0 | 97 | 266 | 465 | 105 | 467 | 341 | 600 | 880 | 519 | 510 | 94 | | | 4344 |
| 1966 | 0 | 182 | 400 | 523 | 130 | 550 | 286 | 691 | 873 | 512 | 463 | 87 | | | 4697 |
| 1967 | 0 | 130 | 295 | 372 | 124 | 509 | 221 | 556 | 659 | 426 | 352 | 46 | | | 3690 |
| 1968 | 338 | 127 | 271 | 494 | 107 | 426 | 355 | 679 | 321 | 583 | 505 | 70 | | | 4276 |
| 1969 | 466 | 122 | 188 | 455 | 386 | 238 | 144 | 558 | 100 | 376 | 238 | 178 | | | 3649 |
| 1970 | 445 | 128 | 222 | 361 | 100 | 250 | 247 | 537 | 100 | 630 | 538 | 97 | | | 3655 |
| 1971 | 453 | 100 | 338 | 452 | 75 | 138 | 281 | 591 | 307 | 368 | 502 | 69 | | | 3674 |
| 1972 | 434 | 96 | 350 | 452 | 120 | 188 | 102 | 427 | 252 | 315 | 468 | 82 | | | 3286 |
| 1973 | 471 | 82 | 416 | 481 | 121 | 279 | 285 | 583 | 533 | 653 | 527 | 94 | | | 4525 |
| 1974 | 452 | 92 | 450 | 495 | 124 | 198 | 184 | 676 | 668 | 493 | 355 | 155 | | | 4342 |
| 1975 | 416 | 51 | 369 | 424 | 130 | 224 | 186 | 251 | 507 | 372 | 120 | 152 | | | 3202 |
| 1976 | 385 | 132 | 371 | 353 | 129 | 339 | 222 | 403 | 684 | 426 | 418 | 120 | | | 3982 |
| 1977 | 430 | 138 | 425 | 556 | 128 | 314 | 286 | 464 | 696 | 439 | 100 | 163 | | | 4139 |
| 1978 | 425 | 107 | 377 | 226 | 115 | 59 | 134 | 231 | 232 | 174 | 94 | 71 | | | 2245 |
| 1979 | 437 | 98 | 476 | 264 | 119 | 64 | 242 | 310 | 399 | 177 | 143 | 23 | | | 2752 |
| 1980 | 329 | 52 | 235 | 151 | 118 | 150 | 229 | 253 | 386 | 94 | 103 | 38 | | | 2138 |
| 1981 | 418 | 94 | 349 | 209 | 106 | 212 | 175 | 365 | 396 | 187 | 147 | 11 | | | 2669 |
| 1982 | 334 | 78 | 346 | 145 | 86 | 158 | 153 | 358 | 275 | 141 | 113 | 54 | | | 2241 |
| 1983 | 253 | 15 | 255 | 178 | 93 | 101 | 146 | 253 | 271 | 152 | 111 | 36 | | | 1864 |
| 1984 | 343 | 67 | 300 | 200 | 67 | 122 | 94 | 286 | 238 | 113 | 131 | 143 | | | 2104 |
| 1985 | 343 | 89 | 370 | 0 | 0 | 0 | 0 | 0 | 194 | 71 | 0 | 0 | | | 1067 |
| 1986 | 318 | 101 | 326 | 0 | 100 | 0 | 155 | 361 | 305 | 156 | 151 | 0 | | | 1973 |

Total acre-feet of ground water pumped from Cow Valley by irrigation wells: 135019 acre-feet

*Well designation: See Table 1 for reference to other well numbering system.

activities. No flow in the channel has been observed at the highway crossing for many years (Frank Elfering, former Watermaster, oral commun., 1986).

