THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

SIERRA VALLEY GROUND WATER STUDY

Memorandum Report

JUNE 1983

State of California

The Resources Agency

Memorandum

To : 1. Ralph Scott
2. Philip Lorens
~~3. Wayne Gentry~~

Date : July 5, 1983

File No.:

Subject: Sierra Valley Ground Water Study

From : Dennis Parfitt
Engineering Geologist
Department of Water Resources

This report presents the findings of the three-year cooperative Sierra Valley Ground Water Study. It discusses the hydrology, geology, water quality, and land and water use in Sierra Valley. The report includes recommendations for water conservation in the valley and measures to be taken by the Sierra Valley Ground Water Management District Board of Directors to aid in their task of basin-wide ground water management.

This investigation was undertaken as a result of SB 1391, the "Sierra Valley Ground Water Basin Act", passed by the State Legislature in 1980. Funding for the study was provided by the State, Sierra and Plumas Counties, and the Sierra Valley Ground Water Management District.

Attachment

SURNAME | 7-5-83 R.A. Scott 7-5-83

ACKNOWLEDGMENTS

Many people helped make the Sierra Valley Ground Water Study and prepare this report.

Land and water use information was provided by Clyde Muir, DWR Associate Land and Water Use Analyst, and his graduate student assistant, Steve Rossi. Water quality analysis was done by Robert Clawson, DWR Senior Engineer, and Lee Gibson, DWR Water Resources Technician II.

Preliminary geologic and hydrologic data were gathered by Freeman Beach, DWR Associate Engineering Geologist, Laura Germain, Jack McMillan, and Brian Lewis, DWR Engineering Geologists, and student assistants Carolyn Thompson and Tom DeHennis. DWR Senior Engineering Geologist Ralph Scott gave technical assistance and advice. Dr. Ken Schmidt, ground water consultant, supervised the aquifer tests and gave technical assistance and advice.

Special thanks are due to the Ground Water Management Board, Plumas County District Attorney, Gary Fry, Sierra County Planning Director, Tim Beals, the Lucky Hereford Ranch, Carl Genasci, and all the residents of the valley who have been so cooperative throughout the course of the study.

CONVERSION FACTORS

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0.03937	25.4
	centimetres (cm) for snow depth	inches (in)	0.3937	2.54
	metres (m)	feet (ft)	3.2808	0.3048
	kilometres (km)	miles (mi)	0.62139	1.6093
Area	square millimetres (mm^2)	square inches (in^2)	0.00155	645.16
	square metres (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometres (km^2)	square miles (mi^2)	0.3861	2.590
Volume	litres (L)	gallons (gal)	0.26417	3.7854
	megalitres	million gallons (10^6 gal)	0.26417	3.7854
	cubic metres (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic metres (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	litres per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	litres per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lb)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8 × °C)+32	(°F−32)/1.8

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(in back pocket)

INTRODUCTION

A three-year investigation of the ground water hydrology of Sierra Valley was begun in July 1980 by the California Department of Water Resources (DWR), Northern District. Funding was provided by the State of California and Plumas and Sierra counties under the terms of a cooperative agreement. In addition, the District provided $10,000 worth of services.

The work was done as a result of the passage of Senate Bill 1391, the "Sierra Valley Ground Water Basin Act" of 1980. This bill authorized formation of a district to manage the ground water resource of Sierra Valley, conduct technical investigations, and collect the data necessary for the District's Board to carry out the provisions of the Act.

Senate Bill 1391 in Brief 1/

Historically, Sierra Valley has had a plentiful surface water supply each spring that begins to dwindle and fall short of agricultural demands sometime between midsummer and fall. This deficiency, combined with substantial changes in land use and increased agricultural production, has required use of more ground water, and the increased pumpage is probably responsible for causing many artesian wells to stop flowing. This, and the concern that out-of-basin interests would tap the water resources of the valley for export, prompted Plumas and Sierra counties to ask for the protective legislation that resulted in passage of SB 1391 in 1980.

Local authority to limit pumping and ban export under certain circumstances constitutes the first legislatively approved approach to ground water management in California. During an overdraft or when significant water quality problems occur, the district has the power to

1/ This is a synopsis of "SB 1391, Towards a Permit System for Ground Water? Towards a New Definition of Ownership of Ground Water?" by Gary G. Fry.

use a permit system for ground water management that, in many ways, is as comprehensive as that now used for surface waters.

This permit system is strongly opposed by those who fear such direct government regulation, but there are two mitigating factors: First, full control of the ground water resource can only be exercised when overdraft exists or is imminent or when there are obvious water quality problems. In the absence of these problems, no such authority can be exercised. Second, full authority can only be exercised by a board of directors comprised of local area residents whose interests and concerns would be the same as their constituents'.

According to the Act, the amount of water a person pumps shall reflect the amount of land that person controls in the basin:

> Sec. 709.5. In the event that the District limits or suspends extractions by district users in order to eliminate existing or threatened conditions of overdraft, rights to the use of the available supply of ground water shall be allocated primarily on the basis of the number of acres overlying the basin or subbasin that a user owns or leases in proportion to the total number of acres overlying the basin or subbasin. The District may adjust any figure so arrived at up or down for any of the following factors:
>
> (1) the number of acres actually irrigated compared to the number of acres owned or leased
>
> (2) crop type
>
> (3) wasteful or inefficient use
>
> (4) reasonable need
>
> (5) any other factor that the District reasonably feels it should consider in order to reach an equitable distribution within the entire District.

A benefit of this plan may be to encourage free-market trading of water by making clearer who owns what and how much. With lively trading, market forces may be sufficient to promote wise allocation of the ground water resource without the need for the District to exercise its full authority.

SB 1401

Senate Bill 1401, referred to as the "SB 1391 Clean-Up Bill", amended and repealed selected sections of SB 1391, The Sierra Valley Ground Water Basin Act. SB 1401 deleted specified provisions requiring the District to limit or suspend ground water extractions for export before limiting extractions by overlying users. The bill also revised provisions of SB 1391 relating to the approval of proposed development projects within the District that propose to extract ground water for water service.

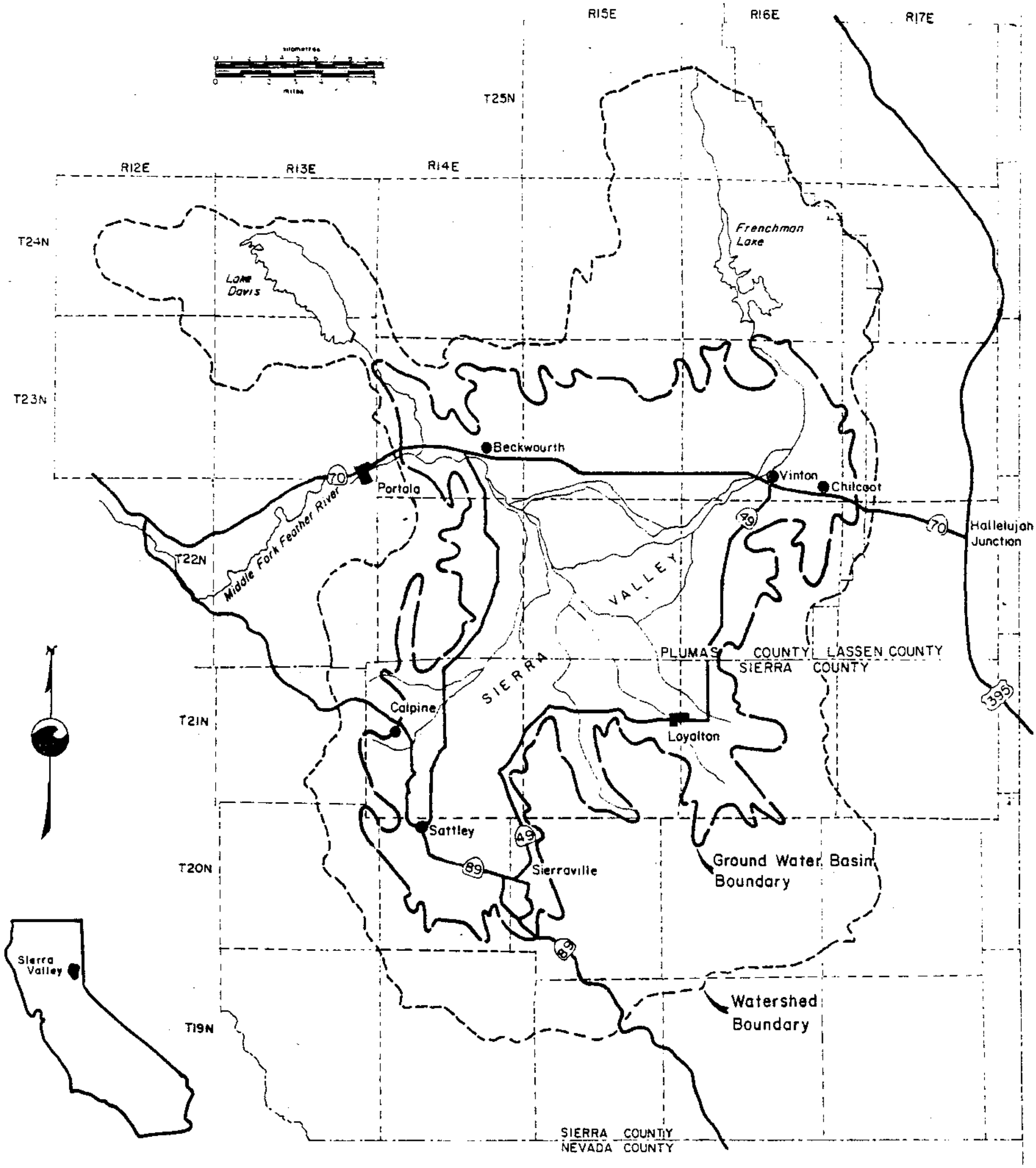
Purpose and Scope

This report was prepared to provide the technical data base and knowledge of the basin that the District's board members, staff, and consultants need to determine alternatives for formulating a comprehensive ground water management plan. It describes the geology, hydrology, land use, and water quality of the basin.

Area of Investigation

Sierra Valley is in Plumas and Sierra Counties in the headwater region of the Middle Fork Feather River (see figure 1). Access to the area is by State Highway 70, either from Oroville or from Reno via Highway 395. State Route 49 enters the valley from the southwest through Yuba Pass, and State Route 89 connects the area with Truckee to the south. The Western Pacific Railroad line runs across the northern half of the valley, parallel to Highway 70.

FIGURE 1



STATE OF CALIFORNIA
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Location Map
Sierra Valley Ground Water Study
1983

Loyalton is the largest town in the study area. Other communities are Sierraville, Sattley, Calpine, Beckwourth, Vinton, and Chilcoot. The economy of the valley is based mainly on agriculture; lumber is secondary, with mills at Loyalton and Sattley.

Most valley residents obtain their residential water from wells and springs. Loyalton and Sierraville have distribution and storage facilities supplied by large community wells and/or developed springs.

Physiography

Sierra Valley is an irregularly shaped, complexly faulted valley in the northern portion of the Sierra Nevada geomorphic province. The valley floor, containing 130,000 acres, is relatively flat and lies about 4,900 feet above sea level. The surrounding rugged mountains rise to elevations ranging from 5,800 to nearly 8,000 feet. Around the borders of the valley, an alluvial apron of varying width slopes down from the adjacent highlands. At various locations around the valley, large masses of bedrock stand out of the valley floor either as inselbergs or as erosional remnants of volcanic flows.

Many streams enter the valley and join to form the Middle Fork Feather River, which drains the valley through a water gap in the northwestern corner near Beckwourth. These streamflows are fed by rainfall, snowmelt, and ground water discharge.

Vegetation in the valley is varied. On the valley floor there are agricultural crops, rangeland grasses, sagebrush and tules. Around the periphery, at slightly above the valley floor, sagebrush and rangeland grasses dominate. Forests of pine, fir, cedar, and hemlock grow in the mountains around the valley.

Climate

Temperatures in the valley range from over 100° to below 0° F. Annual precipitation ranges from 40 to 50 inches in the western part of the valley, to less than 12 inches in the east. For the valley as a whole, mean annual precipitation is about 25.6 inches. Monthly rainfall in July, August, and September is usually less than one inch.

Land Use

In Sierra Valley the valley floor covers about 130,000 acres, a third of which are planted in irrigated crops. These include alfalfa, grain, turf grass, meadow pasture, potatoes, and garlic. The rest of the valley floor is used as summer range for livestock. The valley also provides important habitat for migratory birds of the Pacific Flyway.

Water Use

Water for agriculture, stock, and domestic needs in Sierra Valley, estimated to equal about 78,000 ac-ft in 1981, is supplied from surface water and ground water sources. Surface water, used almost entirely for agriculture, supplies about 80 percent of this total (Appendix A). Ground water is the principal source for domestic, municipal, and industrial water uses. About 15 percent (2,100 ac-ft) of the total pumpage in 1981 was used for these needs, and the remaining 85 percent (12,400 ac-ft) was used for agriculture.

The surface water comes from natural runoff, minor flow from springs, stored water, and imported water. Natural flows of Little Last Chance Creek are regulated by storage provided by Frenchman Reservoir and released and used as needed under the provisions of an annual contract with the State. Water from the Little Truckee River is diverted (about 7,000 ac-ft per season) to supplement the natural flows of Webber Creek near Sierraville. This diversion is used by shareholders in the Sierra Valley Water Company.

Ground water in the valley is extracted by pumping or by artesian flow. A detailed analysis of ground water use is presented in Appendices A and B.

Previous Investigations

The availabililty, occurrence and character of ground water in Sierra Valley have been the focus of several investigations. In 1955, DWR began collecting water quality data and in 1957 began measuring water-levels. These efforts led to the 1961 office report, "The Geology and Geohydrology of Sierra, Mohawk, and Humbug Valleys, Sierra and Plumas Counties". The report describes the area's geologic formations and their water-bearing properties and comments on the origin and character of the ground water.

In 1963, Sierra Valley was discussed in DWR Bulletin 98, "Northeast Counties Ground Water Investigation". This report enlarged upon the 1961 report and included information about water quality problems, ground water development potential, and the basin's ground water dynamics.

In 1973, DWR reported on the results of an interagency, multidisciplinary investigation of the natural resources of Sierra Valley. The portion of the report pertaining to ground water recapped the information of the two previous studies (DWR, 1961, and DWR, 1963) and updated interpretations with the help of ten more years of data. Possible effects of increased agricultural pumping were also discussed.

Other related studies include Master of Science theses by David T. Berry and William Guthe. Berry (1979) described the geology of the

Portola and Reconnaissance Peak Quadrangles and presented an explanation of the geologic history of the area and the formation of Sierra, Mohawk, and Humbug Valleys. Guthe (1981) used two models for estimating runoff and ground water recharge from the Smithneck Creek watershed.

Method and Procedures

To prepare this report, DWR:

1. Conducted a literature search for previous investigations and studies, unpublished data, and technical reports applicable to the Sierra Valley ground water study.
2. Collected water well drillers' reports and electric logs (E-log) for water wells and logs for exploratory test holes and field located the wells and test holes. Official State well numbers were assigned all wells and a master well list (Appendix C) was compiled showing information on each well. There are about 670 known wells in the valley; water well drillers' reports are available for 128 and electric logs are available for 46. These data and previously existing surface and subsurface geologic data were used to construct geologic cross-sections of the valley. From these cross-sections, a plexiglass fence model was constructed showing the configuration of the basin's aquifer system, the connections between recharage areas and confined aquifers, and the general configuration of the basement complex rocks.
3. Established a water-level measurement grid consisting of 168 wells and measured the water level in each well two or more times a year during the term of the study. The grid includes 29 wells that have been measured semiannually since 1958. Continuous water-

level recorders were installed on four wells to record instantaneous water-level changes. Data obtained from the water-level measurements were used to show historic water-level changes and to prepare spring and fall water-level elevation contour maps.

4. Collected water samples from selected wells for water quality analyses. The data were used to detect significant changes in water quality from previous investigations and to provide a better areal coverage of the basin.

5. Installed water meters on five center pivot irrigation systems to provide data for estimating the volume of applied water on irrigated lands. These data and a land use and water source survey (Appendix A) provided a fairly accurate measure of total annual ground and surface water use.

6. Conducted pump tests jointly with Dr. Kenneth Schmidt and DWR personnel on three irrigation wells in the area between Vinton and Loyalton. Specific capacities and aquifer transmissivities were determined from the data obtained. The data were then used to estimate aquifer recharge rates and ground water storage.

7. Requested that surveyors of the Plumas County Road Department determine elevations of selected wells in the eastern part of the valley, between Loyalton and Vinton. These data, when compared to late 1950s DWR elevations, were used to determine the magnitude and extent of subsidence that has resulted from ground water withdrawal.

SUMMARY

The Department of Water Resources started the Sierra Valley Ground Water Study in July 1980 to provide the technical information needed to formulate and implement a ground water basin management plan.

The geologic and hydrologic data showed that the major ground water supply in Sierra Valley is from a series of confined aquifers. These are in sedimentary deposits that underlie the valley floor to a depth of 2,000 feet.

Wells drawing from these aquifers yield up to 3,200 gallons per minute (gpm); artesian wells have been reported by well drillers to flow at rates up to 100 gpm. These aquifers are recharged mainly by infiltration and percolation of streamflow, and rainfall and snowmelt runoff occuring around the periphery of the basin.

Ground water, usually adequate only for stock and domestic purposes, is also available from unconfined aquifers in shallow alluvial and basin deposits and from fractured "hard" rock areas.

Water level elevations in more than 100 wells were measured during the spring and fall of each year of the study. These data were used to draw semi-annual water-level contour maps, hydrographs, and both short-term (1981 to 1983) and long-term (1960 to 1983) ground water elevation-change maps. The water level contour maps show that in the fall of 1981 and 1982, there was a ground water depression in much of the eastern half of the basin as a result of heavy agricultural pumping. Spring water level contour maps show that the fall depressions fill in after the pumping stops and recharge occurs from winter and spring precipitation. Some deep artesian wells in the center of the valley stopped flowing in the mid-60s and early 70s in response to land use changes and accompanying ground water development north and west of Loyalton. Near Vinton, many artesian wells stopped flowing during intensive ground water development in 1979 and 1980. Wells in the center of the valley also responded to this pumping, with water levels reaching all-time lows. The ground water elevation change maps show that between 1960 and 1983, levels in many wells in the eastern part of the basin had declined by 10 feet or more, with about half of the decline occurring after the spring of 1981.

Comparison of 1972 and 1981 land and water use surveys of the valley show that ground water pumpage increased by 780 percent and alfalfa acreage increased by 180 percent. Acreage planted with grain and truck crops also reached all-time highs in 1981.

A hydrologic balance of the basin for the 1981 water year was made. The balance is a computation of all water entering and leaving the basin; any difference between inflow and outflow represents a change in ground water storage. At the end of the water year, a decrease in ground water storage of about 11,000 ac-ft was estimated, a value slightly less than the total ground water withdrawal (14,500 ac-ft) for the year. This indicates that recharge of the ground water aquifers in the basin was very minimal, due to the near drought-conditions that prevailed.

In 1981, a water quality study was made of selected wells in the basin. The study showed that the poorest quality ground water is the thermal water in the west central part of the basin. The best quality water occurs around the boundaries of the basin. Quality of water from some wells in the central portion of the basin has apparently declined slightly since previous sampling rounds.

FINDINGS AND CONCLUSIONS

1. It is not likely that current pumpage will cause serious harm to the wetland habitat important to birds of the Pacific flyway. Current ground water pumpage, mostly in the east half of the basin, represents a small fraction of the total water supply of the basin.
2. Alfalfa, grains, and truck crops in Sierra Valley have increased in acreage since 1972 and account for almost 100 percent of the ground water developed since then.
3. Smithneck Creek drainage is an important ground water recharge area for the eastern half of the basin. Spring ground water elevation contour maps show a ground water mound--a area where ground water levels are higher than in surrounding areas--near Loyalton. The spring 1981 to spring 1983 change map shows levels in this area up by as much as ten feet or more while the rest of the basin showed either declines or little to no change.
4. Development and concentration of ground water pumpage in the Vinton-Loyalton area over the past 15 to 20 years has had the following effects:
   a. Cessation of flow from many artesian wells
   b. Ground subsidence
   c. Creation of a large pumping depression--an area where ground water levels are lower than in surrounding areas due to heavy pumpage--by the end of each irrigation season.
   d. Temporary reversal of ground water flow in the central portion of the basin due to (c) above. This results in groundwater movement from the western half of the basin towards the east.

5. Groundwater pumpage during the 1981 irrigation season exceeded the basin's ability to recover fully before the 1982 irrigation season began. Throughout much of the eastern half of the basin, spring 1982 water levels were lower than those measured in 1981.

6. Groundwater pumpage during the 1982 irrigation season was within the limits of the basin's ability to recover fully before the 1983 irrigation season began. In most of the eastern half of the basin, spring 1983 water levels were equal to, or higher than, spring 1982 levels.

7. Based on 1981 through spring, 1983 data, ground water levels will fully recover in the eastern half of the basin and avoid overdrafting provided:

   a. total pumpage does not exceed 60 to 70 percent of the estimated 1981 pumpage (about 12,000 ac-ft)

   b. at least eight months pass between the end of one irrigation season and the start of the next.

   Greater pumpage, longer irrigation seasons, and shorter recovery periods will produce a decline in spring water-level elevations in the eastern half of the basin.

8. The quality of ground water in the basin has not changed appreciably since previous sampling rounds. The best quality water is found around the borders and the poorest in the west central part. Poor quality is associated with the Hot Springs and Grizzly Valley Faults. An increase in the electrical conductivity of a few well waters in the central part of the basin has been observed, probably the result of the temporary easterly movement of ground water, mentioned in No. 4, above.

RECOMMENDATIONS

The following recommendations concern the conservation and management of water in Sierra Valley. In most instances, these can be implemented within the existing administrative framework at either the county or Management District level. Some recommendations will require capital investment. These may require the District to levy fees on district water users and/or request financial assistance from County, State, or Federal agencies.

Conservation Measures

1. All flowing wells should be fitted with control values, plugs, or other devices that can stop the discharge of ground water during times when it is not being used.
2. All new development (single family, condominiums, subdivisions, etc.) should be required to incorporate proven water conservation technology in the planning and construction of the project. These should include, but not be limited to, low-flush toilets, flow-control inserts on showers, single-control faucets, water-efficient dishwashers and clothes washers, grey-water recycling, and hot-water pipe insulation.
3. Wherever possible, all new development in recharge areas should keep rainwater on site in a retention basin to aid in ground water recharge. Where this is not feasible, the development should be designed to reduce, retard, and disperse runoff. This may be accomplished by mulched and/or terraced slopes to reduce erosion and retain rainfall, porous drain swales and paving materials for

infiltration, outsloped roads to spread runoff evenly down slope, and landscaping with suitable water-conserving erosion control plants that will protect the soil, facilitate infiltration of rainwater, and reduce runoff.

4. Encourage cluster development to reduce the amount of land being converted to urban use. This will reduce the amount of impervious ground cover and aid in ground water recharge.

5. Preserve existing natural drainage areas such as swales, dry washes, etc.--and encourage the incorporation of them in new developments, rather than covering them over, filling them in or otherwise destroying them. This would aid in ground water recharge.

6. Major aquifer recharge areas should be preserved as open space.

7. Encourage the installation of efficient irrigation systems that minimize runoff and evaporation and maximize the amount of water that will reach the plant roots. Drip irrigation, soil moisture sensors and automatic irrigation systems are a few methods of increasing irrigation efficiency.

8. A surface seal should be mandatory on all irrigation and large capacity municipal or industrial wells in the basin. The seal should extend from the ground surface to a depth of 50 feet or to a minimum of 10 feet below the base of any unconfined aquifer, whichever is less. This will stop or reduce the escape of ground water from confined aquifers via the well's gravel pack. A reasonable effort should be made to install surface seals on all existing wells.

Management Measures

1. Spring and fall water level elevation measurements should be taken on about 110 selected wells within the ground water basin. Twenty-nine of the wells are in the DWR ground water monitoring program and will be measured at no cost to the District. The remaining 81 wells will have to be monitored at District expense. The data collected should be evaluated and summarized at the time it is collected. DWR will measure the additional wells and prepare an annual report upon request of the District and conclusion of a cost-sharing agreement.
2. A method for determining actual ground water pumpage from the basin should be established. This can be accomplished by metering flows from wells or by metering the energy consumption of pump motors once the volume per energy unit has been established.
3. Periodic water quality testing of well water should be done to detect changing conditions. The grid of 68 wells used for the 1981 evaluation should be considered as the base. Twenty-eight of the wells are on the DWR ground water monitoring program and are monitored annually by DWR. DWR will monitor the remaining 40 wells upon request of the District and conclusion of a cost-sharing agreement.
4. Rain gages should be installed and maintained in the vicinity of Loyalton, Beckworth, and near the intersection of Dyson and Heriot Lanes. These will provide a better record of the basin's precipitation and more accurate data for calculating the annual hydrologic balance.

5. A compaction recording device and continuous water level recorder to monitor ground subsidence and its relationship to water level fluctuations should be installed in the area of Dyson Lane one-half to one mile west of Highway 49.

   If the data indicate subsidence, reference points established in 1982 should be releveled. The initial grid of reference points should be expanded during future surveys.

6. The District should require an electric log (E-log) to be run on all irrigation wells, large capacity municipal or industrial wells, and exploration test holes to be drilled in the basin. A copy of the E-log should be submitted to the District and DWR and incorporated into the existing data base.

7. The District should have the Smithneck Creek stream gage reactivated as soon as possible, either by the USGS or DWR. The data are needed to provide a more accurate estimate of the hydrologic balance and to provide a data base upon which potential impacts to the drainage and to ground water recharge from subdivisions can be assessed.

8. Four to six multiple-zone piezometers should be installed in the eastern half of the basin to monitor pressure changes in selected producing zones.

9. When feasible, water quality samples from each producing zone should be taken (and later analyzed) during the drilling of irrigation wells, municipal and industrial wells, and exploration test holes. The results should be submitted to the District and DWR. Zones determined to have poor quality water should be identified. In areas of known water quality deficiencies,

poor quality zones should be sealed off with grout to a minimum of 20 feet above and below the upper and lower boundaries of the zone, upon abandonment of a hole or construction of a well.

10. DWR, Northern District, Ground Water and Geology Section personnel should be notified two days before drilling irrigation, and large-capacity municipal and industrial wells, and geothermal and ground water exploration holes. This will give a geologist a chance to visit the drilling site and gain data not usually included in the well drillers' report.

11. The District should incorporate a means of continuous evaluation of data as they become available. It could retain a geohydrologist or contract an agreement with DWR.

12. The feasibility of artificial recharge in the eastern half of the basin should be investigated.

GEOLOGY

Geologic data for this portion of the report came from numerous sources. Areal Geology, Plate 1, is a compilation of geologic mapping contained in "Northeast Counties Ground Water Investigation" (DWR, 1963) and "Geology and Geohydrology of Sierra, Mohawk, and Humbug Valleys, Plumas and Sierra Counties" (DWR, 1961). Geologic cross-sections of the Sierra Valley ground water basin, showing the subsurface distribution of geologic units and structural relationships, are presented in Plate 2. Subsurface geologic data were taken from well drillers' reports, electrical logs from water wells and exploration holes, a gravity anomaly survey (Jackson et al, 1961), and a Master of Science thesis; "Geology of the Portola and Reconnaissance Peak Quadrangles, Plumas County, California" (Berry, 1979).

Geomorphic Provinces

California may be divided into natural geomorphic provinces according to certain characteristic features--relief, landforms, geology, and landscapes--that distinguish each province. These provinces have developed their distinctive characteristics largely as the result of natural geologic processes acting on the rock types and structure over many millions of years.

The Sierra Nevada is a high, continuous mountain range that extends in a north-northwesterly direction for more than 400 miles. Geologically, the Sierra is a great block of granitic rocks and remnants of older metamorphic rocks that have been tilted westward. It is bounded on the east by the Great Basin province, which extends across Nevada into Utah and is characterized by many north and northwest-trending mountain ranges and intervening basins. To the west is the Great Valley province, consisting of the Sacramento and San Joaquin Valleys. To the north, the Sierra Nevada ends in the Lake Almanor/Honey Lake area, and its rock types and structure are thought to continue northward under the cover of the volcanic terrain of the Cascade Mountains province (Oakshott, 1971). The south end of the Sierra Nevada ends in the Tehachapi Mountains at the southern end of the San Joaquin Valley.