The first indication of water in the channel north of the state highway was noted in Township 15 South, Range 41 East, Section 5DC in February 1987 (elevation = 3870 feet). Downstream from this point standing water appears in various ponds and pits carved into the channel until an area around Township 15 South, Range 41 East, Section 4CD. Here the valley opens up and the channel broadens and becomes less distinct. Water disappears from the channel until an area near Township 15 South, Range 41 East, Section 3CC. Where the valley opens up, ground water may be transpired by the rye grass which covers this area. Near Township 15 South, Range 41 East, Section 3CC, the channel becomes distinct again and the bottom of the channel is damp and soft. Two check dams occur in this stretch of the channel and the upstream portion of the channel bottom is damp and soft at each dam. Water appears in the channel continuously from Township 15 South, Range 41 East, Section 3CB to Pence Dam and flows out of the valley at this point. The channel in this area widens from 1 foot to 50 feet at the dam.

The only possible source of water in Cow Creek north of the highway is ground water. Apparently, the water table surface intersects Cow Creek in this location and ground water is discharged to the creek (at approximately 3870 feet in elevation). An area of more than 62,500 acres lies below the 3870 foot contour line from where ground water first discharges to the Cow Creek channel. In this sarea, it is likely that the ground water table is very near or at land surface.

As noted previously, water was observed in Cow Creek on an air photo taken in July 1979. The water table in Cow Valley in 1979 was near its lowest level (an average of 3856 feet in elevation) yet ground water was still discharging from the valley through Pence dam (elevation = 3845 feet). The current rise in elevation of the ground water table likely serves to increase the amount of natural discharge from the system. This is due to an increase in gradient of the water table from the well area to Pence dam. Hypothetically, the amount of natural discharge should decrease as the water table elevation in the well area reaches or falls below 3845 feet in elevation.

## RECHARGE ESTIMATES

Recharge cannot be measured directly in Cow Valley, but can be estimated by several methods. The analysis of water level records, precipitation, and ground water pumpage data can indicate ranges of recharge that are useful in assessing the limits of the ground water system.

### Hydrograph analysis

Examination of hydrograph data from the period 1964 to 1970 indicates that the effective recharge (recharge necessary to replace ground water lost from storage) may be roughly equivalent to discharge from wells for this period of record. The quantity of natural discharge likely remained somewhat constant given a similar expected water table gradient during this period. In other words, the data shows little to no water level change indicating recharge is roughly equivalent to total discharge.

The average water level change measured from spring to spring shows little net change. A net rise of 1.33 feet is noted together with a net decline of 1.50 feet during this seven year period. The seven year net loss in water level elevation equals -0.17 feet. The water table elevation averaged about 3866 feet in the area influenced by wells.

Pumpage averaged 4100 feet; ranging from 3448 to 4697 acre-feet per year. Water year precipitation averaged 12 inches at the Ironside station compared to the long term average of 11.84 inches. Water year precipitation totals ranged from 7.83 to 16.91 inches.

The basin area totals 70 square miles. The entire basin is assumed to receive recharge from precipitation (assuming an 11.84 inch average basin wide). Recharge occurs directly through infiltration in the area of the valley floor and surrounding alluvial fans. On the basin slopes above the alluvial fans, runoff is channeled in numerous small gullies and creeks that have formed in the relatively impermeable rock material. Runoff moves downslope to disappear into the subsurface near the distal end of the fans.

Given an average of 4100 acre-feet per year of effective recharge, one may calculate the percentage of precipitation per year required to replace ground water lost from storage during the stated seven year period. In other words, one may calculate that percentage of precipitation that replaces ground water lost from storage.

Equation 1:

$$\frac{\text{Effective recharge (ft}^3\text{)}}{\text{Basin area (ft}^2\text{)}} = \frac{(4100 \text{ acre-feet})\ (43{,}560 \text{ feet}^2/\text{acre})}{(70 \text{ mile}^2)\ (5280 \text{ feet/mile})^2}$$

$$= \frac{1.79 \times 10^8 \text{ feet}^3}{1.95 \times 10^9 \text{ feet}^2}$$

= .09 feet or 1.1 inches of water on the total area of the basin

Equation 2:

$$\frac{\text{Inches of water from Eq. 1}}{\text{average WY precipitation (during 1964-1970)}} \times 100\% = \frac{1.1 \text{ inches}}{11.84 \text{ inches}} \times 100\%$$

= 9 percent of the precipitation from each WY replaced ground water that was lost from storage during 1964 to 1970.

During the period from 1964 to 1970, as estimated nine percent of the water year precipitation was needed to replace ground water lost from storage. The average precipitation was somewhat above normal (12 inches compared to the long-term average of 11.84 inches). However, as noted above, a measured net decline of -0.17 feet occurred during this period. This suggests that recharge was not quite sufficient to replace ground water removed from wells although precipitation was greater than average. Therefore, the average of 4100 acre-feet per year of ground water that was removed from the system during this time is probably slightly greater than desirable, even during a normal precipitation year. The desired amount of ground water withdrawal (the "safe yield") from the system would be an amount that would produce an average net zero change in spring high water levels.

Linear regression analysis

In Cow Valley, the water level change from one year to the next appears to be dependent upon the amount of the previous seasons pumpage and also the amount of precipitation that occurs from late fall to early spring. Both pumpage and precipitation data were plotted against the average annual water level change to quantify their relationship with the water level change.

The lease squares method was used to fit a line through the plotted data points. The linear equation used to estimtate the predicted relationship (best fit) between the two variables is:

$Y = a + bX$, where,

$Y$ = the dependent variable
$a$ = the Y intercept (the value of Y when $X = 0$)
$b$ = the slope of the line
$X$ = the independent variable used to predict Y

A correlation coefficient can be calculated and used to assess the relationship of the two variables. A positive linear correlation between the two variables equals 1.0, no correlation equals 0.0, and a negative linear correlation equals -1.0.

A. Annual pumpage relationship (Hill method)

Annual pumpage and average water level change at 15 wells were calculated for 29 observation pairs. Annual pumpage figures are considered to be more precise than the calculated average water level change.

Calculated regression line: Y - 2.787098 - .000745X (Figure 14).

The X intercept of 3750 acre-feet is the estimated "safe yield" from the Cow Valley aquifer that could occur with little to no annual water level change. One standard error of estimate was calculated for the data and is shown on the graph as a dashed line on either side of the regression line. Sixty-nine percent of the data fall between the lines. Theory predicts that about 68 percent of the data points should fall between the lines if the sample is normally distributed. The error in estimate suggests that 3750 acre-feet of pumpage is predictive of a range of +1.30 to -1.30 feet in annual water level change.

The correlation coefficient of the data is 0.68. In other words, 68 percent of the variability in Y (water level change) can be explained by the relationship between Y and X (annual pumpage). Any scatter in data is likely the result of several factors:

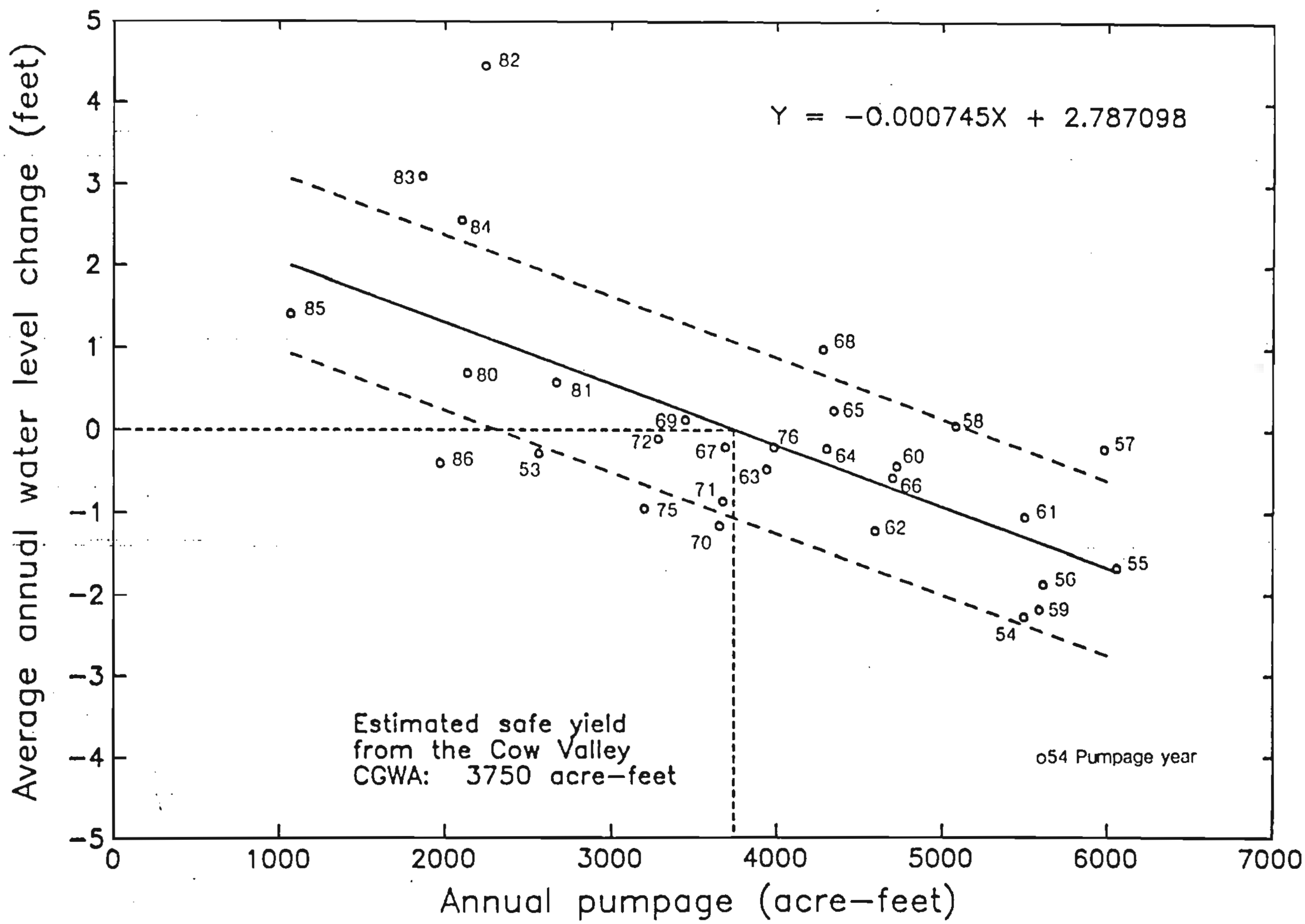



Figure 14. Regression of average water level change and ground water pumpage data.

1. measurement estimate error: water level data from 15 wells was used to calculate the average water level change (X). Some data were estimated when no spring high water level was available. Estimation of one water level measurement will affect two water level change calculations.

2. measurement error: errors in collecting and recording water level data and pumpage data.

3. equipment error: water level and flowmeter measuring equipment have inherent limitations in measurement ability.

4. data assumptions:
   a. data have a linear relationship
   b. values of Y are independent from one measurement to the next (no lag time effect)
   c. the effect of other variables (precipitation and natural discharge is ignored for this calculation)

B. Water year precipitation relationship

Water year precipitation (minus potential evapotranspiration) and the annual water level change at Crow No. 2 (15S/40E-02CCB1) were calculated for 21 observation pairs. Water year precipitation data are considered to be more precise than the annual water level change data.

Calculated regression line: $Y = 2.058531 + 0.445815X$ (Figure 15).

The X intercept of 4.62 is the estimated water year precipitation minus potential evapotranspiration needed for zero water level change to occur from year to year. One standard error of estimate was calculated for the data and is shown on the graph as a dashed line on either side of the regression line.