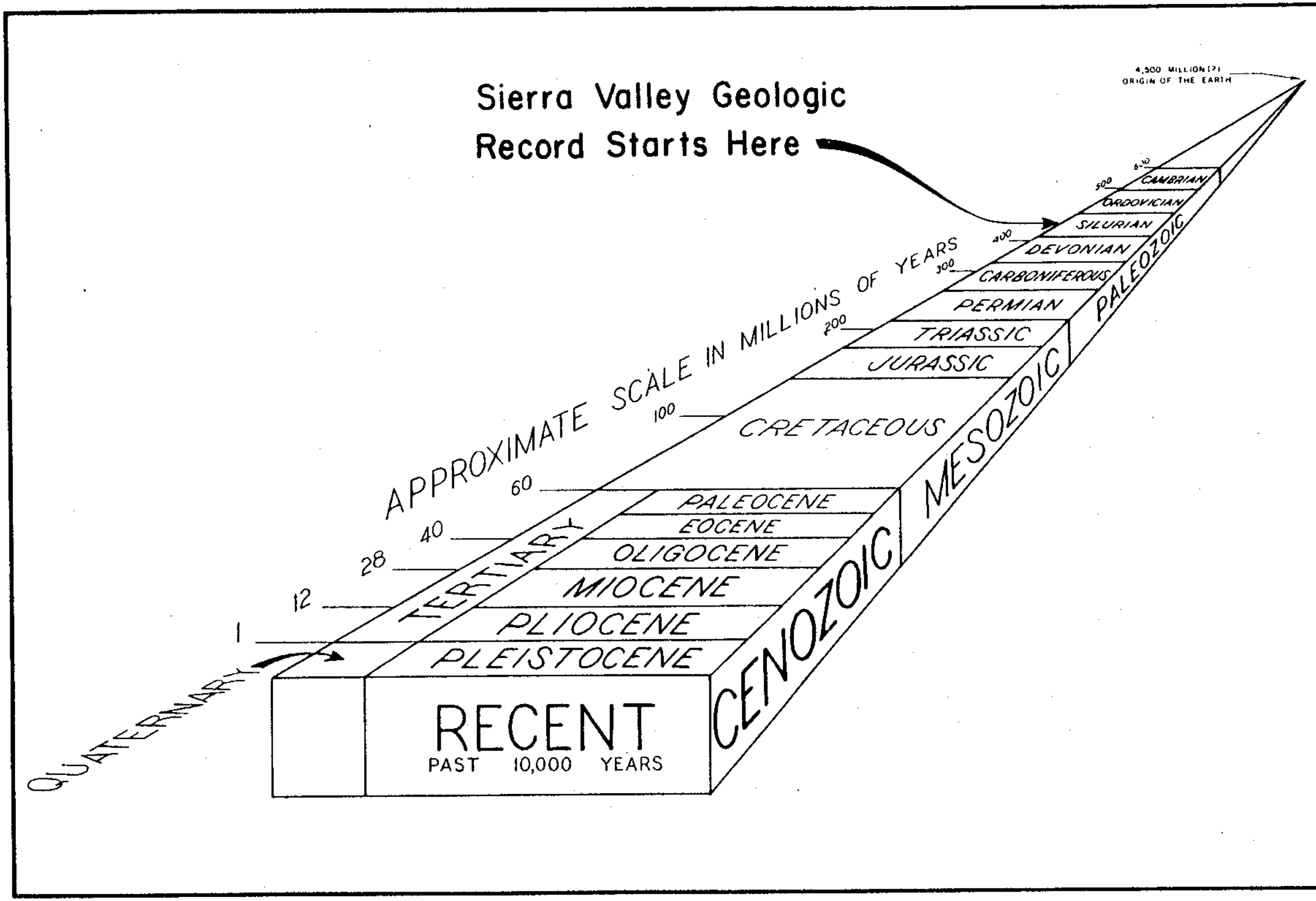
Geologic Setting

Sierra Valley is at the eastern edge of the Sierra Nevada geomorphic province immediately west of the Great Basin geomorphic province. The rocks that underlie the valley are typical of the Sierra Nevada, but the deep alluvium-filled valley is characteristic of the Great Basin province.

The geologic units in Sierra Valley can be divided into three main groups.

The oldest are metamorphosed sedimentary and volcanic rocks intruded by Mesozoic granitic plutons which together are a basement to unconformably overlying Tertiary strata. These Teriary contiental rocks are largely volcanic in origin and include rhyolite, andesite, basalt, and pyroclastic rocks. Quaternary continental deposits of clay, silt, sand, and gravel unconformably overlie the older rock units and are their erosional products (Figure 2).

FIGURE 2



LOOKING BACK IN GEOLOGIC TIME

Geologic Units

Basement Complex Rocks

The basement complex consists of pre-Tertiary rocks unconformably overlain by Tertiary volcanic strata and Quaternary sediments. Its rocks are therefore of two types: metamorphic and granitic.

Metamorphic Rocks - A belt of metamorphic rocks is exposed on the east side of the valley and extends northward from east of Mount Ina Coolbrith (T21N, R16E, S1, MDB&M) to an unnamed hill just north of Chilcoot. It is presumed that these rocks underlie some of the region now covered by Tertiary and Quaternary units. The metamorphic rocks consist of quartzite, slate, marble and metavolcanics of Paleozoic to Mesozoic age.

Granitic Rocks - Exposures of granitic rocks occur along the northern and western edges of the valley, predominantly in the higher elevations. Granite underlies the basin and intrudes into the metamorphic rocks. One 2,231-foot exploratory drill hole (T22N/R15E,S32P1) in the middle of the valley encountered granitic rocks at a depth of 2,165 feet and helped to substantiate basement complex composition.

The granitic rocks range in composition from quartz diorite through true granite. They are usually massive, crystalline, and fractured; they present rounded outcrops, and are a portion of the Sierran batholith of Jurassic to Cretaceous age. There are also granitic pegmatite dikes.

Volcanic Rocks

Volcanic rocks are mainly in the upland areas surrounding the valley or appear as isolated buttes and low hills in the valley. These Tertiary age rocks overlie or are faulted against basement complex rocks. Some drill-holes in the valley find volcanic rocks at depth, and a few penetrate to the underlying basement complex. The volcanics vary in composition and origin and are differentiated into four groups: rhyolite, andesite, basalt, and pyroclastic rocks.

Rhyolite - Light gray to white massive rhyolite occurs as isolated plugs and shallow intrusives northwest of Sattley. The rock is of undetermined age, but may be related to the rhyolitic pyroclastic rocks of Miocene age found elsewhere on the valley.

Andesite - Andesite occurs as plugs, flows, and tuff breccias at various locations around the valley. It is hard, gray, porphyritic, and in some places brecciated.

Basalt - Tertiary basalt caps many peaks in the area and is present both as remnants of flows and as volcanic "necks" that represent centers of eruptions. According to Durrell (1959), these rocks may be related to the Warner basalts further north. They are gray to black olivine basalt that typically shows columnar jointing.

Pyroclastic Rocks - Pyroclastic rocks consist of fragmental material ranging in size from fine ash to large boulders that have been blown into the atmosphere by volcanic explosion. Pyroclastic rocks in Sierra Valley range from pyroxene and hornblende andesitic mudflow breccia to rhyolite tuff. The mudflow breccias range in age from Oligocene to Pliocene (Durrell, 1959). The rhyolite tuff is Miocene age.

Sedimentary Deposits - In Sierra Valley, the continental sedimentary deposits contain the primary aquifers, yield large quantities of water, and are the source of nearly all of the pumped ground water. These deposits range in age from Pleistocene to Recent and are differentiated according to their mode of deposition and particle-size distribution.

Pleistocene Lake Deposits - Lake deposits crop out at widely scattered localities around the basin perimeter, and occur throughout the valley beneath a thin cover of Recent sediments. They vary in thickness, with a maximum of about 2,000 ft. They consist of clay, silt, sand, and gravel, and although are all classified as lake deposits, they also include coarser-grained channel, near-shore, and deltaic sediments. The sediments are generally course-grained around the margins of the valley and grade to finer material toward the middle of the basin. The deposits are vertically stratified and show lateral facies changes. Probable reasons for this variability include diversity of lithology of highland rocks, sediment input from local tributaries, slow filling of the lake, lake level fluctuation corresponding to seasonal and longer-term climatic variations, and topographic changes caused by erosion and seismic activity.

Pleistocene Morainal Deposits - There are a few small glacial moraines around Sierraville. Moraines are a heterogeneous mixture of debris deposited during the Pleistocene glacial epochs. They include poorly sorted pieces and blocks of metamorphic and igneous rocks in a matrix of fine sand and rock flour.

Recent Alluvial Fan Deposits - Alluvial fan deposits occur around the margins of the valley next to highland areas. They are most developed at the mouths of streams entering the valley. In some areas, adjacent fans have coalesced to form alluvial aprons. Fan deposits are stratified, contain poorly sorted sand, gravel, and silt, with occasional clay lenses, and may be as much as 200 ft thick.

Recent Alluvium - Alluvium occurs along stream channels and on a slightly elevated area in the center of the valley. The deposits are up to 50 ft thick and, depending on their location in the valley, overlie Pleistocene lake deposits, basin deposits, fan deposits, volcanic rocks, or basement complex rocks. The alluvium consists of a heterogeneous mixture of poorly sorted sand and silt with some lenses of clay and gravel. Along active stream channels, sand, gravel, cobbles, and occasionally boulders are predominant.

Recent Basin Deposits - Extensive basin deposits are found throughout Sierra Valley. They are up to 35 ft thick and overlie the Pleistocene lake deposits. There are three types. The finest grained (Qb_1) is found in poorly drained areas and consists of dark-gray clay containing some organic material. Because of poor drainage, certain alkali salts have accumulated. A coarser grained silt-to-clayey silt (Qb_2), also containing organics, occurs in broad areas of the valley floor. Some alkali is also found in these sediments. A few areas of the basin are covered by freer draining material (Qb_3) composed of sandy silt with very little alkali.

Recent Sand Deposits - In the northeastern corner of the valley there are unconsolidated, fine-grained sand deposits. These represent an area of once active sand dunes that have stabilized and are now vegetated.

Structure

The geologic structure of Sierra Valley consists of a downdropped fault block, or graben, surrounded by uplifted mountains, or horsts. The primal valley floor was an irregular surface of basement rock, formed by steeply dipping to vertical, normal, and strike-slip faults. Northwest-trending faults are dominant and attendant branch faults offset and are occasionially offset by northeast-trending faults. The southern boundary of the valley, near Sierraville, may be formed by a complex pattern of faults, which included the Mohawk Valley Fault.

Relatively steep gravity gradients (from a 1959 DWR gravity survey) on the northwest and west margins of the valley suggest steep-bounding faults. The trend of these is slightly east of north and, near Beckwourth, trends northwest. Further towards the center of the valley are the most prominent faults. The first, the Grizzly Valley Fault, enters the valley via Mapes Canyon, north of Beckwourth, and extends southeast along Smithneck Creek. The Hot Springs Fault parallels the Grizzly Valley Fault three miles to the southwest. This fault's name refers to the Marble Hot Springs wells and other thermal artesian wells that are located along this trace. An unnamed fault diverges from the Hot Springs Fault near Beckwourth and connects with the Grizzly Valley Fault near Loyalton. Direction of movement and magnitude of vertical displacement along these faults are not known.

South of Vinton, the valley is probably bounded by steeply dipping faults roughly parallel to those on the west side of the valley.

Seismicity

Faulting that began during the Sierra Nevada uplift (Miocene time) has continued intermittently to the present. Geochemical, geophysical, and geological evidence indicate that the Hot Springs and Grizzly Valley Faults may have been active during Quaternary time, and they are still considered active (Berry, 1979).

The region around Sierra Valley has a relatively high potential for seismic activity. Since 1932, 43 earthquakes with a Richter magnitude of 4.0 or greater have been recorded within 34 miles of Sierraville. A 5.6 Richter magnitude earthquake, centered near Loyalton in April 1959, caused about $5,000 worth of damage.

Geologic History

The geology of the Sierra Nevada reflects an extremely active margin between the North American continent and the ocean lithosphere. Most of the Tertiary-age and earlier rocks have their genesis in the resulting forces generated by this activity.

The present study area has physical traces back to the Silurian period (see Figure 2). At this time, a marginal sea apparently existed along the edge of the continent, receiving sediment from inland sources. Probable subduction of the ocean lithosphere eastward under the continent began in the Devonian period. Regional overthrusting and volcanisim occurred in what is today called the Antler orogeny. Similar orogenic events involving western North America occurred during Permian-Triassic (Sonoma orogeny) and Late Triassic-Late Jurassic period (Nevadan orogeny). The metamorphic rocks of the basement complex represent volcanic rocks and sediments deposited as a result of these events.

During the Cretaceous-Early Tertiary period (Cordilleran orogeny), subduction moved westward and the Sierran granitic plutons were intruded into the existing country rock. Volcanic rocks were erupted periodically throughout the Mid-to-Late Tertiary as subduction continued in the area of the present day Coast Ranges.

In Late-Pliocene time, faulting and erosion began to change the landscape toward its present shape (Berry, 1979). Lakes backed up in depressions (grabens) and received sediment from the surrounding highlands (horsts); Plio-Pleistocene Lake Beckwourth filled Sierra Valley to a probable elevation of 5,120 ft above sea level (Berry, 1979).

During the Pleistocene age, glaciers formed in the mountains south and west of Sierraville and contributed sediment and water to the lake. Draining to the west, the lake eroded a water gap and slowly emptied. Today, erosion, sedimentation, and faulting continue.

GEOHYDROLOGY

General Hydrologic Properties of Aquifers

Ground water occupies voids below the land surface in the zone of saturation. Historically its chief source has been precipitation, but only a fraction of the precipitation that falls on a given area percolates into the subsurface to become ground water. Some of the precipitation is returned to the atmosphere by plants and by evaporation in a process called evapotranspiration (ET). The rest becomes surface runoff.

Porosity is the ratio of the volume of voids (interstices) of soil or rock to the volume of its mass. It is an index of water storage when the material is saturated. Most rocks forming the earth's surface have void spaces which may contain water. These range in size from minute pores in clays to large lava tubes in basalt flows.

Permeability is the ability of the material to allow fluids to move through it. The degree of permeability depends on the size and shape of the pore space and the extent, size, and shape of their interconnections. Porosity is not necessarily directly related to permeability. Porosity may be high, but if the voids are small or not interconnected, the permeability is low.

An aquifer is a geologic unit that stores, transmits, and yields significant quantities of water to wells and springs. There are two general types of aquifers. In an unconfined aquifer, the "water table" is defined by the level at which water stands in a well that penetrates the water body just far enough to hold standing water. A confined aquifer is a completely saturated aquifer whose upper and lower boundaries are impervious or semipervious materials. Water stands above the upper boundary of the aquifer in wells that penetrate it. The piezometric surface is the surface to which confined water will rise in a well. A well penetrating a confined aquifer is an artesian well, and if the pressure is great enough to cause the water to rise above ground surface, it is a flowing artesian well.

The storage coefficient is the volume of water taken into or released from storage in a vertical column one square foot across, when the water table or piezometric surface rises or declines one foot. The storage coefficient of a confined aquifer depends on the compressibility of the aquifer and the water. For an unconfined aquifer, storage coefficient is nearly equal to the specific yield and refers to the volume of water that will drain by gravity.

Transmissivity equals the product of the average permeability and the thickness of an aquifer. It is expressed as gallons per day per foot (gpd/ft) width of aquifer under a 100 percent hydraulilc gradient. It represents the rate at which water flows through a specific width of the aquifer.

Hydraulic gradient is the slope of the piezometric surface or water table. It is defined as the change of pressure head per unit of distance of flow in a given direction. Ground water moves from areas of recharge to areas of discharge, or from areas of higher water level to areas of lower water level. The rate of ground water movement is normally very slow, in the magnitude of a few feet to a few hundred feet per year.

The static water level and pumping level are the two water levels before and after turning on a well pump; the difference in these levels is called drawdown. Specific capacity is the rate of discharge of a water well divided by the drawdown. It is commonly expressed in gallons per minute per foot (gpm/ft). Pumping a well in an unconfined aquifer locally depresses the water table and results in the formation of a cone of depression which defines the area of influence of the pumping well. A change in water level in a confined aquifer results in pressure changes in the surrounding aquifer material.

Water level changes not related to pumping in either confined or unconfined aquifers are due to annual and seasonal variations in the rate of recharge and discharge. Minor fluctuations may be due to changing atmospheric pressure, earthquake activity, and even the passage of trains!

The hydrologic cycle (see Figure 3) is the natural circulation of water through evaporation, precipitation, runoff, infiltration, transpiration, percolation, and seepage. Within any hydrologic system, the inflow of water will equal the outflow of water plus or minus any change in storage.

Hydrologic Characteristics of Geologic Units

A number of geologic materials form aquifers. The most common aquifers consist of unconsolidated sand and gravel, which have relatively high porosity, permeability, specific yield, and transmissivity. Permeability distinguishes a nonwater-yielding from a water-yielding material. Crystalline rocks such as granite are considered nonwater-yielding because they contain water only in open fractures. Most alluvium is considered water-yielding, containing water in the many interconnected void spaces between particles of sand and gravel.

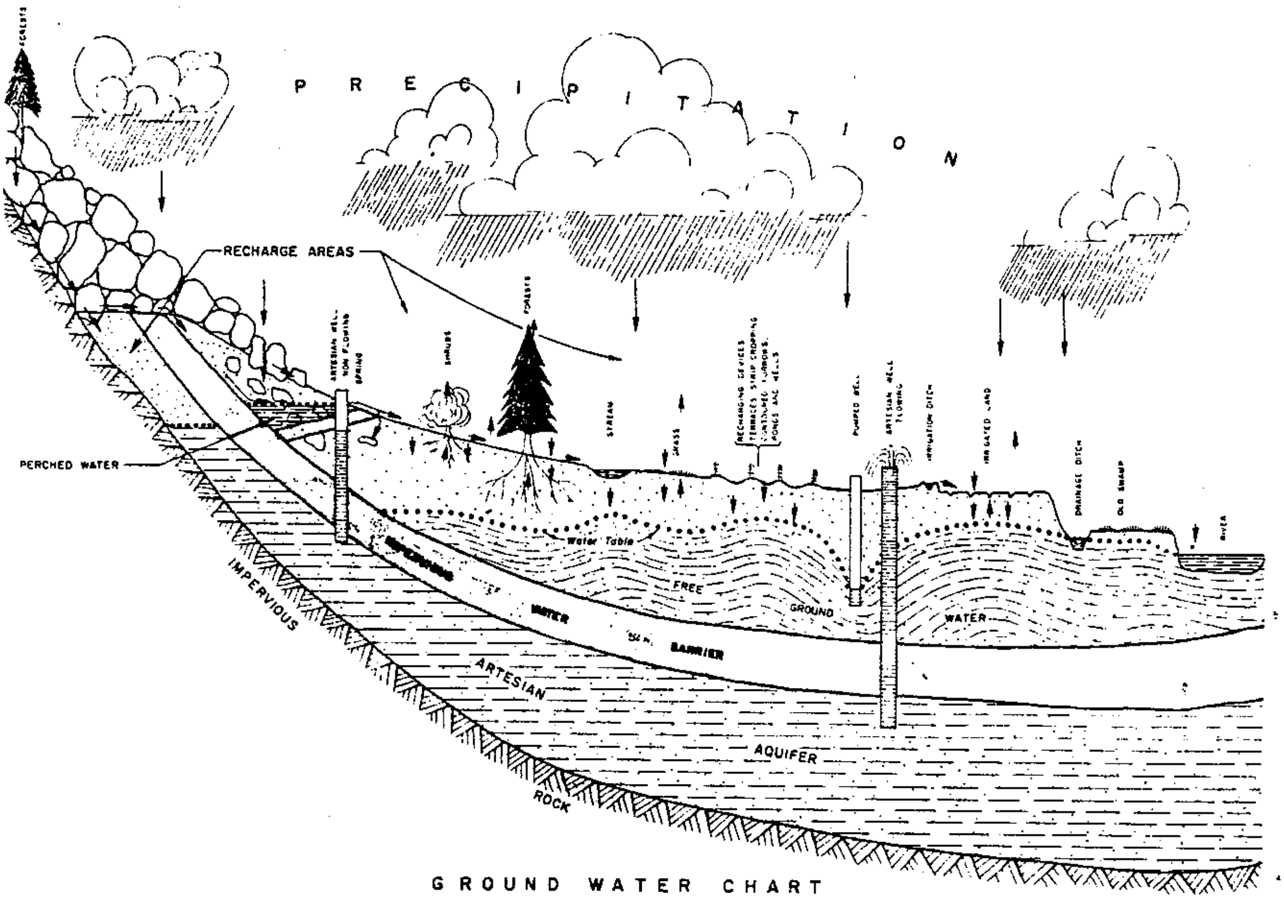


Figure 3. Ground Water Recharge and Discharge

This sketch illustrates the occurrence and consumption of ground water as described in the text. The arrows show the varied pathways that waters take in the hydrologic cycle.

Except for shallow wells, the water-yielding characteristics and water quality of specific aquifers in Sierra Valley cannot be determined precisely due to the method of well construction. The typical large-capacity deep irrigation well penetrates four confined aquifers on its way to a total depth of 520 ft, is perforated from 100 to 515 ft, and gravel-packed from the ground surface to the bottom. The four aquifers may be contributing equally to the reported yield or one may be producing 50 percent of it. One aquifer may be producing poor quality water while the other three produce excellent water. Because of this mingling of effects from different aquifers in a single well, the determination of a particular aquifer's water-yielding properties and water quality cannot, from the available data, be determined.

Nonwater-Yielding Units

Basement Complex Rocks

In Sierra Valley, the basement complex is considered to consist of pre-Tertiary rocks overlain by younger units. These nonwater yielding rocks underlie the basin and crop out in and around it. The quantity of water in them is determined by the size and density of the secondary fractures. Wells drilled in these rocks generally yield little or no water; in some areas, yield may be sufficient for domestic or stock use. The specific yield of these rocks is low, estimated to range from zero to 3 percent, their porosity is low, probably 1 to 10 percent, and their permeability is very low.

Volcanic Rocks

The volcanic rocks--rhyolite, andesite, basalt, and pyroclastic rocks--vary considerably in their water-yielding characteristics. The pyroclastic rocks generally yield little water, except along fractures and fissures. The andesitic and rhyolitic rocks are moderately permeable and yield small amounts of water. Well yield from the basalts depends on the density of joints and fractures (permeabililty) and its location relative to the water table or piezometric surface. In most of the valley the basalts are located at the summits of mountains, well above the zone of saturation. Where basalts are found beneath the zone, well logs indicate that it is not highly jointed and fractured, so the basalts are a very poor source of water. Specific yield of the volcanic rocks ranges from 0 to 15 percent, porosities range from about 10 to 40 percent, and permeability ranges from very low to moderate. Well yields from these rocks are usually sufficient for stock and domestic use only.

Water-Yielding Units

The water-yielding units in Sierra Valley are the sedimentary deposits of Quaternary age. They yield variable quantities of water to wells and include the primary aquifers in the valley.

Pleistocene Lake Deposits

The lake deposits contain confined and semiconfined water-yielding units. In Sierra Valley, they yield large quantities of water to wells and are a major ground water source. The deposits range in porosity from low to high and have estimated specific yields of 1 to 25 percent. Specific capacities of wells completed in these deposits can be as much as 55 gpm/ft with production rates as high as 3,200 gpm.

Pleistocene Morainal Deposits

Glacial moraines can locally yield fair amounts of water, but the extremely fine rock floor matrix makes them locally impermeable. Their location in the valley and limited aerial extent make them a minor source of ground water. Specific yield is estimated to range from 3 to 15 percent.

Recent Alluvial Fan Deposits

The alluvial fan deposits are poorly consolidated and moderately to highly porous and permeable. They have specific yields ranging from 8 to 17 percent, can yield large quantities of water to wells, and are a major ground water source. Towards the middle of the valley, the fan deposits coalesce or interfinger with the basin and alluvial deposits and the lake deposits at depth. Alluvial fans are important ground water recharge areas for these intrabasin deposits.

Recent Alluvium

Alluvial deposits contain lenses of coarse material and are moderately-to-highly permeable and capable of providing fair to good quantities of water to shallow wells. Because the deposits are estimated to be not over 50 ft thick, the water supply is limited. Specific yield of these deposits is estimated to range from 5 to 25 percent.

Recent Basin Deposits

The basin deposits, due to their homogeneity and fineness, have low-to-moderate permeability and estimated specific yields of 3 to 7 percent. Shallow wells completed in these deposits generally yield sufficient quantities of water for stock and domestic use only.

Recent Sand Deposits

The sand deposits are unconsolidated and have high permeability and porosity. Large quantities of water may be extracted from these, but limited areal extent makes them a minor ground water source.

Aquifer Descriptions

Aquifers are geologic formations, groups of formations, or parts of formations that yield and transmit water in sufficient quantities to supply springs and wells. In Sierra Valley the aquifers are only parts of formations because none is composed entirely of water-yielding materials such as sand and gravel.

Finer material such as silt, or sand with silt or clay, may yield water, but only in minor amounts. However, they can transmit water from adjacent aquifers and constitute important ground water storage units. Geologic formations or parts of formations composed of these types of materials are called "aquitards".

Materials composed of large amounts of clay are relatively impermeable and are called "aquicludes"; these neither yield water to wells nor transmit water from adjacent sources. They are boundaries to aquifers and aquitards and confine ground water above and below them.

Information for this study on thickness, depth, and extent of the principal aquifers, aquitards, and aquicludes in Sierra Valley was obtained from drillers' well logs, E-logs of water wells and exploratory test holes, and areal geology. Materials described by well drillers or inferred from E-log interpretations were classified as aquifers, aquitards, or aquicludes, as appropriate to the above definitions. The interpretations of the subsurface and surface data are presented in Plate 2, and are referred to in the following discussion.

Cross-section A-A', representing the basin from northwest of Vinton to south of Loyalton, shows aquifers at the surface and at depth interstratified with aquitards and aquicludes to the left (north) of the Lucky Hereford headquarters. These aquifers are mainly alluvial fan deposits where they are close to the basin-bounding granitic and volcanic rocks. Away from the basin boundary they grade laterally into coarse lake and stream deposits.

The aquitard materials at the surface and at shallow depth are basin, alluvial, and lake deposits. Shallow wells (less than about 200 ft) completed in this area yield moderate amounts of unconfined water; deeper wells penetrating the confined aquifers can produce as much as 3,000 gpm. South of the Lucky Hereford headquarters, a thin layer of aquitard material overlies the aquifer. These are basin deposits and fine-grained alluvium overlying alluvial fan and coarse-grained stream deposits. Near Loyalton are lenses of fine-grained alluvial materials that locally confine some shallow ground water.

Cross-section B-B' shows a general north-south section through the center of the valley. Basin, alluvial, and lake deposits comprise the upper 50 to 200 ft of aquitard material that overlies a thick sequence of interstratified aquifers and aquicludes. The aquifers consist of alluvial fan deposits near the basin boundaries and grade to alluvial and coarse-grained lake deposits towards the center of the basin. The aquicludes are predominantly fine-grained lake deposits. Shallow wells near this cross-section produce moderate quantities of unconfined ground water, usually sufficient for stock and domestic needs. Deep wells here can produce artesian flows of 20 to 100 gpm; when pumped, yields of 1,000 to 2,000 gpm are reported.

Cross-section C-C' extends southwesterly across the valley from just north of Vinton to just west of the Marble Hot Springs. The upper 30 to 50 ft of aquitard material consists of basin and alluvial deposits. Beneath these is a sequence of interstratified aquifers and aquicludes composed of alluvial and lake deposits. Aquifer materials at the margins of the basin are alluvial fan and stream sediments. Shallow wells near this section have reported yields of 5 to 20 gpm; deep wells (greater than 350 ft) can yield 250 to 1,500 gpm.

Cross-section D-D', extending northeast-southwest through Loyalton, shows a sequence of relatively coarse-grained alluvial fan and stream sediments interspersed with lenses of finer materials. In this area, shallow confined water is present and shallow wells here are reported to produce 2 to 20 gpm. Deep wells (greater than 250 ft) have reported yields of 750 to 2,500 gpm.

Hydrologic Aspects of Faults

Fault zones may be separated into three general hydrogeologic categories: those which readily transmit ground water; those which act as ground water barriers; and those which do neither.

When brittle, massive, or lithified rocks, such as the basement complex and volcanic rocks, are faulted, many fractures may develop along the plane of movement. This zone of fracturing varies in width and density of individual fractures, and may contain little or no fault gouge. Such fault zones will readily transmit ground water. The Hot Springs, Grizzly Valley, and Mohawk Valley Faults are believed to belong to this group.

Faults acting as ground water barriers are located within sedimentary deposits and certain water-yielding volcanic rocks. The barrier is formed by offset of permeable beds against less permeable beds, or the formation of fault gouge in the fault zone that transects and thus destroys the continuity of water-yielding materials. Such ground water barriers may not completely stop the flow of water but merely impede it. The Hot Springs Fault may also fall into this group where it extends into the sedimentary deposits of the valley.

Faulting has no hydrologic effect when fault gouge forms in already impervious rock, or no barrier develops as the result of offset in pervious materials. Faults of this type have no known representatives in Sierra Valley. Using hydrologic data, they are difficult to detect because they produce no change in the movement of ground water.

OCCURRENCE AND MOVEMENT OF GROUND WATER IN SIERRA VALLEY

To determine the occurrence and movement of ground water in Sierra Valley, data from various sources were used. Spring and fall well water level measurements provide valuable information on aquifer recharge and discharge points and on the general directions of ground water movement. When this information is added to other data, such as water quality analyses, amounts and locations of pumpage, pump tests, and surface and subsurface geology, a picture of the basin's ground water dynamics emerges. Available information provides a fairly complete analysis, though continued data collection and analyses are needed to refine it.