The correlation coefficient of the data is 0.60. In other words, 60 percent of the variability in the water level change can be attributed to precipitation effects. The scatter in the data is the result of several factors:

1. measurement estimate, measurement error, and equipment error: see above

2. data assumptions
   a. see above data assumptions
   b. the effect of other variables (pumpage and natural discharge) are ignored for this calculation
   c. precipitation data from Ironside is assumed to be applicable to the Cow Valley drainage basin.

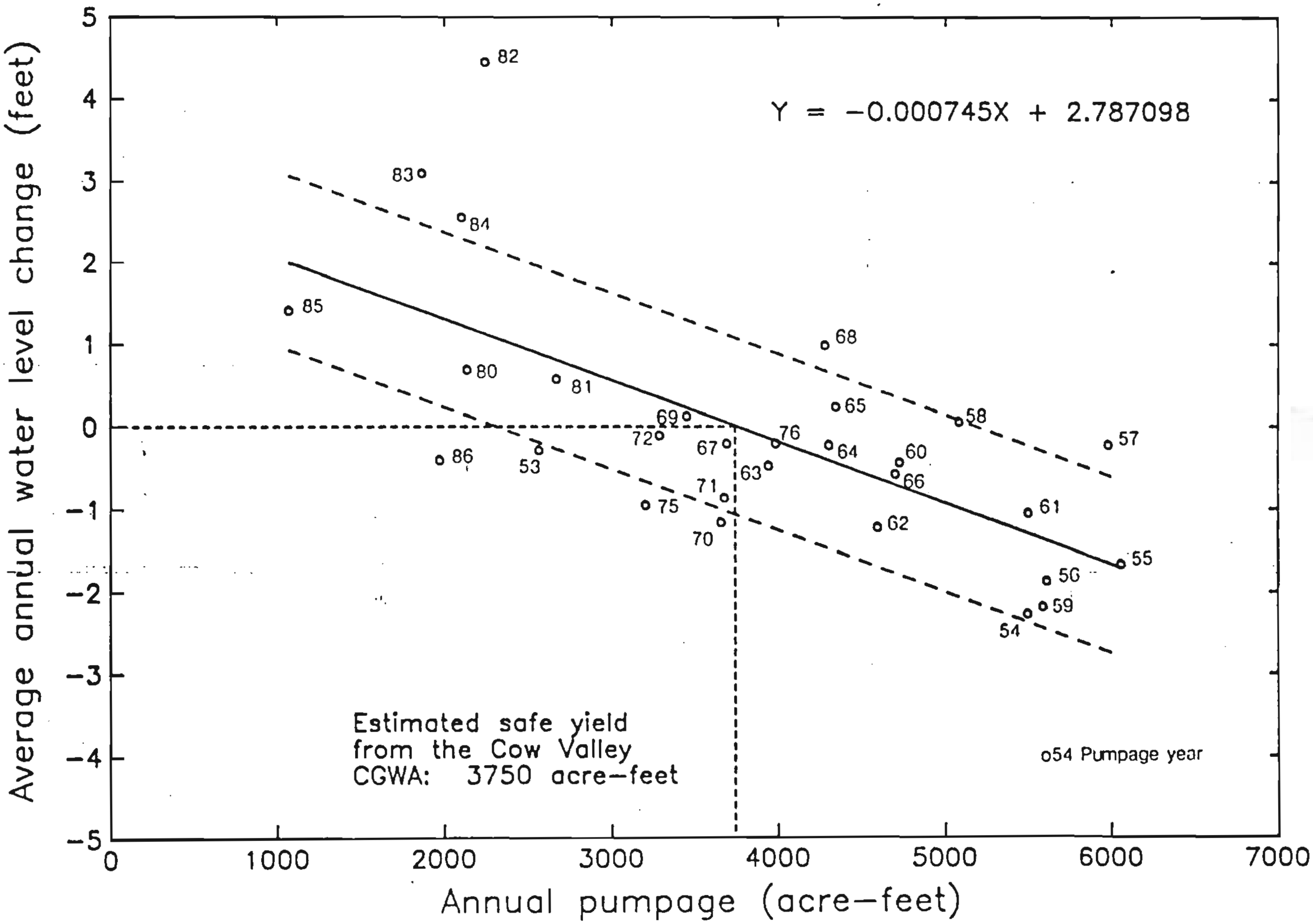



Figure 14. Regression of average water level change and ground water pumpage data.

The long term (1957 to 1986) average water year precipitation minus potential evapotranspiration equals 5.85 inches compared to the estimate of 4.62 inches derived from the regression equation. This comparison indicates that precipitation during 1957 to 1986 has been greater than normal. Data from the Vale record indicates that this may be the case in the regional area. A longer term precipitation record would more accurately aid in evaluating the relationship between precipitation and water level change.

SUMMARY/CONCLUSIONS

Changing trends in water application methods, precipitation and farming economics have dramatically influenced the ground water situation in Cow Valley and will continue to do so. These factors in combination with the control provisions of the Critical Area order of 1959 resulted in a reduction of ground water pumpage for irrigation. Since 1980, a relatively continuous rise in ground water level has occurred. The 1985 water table elevation averages about 3870 feet compared to the lowest level of approximately 3858 feet measured in 1977. Ground water levels may return to pre-development levels (about 3882 feet in elevation) by the mid-1990's if current precipitation and pumpage patterns are maintained.

Ground water rights for slightly less than 5300 acre-feet exist in the Cow Valley Critical Ground Water area. Water levels could decline to unacceptable levels for irrigators if grund water is pumped to the full extent of existing rights. Recharge estimates for 1964 to 1970 suggest that an annual pumpage figure of less than 4100 acre-feet is the maximum amount of ground water that can be removed from the system without a significant change in yearly water level. This amount of water was calculated to be nine percent of the average water year precipitation during this period. These calculations were made when the water table elevation averaged 3866 feet in the well area.

The relationship between pumpage and water level change suggests that the maximum ground water withdrawal per year may be closer to 3750 acre-feet per year for the entire period of record in order to maintain a zero water level change.

The effects and amount of natural discharge from the system are unknown. However, the water table gradient from the well area to Pence dam is an important aspect of the ground water system. Increases in natural discharge from the system are evidenced by a reconnaissance of the Cow Creek channel north of State Highway 26. This is a result of rising water levels that have created a steeper water table gradient from the well area to Pence dam. Potential ground water storage area has become unavailable for recharge due to rising water levels. The effect of increased natural discharge is to lose available ground water as runoff to the Willow Creek basin and also as evapotranspiration to the atmosphere.

It has been suggested that by drawing the water table surface down to or below the elevation of Pence dam, one would increase the available ground water storage area in Cow Valley. Natural discharge from the valley would theoretically decrease. At the current water table elevation, one would have to remove at least 30 feet of head from the ground water system. This amount of decrease in head could affect irrigators by forcing a change (lowering) in pump setting.

A storage coefficient for the aquifer system calculated by Brown and Newcomb (1962) does not accurately characterize the system. A longer term aquifer test should be performed to calculate reliable storage, transmissivity, and drawdown values. This information could be used for ground water management in the area. Boundary effects and seasonal well interference could be estimated (the original well interference problems in Cow Valley associated with well spacing may no longer exist due to a decrease in pumpage at some wells and non-use at other wells).

The frequency and timeliness of data collection in Cow Valley could be improved to assist in analysis of the data. Good water level data is necessary in order to determine its relationship to pumpage and precipitation.

RECOMMENDATIONS

1. Pursue cancellation of unused ground water rights when five years of consecutive non-use can be determined.

2. Establish a recording gage at Pence Dam to measure outflow from Cow Creek. Observe the Cow Creek channel to determine its approximate intersection with the ground water table. Determine the annual use of surface water rights on Cow Creek.

3. Perform a long term aquifer test to determine reliable aquifer characteristics for use in ground water management.

4. Improve frequency and timeliness of data collection to assist in data analysis.

5. Maintain a continuous water level recorder to determine the flux of water table in Cow Valley and lag time factor for recharge effects.

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