This is a description of the typical yearly changes in ground water conditions in Sierra Valley:

At the end of the irrigation season, generally in mid-September, water levels in deep wells (deeper than 200 to 300 ft) begin almost immediately to rise at rates of 2 to 3 ft per week. In early November, the first of the winter storms drops a few inches of rain, and in a few days, water levels in the shallow wells begin to slowly rise. By the end of November, recovery in the deep wells has slowed to about 1 ft per week. This rate remains fairly constant throughout the rest of the winter and spring. By late December, most of the wells that stopped flowing the previous summer begin to flow again. Flowing wells that were down to a trickle in September now flow at 1 to 2 gpm. In January, the water level is near ground surface in the shallow wells. It remains there throughout spring and then slowly declines during summer. Water levels in deep wells continue their slow, steady rise. In some of these wells, the water rises to the ground surface. The last spring storm often leaves the valley in April, and by mid-May, the large-capacity irrigation wells, most of which are in the eastern half of the valley, begin pumping. The shallow wells are not affected, but the deep wells in the area of pumping show a reduction of flow or declining water levels within a day or two. As pumping continues, the water level in nearby nonpumping wells declines as much as one-half to one foot per day. By the end of the irrigation season, water levels in deep wells decline 60 ft or more, while others are down only a few feet. The pumps are then turned off, and the cycle repeats itself.

This scenario summarizes the general fluctuations of ground water in Sierra Valley for a typical year without overdraft. Changes will follow changing weather conditions. During a drought period, ground water pumping would probably increase and flowing wells would be fewer or may not recover from the previous season. Frequent summer rains would decrease the need for ground water pumping and flowing wells that normally stop flowing in the summer may continue flowing throughout the cycle.

Movement of Ground Water

The main direction of ground water movement in the unsaturated zone is down. Infiltration and percolation are words that describe this movement. Infiltration is the process by which water enters the soil or rock mantle from the surface, and percolation is the process by which the water moves below the land surface.

In the zone of saturation, ground water tends to flow horizontally more easily than vertically. The horizontal direction of flow can be graphically presented by drawing flow lines on a ground water elevation contour map so that the intersection of the flow lines and water level contour lines form right angles. Thus, it can be seen that in the spring (Plates 3 and 4) ground water moves from the edges of the basin to the area within the 4,880-ft water level contour line. This contour line is open west of Beckwourth, suggesting ground water outflow from the basin in this area.

The fall water level contour maps (Plates 5 and 6) show that a closed depression exists in fall in most of the eastern half of the basin. This depression results from ground water withdrawal rates between spring and fall exceeding recharge rates. Its effect on the direction of ground water flow in the western half of the basin is reverse from the spring flow direction, i.e., it flows toward the area within the closed 4,860-ft water level contour line. In winter and spring, when ground water recharge exceeds withdrawal, this easterly movement of groundwater slows, stops, and then resumes its normal westerly direction as the depression fills.

Fluctuations of Ground Water Levels

Ground water levels fluctuate annually in response to pumpage and evapotranspiration and to recharge from infiltration and percolation. Levels are usually highest in spring and lowest in fall. Long-term fluctuations occur when recharge exceeds or falls short of discharge. This section describes long-term and seasonal changes in water levels from the earliest ground water measurements in the late 1950s and early 1960s up to the spring of 1983.

The earliest DWR water level measurements were made in 1957 and provided a data base to which more recent measurements can be compared.

Changes in water level elevations from 1960 to 1983 are shown in Plate 7. This map shows most of the eastern half of the groundwater basin, with water levels in 1983 10 ft or more lower than in 1960. This decline has occurred in wells tapping confined aquifers and is reflected in reduction or loss of artesian flow from wells in the area.

Water level contours for spring 1981 and spring 1983 are shown in Plates 3 and 4, respectively. Comparison of these levels is shown in Plate 8. These plates show that water level declines of 5 ft or more have occurred in most of the eastern half of the ground water basin in just the past few years, accounting for probably half of the water elevation declines that have occurred since 1960. These water table declines reflect changes in land use and changes in water supply sources during the same period. It must be noted that these contour maps represent composite ground water levels and may include water from both free and confined aquifers. Though these levels commonly do not indicate the surface of a single water table or piezometric surface, they are representative of the changing hydrologic conditions in the basin when the same wells are consistently used over time.

Hydrographs of fluctuations of water levels in wells are shown in Plate 9. Hydrographs of four wells in which continuous water level measurements were made show water level changes during the term of this study. Long-term and seasonal fluctuations in water levels in four wells are also shown.

In Plate 9, Diagram 1, the record of water levels in well T23/R16E-32K1, two miles west of Vinton, shows a few feet of rise in the water level between summer and winter. After October 1981, peaks develop in response to periods of rainfall and represent temporary ground water storage. These fluctuations are characteristic of wells in shallow unconfined aquifers. Wells T22N/R16E-17C1 and T22N/R15E-36J2, 3-1/2 to 4 mi southwest and west of Vinton, respectively, show spring-to-fall water level declines of more than 30 ft. These rapid declines are responses to ground water pumpage nearby and are characteristic of wells completed in confined aquifers from which other wells are also pumping. Temporary reversals or decreases in the rate of water level decline show times when irrigation pumpage was idle or limited. Fall-to-spring water level recovery is continuous until the onset of the next irrigation season. Well T23/R14E-26H2, near Beckwourth, shows water level fluctuation of about 10 ft between May and September. The water level recoveries and declines closely parallel seasonal rainfall patterns and are characteristic of wells in unconfined aquifers.

Plate 9, Diagram 2, shows seasonal and long-term fluctuations of water levels in four wells in the ground water basin. Well T22/R16E-17E2, near the intersection of Highway 49 and Dyson Lane, is representative of most artesian wells in the general area west and southwest of Vinton. Spring and fall levels had shown no significant change until about 1980 when spring-to-fall fluctuations greatly increase and spring water elevations show substantial annual declines. These can be attributed to the development of fourteen center pivot and two lateral ground water irrigation systems in this part of the basin between 1979 and 1981. Well T22N/R15E-22Q1, in the center of the valley near the intersection of Heriot and Dyson Lanes, is typical of deep artesian wells that stopped flowing in the mid-1960s and early 1970s. Spring water levels show a gradual lowering between 1965 and 1975, a leveling out for a few years and then a resumption of annual declines. This trend corresponds to land use and irrigation water-source changes in the valley and shows that there is hydraulic connection with irrigation wells drilled in the 1960s and '70s, and 1980-81. Wells T23E/R15E-36J1 and T23N/R14E-25K1 show water level fluctuations that are typical of wells completed in the unconfined aquifers of the basin. The water levels respond to variations in annual rainfall more than to pumping. The 1976-77 drought shows this quite clearly. These two wells are different in that 36J1 is a deep well with artesian water while 25K1 is shallow with unconfined water. The reason for the similarities in hydrographs is that artesian water in 36J1 is entering the unconfined aquifer via the gravel pack and possibly through leaky casing, so the water levels reflect the elevation of the local unconfined water table.

Ground Water Recharge

The rate (gpd, ac-ft/yr, etc.) at which ground water flows through a particular section of the basin is a function of the hydraulic gradient, the transmissivity of the aquifer, and the width, measured perpendicular to the hydraulic gradient, of the portion of the aquifer under consideration. Rate of flow is expressed as: $Q = TIL$, where Q is the quantity of water flow in gallons per day, T is the coefficient of transmissivity in gallons per day per foot of width, I is the hydraulic gradient in feet per mile, and L is the horizontal width, in feet, of the portion of the aquifer being considered.

The hydraulic gradient and width of the area being considered can be determined directly from ground water level contour maps, while the determination of transmissivity usually requires an aquifer test.

Total basin recharge, using transmissivity values calculated with data from three pump tests (see Appendix D) and average hydraulic gradients from the 1981 and 1983 spring water level elevation contour maps (Plates 3 and 4), is estimated to be about 70 ac-ft/day. Under existing conditions most of this (about 50 ac-ft/day) enters the eastern half of the basin from surrounding recharge areas. Elsewhere, recharge rates are considerably less because of generally lower hydraulic gradients. Unlike the eastern part of the basin, where large quantities of ground water are pumped during the summer and fall irrigation season (about 65 ac-ft/day), creating substantial changes in storage and thus room for recharge, the western half experiences only minor changes in storage and hence little recharge. Water available for recharge is rejected and runs off as streamflow out of the basin because of the absence of underground storage space.

A recharge rate of about 3 ac-ft/day is estimated to be entering the basin from the area north of Sierraville (T = 21,000 gpd/ft, I = 8 ft/mi, W = 3 mi) and 17 ac-ft/day (T = 30,000 gpd/ft, I = 20 ft/mi, W = 9 mi) from the rest of the recharge areas. Recharge in the confined aquifers of the basin comes from infiltration and percolation of rainfall and streamflow in areas where the confining bed rises to or near the surface (see Figure 3).

Recharge in the unconfined aquifer of the basin comes from infiltration and percolation of rainfall, streamflow, and applied irrigation water. The rate of recharge is influenced by: (1) the vertical permeability of the surface deposits; (2) vegetative cover; (3) frequency, intensity, and volume of precipitation; (4) topography, (5) temperature, and (6) available storage space. Water level measurements in the few wells that are drilled solely into the unconfined aquifer show that there is relatively little change in storage between spring and fall. (Fall water levels are about 2 to 7 ft below spring levels.) This is because: (1) few wells draw from the aquifer, and (2) infiltration and percolation of applied irrigation water either provides recharge during the summer and fall or reduces natural discharge from the zone of saturation.

Ground Water Discharge

Sierra Valley is a well-defined ground water basin with a bedrock boundary. Subsurface inflow could enter only along pervious fault zones. Mineralized thermal water found in wells along the traces of Hot Springs, Grizzly Valley, and Mohawk Valley faults is evidence of water movement, but not necessarily of inflow from outside of the basin.

There are few data concerning subsurface outflow from the valley. A small amount of water seeps into the railroad tunnel east of Chilcoot, forms a small stream, and flows east out of the basin. Local residents say the tunnel intercepted the water table and caused a drop in water levels in surrounding wells.

Evapotranspiration (ET), effluent (outflowing) reaches of streams, springs, and pumping and flowing wells are the main sources of ground water discharge in the valley.

Effluent streams receive ground water discharge from unconfined aquifers where the water table is higher than the water surface of the stream. This discharge is greatest during the winter and spring and declines to almost nothing by fall.

Springs occur in the valley at or near the ground water basin boundary. They reveal areas where the ground water surface intersects the ground surface or where a subsurface barrier to ground water movement forces the water to the ground surface. Flow from springs vary; some flow year round, while others dry up in the summer or fall.

Wells, by their general method of construction in Sierra Valley, are direct conduits for the discharge, and in some cases, recharge of ground water. A flowing well discharges confined ground water and if it is open to more than one aquifer, as many wells in Sierra Valley are, conditions permit ground water flow from one aquifer to another. This can work in both directions--deep aquifers supplying ground water to shallower aquifers or shallow aquifers supplying deeper ones. The determining factor is the hydrostatic pressure differential in the individual aquifers (see Figure 4). It is suspected that this condition may be partly responsible for the apparent changes in water quality in the valley, poor quality ground water from one aquifer having a pathway to good quality ground water in other aquifers. Flowing artesian wells are present in many parts of the valley and discharge confined ground water at varying rates; flow during the winter and spring is usually greater than the summer and fall flows.

When a well is not flowing or flowing at a rate less than that needed, it may be pumped. Pumping accelerates ground water discharge and, depending on the rate of pumping and location in a basin, may affect (1) other wells, (2) the hydraulic gradient, (3) recharge rates, and (4) the physical characteristics of the aquifer itself.

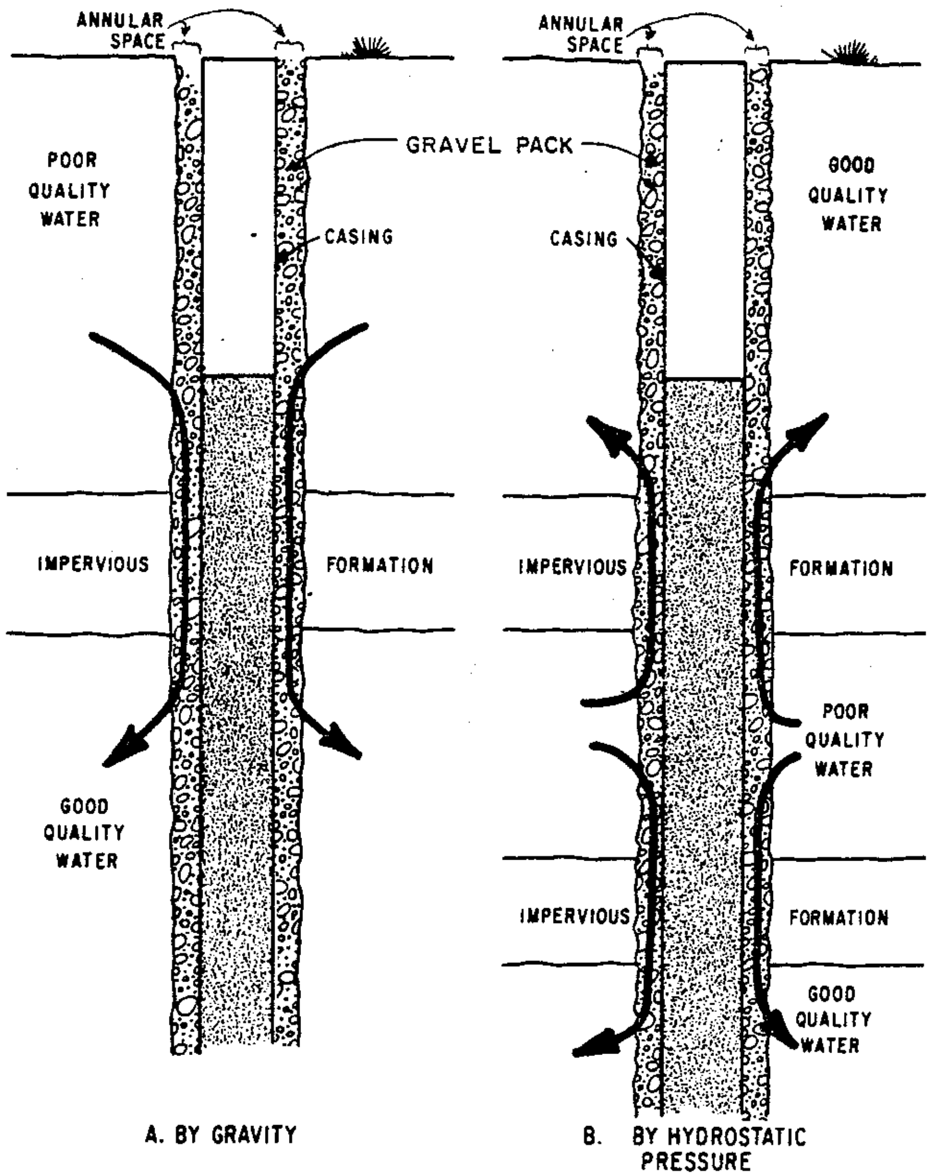


Figure 4. Interchange of Water Between Formations Via Wells.

Most irrigation wells in Sierra Valley are constructed in a manner that allows the free movement of water up or down within the annular space where the gravel pack is placed; aquifer recharge, discharge, and water quality degradation can occur in this manner.

GROUND WATER IN STORAGE

Groundwater in storage is the volume of water that would be released from storage from each depth zone or the amount required to resaturate the zone. Unconfined conditions are assumed.

Groundwater in storage in the Sierra Valley basin has been estimated for six depth zones: 5 to 100 ft and for each 100 ft thereafter to 600 ft, as measured from the ground surface. Storage quantities are reported from the upper surface of the zone of saturation, usually averaging about 5 ft in depth, for the total or estimated area underlain by sediments in the basin. Quantities of ground water in storage for each depth zone are shown in Table 1.

TABLE 1

GROUND WATER IN STORAGE, SIERRA VALLEY

Depth Zone	Average Specific Yield (in percent)	Volume of Basin Deposit (millions of ac-ft)	Ground Water Storage (millions of ac-ft)	Cumulative Total (millions of ac-ft)
5-100 ft	9.23	13	1.14	1.14
100-200 ft	9.18	11	1.01	2.15
200-300 ft	8.12	10	0.81	2.96
300-400 ft	7.09	10	0.71	3.68
400-500 ft	7.98	10	0.80	4.48
500-600 ft	8.86	10	0.89	5.37

Storage capacity was estimated by determining average specific yields for each 100-ft interval and multiplying this by the volume of basin sediments estimated to occur in each zone.

Specific yields range from 3 percent for clay to 25 percent for sand and gravel and were obtained from sediment descriptions contained in well drillers' reports (Table 2).

Storage calculated from the average depth to water to 600 ft is estimated to be 5,370,000 ac-ft. There is alot of water below 600 ft, but it was not considered in these calculations.

TABLE 2

APPROXIMATE SPECIFIC YIELD FOR SELECTED DRILLERS' CALLS

Percent	Drillers' Call
Three	Clay
	Hardpan
	Shale
Five	Clay and Gravel
	Clay and Rocks
	Clayey Sand
	Sandy Clay
	Silt
Ten	Clay and Rock
	Clay, Sand and Gravel
Twenty	Sand
Twenty-five	Gravel
	Sand and Gravel

HYDROLOGIC BALANCE

A hydrologic balance is a quantitative evaluation of the total water picture within a basin for a given period of time; water gain is balanced by water loss, plus or minus changes in basin storage. Stated as an equation, the hydrologic balance for a basin with groundwater is. Inflow - Outflow = Change in Storage.

The purpose of the hydrologic balance is to assure that the ground water hydrology estimates used in an investigation are reasonable and valid. Items totaled as inflow include precipitation, surface and subsurface inflow, and imported water. Outflow items include evapotranspiration and surface and subsurface outflow.

This hydrologic balance is for the 1980-81 water year (October 1 to September 31), since the major inflow/outflow items for this period are known or can be accurately estimated.

Inflow

The average annual precipitation in Sierra Valley ranges from less than 12 inches at Chilcoot to more than 60 inches near the watershed boundary southwest of Sierraville. In computing the total average annual precipitation falling on the ground water basin, the area between rainfall contour intervals within the basin boundary was planimetered and then multiplied by the average of two contours that bound it. The average annual volume of precipitation falling within the basin boundary was calculated to be 217,900 ac-ft. To adjust this figure to the 1980-81 water year, an adjustment factor of 0.6 was used. This was arrived at by constructing a rating curve relating streamflow at the "near Portola" gage to rainfall at Sierraville and Vinton. Gaged rainfall at these two stations for the 1980-81 water year was 50 percent and 88 percent of normal, respectively; a basin-wide estimate of 60 percent of normal is therefore reasonable. Total inflow to the basin from precipitation is calculated to be 130,800 ac-ft.

Surface stream inflow can be divided into gaged and ungaged flow. Gaged streams contributing inflow to the basin are Big Grizzly Creek (DWR #A55383) and Little Last Chance Creek (DWR #A55525) and accounted for 21,900 ac-ft of inflow during the 1980-81 water year. Ungaged stream inflow was estimated by correlating watershed areas of similar aspect, vegetation, and precipitation patterns to corresponding gaged watersheds. The ungaged average annual surface stream inflow was thus estimated to equal 113,700 ac-ft/yr. To adjust this volume to the 1980-81 water year, a rating curve was constructed relating flow at the Berry/Miller Creek gage (DWR #A55720, period of record 1936 to 1977) and rainfall at Sierraville. An adjustment factor of 0.4 was used. Thus, for the 1980-81 water year, ungaged tributary inflow to the basin is estimated to equal 45,500 ac-ft. Water imported to the basin in the Little Truckee Ditch during the water year equaled 7,100 ac-ft.

Subsurface inflow is estimated to be about 2,000 ac-ft/yr. This quantity was arrived at by assuming that the average coefficient of permeability of the basin-bounding rock units is 3.5 gpd/ft , that the average hydraulic gradient is 60 ft/mi, and that only the upper 100 ft of the rock units in contact with the basin sediments are contributing to subsurface inflow.

Outflow

Surface outflow, measured at the "near Portola" gage (DWR #A55420) for the 1980-81 water year, was 38,500 ac-ft. Evapotranspiration estimated using 1981 climatological data and vegetation distributions (appendix A), equals 179,200 ac-ft. Subsurface outflow, which probably occurs only in the area of the surface outflow, is estimated to equal about 500 ac-ft/yr based on the assumption that there is alluvial fill and weathered bedrock to a depth of 50 ft in the gorge at the "near Portola" gage and that the hydraulic conductivity of these is about 3,200 gpd/ft^2.

In total, the basin balance for the 1980-81 water year is:

$$\underset{\text{(inflow)}}{\underline{207{,}300\text{ ac-ft}}} - \underset{\text{(outflow)}}{\underline{218{,}200\text{ ac-ft}}} = \underset{\text{(change in storage)}}{\underline{-10{,}900\text{ ac-ft}}}$$

In the Sierra Valley ground water basin, changes in ground water storage can occur in the free ground water aquifer that underlies the valley floor to a depth of 35 to 100 ft or in the forebay areas of the confined aquifer system located around the periphery of the basin. Changing water table elevations in either of the two areas will result in a change in the volume of ground water in storage. By comparing fall 1980 water level measurements to fall 1981 measurements, it was found that little or no change occurred in the free ground water aquifer while declines ranged from 0.7 to more than 25 ft in wells tapping the confined aquifers.

The 10,900 ac-ft deficit can be accounted for by assuming that the water table in the forebay areas declined 2.5 ft between fall 1980 and fall 1981, that the aquifer material here has a specific yield of 12 percent, and that this area is about 0.75 mi wide around the perimeter of the basin.

Factors that contributed to the decline in water levels are:

1. Below-normal rainfall that lengthened the irrigation season.
2. Below-normal surface stream inflow that increased the demand for ground water.

These two factors set up a condition in the valley that resulted in ground water withdrawals of 12,800 ac-ft during the 1981 irrigation season (April through October).

SUBSIDENCE

Sinking of the land surface, called subsidence, has important consequences. In general, subsidence can damage well casings and pump equipment, affect canal gradients, require releveling of agricultural lands for irrigation efficiency, increase flood hazards, and damaged structures such as roads, buildings, etc.

Subsidence is caused by the removal of fluids or solids from beneath the land surface. Temporary or long-term declines in underground water levels can cause shrinkage of fine-grained (clay) sedimentary materials by reducing the hydraulic pressure between individual grains. Lowering the hydraulic pressure causes individual particles to become more closely packed, compresses the sediments, and causes surface subsidence. Subsidence is greatest where aquicludes or aquitards are thickest and contain thin sand interbeds that expedite drainage.

In Sierra Valley, land has subsided as much as 1.5 ft or more in the eastern half of the groundwater basin. It can be seen at some wells where the concrete well pads, once flush with the land, now "hang" from well casings. The surface level has fallen enough to see underneath some of the pads, and others have cracked and fallen because of the lack of ground support.

Subsidence is suspected to have occurred in the general area bounded by Highway 70 on the north, Highway 49 on the east, Highway 89 on the south, and Herriot Lane on the west. Water level declines of a few feet to over 20 ft since 1960 are documented in this area (see Plate 8). Preliminary data show that ground subsidence of 2.2 ft or more has occurred at a well (T22N/R16E-17E1) that has had a 12-ft water level decline since 1968. Poland and Davis (1969) report that the ratio of water level decline to subsidence is about 0.01 to 0.2 ft of subsidence per foot of water level decline. The ratios calculated for two wells with water level declines of 12 and 9 ft are 0.183 and 0.166, respectively. These ratios support the estimated subsidence of 2.2 and 1.5 ft.

During the winter of 1983, the Plumas County Road Department surveyed elevations from the U. S. Geodetic Survey benchmarks on the eastern edge of the basin to 32 wells in the eastern half of the valley. It was planned to compare these elevations to 1958 DWR levels of these wells to document the extent and magnitude of ground subsidence. However, it was later learned that the 1958 DWR survey notes had been destroyed. The Plumas County Road Department has now established baseline data to which future subsidence surveys can refer.

Of the 32 wells surveyed, reference points on 7 showed gains of 0.1 to 0.7 ft; 14 showed losses of 0.1 to 2.2 ft; 3 remained unchanged. Eight had been altered or destroyed so that no comparisons could be made.

Although these elevation comparisons cannot be confirmed, it is reasonable to conclude that some subsidence of 1 or 2 ft has occurred in Sections 17, 18, 19, 30, and 31 of T22N/R16E, MDBM, and in Section 36 of T22N/R15E, MDBM. Releveled wells in this area all showed elevation losses, and wells with "hanging" well pads, mentioned previously, are also found here. Lesser amounts of subsidence are likely to have occurred elsewhere in the eastern half of the basin.

It should be noted that an elevation change of a well's reference point, although indicative of land subsidence, can minimize the amount of subsidence. As illustrated by the hanging well pads, the ground can subside around a well, leaving the well's reference point elevation unchanged or showing only modest subsidence. The reason for this is that the well may be "anchored" to deeper, non-compressible portions of the basin's deposits, while the upper, compressible material shrinks and lowers the ground surface around the well casing.

Future surveys should develop an extensive grid of permanent reference points and expand the area covered in the 1983 survey. Collapsed casing in wells, down-hole loss of pumping strings, and hanging well pads should be reported to the management district.

APPENDIX D[1]

1982 and 1983 AQUIFER TESTS
IN SIERRA VALLEY

1/ Prepared by Dr. K. D. Schmidt.

LAND AND WATER USE CHANGES - 1954 to 1981

A land-use and water-source survey of Sierra Valley was conducted in 1981, (Appendix A). Crop types and irrigation water sources, either surface water or ground water, were identified and are presented in Plate 10. Similar land- and water-use surveys were conducted in 1954, 1963, 1972, and 1978. Table 3 summarizes these surveys.

TABLE 3

IRRIGATED CROPS BY WATER SOURCE IN SIERRA VALLEY

ACRES

Crop Type and Water Source	1954 1/	1963 2/	1972 2/	1978 2/	1981
Alfalfa (total)	1,210	1,184	1,991	3,573	5,720
Surface Water	-	1,104	1,991	2,018	2,014
Ground Water	-	80	0	1,555	4,706
Grain (total)	1,370	1,481	0	1,625	3,663
Surface Water	-	1,481	0	1,314	2,021
Ground Water	-	0	0	311	1,642
Pasture (total)	36,200	37,448	27,682	24,548	33,332
Surface Water	-	37,018	27,202	23,577	32,638
Ground Water	-	430	480	971	694
Truck Crops (total)	0	0	0	331	748
Surface Water	-	-	-	0	55
Ground Water	-	-	-	331	693
Total Irrigated Acreage	38,780	40,113	29,671	30,077	43,463
Surface Water	-	39,603	29,193	26,909	36,728
Ground Water	-	510	480	3,168	6,735

1/ Water source data not available
2/ Water source estimated from "date drilled" well records

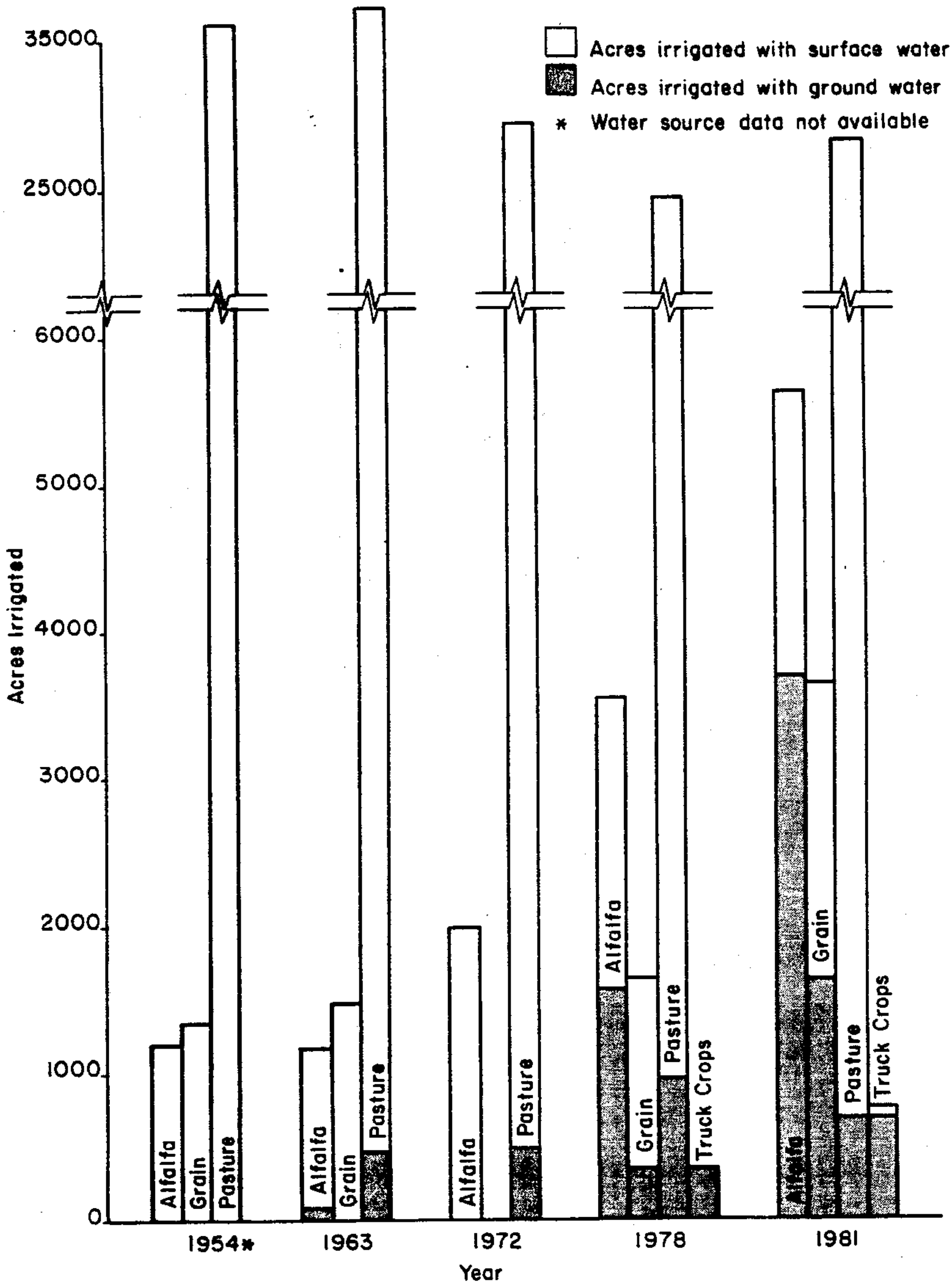
Figure 5 graphically presents the data contained in Table 3. Figure 6 shows estimated ground water usage for irrigated crops for the 1963, 1972, 1978, and 1981 surveys.

The data show that from the 1954 to the 1963 survey, little change in crop types and irrigated acreage occurred. The 1954 ground water usage was probably less than the amount used in 1963. The 1972 survey revealed a 10,000-acre reduction in pasture and an almost doubling of alfalfa acreage over the 1963 survey; estimated ground water usage remain unchanged. By 1978, alfalfa acreage had increased 75 percent over 1972, grains recorded a strong comeback, and truck crops made a modest start. Pasture acreage had decreased, but overall ground water pumpage increased by over 500 percent.

Between 1978 and 1981, alfalfa acreage increased 60 percent, both grain and truck crop acreage more than doubled, and pasture increased by almost 9,000 acres; estimated ground water usage almost doubled.

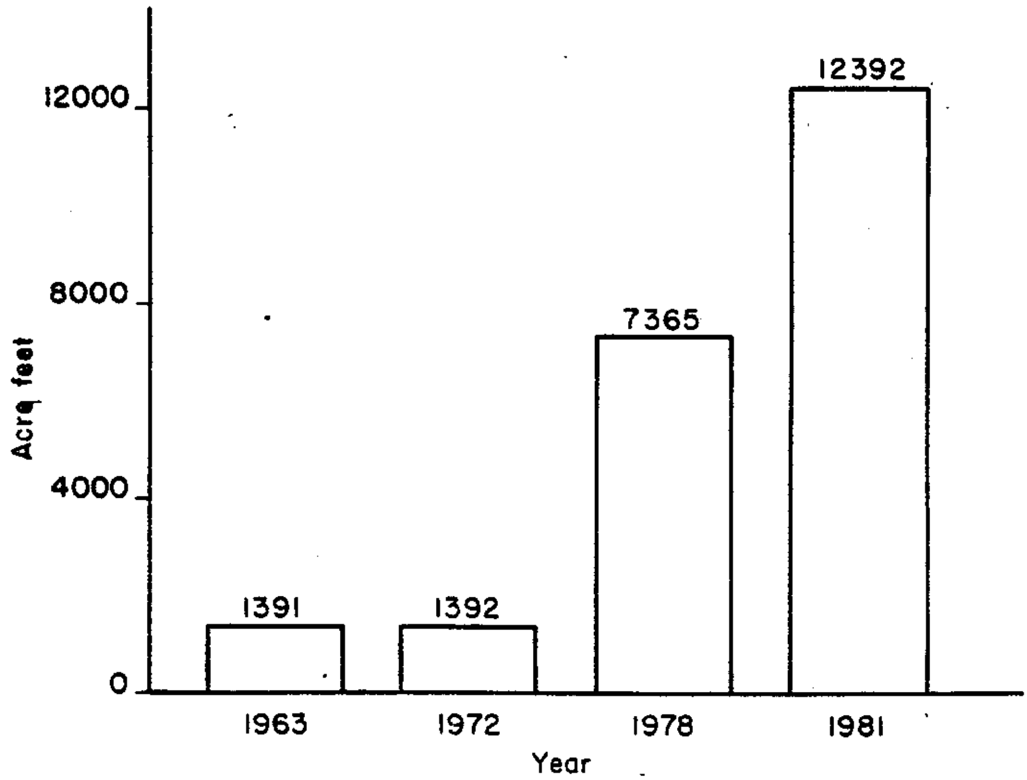
The most significant change in land and water use in Sierra Valley has been for alfalfa production. From 1972 to 1981, alfalfa acreage doubled; while the amount of acreage irrigated with surface water remained unchanged at about 2,000 acres, acreage irrigated with ground water increased from zero to 4,706 acres.

FIGURE 5



Irrigated crops by water sources in Sierra Valley

FIGURE 6



Ground water use for irrigation in Sierra Valley

WATER QUALITY

The first major survey of the water quality of streams and ground water in Sierra Valley was conducted between 1955 and 1957. Findings were published in DWR Bulletin 98, "Northeast Counties Ground Water Investigation", dated February 1963. Additional sampling has been done periodically since 1957 as part of the Department's ground water quality monitoring program and results have been published in the Bulletin 130 series. In the fall of 1972 and spring of 1973, additional wells were sampled as part of an interagency study of the natural resources of Sierra Valley and were published in a report dated October 1973.

To determine the present quality, provide better areal coverage and detect any significant changes, samples of the ground waters of Sierra Valley were collected during the summers of 1980 and 1981. These were collected directly from wells or at the nearest points in the distribution systems where samples could be taken. When possible, they were collected during a period of well use so that it would represent ground water from the major producing zone or aquifer. They were collected in plastic sample bottles, and temperature, electrical conductivity, and pH measurements were made at that time. Selected samples were sent to the Department's laboratory at Bryte for additional determinations.

Water Quality Criteria

The largest uses of ground water in Sierra Valley are irrigation, stockwater, and domestic needs. Since suitability of water quality for irrigation is dependent on crop, soil, climate, method of irrigation, etc., no specific criteria suit all cases. However, guidelines have been developed by a University of California committee of consultants to interpret the suitability of water for irrigation use (see Appendix F). These guidelines have been used in this study.

Guidelines for stock water are also included in Appendix F. Appendix G contains the recommended criteria for domestic water supplies that were used in this study to evaluate the ground water quality.

Study Results

The groundwater quality data developed during this study are presented in Appendix H. Both new and historic analyses are included and each provides valuable information in evaluating water quality.

Precipitation and surface runoff that are the major sources of ground water recharge in Sierra Valley are of excellent mineral quality. They are biocarbonate in character and usually have an electrical conductivity of less than 200 microsiemans per centimetre (uS/cm).

Ground water found in the recharge areas that rim the valley is biocarbonate in character and reflects the excellent mineral quality of the recharge sources. As shown in Plate 11, this water is considered to have no quality problems and to be suitable for existing uses. As the water moves from the recharge areas through the alluvial deposits into the central portion of the basin, it becomes more mineralized, with sodium being the predominant cation.

Sodium chloride waters are found in the hot springs, thermal artesian wells, and in a few low-temperature wells. The thermal waters probably come from superheated mineralized water of magmatic source that has moved along several of the numerous fault zones crossing the valley and commingled with the ground water in the valley fill. The resulting waters are generally sodium chloride in character and contain varying amounts of other dissolved magmatic constituents, such as boron and fluoride. These waters are usually poor in quality and unsuitable for most uses. The location of these poorer quality waters is shown in Plate 10.

Temperature

The ground waters of Sierra Valley vary greatly in temperature, with some wells producing water of less than 55° F while others exceed 150° F. The highest water temperatures are generally associated with deep artesian wells in the west central portion of the valley along and between the Grizzly Valley and Hot Springs Faults. Ground waters exceeding 68° F are also found elsewhere, but usually they are also associated with deep wells.

Electrical Conductivity

Ground water can be viewed as an electrolyte solution because nearly all its dissolved constituents are present in ionic form. Electrical conductivity (EC), the capability of the water to conduct an applied electrical current, is a general indication of the total dissolved ionic constituents and relates to the salinity of the water. Water with EC values greater than 700 uS/cm is generally considered poor quality drinking water, and water with EC values in excess of 1700 uS/cm is generally unfit for livestock. Agricultural crops have varying tolerances to saline water, depending on crop type; in general, reductions in crop yields correspond with increases in EC (see Appendix F).

The EC of ground waters in Sierra Valley vary greatly (Plate 12) from less than 200 uS/cm to about 2600 uS/cm. The ground waters having the highest EC values are the thermal waters in the west central portion of the basin. An even larger area of the western and central portions of the basin is underlain by groundwaters that have EC values in excess of 800 uS/cm. Most of these waters have ECs that exceed the recommended maximum for drinking water and are considered marginal for irrigation use.

Over the period of monitoring, about 30 percent of the well waters monitored have shown increases in EC of 200 to 500 uS/cm. Most of the waters with increases were from wells located in the central portion of the basin.

Boron

Boron in drinking water is generally not a hazard to human beings; however, boron in irrigation water can be very important. It is an essential element in the nutrition of plants, yet if present in concentrations as low as 0.5 to 1.0 milligrams per litre (mg/L) in irrigation water, it can be harmful to certain crops.

Alfalfa, a major crop irrigated by ground water within the study area, can tolerate boron concentrations as high as 2 to 4 mg/L.

Boron concentrations in Sierra Valley ground water show a similar pattern to the EC pattern, with very high levels associated with the thermal waters in the west central portion of the basin but much lower levels in the basin fringes and recharge areas. Boron concentrations in the thermal waters have exceeded 8 mg/L, while in the basin fringes they are usually less than 0.3 mg/L. An area in the northeastern portion of the basin between the Buttes and Vinton is underlain by ground water with boron concentrations exceeding 2 mg/L.

Fluoride

There is considerable information indicating that 2 to 3 mg/L of fluoride in drinking water can cause mottling on the teeth of growing children. There is also abundant literature that shows that levels of

0.8 to 1.5 mg/L of fluoride in drinking water help prevent tooth decay. Current drinking water standards are related to the annual average of maximum daily temperatures, based on reasoning that people in warm climates will drink more and receive more fluoride. The annual average of maximum daily temperatures in Sierra Valley is in the 58 to 64° F range. Therefore, the optimum fluoride concentrations in domestic supplies should be 1.0 mg/L with the average concentration during any month not exceeding 2.0 mg/L.

Only in an area along the Hot Springs Fault are the fluoride levels found at concentrations exceeding the 2.0 mg/L. These higher levels were found in the thermal waters that do not meet other drinking water standards. Over the period of monitoring in the basin, fluoride concentrations have remained about the same in these well waters. At several other locations in the basin, monitoring data indicate that some reductions in fluoride concentrations have occurred.

Sodium Hazard

The adjusted sodium absorption ratio (adj. SAR) has been developed for evaluation of sodium hazard to permeability and has been used in this study (Appendix F). Adj. SAR values have been calculated for the ground waters of Sierra Valley and show a great diversity of values. Thermal waters in the west-central portion have adj. SAR values that range from 17 to 23, posing possible severe problems. Most of the central portion of the basin is underlain by waters with adj. SAR values of 3 to 9, indicating increasing potential for problems. Only in the fringe areas of the ground water basin and in major recharge areas are ground waters found free of sodium hazard.

Over the period of monitoring, the adj. SAR values have increased in only a few well waters from the central portion of the basin; elsewhere they have remained unchanged.

<u>Nitrate, Ammonia, and Other Constituents</u>

Only a couple of wells in the valley have been found to yield water containing nitrate in excess of drinking water standards. Ammonia has also been detected in several well waters at excessive levels, indicating that anaerobic environments must exist locally in the ground water basin. Hydrogen sulfide had also been detected in some wells, also indicating a anaerobic environment.

Some well waters are discolored with dissolved organics, and a few wells in the central portion of the basin and in the area between the Buttes and Vinton produce waters with iron in excess of recommended levels.

BIBLIOGRAPHY

Berry, David T. "Geology of the Portola and Reconnaissance Peak Quadrangles, Plumas County, California". Master of Science Thesis, University of California, Davis. 87 p. 1979.

California Department of Water Resources. "The Geology and Geohydrology of Sierra, Mohawk, and Humbug Valleys, Sierra and Plumas Counties". Office Report (unpublished). 45 p. plus tables and plates. 1961.

---. "Northeastern Counties Ground Water Investigation". Bulletin 98. 224 p. plus appendices and plates. 1963.

---. "An Interagency-Multidisciplinary Investigation of the Natural Resources of the Sierra Valley Area, Sierra and Plumas Counties. A Cooperative Study by Federal, State, and Local Agencies". 276 p. plus appendices. 1973.

Durrell, C. "Tertiary Stratigraphy of the Blairsden Quadrangle, Plumas County, California". Calif. Univ., Dept. Geol. Sci. Bull., V. 34, No. 3, p. 161-192. 1959.

Fry, Gary G. "SB 1391. Towards a Permit System for Ground Water? Towards a New Definition of Ownership of Ground Water?" Proceedings of the Thirteenth Biennial Conference on Ground Water. California Water Resources Center, University of California, Davis. Report. No. 53, p. 12-18. 1981.

Guthe, William G. "A Water Budget Analysis of Runoff and Groundwater Recharge for Smithneck Creek, California". Master of Arts Thesis, University of California, Davis. 134 p. 1981.

Jackson, W. H., et al. 1961. "Gravity Study of the Structural Geology of Sierra Valley, California" in short papers in Geologic and Hydrologic Sciences, Articles 1-146, Geological Survey Research, p. 254-256.

Oakeshott, Gordon B. 1971. "California's Changing Landscapes" McGraw-Hill Book Company, U.S.A. 388 p.

Poland, J. F., and G. H. Davis. "Land Subsidence Due to Withdrawal of Fluids". The Geological Society of America, "Review in Engineering Geology". V. 2, p. 187-269. 1969.

GLOSSARY

Acre-foot--The volume of water required to cover one acre to a depth of one foot: 43,560 cubic feet or 325,851 U.S. gallons. Commonly used in measuring volumes of water or reservoir storage space.

Alluvial Fan Deposit--A cone-shaped deposit of alluvium left by a stream where it runs out onto a level plain or meets a slower stream. The fans generally form where streams issue from mountain canyons onto the lowland.

Alluvium--A geologic term describing beds of sand, gravel, silt, and clay deposited by flowing water.

Aquifer--A geologic formation, group of formations or part of a formation that is water bearing and transmits water in sufficient quantity to supply springs and pumping wells.

Aquifer System--A heterogeneous body of interbedded permeable and poorly permeable material that functions regionally as a water-yielding unit; it comprises two or more permeable beds separated at least locally by confining beds that impede ground water movement but do not greatly affect the regional hydraulic continuity of the system.

Aquifer Test--Test pumping of a water well at a constant rate of discharge while the drop in the ground water level (drawdown) is recorded in the well and in nearby observation wells. The drawdown is plotted versus time after pumping begins to determine transmissivity.

Artesian Well--A well deriving its water from an artesian or confined water body. The water level in an artesian well stands above the top of the artesian water body it taps. If the water level in an artesian well stands above the land surface, the well is a flowing artesian well.

Artificial Recharge--Replenishment of the ground water supply by means of spreading basins, recharge wells, irrigation, or induced infiltration of surface water. Modification of the natural recharge pattern to increase rate of recharge.

Breccia--A rock consisting of sharp fragments embedded in a fine-grained matrix, as sand or clay.

Clay--A fine-grained geologic material (grain size less than 0.004 mm in diameter) which has very low permeability.

Confined Ground Water--Ground water under pressure whose upper surface is the bottom of an impermeable bed or a bed of distinctly lower permeability than the material in which the confined water occurs. Confined ground water moves under the control of the difference in head between the intake and discharge areas of the water body.

Confining Bed--A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers.

Contact--A plane or irregular surface between two different types or ages of rocks.

Effluent Stream--A stream or reach of a stream whose flow is being increased by inflow of ground water.

Electrical Conductivity (EC)--The measure of the ability of water to conduct an electrical current the magnitude of which depends on the concentration of minerals on the water. Related to total dissolved solids.

Evapotranspiration (ET)--That portion of rainfall or water applied to plants that is returned to the air through direct evaporation or by transpiration of plants.

Fault--A fracture, or fracture zone, along which has been displacement of the earth on one or both sides. This displacement may be a few centimetres or many kilometres. An Active Fault is one which has had surface displacement within Holocene time--about the last 11,000 years. (The inverse of this, that older faults are inactive, is not necessarily true. A Potentially Active Fault is one which shows evidence of displacement during Quaternary time (last 2 to 3 million years).

Forebay--The recharge area of a confined aquifer.

Geohydrology--A science that deals with the character, source, and made of occurrence of underground water.

Graben--A depressed segment of the earth's crust bounded on at least two sides by faults.

Gravel Packed Well--A well in which filter material (sand, gravel, etc.) is placed in the annular space between the casing and the borehole to increase the effective diameter of the well, and to prevent fine-grained material from entering the well during pumping.

Ground Water--(a) That part of the subsurface water that is in the zone of saturation; (b) loosely, all subsurface water as distinct from surface water.

Ground Water Basin--(a) A subsurface structure having the character of a basin with respect to the collection, retention, and outflow of water. (b) An aquifer or system of aquifers, whether or not basin shaped, that has reasonably well defined boundaries and more or less definite areas of recharge and discharge.

Ground Water Mound--A rounded, mound-shaped elevation in a water table or other potentiometric surface that builds up as a result of the downward percolation of water, through the zone of aeration or an overlying confining bed, into the aquifer represented by the potentiometric surface.

Ground Water Pumpage--The quantity of ground water pumped.

Head--(a) The pressure of a fluid on a given area at a given point caused by the height of the fluid surface above the point; (b) Water-level elevation in a well, or elevation to which the water of a flowing artesian well will rise in a pipe extended high enough to stop the flow.

Horst--A block of the earth's crust separated from adjacent blocks that have been relatively depressed.

Hydraulic Gradient--The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

Hydrograph--A graph showing the changes in the water level in a well with respect to time.

Hydrologic Balance--An accounting of the inflow to, outflow from, and storage in a hydrologic unit; the relationship between evaporation, precipitation, runoff, and the change in storage, expressed by the hydrologic equation.

Hydrology--A science dealing with the origin, distribution, and circulation of water through precipitation, streamflow, infiltration, groundwater storage, and evaporation.

Impermeable--Not permitting the passage of water; impervious.

Imported Water--Water transported into a watershed from a different watershed.

Infiltration--The flow or movement of water through the soil surface into the ground.

Inselberg--A steep-sided, round-topped mound which occurs in isolation rising above the general level of a basin.

Lens--An underground deposit bounded by converging surfaces (at least one of which is curved), thick in the middle and thinning out towards the edges, resembling a convex lens.

Lithosphere--The outer, rigid, part of the earth's crust.

Orogeny--A period of mountain-building that extends in time for some tens of millions of years.

Overdraft--The condition of a ground water basin where the amount of water withdrawn exceeds the amount of water replenishing the basin over a period of time.

Percolation--The slow passage of water through the earth to the ground water table.

Perforations--Openings in a well casing to admit ground water into the well. Perforations may be made either before or after installation of the casing.

Permeability--The ability of a geologic material to transmit fluids. The degree of permeability depends on the size and shape of the pore space and the extent, size, and shape of their interconnections.

Permeability Coefficient--A coefficient expressing the rate of flow of fluid through a cross section of permeable material under a hydraulic or pressure gradient.

Piezometer--An instrament for measuring and recording changes in ground water levels.

Piezometric Surface--The surface to which the water in a confined aquifer will rise.

Porosity--Voids or open spaces in alluvium and rocks that can be filled with water.

Porphyritic--A texture term which describes rocks containing relatively large crystals set in a finer-grained matrix.

Pump Tax, Ground Water Charge, Production Assessment, Replenishment Assessment--Assessments levied on the amount of ground water pumped.

Pumpage--(a) The quantity of ground water pumped.

Pumping Lift--The distance water must be lifted in a well from the well pumping level to the discharge pipe to the well.

Recharge--Replenishment of ground water by infiltration of water from rainfall, streams, and other sources. Natural Recharge occurs without human intervention.

Safe Yield--The maximum quantity of water which can be withdrawn annually from a ground water supply under a given set of conditions without causing lowering of the ground water levels resulting eventually in depletion of the supply.

Sand--A term which denotes either (1) particles with diameter ranging from 1/16 to 2 mm or a sediment composed primarily of these particles.

Silt--A term which denotes either (1) particles with diameter ranging from 1/256 to 1/16 mm or (2) a sediment composed primarily of these particles.

Specific Capacity--The rate of discharge of a water well per unit of drawndown commonly expressed in gallons per minute per foot.

Specific Yield--The quantity of water that a unit volume of permeable rock or soil, after being saturated, will yield when drained by gravity. It may be expressed as a ratio or as a percentage by volume.

Spring--A place where ground water flows naturally from rock or soil onto the land surface or into a body of surface water. Its occurrence depends on the nature and relationship of rocks, permeable strata, the position of the water table, and topography.

Subduction--The process of one tectonic plate sliding beneath another.

Subsurface Inflow--Ground water movement through the subsurface into a ground water basin.

Subsurface Outflow--Ground water movement through the subsurface out of a ground water basin.

Sustained Yield--The volume of ground water that can be extracted annually from a ground water basin without causing adverse effects.

Total Dissolved Solids (TDS)--The total quantity of minerals in solution in water, expressed in milligrams per litre.

Transmissivity--The rate at which ground water will flow through a unit width of the aquifer.

Unconfined Ground Water--Ground water that has a free water table; i.e., water not confined under pressure beneath relatively impermeable rocks.

Unconsolidated Material--(a) A sediment that is loosely arranged or unstratified, or whose particles are not cemented together; (b) Soil material that is in a loosely aggregated form.

Water-Bearing--The capability of yielding ground water of potable quality adequate for most beneficial purposes.

Water Table--That upper surface of an uncontined body; the level at which water stands in wells.

Well Log--A record made by the driller of a water well that lists underground materials encountered during drilling and information on the construction of the well (such as casing perforations and sanitary seal).

APPENDIX A

LAND AND WATER USE IN SIERRA VALLEY IN 1981

State of California

The Resources Agency

Memorandum

To : Ralph Scott
Laura Germain

Date : June 1, 1982

File No.:

Subject: Land and Water Use in Sierra Valley in 1981

From : Robert McGill, Chief
Land and Water Use Section
Department of Water Resources

The following discussion, prepared mainly by Clyde Muir of this section, was developed as the result of a 15-month study of climatological conditions, land use, and applied water use measurements made in Sierra Valley during 1981. Clyde Muir was aided by Steve Rossi, graduate student assistant, in preparing the land use survey.

Note that this report was prepared in two sections, the main body that includes the general findings and another section following that includes mainly technical supporting data.

In order to obtain at least a few measurements of agricultural ground water pumpage, flow meters were placed on five well systems before the 1981 irrigation season began. Table 3 shows the result of that activity and demonstrates that not enough water was pumped and applied to actually meet crop evapotranspiration (ET) demands in nearly all cases. We assumed that this was probably true for all the well irrigation in the valley.

Knowing crop acres and generating reasonable applied water values, reported in Table 5, total agricultural applied water use is shown in Table 6. About 12,400 ac-ft was pumped from the underground and 63,000 from local streams for irrigation. An additional 2,100 ac-ft was pumped from the underground to meet municipal-industrial needs, while only 50 ac-ft is used from surface sources. Total water use is summarized below.

Water Use in Sierra Valley, 1981
Acre-Feet (Rounded)

	Ground Water Pumpage	Surface Water Use	Total
Agriculture	12,400	63,200	75,600
M&I	2,100	50	2,150
Total	14,500	63,250	77,750

Attachment

SURNAME | McGill 6/2/82

ESTIMATED GROUND WATER PUMPAGE FOR SIERRA VALLEY IN 1981

Introduction

During the summer of 1981, the Land and Water Use Section installed flow meters on five sprinkler irrigation systems within Sierra Valley in order to determine pumpage. Other work elements were making a detailed land use survey of the valley and establishing a climate station near Sierraville. The goal of this work effort was to obtain enough data to estimate current ground water pumping within the valley. The metering program was designed to sample pumping quantities from several wells that seemed to be fairly typical of those in the valley. These data, coupled with the land use and water source survey data, would afford a fairly accurate measure of total annual ground and surface water use. The main purpose of determining the climatological data base was to develop estimates of seasonal crop evapotranspiration (ET).

Methods

Land Use Survey

The 1981 land use and water source survey was accomplished by transferring crop field boundaries from U-2 infrared aerial photographs to 1:24,000 scale U. S. Geological Survey (USGS) quadrangle maps. The source of water, either surface or ground water, was noted for each parcel. To assure accurate crop identification, all land use parcels were visited by the survey team where access permitted. Some fields were found to utilize surface water sources during the early part of the growing season and when those sources dried up, ground water was pumped to finish out the irrigation season; these fields were classified as having a combination water source. Precipitation during the 1981 water year in Sierra Valley watershed was unusually dry, so most of the combination systems were put to use.

Completed land use maps were tabulated at the end of the survey using the "cutting and weighing" method. Table 1 presents the result of the 1981 survey and includes the result of a 1954 survey for comparison.

TABLE 1

IRRIGATED CROPS IN SIERRA VALLEY, 1981
(in acres)

Crop	Ground Water	Surface	Total	1954 Total
Alfalfa	3,662	1,685	5,347	1,210
Alfalfa-X 1/	44	329	373	-
Garlic	7	7	14	-
Grain	1,350	1,754	3,104	1,370
Grain-X 1/	292	267	559	-
Meadow Pasture	365	5,582	5,947	11,300
Meadow Pasture-X 1/	329	27,056	27,385	24,900
Potatoes	86	-	86	-
Safflower	184	48	232	-
Safflower-X 1/	151	-	151	-
Grass Turf	265	-	265	-
Total	6,735	36,728	43,463	38,780

1/ Partially irrigated

Climatological Station

A climatological station was installed on April 29, 1981, to provide basic data for computing crop ET. The station was located within a flood-irrigated native pasture site on the north edge of Sierraville and was named Sierraville .5 NNE. The station was serviced weekly by a local high school student who wound clocks, changed recorder charts, inked pens, and recorded Class A pan hook gage, water supply tank and anemometer readings.

The Class A evaporation pan was connected to a water supply tank which supplied water to the pan for an entire month without refilling. Water flow to the pan was controlled by a float valve which maintained the pan water level within the proper freeboard zone.

Ideally, pan evaporation should be measured in a well irrigated grass pasture with irrigation extending for a substantial distance in all directions. Unfortunately, the pan site at Sierraville only partially met this criteria. By mid-summer the surrounding environment at Sierraville

.5 NNE was dryland. Due to the dryland nature of this climate station for over half the summer, the pan data collected here were rejected in favor of a synthesized pan record based on Kohler equation climatological data and ET/EP coefficients developed in past studies for the Sacramento Valley. The Kohler equation integrates solar radiation, wind, humidity, and temperature data--all functions of evaporative demand. Table 2 reports pan evaporation and grass ET.

TABLE 2

ESTIMATED PAN EVAPORATION AND
POTENTIAL EVAPOTRANSPIRATION (PET),
GRASS FOR SIERRA VALLEY
(in inches)

Months (Growing Season Only)	Computed Kohler PET Grass Sierra Valley 1981	PET/EP 1/ Coefficients Sacramento Valley	Computed EP Sierraville .5 NNE
May	5.3	0.80	6.6
June	7.0	0.78	9.0
July	6.6	0.84	7.9
August	6.0	0.85	7.1
September	3.4	0.77	4.4
Seasonal Total	28.3	0.81	35.0

1/ Monthly Kohler grass PET values were used to reconstruct Sierraville pan values by dividing Kohler PET grass by Gerber coefficients relating Gerber pan to Gerber PET of grass.

Water Meter Measurements

In order to determine pumpage and unit crop applied water values, five water meters were installed on sprinkler irrigation systems on April 13, 1981. Three meters were put on center pivot systems on alfalfa and one on a side-roll wheel line system on alfalfa. The fifth meter was installed on a center pivot system on turf. Additionally, private water meters on four linear move systems were read monthly but readings were deemed too questionable for use due to the mechanical condition of the meters.

Water meters were read on or near the first day of each month from May 1 through November 1. The results of the metering program are shown below.

TABLE 3

METERED PUMPING SIERRA VALLEY, 1981
(acre-feet per acre)

Field Number	1	2	3	4	5
Crop Irrigated	Alfalfa	Turf	Alfalfa	Alfalfa	Alfalfa
Months					
April	0	0.1	0	0	0
May	0.3	0.3	0.2	0.2	0.2
June	0.3	0.5	0.3	0.4	0.2
July	0.5	0.6	0.3	0.6	0.2
August	0.7	0.5	0.5	0.5	0.5
September	0.2	0.4	0.2	0.4	0.4
October	0	0.2	0	0	0
Total	2.0	2.6	1.5	2.1	1.5

Table 3 shows that the average pumpage for the four metered alfalfa fields was 1.8 acre-feet per acre. The turf field, as shown, received 2.6 acre-feet per acre during the irrigation season.

Table 4 shows that a full alfalfa or turf irrigation requirement should have approached 2.8 feet. It is concluded that generally too little water was applied throughout the irrigation season. In a few instances, systems applied the correct monthly amount of water to match crop water use. During the month of August, all four monitored alfalfa systems applied very nearly the correct theoretical amount. The monitored turf system came nearest most often to applying the correct theoretical monthly amount of water.

TABLE 4

MONTHLY UNIT APPLIED WATER REQUIREMENT
FOR ALFALFA AND TURF
(acre-feet per acre)

Month	Estimated PET Grass	Precipitation at Vinton	ET Applied Water	Theoretical Pumping Requirement 1/
April	0.2	0.1	0 2/	0
May	0.4	0.1	0.3	0.4
June	0.6	T	0.6	0.8
July	0.5	0	0.5	0.6
August	0.5	0	0.5	0.6
September	0.3	T	0.3	0.4
Seasonal Total	2.5	0.2	2.2	2.8

1/ Unit applied water requirement; requires an increment over ETAW to allow for application inefficiency; 80 percent efficiency was assumed for this study.

2/ No irrigation requirement in April for deep-rooted alfalfa due to sufficient stored soil moisture from rainfall to meet crop needs; a small amount of water is applied to turf for adding fertilizer and because of shallow rooting.

T = trace

Crop Applied Water

Table 5 was developed using 1981 estimated monthly pan evaporation as a starting point. By using pan-to-crop coefficients that reflect growing season length, percent ground cover and irrigation practice, ETAW values were developed for the crops shown in Table 5. It should be noted that 1981 being a rather dry year produced consistently higher ETAW values than those representing long-term mean conditions. The reader should note that in the case of alfalfa on ground water, applied water did not meet ET demand; this must have had a dampening effect on crop yield. Due to droughty conditions, 1981 surface water values, similarly, were below what typical ET demands would be had water been available.

TABLE 5

UNIT ETAW AND AW
SIERRA VALLEY, 1981
(in feet)

Crop	ETAW 1981	ETAW Mean 1/	1981 Applied Water: Ground Water	1981 Applied Water: Surface Water
Alfalfa	2.2	1.9	1.8	1.4
Alfalfa-X 2/	0.8	0.7	1.0	0.8
Garlic	0.5	0.4	0.6	0.6
Grain	1.8	1.5	1.8	1.4
Grain-X 2/	0.6	0.6	0.8	1.1
Meadow Pasture	2.4	2.1	3.4	2.6
Meadow Pasture-X 2/	1.4	1.4	2.5	1.6
Potatoes	1.7	1.4	2.1	0
Safflower	0.7	0.6	0.6	0.5
Safflower-X 2/	0.2	0.2	0.3	0
Grass Turf	2.4 3/	2.1	2.6	0

1/ Values based on pan evaporation estimated for period 1959-1981.

2/ Partially irrigated.

3/ More than alfalfa because 0.2 foot of water was applied to turf in April.

Table 6 reports applied water by crop type and by water source. Crop acres measured in 1981 were multiplied by appropriate unit applied water values. In summary, Table 6 shows that about 12,400 acre-feet were pumped for agricultural use in 1981. Over 63,200 acre-feet, or roughly five times as much surface water, were diverted from local streams for irrigation. Total irrigation use was about 75,600 acre-feet.

TABLE 6

1981 APPLIED WATER, SIERRA VALLEY
(in acre-feet)

Crop	Unit Applied Water 1981		Crop Acres		Applied Water		
	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Total
Alfalfa	1.8	1.4	3,662	1,685	6,592	2,359	8,951
Alfalfa-X 1/	1.0	0.8	44	329	44	263	307
Garlic	0.6	0.6	7	7	4	4	8
Grain	1.8	1.4	1,350	1,754	2,430	2,456	4,886
Grain-X 1/	0.8	1.1	292	267	234	294	528
Meadow Pasture	3.4	2.6	365	5,582	1,241	14,513	15,754
Meadow Pasture-X 1/	2.5	1.6	329	27,056	822	43,290	44,112
Potatoes	2.1	0	86	0	181	0	181
Safflower	0.6	0.5	184	48	110	24	134
Safflower-X 1/	0.3	0	151	0	45	0	45
Grass Turf	2.6	0	265	0	689	0	689
Total			6,735	36,728	12,392	63,203	75,595

1/ Partially irrigated

Municipal and Industrial Water Use

Water use for municipal purposes in Sierra Valley was determined starting with an estimate of 200 domestic-sized wells scattered throughout the valley exclusive of the town of Loyalton. Based on 2.3 persons per residence, 1 well per residence, and an average daily use of 100 gallons per person, annual residential use for the valley was estimated at 52 acre-feet.

The town of Loyalton, with several large wells, provided records that showed 627 acre-feet were pumped in 1981. To this, 1,427 acre-feet of industrial use were added for the Sierra-Pacific Industries sawmill 1/, located at Loyalton. In addition, it was estimated that another 50 acre-feet of surface water were utilized throughout the valley, most of it in or near Sierraville.

Table 7 summarizes Sierra Valley municipal-industrial water use for 1981.

TABLE 7

MUNICIPAL AND INDUSTRIAL WATER USE
IN SIERRA VALLEY, 1981
(in acre-feet)

	Water Source		
	Ground Water	Surface Water	Total
Industrial use	1,427	0	1,427
Municipal use, general	52	50	102
Municipal use, Loyalton	627	0	627
Total	2,106	50	2,156

1/ Personal communication, May 1981

APPENDIX

ESTIMATED GROUND WATER PUMPAGE FOR SIERRA VALLEY

This section summarizes in greater detail the collection of climatological data at Sierraville .5 NNE, which was used to compute water use by grass and to estimate pan evaporation for 1981. Also summarized are soil and crop conditions at sites where applied water was metered.

Climatological Data (Sierraville .5 NNE)

To compute crop evapotranspiration, four climatological instruments were operated: a Class A evaporation pan; an anemometer to record wind; a pyranograph to record solar energy; and a hygrothermograph to record air temperature and relative humidity. The data collection instrumentation could operate dependably for seven days without servicing.

Evaporation Pan. For best results, a Class A pan should be located within a well irrigated and managed flood-irrigated or high water table grass pasture. The pasture site at Sierraville .5 NNE never met these criteria during the period of pan operation from April 29 through November 1, 1981. Measured pan evaporation (Ep) rates were too high for applying established irrigated pasture site pan-to-crop coefficients to compute crop evapotranspiration. For that reason, monthly Ep was estimated by dividing computed grass evapotranspiration by established pan-to-crop coefficients.

Table 1 shows data used to estimate pan evaporation for 1981 and mean monthly amounts for 1959-81; these data represent pan evaporation rates which can be expected to occur from well irrigated and managed pasture sites.

Anemometer (Wind). A new Belfort Instrument Company three-cup totalizing anemometer was mounted with the cups two meters above the short grass pasture. Since the Sierraville .5 NNE station anemometer was read weekly and daily readings were needed to compute daily evapotranspiration, a companion anemometer which was read daily was installed at a two-meter height at a good location at the Beckworth DWR watermaster climatological dryland pan station. Beckworth daily wind readings were used to prorate

TABLE 1

ESTIMATED CLASS A EVAPORATION PAN DATA FOR SIERRA VALLEY
(In Inches)

Month	Computed PET Grass At Sierra-ville .5 NNE	$\frac{PET}{Ep}$ Coefficients Developed At Gerber 1SW and Newville 1E	Pan Evaporation At Sierraville .5 NNE: 1981 Estimated[1/]	Pan Evaporation At Sierraville .5 NNE: 1959-81[1/] Extrapolated (Estimated)
Jan.	-	-	.9[a/]	.9[a/]
Feb.	-	-	1.4[a/]	1.4[a/]
Mar.	-	-	2.8[a/]	2.8[a/]
Apr.	-	-	4.2[b/]	3.8[e/]
May	5.3	.80	6.6[c/]	6.5[e/]
Jun.	7.0	.78	9.0[c/]	7.6[e/]
Jul.	6.6	.84	7.9[c/]	6.8[e/]
Aug.	6.0	.85	7.1[c/]	6.2[e/]
Sep.	3.4	.77	4.4[c/]	4.0[e/]
Oct.	-	-	2.0[d/]	2.6[e/]
Nov.	-	-	1.5[a/]	1.5[a/]
Dec.	-	-	.8[a/]	.8[a/]
Totals	-	-	48.6	45.0

a/ 1959-65 average at Alturas 2E

b/ Tulelake 3NE, 1981

c/ PET ÷ $\frac{PET}{Ep}$ Coefficient = Ep

d/ Estimated

e/ Extrapolated using 1959-81 Fleming F&G station

1/ For well irrigated and managed grass pasture environment.

the Sierraville .5 NNE weekly readings. This dual set-up showed that insignificantly more wind usually occurs in the main body of the valley than in the Sierraville area. A summary of wind readings are shown in Table 2.

TABLE 2

DAILY WIND, ACCUMULATED MILES AT TWO-METER HEIGHT

	Maximum		Minimum	Average	
Month	Miles	Average M.P.H.	Miles	Miles	M.P.H.
May	277	12	28	106	4.4
Jun.	177	7	61	103	4.3
Jul.	221	9	62	102	4.2
Aug.	186	8	59	103	4.3
Sep.	152	6	50	95	4.0

Pyranograph (Solar Radiation). Solar radiation was continuously recorded on strip charts by a portable Belfort bimetallic strip instrument like the one shown in Figure 1. A summary of total incoming solar radiation data is shown in Table 3.

TABLE 3

DAILY SOLAR RADIATION
(In Langley's)

Month	Maximum	Minimum	Average
May	(827)	(280)	(662)
Jun.	885	576	773
Jul.	798	552	700
Aug.	708	378	608
Sep.	534	204	409

Hygrothermograph (Temperature and Humidity). Air temperature and relative humidity were continuously recorded on a hair hygrothermograph strip chart recorder like the one shown in Figure 2. Readings were checked against readings from a sling psychrometer; a correction curve was developed for the relative humidity data. A summary of air temperature is shown in Table 4. A summary of relative humidity is presented in Table 5.

FIGURE 1

CONTINUOUS RECORDING PYRANOGRAPH FOR
MEASUREMENT OF TOTAL INCOMING SOLAR RADIATION

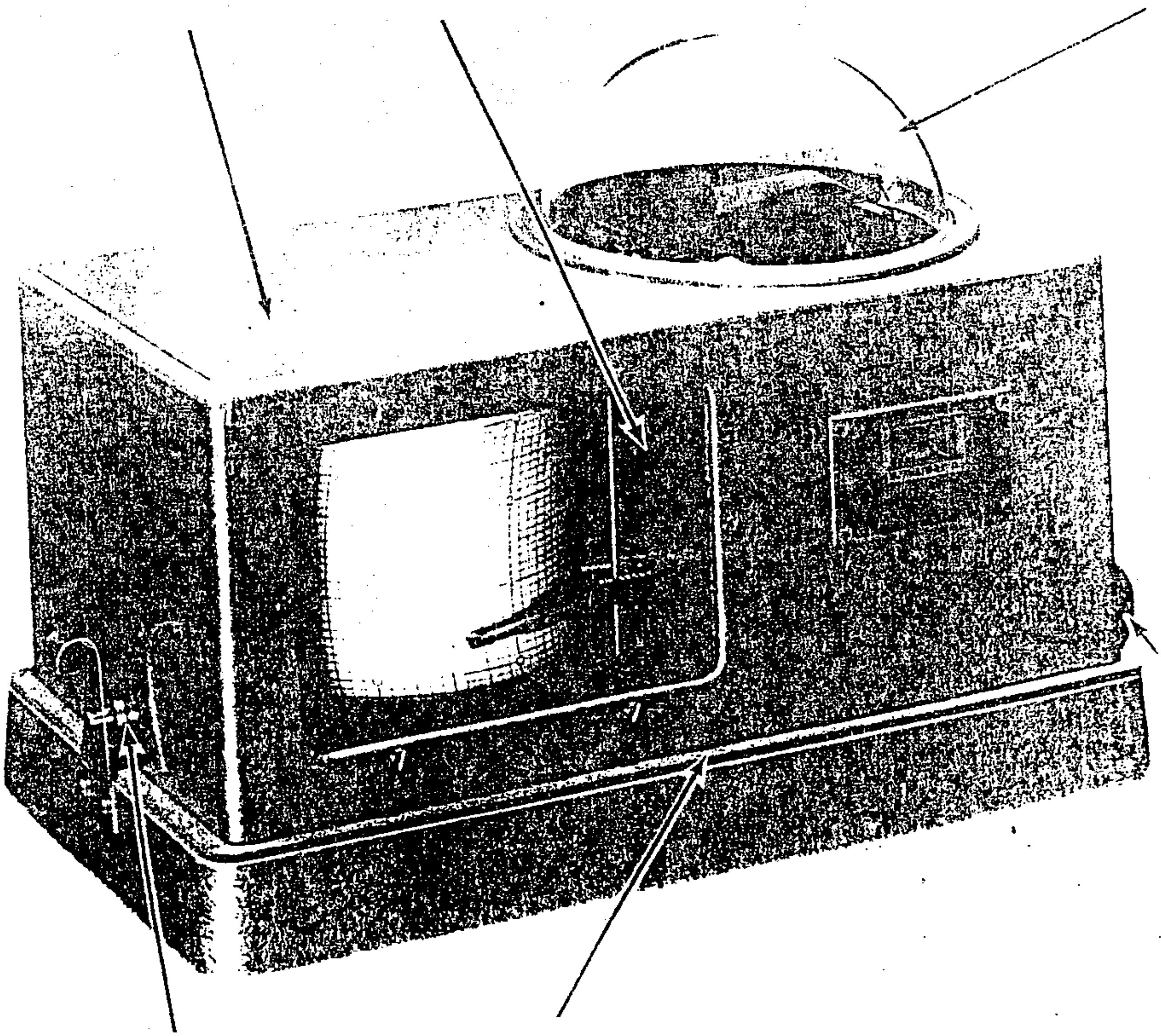
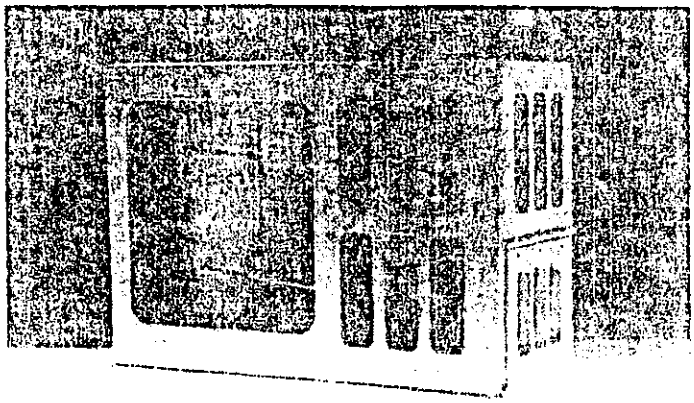


FIGURE 2

CONTINUOUS RECORDING HYGROTHERMOGRAPH FOR MEASUREMENT OF AIR TEMPERATURE AND RELATIVE HUMIDITY



HYGROTHERMOGRAPH

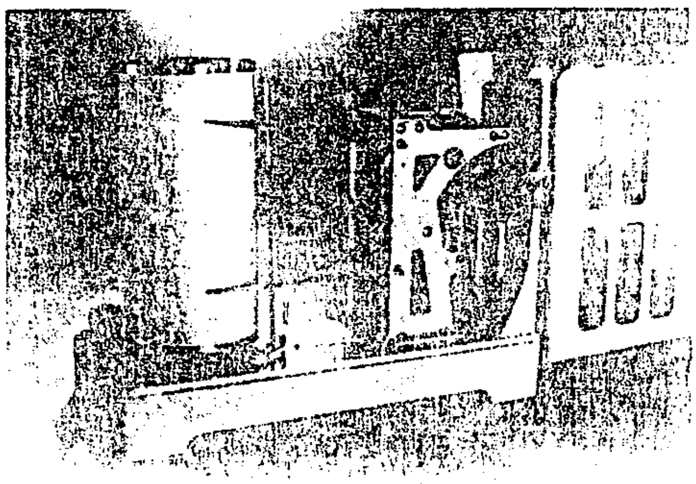


TABLE 4

DAILY AIR TEMPERATURE
(In °F)

Month	Average Maximum	Average Minimum	Mean	Absolute Maximum	Absolute Minimum
May	(67.5)	(37.2)	(52.4)	(80)	(28)
Jun.	77.9	42.0	60.0	90	27
Jul.	84.2	38.0	61.1	91	28
Aug.	87.6	39.4	63.5	99	29
Sep.	79.1	36.7	57.9	90	26

( ) Data missing for May 1 through May 6, 1981.

TABLE 5

DAILY RELATIVE HUMIDITY
(In Percent)

Month	Maximum	Minimum	Average
May	(99)	(33)	71
Jun.	99	29	69
Jul.	100	29	66
Aug.	100	23	65
Sep.	100	25	66

( ) Data missing for May 1 through May 6, 1981.

Precipitation. Precipitation was measured weekly during other instrument servicing. The aluminum seven-inch maximum capacity precipitation gauge was a Forester type having an eight-inch orifice and central collection tube. Precipitation for the entire year is available from a gauge at Vinton; the Vinton area received 74 percent of normal precipitation for the 1981 water year. A summary of precipitation within Sierra Valley is shown in Table 6.

Computed Crop Evapotranspiration

Crop evapotranspiration data were needed so that crop-applied water could be estimated and compared with metered applied water amounts. Evapotranspiration estimates were intended to be made using two approaches: (1) by measuring evaporation from Class evaporation pan at Sierraville

TABLE 6

PRECIPITATION FOR 1981, SIERRA VALLEY
(In Inches)

Month	Vinton[1/]	Sierraville R.S.	Sierraville .5 NNE[2/]
May	1.22	1.08	.73
Jun.	.01	.00	.00
Jul.	.00	.00	.00
Aug.	.00	.00	.00
Sep.	.29	.53	.34
Oct.	2.18	3.77	2.78

1/ Private observer for National Weather Service.
2/ Weekly readings; other stations read daily.

.5 NNE and applying established pan-to-crop evapotranspiration coefficients and (2) by computing evapotranspiration empirically using the Kohler equation which utilizes four climatological parameters. Unfortunately, measured pan evaporation data could not be used for this computation due to site problems mentioned previously.

Kohler Equation (PET Grass). The Kohler equation was used to compute potential evapotranspiration of grass (PET). PET grass was used to estimate pan evaporation.

The Kohler equation requires inputs of daily solar radiation, wind, air temperature and humidity to develop daily grass PET; monthly PET values were used in this study.

Climatological data can either be collected over dryland or irrigated grass environments without significantly altering the accuracy of computed grass evapotranspiration. Figure 3 graphically depicts, in nomograph form, the relationship between the various Kohler equation climatological inputs for computing PET grass. Table 7 presents daily climatological data collected from Sierraville .5 NNE and resultant daily potential evapotranspiration for grass. Table 8 is a summary of daily PET grass rates.

Soils

Table 9 summarizes soil conditions at metered applied water sites. The data were taken from the publication "Soil Survey of Sierra Valley Area, California, Parts of Sierra, Plumas, and Lassen Counties". The

FIGURE [illegible]

KOHLER NOMOGRAPH

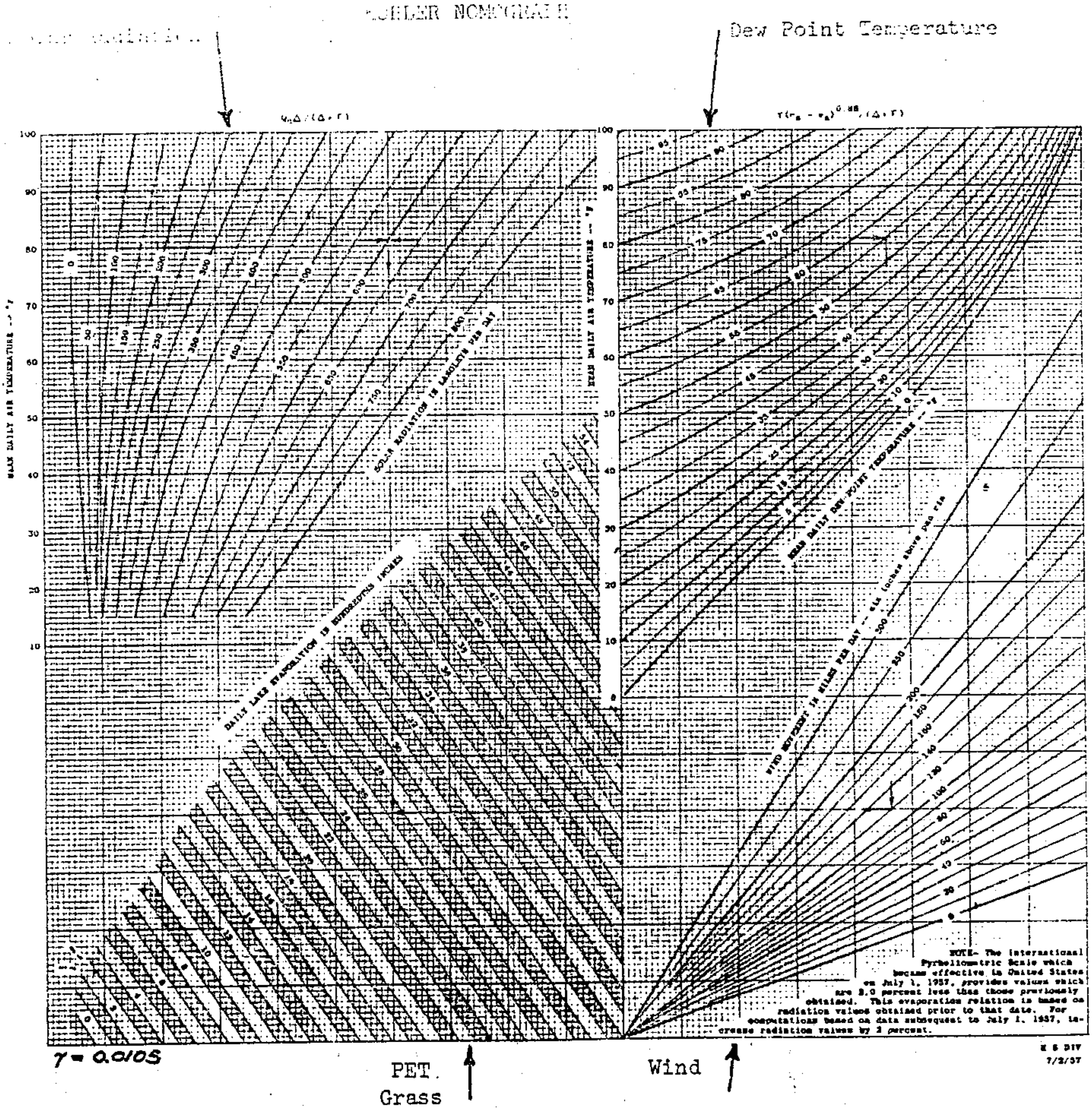


TABLE 7

CLIMATOLOGICAL DATA AND COMPUTED POTENTIAL EVAPO-TRANSPIRATION (PET) FOR GRASS

By: Muir/Jacobus Date: Feb. 1982 Station: Sierraville .5NNE Assumed Barometric Pressure: 25.0 Inches Hg

Date May	Max. Dry Bulb (°F)	Max. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Min. Dry Bulb (°F)	Min. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Wind at 79" (Mi.)	Aver. Dry Bulb (°F)	Aver. Dew Point (°F)	Wind at 22" (Mi.)	#225 Indic. Solar Rad. (Lang.)	x 0.9705 Correc. Solar Rad. (Lang.)	Daily PET Grass (In)
1	73	93	.9	35	37	33	18	42	157	55	38	111	-	-	(.22)
2	61	90	1.2	34	36	36	14	34	135	48	34	95	-	-	(.27)
3	-	-	1.2	34	-	-	14	34	92	-	34	65	-	-	(.17)
4	-	-	1.2	34	-	-	14	34	130	-	34	92	-	-	(.17)
5	-	-	1.2	34	-	-	14	34	132	-	34	93	-	-	(.21)
6	-	-	1.2	34	-	-	14	34	68	-	34	48	-	-	(.12)
7	63	-	1.2	34	-	38	14	37	114	-	36	81	780	757	(.14)
8	69	98	.2	28	28	44	13.5	46	107	48	37	76	756	734	.18
9	73	98	.3	37	36	41	15.5	48	107	54	42	76	744	722	.19
10	71	98	.2	31	31	38	15.8	44	107	51	38	76	780	757	.20
11	72	95	.6	34	35	38	16	45	54	54	40	38	804	780	.21
12	72	97	.3	30	29	41	15.3	46	50	50	38	35	780	757	.19
13	72	98	.2	33	33	45	14	49	55	52	41	39	654	635	.15
14	62	98	.4	43	44	50	10.7	44	277	53	44	196	654	635	.18
15	56	97	.5	45	44	56	8.5	40	138	50	42	98	708	687	.17
16	60	88	1.3	29	32	45	11.5	38	138	46	34	98	852	827	.21
17	63	99	.1	30	30	42	13	39	138	46	34	98	420	408	.09
18	50	97	.4	42	41	65	5.8	38	81	46	40	57	348	338	.05
19	53	98	.2	34	34	55	8.2	38	128	44	36	90	780	757	.17
20	59	98	.2	31	31	57	8.8	43	109	45	37	77	654	635	.13
21	65	97	.3	35	34	49	11.5	45	92	50	40	65	684	664	.16
22	70	98	.3	38	37	43	14	47	59	54	42	42	756	734	.19
23	72	98	.4	46	45	53	11.5	54	70	58	50	50	546	530	.13
24	69	97	.5	49	48	57	10	53	155	58	51	110	450	437	.10
25	69	97	.5	45	44	60	9.3	54	28	56	50	20	288	280	.05
26	65	96	.5	37	36	55	10	48	42	50	42	30	558	542	.11
27	72	98	.3	39	38	35	17	43	68	55	41	48	780	757	.21
28	79	97	.4	39	38	39	17.5	52	65	58	46	46	828	804	.23
29	80	97	.5	45	44	42	16.5	55	148	62	50	105	786	763	.24
30	72	97	.4	44	43	38	16	45	148	58	44	105	840	815	.25
31	80	97	.4	39	38	42	16.5	55	83	59	47	59	828	804	.23
Totals	1822	2511			966	1237			3275	1360		2319		16559	5.32
Avg.	67.5	96.6			37.2	45.8			106	52				662	.20

( ) Indicates estimated data

TABLE 7 (Continued)

By: Muir/Jacobus Date: Feb. 1982 Station: Sierraville .5NNE Assumed Barometric Pressure: 25.0 Inches Hg

Date June	Max. Dry Bulb (°F)	Max. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Min. Dry Bulb (°F)	Min. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Wind at 79" (Mi.)	Aver. Dry Bulb (°F)	Aver. Dew Point (°F)	Wind at 22" (Mi.)	#225 Indic. Solar Rad. (Lang.)	x 0.9705 Correc. Solar Rad. (Lang.)	Daily PET Grass (In)
1	(65)	97	.4	39	38	44	12.8	42	155	52	40	110	594	576	.15
2	67	92	1.3	45	48	55	10.3	50	110	58	48	78	714	693	.19
3	79	98	.3	39	38	38	17.8	51	80	58	45	57	822	798	.23
4	85	98	.3	44	43	40	18.5	58	61	64	51	43	822	798	.24
5	82	98	.4	47	46	36	19.3	52	105	64	50	74	798	774	.25
6	76	97	.5	48	47	44	15	53	132	62	50	93	786	763	.24
7	72	92	1.4	52	54	40	15.5	46	170	63	49	120	750	728	.24
8	68	82	3.4	52	58	64	18.3	32	177	63	42	125	660	641	.23
9	72	97	.5	47	46	34	17.3	42	103	59	44	73	840	815	.25
10	72	98	.3	42	41	39	15.8	45	82	56	44	58	702	681	.18
11	68	99	.1	35	35	49	12	48	134	52	42	95	690	670	.17
12	58	92	1.0	34	36	49	10.3	36	147	47	36	104	876	850	.23
13	62	99	.1	27	27	41	13	38	122	44	32	86	912	885	.22
14	68	96	.4	33	32	34	16.3	38	105	50	36	74	900	873	.24
15	81	99	.1	31	31	38	18.8	51	73	56	41	52	888	862	.25
16	75	99	.1	38	38	37	17	47	141	56	42	100	822	798	.24
17	82	98	.2	38	37	37	19	53	77	60	46	54	816	792	.24
18	85	92	1.1	39	41	38	19.8	55	84	63	47	59	822	798	.25
19	86	98	.4	47	46	37	19.8	56	91	66	52	64	840	815	.26
20	83	98	.4	45	44	40	17.7	56	88	64	50	62	822	798	.25
21	90	98	.3	44	43	41	19	63	69	66	54	49	852	827	.26
22	(86)	98	.4	45	44	36	20	57	113	65	51	80	840	815	.27
23	82	98	.3	40	39	29	22	46	77	60	43	54	798	774	.23
24	84	98	.3	38	37	39	18.5	56	99	60	47	70	822	798	.24
25	85	92	1.5	54	56	46	16.5	61	96	70	58	68	774	751	.25
26	85	98	.4	47	46	41	18.5	58	86	66	52	61	840	815	.26
27	87	98	.3	41	40	41	18.7	60	68	64	50	48	834	809	.25
28	87	99	.1	43	43	43	17.7	62	74	65	52	52	816	792	.25
29	83	99	.1	43	43	36	19.7	53	84	63	48	59	798	774	.24
30	83	98	.3	43	42	37	19.3	53	94	62	48	66	654	635	.19
31															
Totals	2338	2895			12.59	1223			3097	1798		2188		23198	6.99
Avg.	77.9	96.5			42.0	40.8			103	60				773	.23

( ) Indicates estimated data

TABLE 7 (Continued)

By: Muir/Jacobus Date: Feb. 1982 Station: Sierraville .5NNE Assumed Barometric Pressure: 25.0 Inches Hg

Date July	Max. Dry Bulb (°F)	Max. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Min. Dry Bulb (°F)	Min. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Wind at 79" (Mi.)	Aver. Dry Bulb (°F)	Aver. Dew Point (°F)	Wind at 22" (Mi.)	#2557 Indic. Solar Rad. (Lang.)	Correc. Solar Rad. (Lang.)	Daily ET Grass (In)
1	82	97	.4	39	38	33	20	51	79	60	45	56	798	774	.23
2	87	98	.4	46	45	38	29	58	76	66	52	54	648a/	Brand new instrument installed, no correction needed.	.20
3	91	97	.5	47	46	38	21	61	94	68	54	66	696		.23
4	88	98	.4	49	48	39	20	59	119	68	54	84	552		.18
5	82	93	1.4	55	57	49	15	60	137	70	58	97	666		.22
6	75	97	.5	51	50	44	15	51	221	62	51	156	660		.21
7	80	92	1.0	38	40	36	18.5	51	64	60	44	45	720		.21
8	80	93	.8	31	33	33	20	48	92	56	40	65	732		.21
9	79	100	0	32	32	36	18.5	50	116	55	41	82	690		.20
10	76	81	2.9	39	45	39	17	49	146	60	44	103	738		.23
11	75	100	0	31	31	36	17.5	46	90	53	38	64	738		.20
12	74	96	.4	35	34	33	18.3	42	124	54	38	88	720		.21
13	84	99	.1	29	28	34	21	51	62	56	40	44	744		.21
14	87	99	.1	38	37	29	23.5	51	86	62	44	61	714		.23
15	89	97	.4	37	36	37	20.5	59	96	62	48	68	702		.21
16	84	97	.4	37	36	38	19	55	103	60	46	73	714		.21
17	82	100	0	28	28	36	19	53	103	55	40	73	720		.20
18	83	99	.1	33	32	32	21	50	103	58	41	73	726		.22
19	86	95	.5	34	33	33	21.4	53	95	60	44	67	720		.22
20	87	99	.1	34	33	37	20	58	99	60	46	70	720		.21
21	88	100	0	35	35	32	22.4	54	97	62	44	69	702		.22
22	89	98	.3	37	36	34	21.5	57	97	62	47	69	708		.22
23	89	100	0	37	37	35	21.5	57	94	63	47	66	720		.22
24	86	100	0	40	40	35	20.5	55	91	63	48	64	702		.22
25	87	98	.3	38	37	37	20.4	57	91	62	48	64	666		.20
26	89	92	1.3	43	46	38	20.4	59	91	68	51	64	678		.22
27	89	98	.4	45	44	45	17.5	64	93	66	54	66	660		.20
28	90	99	.1	43	42	31	23.3	55	108	66	49	76	702		.23
29	84	97	.4	37	36	31	21.5	50	112	60	44	79	690		.21
30	83	97	.3	34	33	32	20.7	50	99	58	42	70	708	a/	.21
31	84	99	.1	31	30	32	21	51	90	57	41	64	684		.20
Totals	2609	3005		-	1178	1112			3168	1892		2240		21714	6.59
Avg.	84.2	96.9			38.0	35.9			102	61				700	.21

TABLE 7 (Continued)

By: Muir/Jacobus Date: Feb. 1982 Station: Sierraville .5NNE Assumed Barometric Pressure: 25.0 Inches

Date Aug.	Max. Dry Bulb (°F)	Max. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Min. Dry Bulb (°F)	Min. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Wind at 79" (Mi.)	Aver. Dry Bulb (°F)	Aver. Dew Point (°F)	Wind at 22" (Mi.)	#2557 Indic. Solar Rad. (Lang.)	Correc. Solar Rad. (Lang.)	Daily PET Grass (In)
1	80	98	.2	30	30	32	20	48	155	55	39	110	696	Brand new pyranograph installed 2/7/82; no correction needed	.21
2	82	97	.3	29	30	33	20.3	50	123	56	40	87	708		.21
3	81	99	.1	29	29	38	18.2	53	152	55	41	108	678		.20
4	84	100	0	34	34	31	21.5	34	99	59	34	70	696		.22
5	91	99	.1	30	30	29	24.4	54	59	60	42	42	696		.21
6	96	99	.2	38	38	26	27.5	55	69	67	46	49	666		.22
7	97	98	.3	38	39	23	29.3	53	72	68	46	51	666		.22
8	99	93	.9	38	40	27	27.8	59	77	70	48	54	654		.22
9	96	93	1.0	43	45	36	22.5	65	110	70	54	78	612		.21
10	95	97	.5	47	48	(30)	25.3	58	80	72	52	57	582		.28
11	91	99	.2	42	42	28	24.8	53	67	66	48	47	642		.20
12	94	99	.3	43	44	28	26	55	104	69	49	74	624		.21
13	87	98	.4	45	46	38	19.7	58	114	66	52	81	606		.19
14	85	100	0	42	42	32	21.5	52	93	64	47	66	618		.19
15	87	98	.3	37	38	34	21.3	55	93	62	46	66	612		.19
16	93	96	.5	37	38	30	24.7	57	93	66	47	66	582		.19
17	86	90	1.6	48	51	38	19.3	57	70	68	52	50	378		.12
18	88	99	.1	43	43	35	21	57	104	66	50	74	588		.19
19	78	97	.5	43	44	41	16.5	52	186	61	48	132	618		.19
20	79	99	.1	31	31	33	19.5	47	118	55	39	83	600		.17
21	84	99	.1	32	32	34	20.3	52	107	58	42	76	600		.17
22	88	99	.1	37	37	33	22	55	107	62	46	76	612		.19
23	84	98	.3	37	38	32	21	51	107	61	44	76	600		.18
24	80	87	1.9	30	44	38	18	52	173	62	41	122	600		.21
25	85	68	5.0	36	46	37	19.6	56	151	66	46	107	600		.21
26	87	95	.6	35	36	36	20.4	57	86	62	46	61	588		.17
27	93	99	.1	39	39	33	23.2	60	68	66	50	48	570		.17
28	88	98	.4	43	44	33	22	55	97	66	49	69	576		.18
29	86	98	.3	40	41	33	21.3	53	97	64	46	69	552		.17
30	84	90	1.5	42	45	38	19	55	97	64	48	69	540		.16
31	88	98	.3	37	38	37	20.3	58	69	63	48	49	504		.14
Totals	2716	2977			1222	1026			3197	1969		2267	18864		5.99
Avg.	87.6	96.0			39.4	33.1			103	64			608		.19

( ) Indicates estimated data

TABLE 7 (Continued)

By: Muir/Jacobus Date: Feb. 1982 Station: Sierraville .5NNE [illegible] 25.0 [illegible]

Date Sept.	Max. Dry Bulb (°F)	Max. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Min. Dry Bulb (°F)	Min. R.H. (%)	Wet Bulb Depression (°F)	Dew Point (°F)	Wind at 79" (Mi.)	Aver. Dry Bulb (°F)	[illegible] Point (°F)	[illegible] (Mi.)	#2557 Solar Rad. (Lang.)	Solar Rad. (Lang.)	[illegible] Gauge (In.)
1	81	99	.1	38	38	36	19	51	124	60	44	88	516	Brand new pyranograph installed 2/7/82; no correction needed.	.15
2	82	99	.1	34	34	34	20	51	86	58	42	61	534		.15
3	81	99	.1	32	32	34	19.6	50	93	56	41	66	510		.13
4	79	99	.1	30	30	27	21.7	42	83	55	36	59	510		.14
5	81	96	.5	31	32	35	19.4	50	83	56	40	59	516		.14
6	83	94	1.0	33	35	30	21.8	49	83	59	41	59	516		.15
7	86	95	.5	31	32	36	20	56	70	59	44	50	480		.13
8	82	99	0	40	40	40	17.7	56	78	61	48	55	360		.09
9	87	95	.5	42	43	39	19.3	59	106	65	50	75	456		.14
10	88	99	.2	39	39	36	20.8	58	73	64	48	52	462		.13
11	90	99	.2	40	40	37	20.8	60	81	65	50	57	432		.13
12	90	99	.2	41	41	35	21.5	59	81	66	50	57	396		.12
13	85	100	0	44	44	40	18.3	58	81	64	51	57	360		.10
14	88	100	0	41	41	31	22.8	53	77	64	47	54	426		.13
15	89	97	.4	38	39	32	22.7	55	77	64	46	54	324		.10
16	88	98	.3	39	40	35	21	57	91	64	48	64	300		.09
17	84	98	.4	43	44	41	17.5	58	50	64	50	35	204		.06
18	84	99	.1	38	38	30	22	49	120	61	44	85	420		.13
19	78	92	1.1	44	46	36	18	49	130	62	46	92	462		.14
20	76	97	.4	34	35	38	17	49	152	56	42	108	432		.12
21	77	99	.1	26	26	25	22	38	85	52	32	60	420		.11
22	74	91	.8	23	26	26	20.5	37	84	50	30	59	420		.10
23	71	96	.4	27	28	33	17.5	40	81	50	34	57	306		.07
24	66	99	.1	28	28	38	14.5	40	124	47	34	88	252		.06
25	64	97	.4	40	41	43	12.8	41	127	52	40	90	402		.10
26	70	88	1.6	40	43	42	14.5	46	127	56	43	90	384		.10
27	69	97	.4	42	43	46	13	47	127	56	44	90	378		.10
28	62	94	.9	39	41	49	11	42	112	52	40	79	318		.07
29	67	97	.3	32	33	36	15.5	39	78	50	36	55	384		.08
30	71	96	.4	28	29	37	16	44	-	50	36	-	396		.09
31															
Totals	2373	2907		-	1101	1077			2764	1738		1955	12276		3.35
Avg.	79.1	96.9			36.7	35.9			95	58			409		.11

TABLE [illegible]

DAILY POTENTIAL EVAPO-TRANSPIRATION FOR GRASS
(In Inches)

Month	Maximum	Minimum	Average
May	.27	.05	.17
Jun.	.27	.15	.23
Jul.	.23	.18	.21
Aug.	.28	.12	.19
Sep.	.15	.06	.11

cooperative survey was issued by the Soil Conservation Service, Forest Service, and California Agricultural Experiment Station.

Soil profile information indicates that some alfalfa may be growing in high water table conditions, which could cause a reduction in crop vitality. As more irrigation development takes place, high water table conditions may become worse.

TABLE 9

SUMMARY OF SOIL AND RELATED CONDITIONS AT METERED APPLIED WATER SITES

Meter Site No.	Crop: Type	Crop: Metered Applied Water (AF/A)	Crop: Yield (T/A)	Soils: Series Name	Soils: Soil Map Symbol	Soils: Percent of Area Irrigated (Est)	Soils: Depth to Water Table (Ft)	Soils: Depth to Hard Pan (In)
1	Alfalfa	2.0	5.1	Ormsby loamy coarse sand	OrA	60	2-6	None
				Beckwourth-Loyalton complex saline-alkali	BmA	40	3-7	None
2	Turf			Ormsby loamy coarse sand	OrA	95	2-6	None
				Ramelli clay	Ra	5	0-5	None
3	Alfalfa	1.5	2.2	Beckwourth sandy loam	Bk	50	3.5-5	None
				Bellavista loam	BoA	25	-	20-40
				Beckwourth loamy coarse sand	Bf	10	3-7	None
				Balman loam	BcB	5	5-7	None
				Bidwell sandy loam	BrB	5	None	None
				Beckwourth	Bn	3	2-7	None
				Loyalton fine sandy loam	Lo	2	None	None
4	Alfalfa	2.1	4.1[a/]	Bidwell sandy loam	BrA	70	None	None
				Bellavista loam	BoA	12	-	20-40
				Dotta sandy loam	DfC	12	None	None
				Bidwell sandy loam	BrB	6	None	None
5	Alfalfa	1.5	4.0	Smithneck sandy loam	Sw	100	3->5	None

a/ Young stand

APPENDIX B

MARGINAL PUMP LIFTS BY CROPS - SIERRA VALLEY

TO: Ralph Scott
Laura Germain

FROM: W. L. Quincy

Date: June 28, 1982

Subject: Marginal Pump Lifts by Crops - Sierra Valley

Introduction

The following narrative and supporting data are being submitted in compliance with your recent request for the economic limits of pumping ground water for Sierra Valley's agriculture. The analysis was based almost entirely on secondary data and represents the economic conditions for agriculture in 1981.

Land Class

Sierra Valley, which contains about 118,000 acres of irrigable land between elevations 4,880 and 5,000 feet, is a livestock oriented agricultural area. It is an important summer range for cattle brought in from the lower valley winter ranges after their dryland feed supply is utilized. About 80 percent (94,200 acres) of the land has slopes of 6 percent or less which can be irrigated with very low cost systems. However, drainage is a major deterrent to the optimum utilization of about 22 percent (25,700 acres) of these Class Vw lands. The remaining 20 percent (24,000 acres) are land with slopes up to 20 percent which makes irrigation difficult and expensive. A more complete breakdown by soil classes and their characteristics is shown in Tables I and II respectively attached.

Land Use

Land use surveys summarized in Table II indicate the total irrigated acreage has increased about 10 percent from 40,200 acres in the mid-1950's to 43,600 acres recorded in the 1981 survey by the N.D. Land and Water Use Unit personnel. Alfalfa hay and irrigated grain acreage which supports the resident livestock herds made the most significant increases from 1,200 to 5,700[1] acres for alfalfa and from 1,400 to 3,700[1] acres for grain. Production surplus to local demand also has a ready market in the valley and SF Bay dairy industry.

1/ Includes fully and partially irrigated plantings.

Although the partially irrigated meadow pasture may be a subjective interpretation and therefore vary between surveys, the recorded data show this crop increased about 3 percent from 26,300 to 27,400 acres while the fully irrigated portion declined 47 percent from 11,300 to 6,000 acres.

New crops reported in the 1981 survey included safflower, grass turf, garlic and potatoes which combined were planted on more than 700 acres. The safflower crop was an experiment which proved unsuccessful. However, the latter three crops appear to have an established but limited role in the total crop pattern.

Climate

Although the distance to markets is a factor, climatic conditions are the primary constraints to a more intensive agricultural economy. The following narrative and maps from a prior study1/ explain the problems quite well.

"A detailed summary of available climate information for the Sierra Valley study area was assembled by the Agricultural Extension Service of the University of California. This basic climate data is a collection from all of the Weather Bureau (National Weather Service) sources in or near the study area. A copy of the detailed summary was provided each of the counties. The following is a brief summary of the data.

The generally high elevation of Sierra Valley and the mountainous character of the area around it result in a continental temperature regime for the Sierra Valley study area, with temperature extremes ranging from maximum about 100 degrees to minimums below zero. The daily range of temperature varies from about 28 degrees during the winter to 45 degrees or more during the summer. This range, along with the absolute values, provides a stimulating environment, including a distinct variety of seasons.

In January, the average minimum temperature is below freezing, with extreme low readings of 30 degrees or more below zero being a matter of record. Average maximum temperatures are in the 40's. Heating requirements are high. Midsummer daytime readings are generally warm. The

1/ Pages 9-13 "... Natural Resources of the Sierra Valley Study Area", Central District, DWR, October 30, 1973.

average maximum in July in the valley is in the middle or upper 80's, while the minimum readings average in the high 30's and low 40's. Frost can be expected every month of the year.

The growing season in the study area is very short. The median date of the last spring freeze occurs late in June. The median date for the first fall freeze occurs in July. Plates 4 and 5 show the average length of the 32 degree and 28 degree growing seasons, respectively.

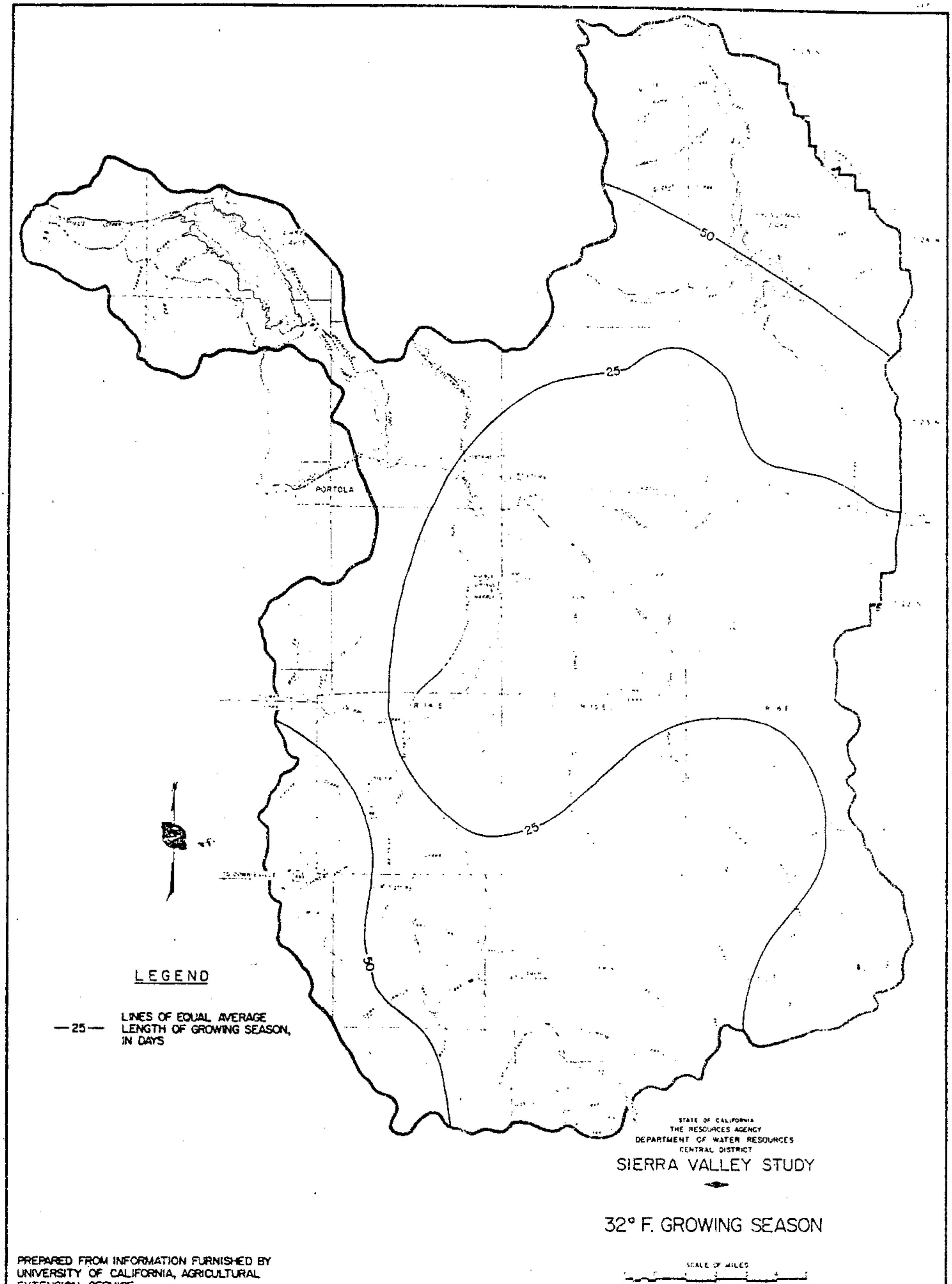
Seasonal totals of precipitation range from 40 to 50 inches in the western part of the study area, but drop to less than 15 inches in the eastern part. Plate 6 shows average annual precipitation in the area. With maximum precipitation occurring in the winter, much of the moisture at higher elevations falls in the form of snow. Precipitation totals during July, August, and September are usually less than 1 inch.

Humidities are low during the summer, but remain high throughout the winter period, with intermediate values in the spring and fall.

On the average, winds are light and variable over much of the Sierra Valley study area. Exposed locations frequently experience strong winds during the winter months. The direction of the winds normally depends on the valleys or canyons in the immediate area. Historical wind direction at Sierraville has been from the southwest.

Sunshine is fairly abundant throughout the entire year, with the area receiving around 3,200 hours of sunshine per year. Considering the maximum possible sunshine during the four seasons, the study area receives about 97 percent during the summer, 70 percent during spring and autumn, and only about 60 percent during the winter."

While Table III's "probable ultimate" projections are climatically suitable to the area, they were made without consideration of (1) the cost of developing additional irrigation water and (2) the comparative advantage (or more appropriately - disadvantage) of locally produced agricultural commodities with those from other areas. Alfalfa and grain acreage has made impressive increases in the last 25 years and truck crops (with turf included) have made a modest start. But meadow pasture, particularily the fully irrigated portion of the total, is



50
25
25
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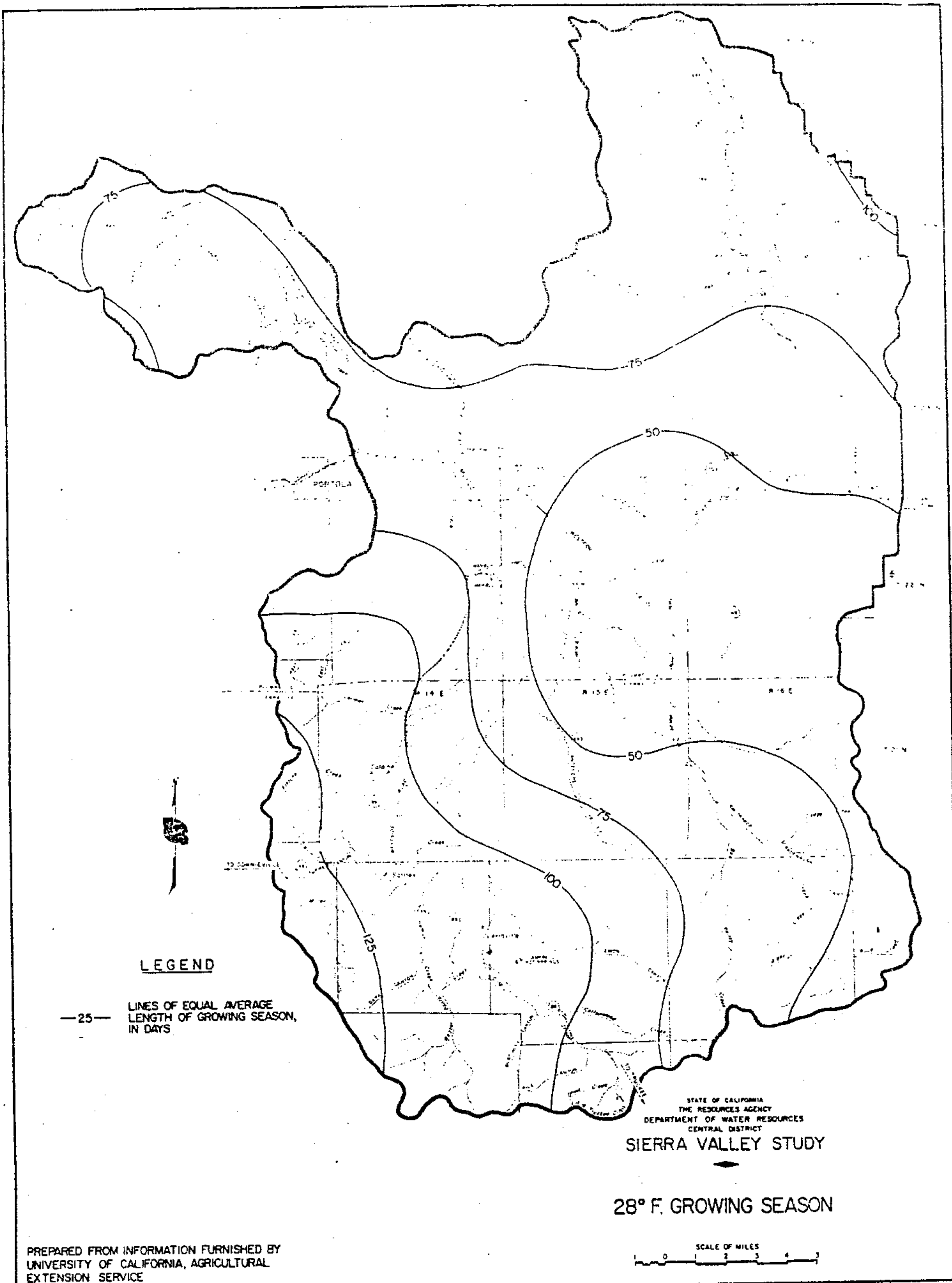
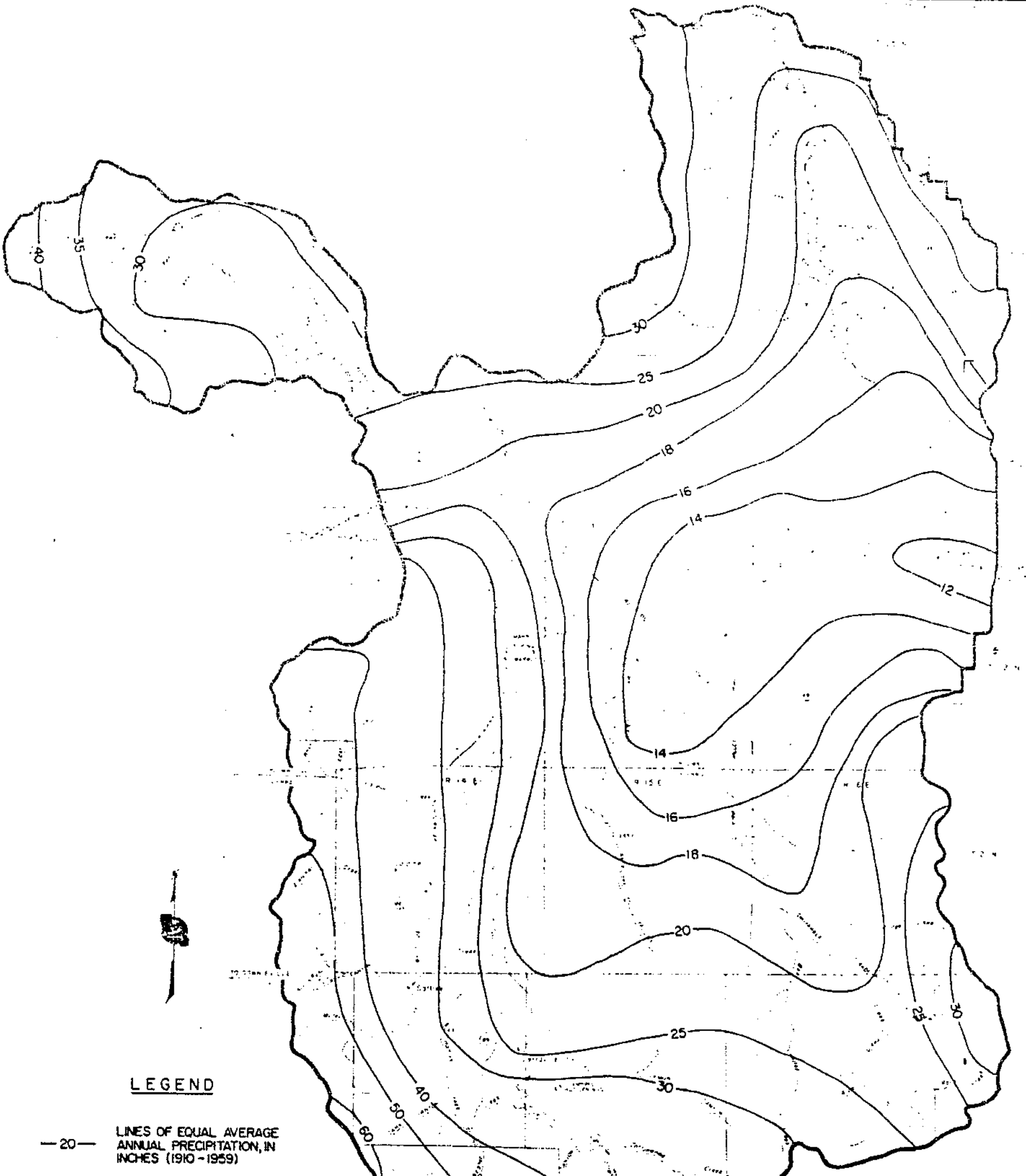
PORTOLA
LEGEND
— 25 — LINES OF EQUAL AVERAGE LENGTH OF GROWING SEASON, IN DAYS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
CENTRAL DISTRICT
SIERRA VALLEY STUDY
32° F. GROWING SEASON
SCALE OF MILES
PREPARED FROM INFORMATION FURNISHED BY UNIVERSITY OF CALIFORNIA, AGRICULTURAL EXTENSION SERVICE



SIERRA VALLEY STUDY

28° F. GROWING SEASON



LEGEND

—20— LINES OF EQUAL AVERAGE ANNUAL PRECIPITATION, IN INCHES (1910 - 1959)

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
CENTRAL DISTRICT

SIERRA VALLEY STUDY

AVERAGE ANNUAL PRECIPITATION

SCALE OF MILES

miserably short and, being a low income crop, not likely to increase to its projected level.

The safflower acreage was an experimental planting which was a disaster, economically, thus eliminating it from further consideration. Grass turf with its limited market and truck crops[1/] which are not competitive with other areas will not be a significant part of the total crop pattern in the future although the income from each would provide adequate payment capacity for a water supply.

Based on current economic conditions, the payment capacities and the maximum pumping depths of the three major crops are estimated to be:[2/]

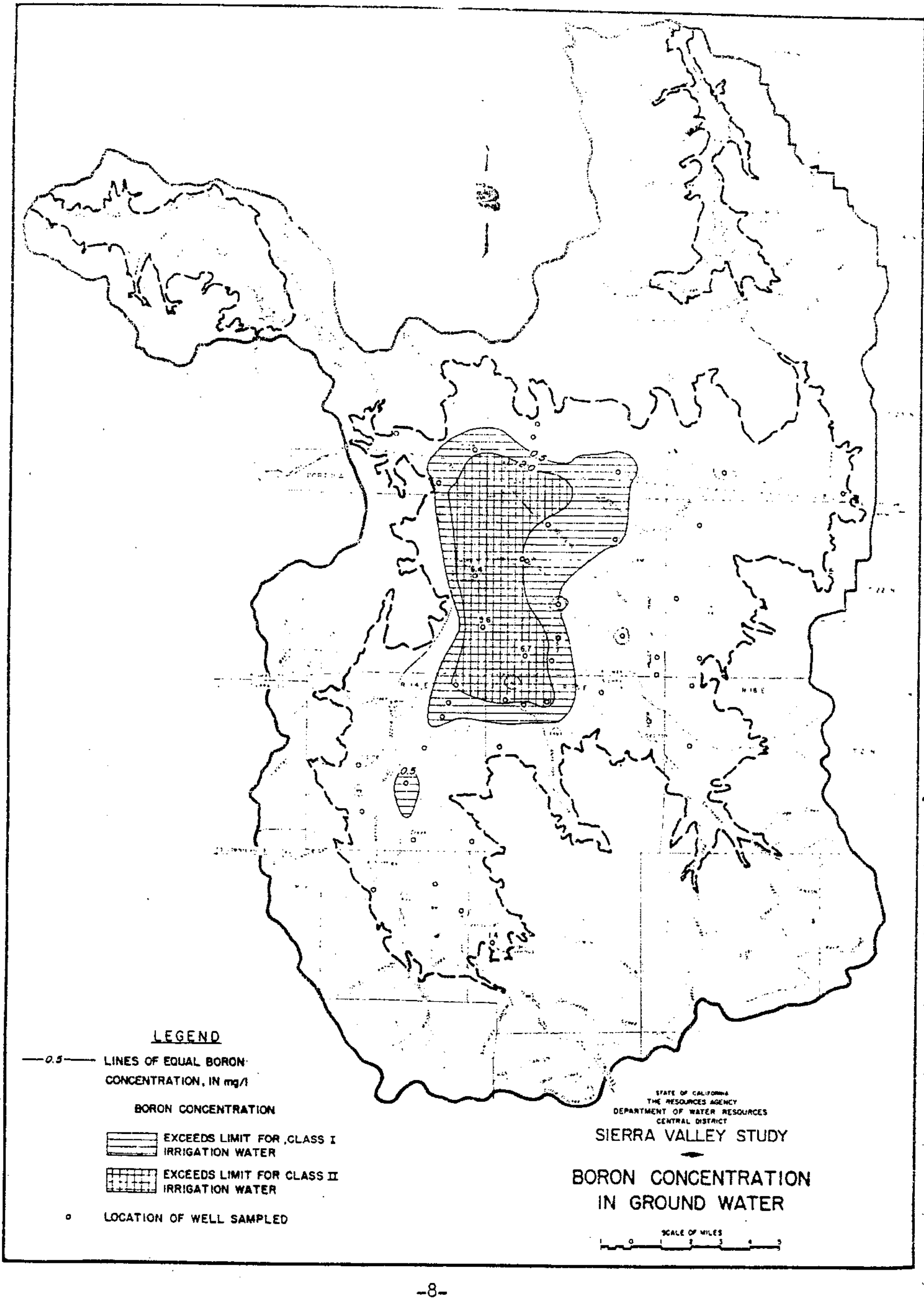
	Alfalfa	Grain	Meadow Pasture
Payment Capacity			
per acre	$49.00	$35.00	$32.00
per acre-foot	$27.20	$19.40	$ 9.40
Applied Water[3/]	1.8	1.8	3.4
Marginal Pump Lift	220'	160'	80'

Data from 22 wells in the NE portion of the valley indicate the ~~average~~ pump lift ranges from slightly more than 40 feet to almost 200 feet. The average lift was about 120 feet which is within the payment capacity of alfalfa and grain crops but not meadow pasture. Thus, the "probable ultimate" (whenever that may be) for alfalfa and grain in the valley is within the realms of reality and "truck" crop acreage may increase slightly if they are climatically adaptable.

Other than the climate and short growing season in general, another determent to growing some crops is the boron content of the ground water underlying about 30,000 acres in the northwest portion of the valley.[4/] Ground water in and near the Marble Hot Springs area contains more than

---

1/ Potatoes and onions.
2/ Detailed cost and income data in Table III attached.
3/ Application of ground water for 1981 as presented by the N.D. Land and Water Use Unit.
4/ See "Plate 47" attached from the report "... Natural Resources of the Sierra Valley Study Area", Central District, DWR October 30, 1973. Page 180.


LEGEND
0.5 LINES OF EQUAL BORON CONCENTRATION, IN mg/l
BORON CONCENTRATION
EXCEEDS LIMIT FOR CLASS I IRRIGATION WATER
EXCEEDS LIMIT FOR CLASS II IRRIGATION WATER
LOCATION OF WELL SAMPLED
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
CENTRAL DISTRICT
SIERRA VALLEY STUDY
BORON CONCENTRATION IN GROUND WATER
SCALE OF MILES
1 0 1 2 3 4 5

6.0 ppm of boron, a level toxic even to alfalfa which has a boron tolerance of slightly more than 3.0 ppm. That level exceeds the tolerance level of other climatically adaptable crops which would limit future use of the boron-affected land to the current crop pattern unless better quality water is brought into that area.

TABLE I

SIERRA VALLEY
LAND CLASS DATA

Class	Acres 1/	Percent
V	29,030	24.6
Vw	25,740	21.8
Vs	3,600	3.0
Vp	17,340	14.7
Vps	4,520	3.8
Vx 2/	13,960	11.8
Total "V"	(94,190)	(79.7)
H	8,930	7.6
Hp	2,180	1.8
Hx 2/	12,860	10.9
Total "H"	(23,970)	(20.3)
Total Irrigable	118,160	100.0
Total Valley	336,800 3/	

1/ Table 34, "Northeast Counties Investigation", DWR Bulletin 58, June 1960.

2/ Coarse textured (Vl) rocky (Vr) soils with low water-holding capacity.

3/ Op cit Table 1, page 23.

LAND CLASSIFICATION STANDARDS

Land class	Characteristics
	Irrigable Valley Lands
V	Smooth lying valley lands with slopes up to 6 per cent in general gradient, in reasonably large-sized bodies sloping in the same plane; or slightly undulating lands which are less than 4 per cent in general gradient. The soils have medium to deep effective root zones, are permeable throughout, and free of salinity, alkalinity, rock or other conditions limiting crop adaptability of the land. These lands are suitable for all climatically adapted crops.
Vw	Similar in all respects to Class V, except for the present condition of a high water table, which in effect limits the crop adaptability of these lands to pasture crops. Drainage and a change in irrigation practice would be required to affect the crop adaptability. For the purpose of this investigation, it was assumed that there would be no future change in use of these lands.
Vs	Similar in all respects to Class V, except for the presence of saline and alkaline salts, which limits the present adaptability of these lands to crops tolerant to such conditions. The presence of salts within the soil generally indicates poor drainage and a medium to high water table. Reclamation of these lands will involve drainage and the application of additional water over and above crop requirements in order to leach out the harmful salts.
Vl	Similar in all respects to Class V, except for having fairly coarse textures and low moisture-holding capacities, which in general make these lands unsuited for the production of shallow-rooted crops because of the frequency of irrigations required to supply the water needs of such crops.
Vp	Similar in all respects to Class V, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops, such as irrigated grain and pasture.
Vr	Similar in all respects to Class V, except for the presence of rock on the surface or within the plow zone in sufficient quantity to prevent use of the land for cultivated crops. These lands are suitable for irrigated pasture crops.
Vhs	Similar in all respects to Class V, except for the limitations set forth for Classes Vh and Vs, which makes these lands best suited for the production of shallow-rooted, salt-tolerant crops.
Vls	Similar in all respects to Class V, except for the limitations set forth for Classes Vl and Vs, which makes these lands best suited for the production of deep-rooted, salt-tolerant crops.
Vps	Similar in all respects to Class V, except for the limitations set forth for Classes Vp and Vs, which restrict the crop adaptability of these lands to shallow-rooted, salt-tolerant crops.
Vpr	Similar in all respects to Class V, except for the limitations set forth for Classes Vp and Vr, which restrict the crop adaptability of these lands to irrigated pasture.
	Irrigable Hill Lands
H	Rolling and undulating lands with slopes up to a maximum of 20 per cent for rolling large-sized bodies sloping in the same plane; and grading down to a maximum slope of less than 12 per cent for undulating lands. The soils are permeable, with medium to deep effective root zones, and are suitable for the production of all climatically adapted crops. The only limitation is that imposed by topographic conditions, which affect the ease of irrigation and the amount of these lands that may ultimately be developed for irrigation.
Hl	Similar in all respects to Class H, except for having fairly coarse textures and low moisture-holding capacities, which in general makes these lands unsuited for the production of shallow rooted crops because of the frequency of irrigation required to supply the water needs of such crops.
Hp	Similar in all respects to Class H, except for depth of the effective root zone, which limits use of these lands to shallow rooted crops.

TABLE II

SIERRA VALLEY
LAND USE DATA

Use	Mid-50's1/	1981 2/ Ground Water	Surface Water	Total	"Probable 5/ Ultimate"
Alfalfa	1,210	3,660	1,690	5,350	14,200
Alfalfa-X3/	-	40	330	370	-
Grain	1,370	1,350	1,750	3,100	9,100
Grain-X3/	-	290	270	560	-
Meadow Pasture	11,300	370	5,580	5,950	41,400
Meadow Pasture-X3/	26,310	330	27,060	27,390	23,400
Safflower	-	180	50	230	-
Safflower-X3/	-	150	-	150	-
Grass Turf	-	270	-	270	-
Truck4/	-	90	-	90	9,400
Total	40,190	6,730	36,730	43,560	97,500

1/ Table 31, page 110, "Northeast Counties Investigation", DWR Bulletin 58, June 1960.

2/ Northern District Land and Water Use Unit's data.

3/ Partially irrigated.

4/ Garlic and potatoes.

5/ Table 36, op cit p. 127.

TABLE III

SIERRA VALLEY
CROP PAYMENT CAPACITY

Item	Economic Data (per acre) Alfalfa Hay	Grain (Barley-wheat)	Meadow Pasture
Variable Costs	($127.30)	($107.40)	($ 50.60)
Labor	52.60	30.50	15.80
Fuel & repairs	15.30	17.90	4.60
Materials	59.40	59.00	30.20
Fixed Costs	(234.40)	(144.20)	(96.70)
Interest	130.90	89.70	63.50
Depreciation	91.60	46.40	27.50
County taxes	11.90	8.10	5.70
General Overhead	7.30	4.10	3.10
Management	22.00	15.30	9.60
Total Costs	391.00	271.00	160.00
Yield	5.5 Ton	45 cwt	8 Aum
Price	$ 80.00	$ 6.80	$ 24.00
Gross income	$440.00	$306.00	$192.00
Payment capacity	$ 49.00	$ 35.00	$ 32.00
P.C - per Ac/ft	27.20	19.40	9.40
Applied water1/	1.8	1.8	3.4
Marginal pump lift	220'	160'	80'

1/ Application of ground water for 1981 as presented by the ND Land and Water Use Unit.

APPENDIX D[1]

1982 and 1983 AQUIFER TESTS
IN SIERRA VALLEY

1/ Prepared by Dr. K. D. Schmidt.

1982 AND 1983 AQUIFER TESTS IN SIERRA VALLEY

A total of three aquifer tests were conducted during the summers of 1982 and 1983 in the eastern part of Sierra Valley. These tests were conducted for the Sierra Valley Groundwater Management District as part of a cooperative program with the California Department of Water Resources (DWR), Northern District. Sierra and Plumas Counties, and subsequently the District, conducted these aquifer tests, with assistance from the DWR, as part of a three year study of groundwater conditions in Sierra Valley. Because of weather conditions, it is feasible to conduct such tests only during the summer or fall. In addition, pumping patterns in this part of the valley necessitate conducting such tests either before the onset of heavy pumping, or after heavy pumping has stopped. Because of road conditions, the fall is the best time for such tests.

Lucky Hereford Old Well No. 4

An aquifer test was conducted on Well T22N/R15E-36J1, or Lucky Hereford Old Well No. 4, on October 21, 1981. No other large-capacity wells in the vicinity were pumping at the time. The well is 775 feet deep and is perforated from 260 to 764 feet in depth. Pumping began at 9:30 A.M. on October 21, 1981. Although a 24-hour pump test was planned, an electrical malfunction shortened the test to about 12 hours, and pumping stopped about 9:50 P.M. The discharge was measured by an orifice plate, and averaged 1,800 gpm during the test. Water levels in the pumped well were measured by a two-line electric sounder. Depth to water was 39.8 feet prior to pumping. DWR measured water levels in nearby wells for several days prior to the test. These measurements indicated that water levels in the vicinity were slightly rising. Depth to water in Old Well No. 4 after eight and one-half hours of pumping (the last measurement made) was 120.2 feet. Thus the specific capacity (discharge divided by drawdown) was 22.4 gpm per foot.

Information on three nearby wells that were used as observation wells during the test is as follows:

State No.	Perforated Interval (feet)	Distance from 36J1 (feet)
36H1	20-462	1,850
36N1	268-792	5,300
36Q1	105-420	1,700

Drillers logs indicate that Old Well No. 4 taps about 40 feet of permeable strata above a depth of 440 feet and about 65 feet below a depth of 560 feet. Wells 36H1 and 36Q1 tap only the upper of these two strata. Well 36N1 only tapped about 15 feet of permeable strata above a depth of 440 feet, but tapped almost 90 feet of permeable materials below a depth of 520 feet.

The two observation wells closest to Old Well No. 4 were thus perforated only opposite the upper part of the zone tapped by the pumped well. However, the most distant observation well was perforated over about the same depth interval as the pumped well. Drawdowns in the observation wells were measured with an electric sounder or tape and were corrected for the water-level recovery that was occurring during the drawdown test. The uncorrected drawdown was 5.2 feet in Well 36H1 after eight and one-half hours of pumping, and was 8.4 feet in Well 36Q1. The corrected drawdowns were 5.6 and 8.9 feet, respectively. No drawdown was measured in Well 36N1, instead the water in that well rose during pumping of Old Well No. 4. Because Wells 36H1 and 36Q1 do not tap the same water-bearing strata as the pumped well, measurements for them cannot be used to determine aquifer characteristics.

The storage coefficient cannot be determined solely from measurements in the pumped well. However, the transmissivity can be determined from such measurements. The Modified Jacob Method of the Theis non-equilibrium approach was used. Drawdown measurements yielded a transmissivity of 21,600 gpd per foot, which is considered to be slightly high, because of the regional water-level recovery that was occurring in the vicinity during the test. Corrected recovery measurements yielded a transmissivity of 17,900 gpd per foot, which is believed to be more representative. The lack of drawdown in Well 36N1 suggests that either a confined aquifer is not present, or the water-bearing strata at that well are not hydraulically connected to those at Old Well No. 4.

Within 36 hours after pumping stopped, depth to water in Old Well No. 4 was 41.9 feet, about two feet below the static water level prior to pumping. The water level in Well 36H1 had recovered to a depth of 38.3 feet after 36 hours, about 0.4 feet below the static water level prior to pumping. The water level in Well 36Q1 had recovered to a depth of 37.5 feet after 36

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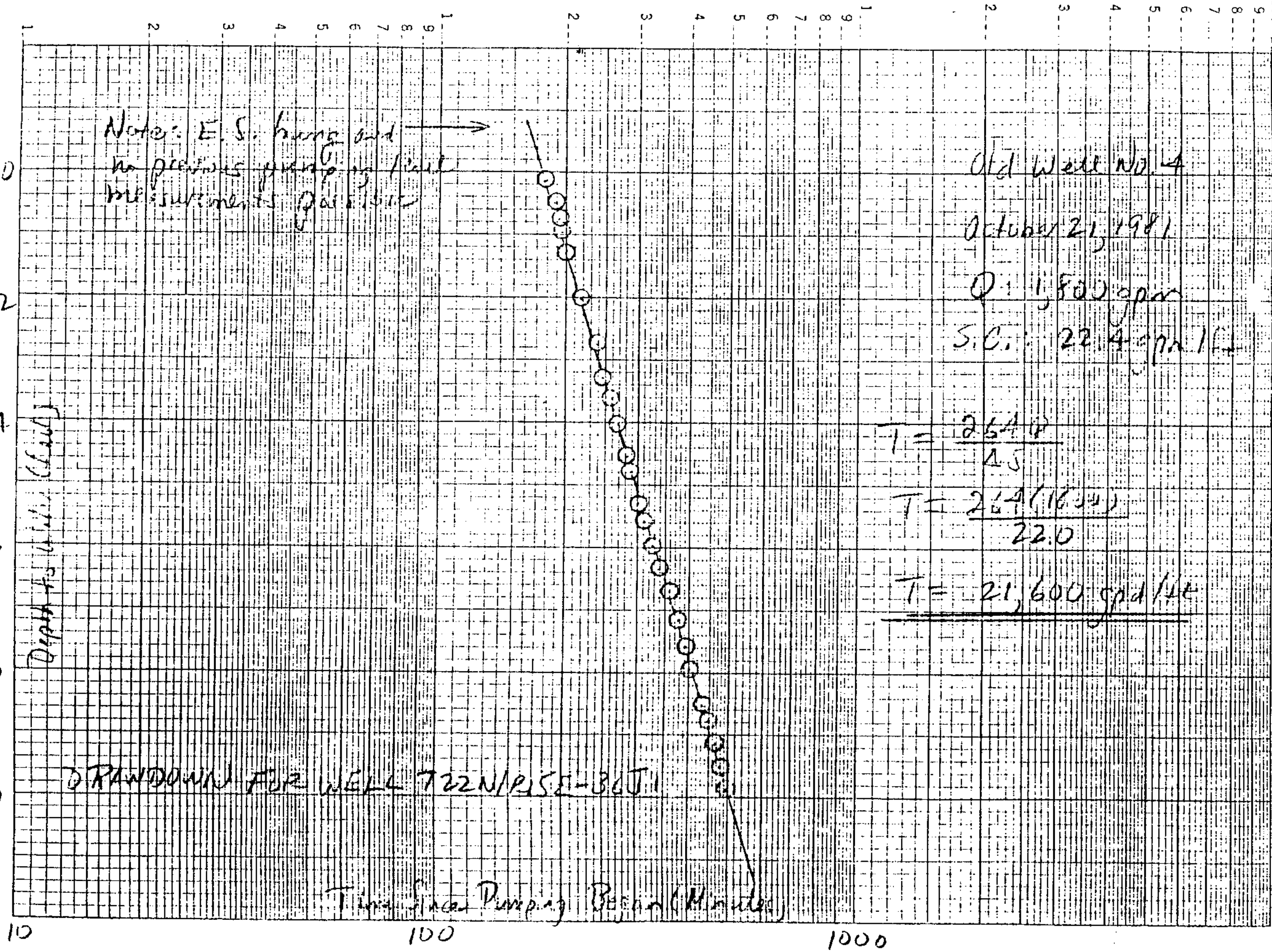

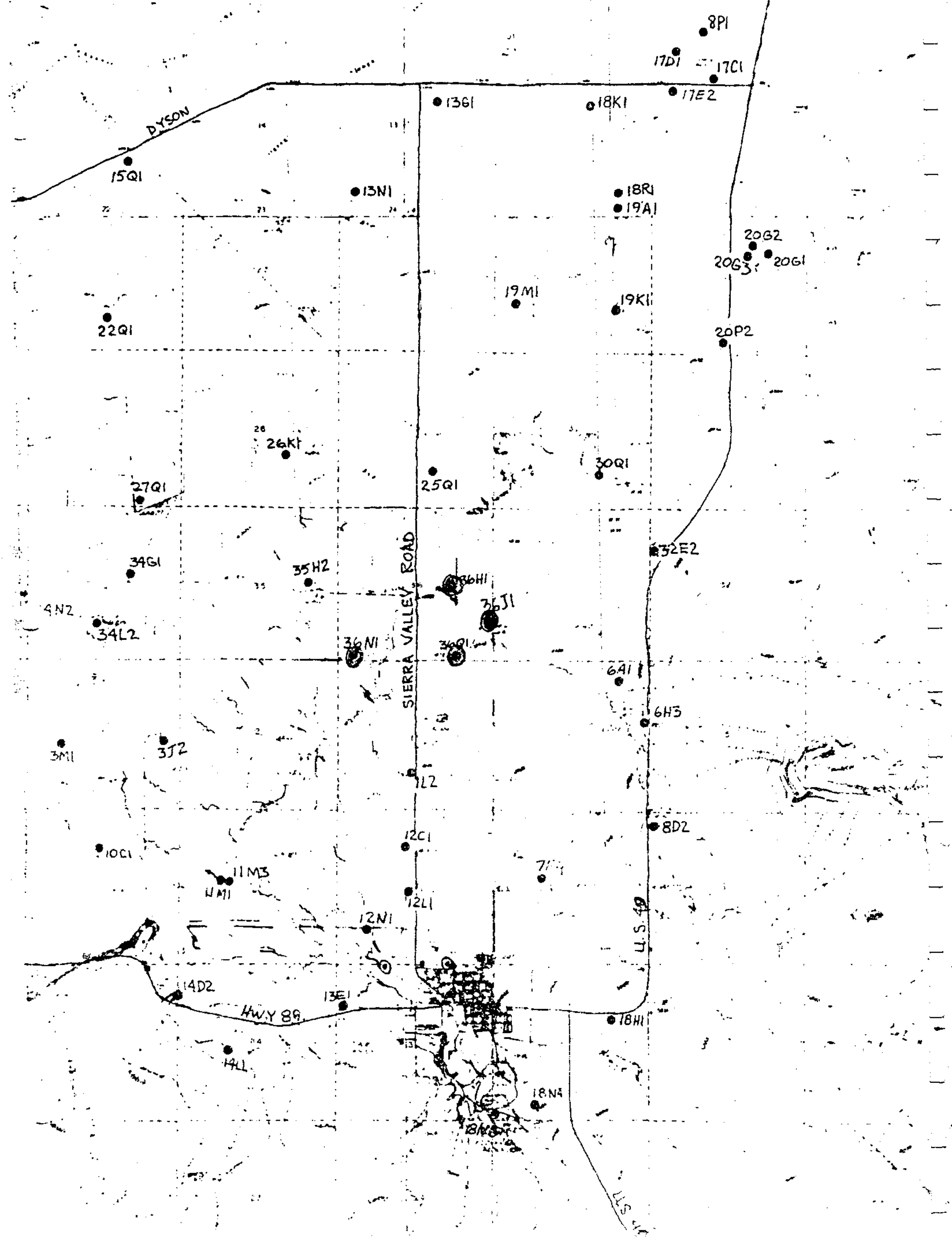

8P1
17D1
17C1
17E2
18K1
13G1
DYSON
15Q1
13N1
18R1
19A1
20G2
20G3
20G1
19M1
19K1
22Q1
20P2
26K1
25Q1
30Q1
27Q1
32E2
34G1
35H2
36H1
36J1
4N2
34L2
36N1
36Q1
SIERRA VALLEY ROAD
6A1
6H3
3M1
3J2
1L2
8D2
12C1
10C1
11M3
11M1
12L1
12N1
U.S. 49
14D2
13E1
HWY 89
18H1
14L1
18N4

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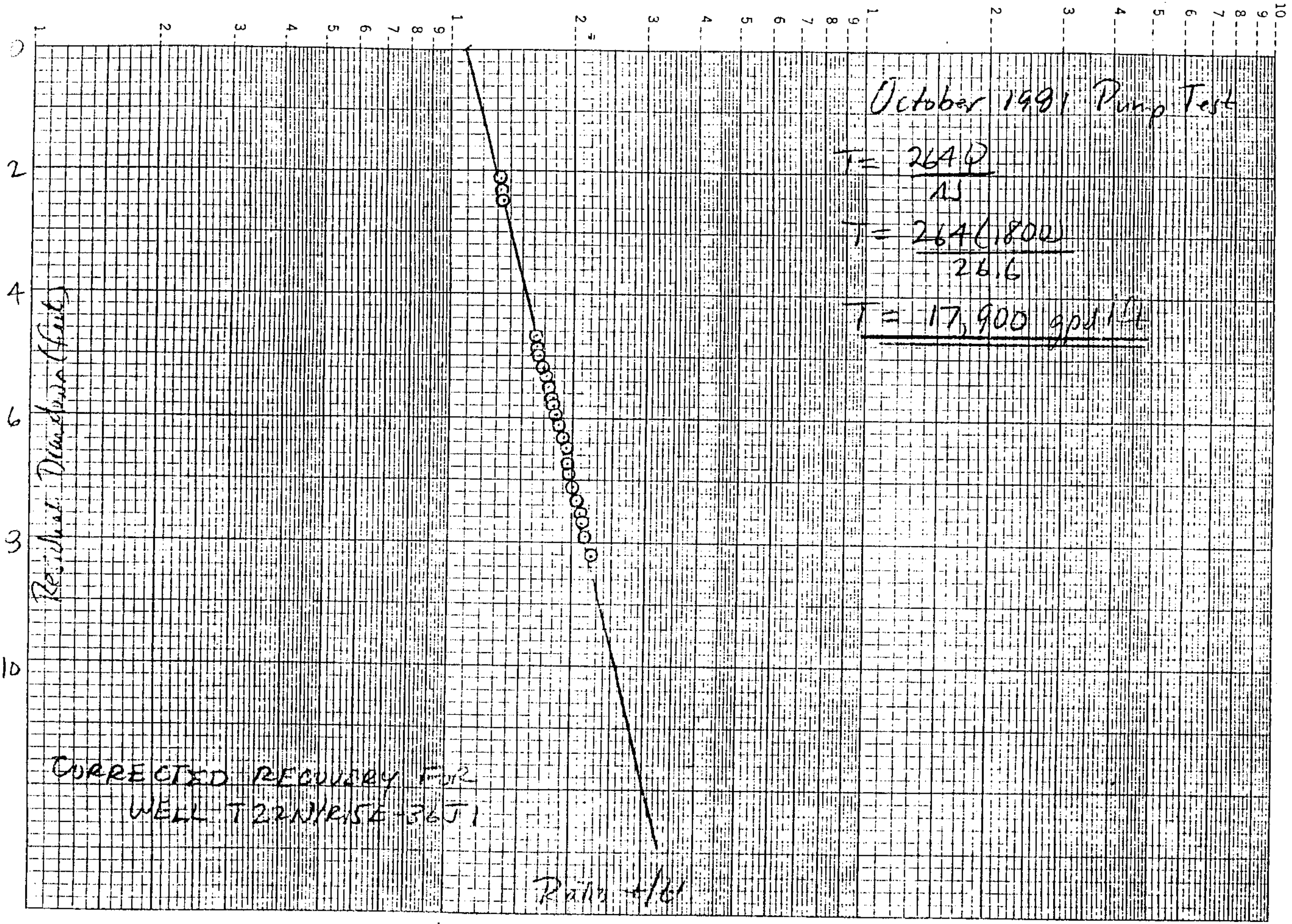


hours, about two feet below the static water level prior to pumping.

Genasci Well Near Loyalton

An aquifer test was conducted on Well T21N/R15E-12P3, or the Genasci Well, in October, 1982. The well is located about one-quarter mile west of the Loyalton grammar school. At the time, no other large-capacity wells in the vicinity were pumping. The well is 514 feet deep and is perforated from 230 to 514 feet in depth. Pumping began at 9:40 A.M. on October 18, 1982 and stopped at 8:55 A.M. on October 19. The test duration was thus slightly greater than 23 hours. A Hersey Sparling continuously recording flow meter provided by DWR was used to measure the well discharge. The well discharge could not be maintained constant during this test. Instead, the discharge fell from more than 1,450 gpm early in the test, to less than 1,300 gpm near the end of the test. A total of 5.68 acre-feet was pumped from the well during the test, and the average discharge was thus 1,330 gpm. Water levels in the pumped well were measured with an electric sounder. DWR measured water levels for several days prior to the start of the test. These measurements indicated that water levels in the vicinity were slightly recovering from summer pumping. Depth to water in Well 12P3 was 34.8 feet prior to pumping. At the end of the test, depth to water was 152.7 feet. Thus the specific capacity at the end of the test was 10.9 gpm per foot.

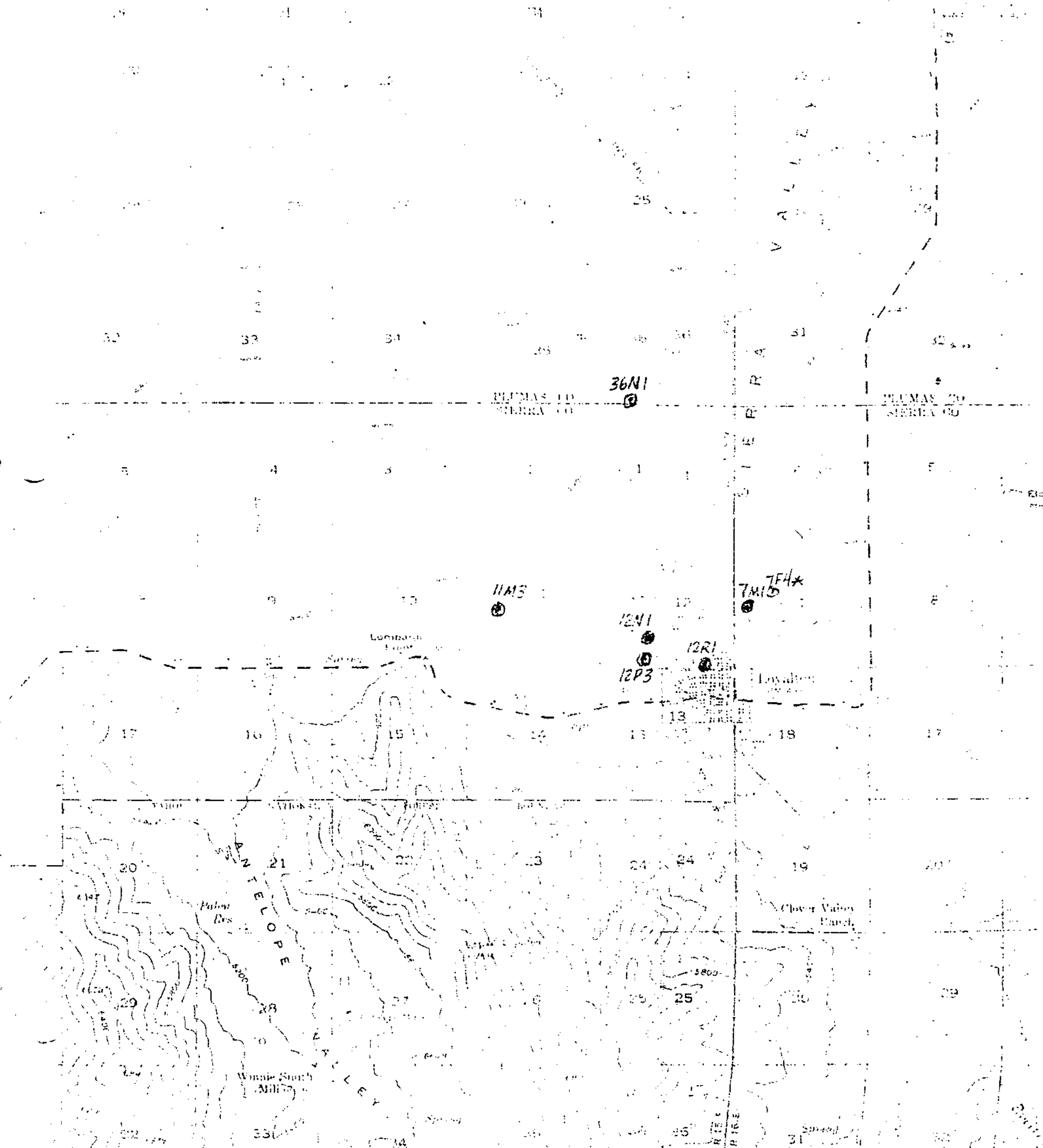
Information on five nearby wells that were used as observation wells is as follows:

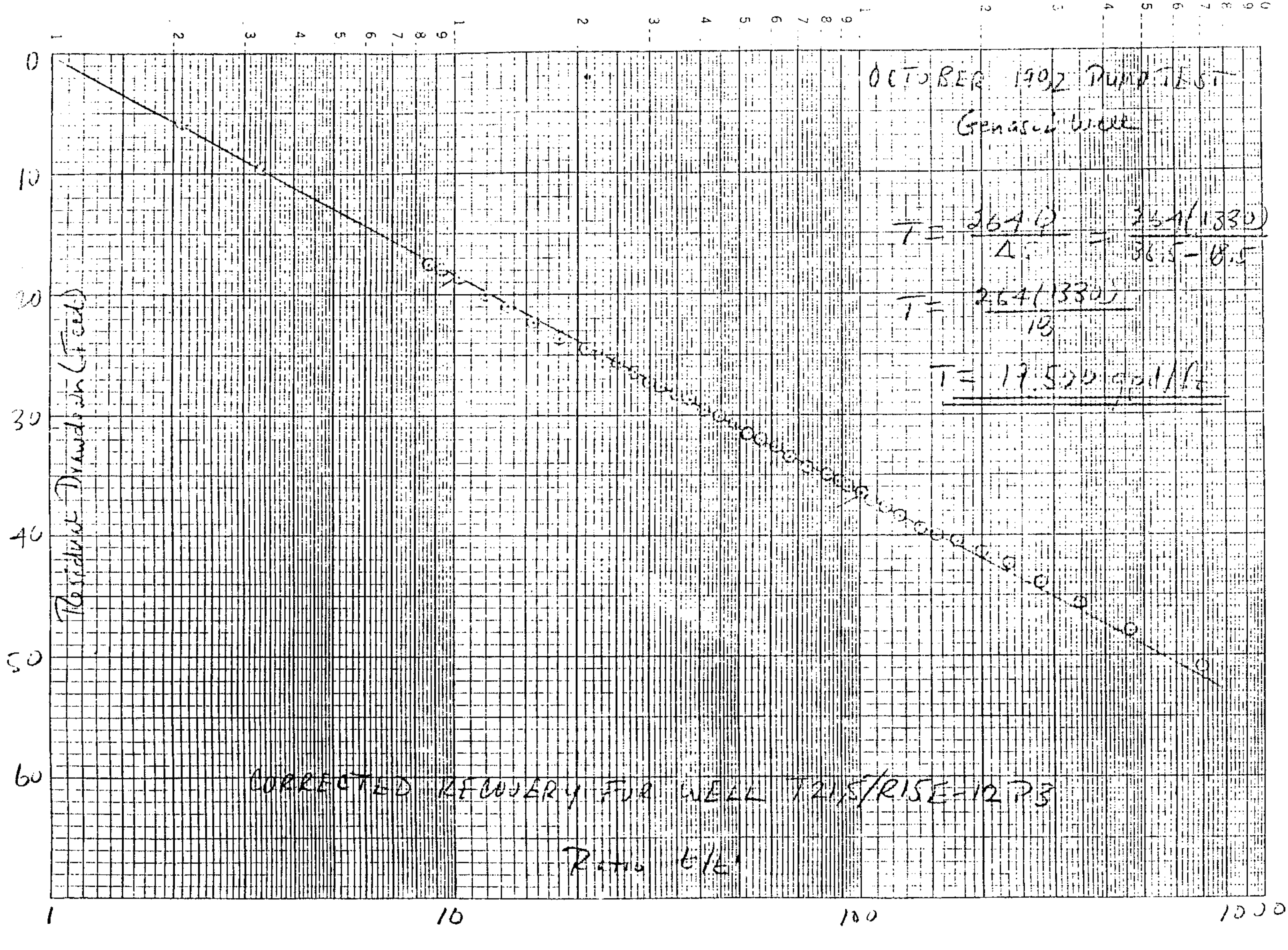
State No.	Perforated Interval (feet)	Distance from 12P3 (feet)
T22N/R15E-36N1	268-792	10,400
T21N/R15E-11M3	T.D. 406	6,200
-12N1	T.D. 40	900
-12R1	150-380	2,500
T21N/R16E-7M1	122-370	4,600

Well 12R1 is located southeast of the Loyalton High School and is operated by the Town of Loyalton. Well 36N1 is the same well used as an observation well for the aquifer test on Lucky Hereford Old Well No. 4 in 1981. Well 11M3 is a domestic well at the Genasci Ranch. None of the observation wells are perforated over the same depth interval as the pumped well, however Wells 12R and 7M1 are perforated over part of the depth interval tapped by the pumped well. The pumped well taps some permeable strata about 100 feet deeper than most other wells in the vicinity.

The water level in Well 7M1 fell from 45.1 feet prior to pumping, to 45.9 feet at the end of the pumping. The water level in this well was virtually constant prior to the test. The water level in this well showed little response to pumping of Well 12P3 until after about 13 hours. The total drawdown was thus 0.8 foot. Water levels in Well 12R1 did not respond to pumping of Well 12P3, instead there was a slight rise in water level. Such a water-level rise was also measured before pumping of 12P3 began. Water levels in Well 12N1 also slightly rose during pumping of Well 12P3. Water levels in Well 11M3 fluctuated slightly due to pumpage of the well itself, but no overall trend was apparent. Water levels in Well 36N1 were hard to measure.

*7F4 was not moni
during the test. Has
from the week be-




OCTOBER 1992 PUMP TEST
Genasci Well
T = 264Q/Δs = 264(1330)/36.5 - 18.5
T = 264(1330)/18
T = 19.500 gpd/ft
Residual Drawdown (Feet)
CORRECTED RECOVERY FOR WELL T21S/R15E-12P3
Ratio t/t'
0
10
20
30
40
50
60
1
10
100
1000

Although they fluctuated somewhat, overall they rose during pumping of Well 12P3. Thus Well 7M1 was the only observation well that showed a response to pumping of Well 12P3. Because Well 7M1 only taps the upper part of the aquifer tapped by the pumped well, measurements for it cannot be used to determine aquifer characteristics.

The storage coefficient cannot be determined from pumped well measurements, however the transmissivity can be. Because of the slight decrease in discharge during pumping that occurred during this test, recovery measurements are more useful than drawdown measurements. Based on corrected recovery measurements for the pumped well, the transmissivity was 19,500 gpd per foot. This value is very close to that determined from the 1981 aquifer test on Lucky Hereford Old Well No. 4, which is located about two and one-half miles north of Well 12P3. Results of the aquifer test at Well 12P3 do not indicate that a confined aquifer is present. Instead, the time lag for the drawdown in Well 7M1 suggests that a water-table aquifer is present. unconfined? even tho there is considerable clay above prod. zone?

The water level in Well 12P3 rose to a depth of 40.2 feet after slightly less than one day of recovery, or about 5.4 feet below the static level prior to pumping. The water level in Well 7M1 continued to decline for ten hours after pumping of 12P3 stopped. However, within two days after pumping stopped, the water level had risen to a depth of 45.6 feet, about 0.5 foot below the static level prior to pumping. However, the Loyalton Well (12R1) was pumped at a rate of about 700 gpm for about five hours on the morning of October 20. This could explain why water levels in Well 7M1 had not shown more recovery by the following day.

Lucky Hereford Well No. 10 Test

An aquifer test was conducted on Well T23N/R16E-32Q1, or Lucky Hereford No. 10, on October 19, 1982. This well is located about two miles west of Vinton and about three-fourths of a mile south of Highway 24. The well is 820 feet deep and perforated from 524 to 820 feet in depth. Pumping commenced at 3:00 P.M. on October 19 and was stopped at 11:21 A.M. on October 20, 1982. The well was thus pumped continuously for slightly more than 20 hours during the pump test. A Hersey Sparling continuously recording flow meter provided by DWR was used to measure the well discharge. The discharge was maintained relatively constant during the test. A total of 11.80 acre-feet of water were pumped during the test, and the average discharge was 3,150 gpm.

Water levels in wells in the vicinity were rising prior to the pump test. DWR maintains a water-level recorder on Well T23N/R15E-36J2, about one and one-half miles west of the pumped well. Prior to the test, the water level was rising at an average rate of about 0.4 foot per day. The water level in Well 36J2 had been rising since about August 20, when the water level was at the deepest point during the year.

Water levels in the pumped well were measured with an electric sounder. The static water level in Well 32Q1 was 68.7 feet deep prior to pumping. At the end of the test, the pumping level was about 125.8 feet deep, thus the specific capacity was

55.2 gpm per foot. Seven nearby wells were used as observation wells and information on these follows:

State No.	Perforated Interval (feet)	Distance from 32Q1 (feet)
T23N/R15E-36J1	T.D. 622	8,300
36J2	T.D. 386	8,300
T23N/R16E-29G1	352-822	6,900
30C1	273-690	11,000
30R1	477-801	5,600
32K1	50-100	1,500
T22N/R16E-6R2	589-816	6,000

Thus two of these wells tapped shallow strata above 120 feet in depth, whereas the five others tapped deeper strata. Wells 30R1 and 6R2 probably tap strata similar to that tapped by the pumped well.

Drillers and electric logs for wells in the vicinity of Well 32Q1 indicate that two confining beds are present between about 250 and 550 feet in depth. The major aquifer is between 550 and 800 feet in depth. Under long-term pumping conditions, one would expect that the aquifer might function as a leaky artesian aquifer.

The water level in Well 30R1 showed the only noticeable response to pumpage of 32Q1 of all of the observation wells. The water level in this well showed little response during the first few hours of pumping. However, the water level in Well 30R1 fell from 67.7 feet prior to pumping to 70.2 feet at the end of pumping. The water level in this well continued to fall to a depth of 70.6 feet about two hours after pumping stopped. Considering the recovery that was occurring prior to the pump test, the corrected total drawdown in Well 30R1 was about 3.0 feet.

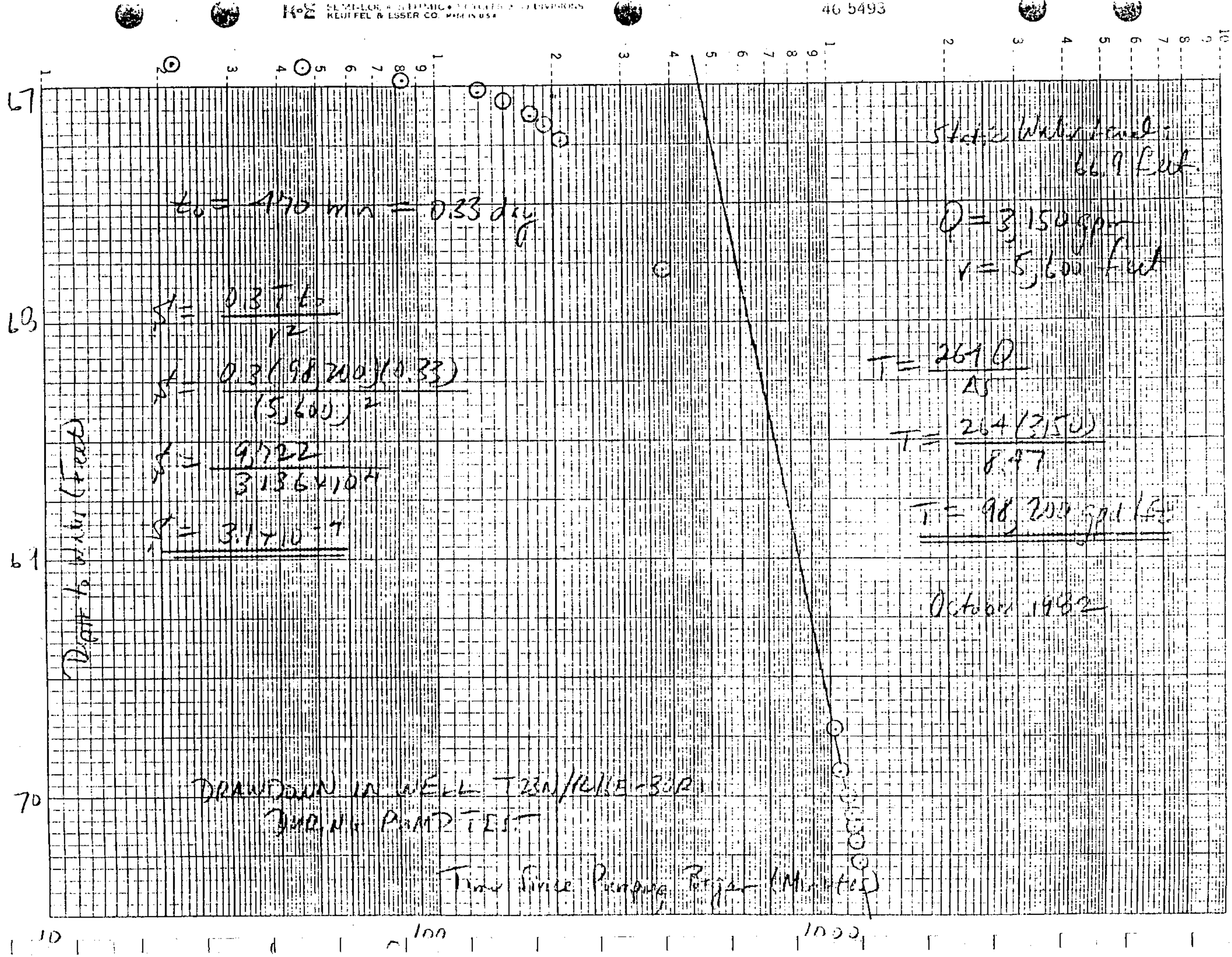
The water level in Well 29G1 rose from about 12.9 feet deep prior to pumping to 12.8 feet at the end of pumping. This rise was the same as that later observed during the recovery, indicating that Well 29G1 was not affected by pumping of Well 32Q1. The water level in Well 30C1 rose from 11.0 feet deep prior to pumping to 10.9 feet at the end of pumping, thus showing a similar pattern to Well 29G1. The water level in Well 36J2 rose from about 52.2 feet prior to pumping to 52.0 feet at the end of pumping. The water level in this well thus showed a similar pattern to that for Wells 29G1 and 30C1. The water level in Well 6R2 rose from a depth of 57.9 feet prior to pumping to 57.5 feet at the end of pumping. Water levels in this well thus seemed to follow the regional rate of water-level rise and it was apparently unaffected by the pumping of 32Q1.

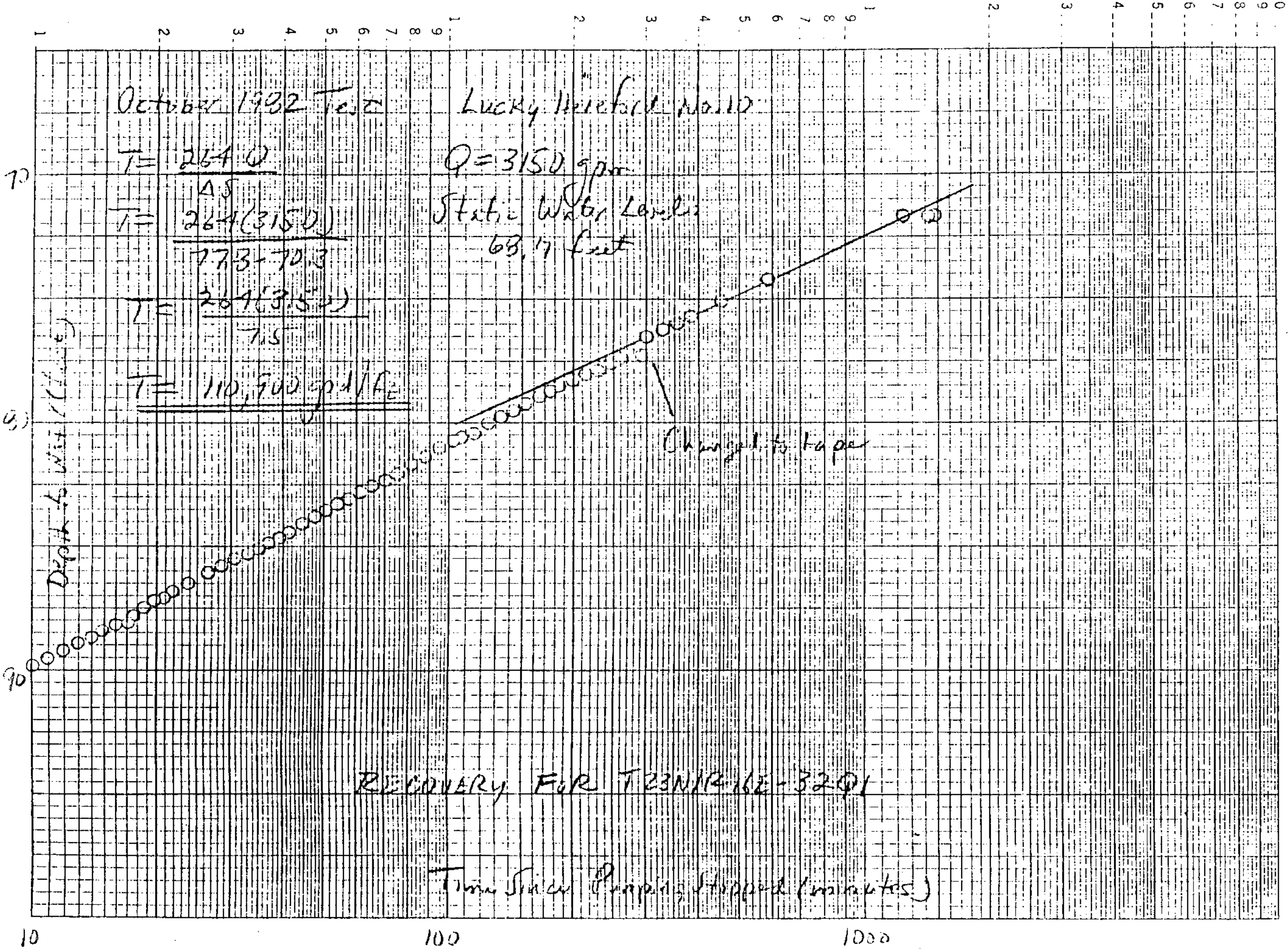
The water level in Well 32K1, a shallow well near the pumped well, remained relatively constant during the pump test. The water level in Well 36J1, a deep well about one and one-half miles west of the pumped well, rose about 0.1 foot during the pumping period. Neither of these wells showed a response to pumpage.

Drawdown in the pumped well could not be measured during much of the first hour of pumping, due to problems with the electric sounder hanging up between the casing and pump column. The water level was also difficult to measure because of oil floating on top of the water in the well. However, the drawdown remained relatively constant after about 40 minutes of pumping for the duration of pumping. Because of these factors, the water levels in the pumped well during drawdown could not be used to determine aquifer parameters. However, water-level measurements in Well 30R1 were used to determine both transmissivity and storage coefficient. Using the Modified Jacob Method, transmissivity was determined to be 98,200 gpd per foot, and the storage coefficient to be 0.00031. The transmissivity value is in good agreement with that expected based on the specific capacity. The time lag prior to when drawdown occurred in well 30R1 also is not indicative of a totally confined aquifer, as was the case for the Genasci Well pump test previously discussed.

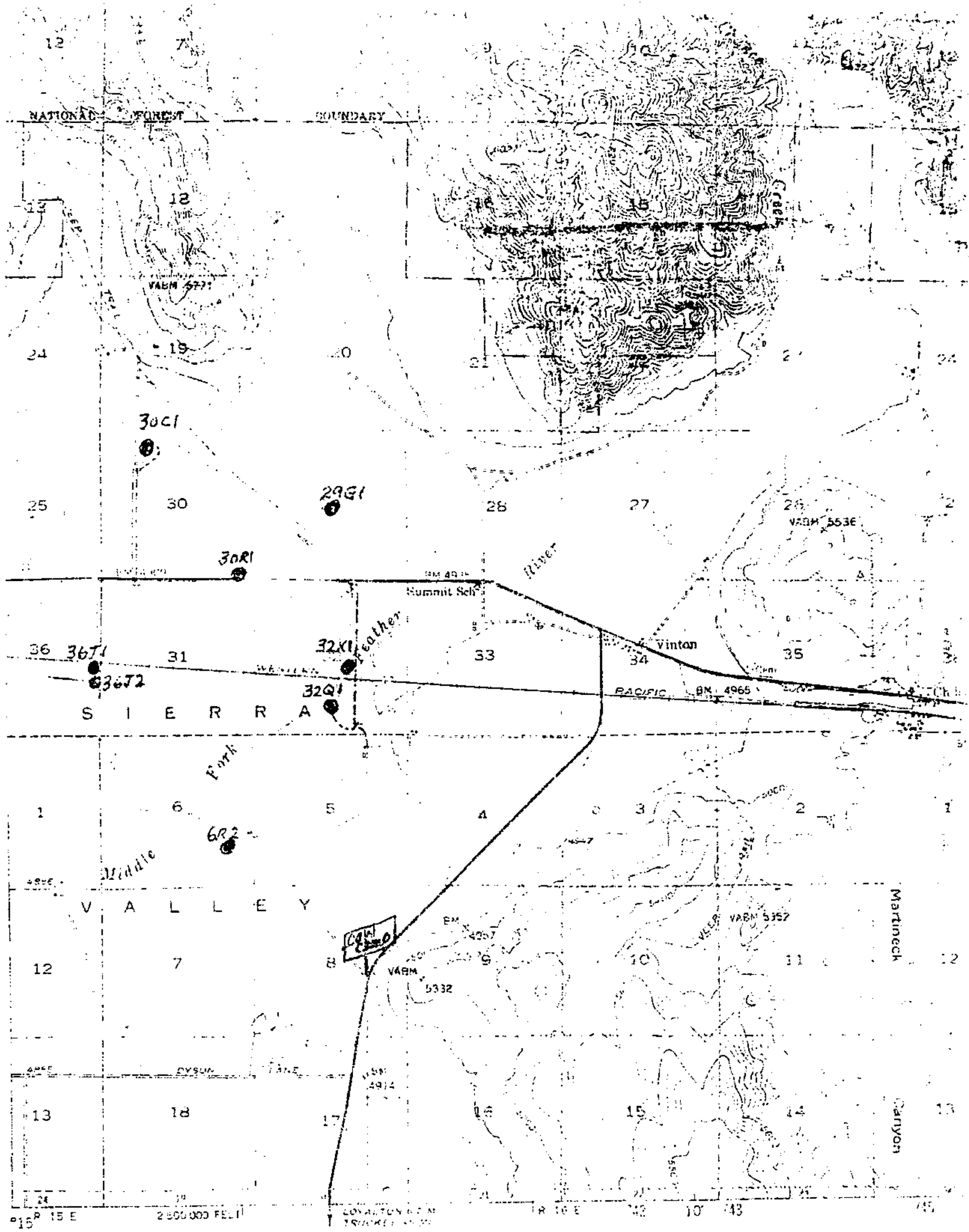
The water level in Well 32Q1 recovered to a depth of 71.9 feet deep about one day after pumping stopped. Depth to water at this time was thus 3.2 feet below the static level prior to pumping. Transmissivity was determined from recovery measurements in the pumped well, and was 110,900 gpd per foot. This value is in good agreement with that derived from drawdown measurements in Well 30R1. The water level in Well 30R1 did not begin to recover until about four and one-hours after pumping stopped. About one day after pumping stopped, depth to water in Well 30R1 was 69.3 feet, about 2.3 feet below the static level prior to pumping. Between 10 and 11 A.M. on October 21, 1982, the pump in Well 30R1 had to be turned on for irrigation, and thus additional recovery measurements were not possible. Because of the relatively short time period over which the water level in Well 30R1 actually recovered, recovery measurements for this well could not be used to determine aquifer characteristics.

Water levels in Wells 30C1, 29G1, and 36J2 continued to rise


K+E KEUFFEL & ESSER CO.
46 5493
Depth to Water (Feet)
67
70
Time Since Pumping Began (Minutes)
10
100
1000
Static Water Level: 66.9 feet.
$t_0 = 470$ min $= 0.33$ day
$Q = 3,150$ gpm
$r = 5,600$ feet
$S = \frac{0.3 T t_0}{r^2}$
$S = \frac{0.3(98,200)(0.33)}{(5,600)^2}$
$S = \frac{9722}{3136 \times 10^4}$
$S = 3.1 \times 10^{-7}$
$T = \frac{264 Q}{\Delta s}$
$T = \frac{264(3150)}{8.47}$
$T = 98,200$ gpd/ft
October 1982
DRAWDOWN IN WELL T23N/R1E-30R1
DURING PUMP TEST



October 1992 Test
Lucky Weirfield No. 10
T = 264 Q / ΔS
Q = 3150 gpm
T = 264(3150) / 77.3 - 70.3
Static Water Level: 68.7 feet
T = 264(3150) / 7.5
T = 110,900 gpd/ft
Changed to tape
Depth to Water (feet)
70
80
90
RECOVERY FOR T23N R14E-32Q1
Time Since Pumping Stopped (minutes)
10
100
1000



Mapped by the U. S. Forest Service

Edited and published by the Geological Survey

Control by USGS, USC&GS, USFS, and USBR

Topography from aerial photographs by KEK plotter
Aerial photographs taken 1947 Field check 1950

Polyconic projection. 1927 North American datum
10,000-foot grid based on California coordinate system, zone 1

Dashed land lines indicate approximate locations

1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

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at about the same rate as occurred during the pumping of 32Q1. This confirms that pumping of Well 32Q1 did not have a measurable impact on any of these wells during the pump test. It was necessary to begin pumping of Well 6R2 at 3:37 P.M. on October 20, 1982, and thus few recovery measurements were possible at this well. Water levels in the shallow observation well (32K1) and in deep well 36J1 continued to remain relatively constant during the recovery period.

APPENDIX E

GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR AGRICULTURE

University of California
Cooperative Extension
January 15, 1975

WATER QUALITY

Guidelines for Interpretation of Water Quality for Agriculture
(UC-Committee of Consultants)

Guidelines were originally distributed to Cooperative Extension staff in December 1973. Suggestions for needed changes, additions, and corrections have been made as received. The present "guidelines" are revised to January 15, 1975 and include -

1. Guidelines for Interpretation of Quality of Water for Irrigation.
2. Assumptions and Comments on "Guidelines".
3. Crop Tolerance and Leaching Requirement Tables - Field Crops.
4. " " " " " " --Vegetable Crops.
5. " " " " " " - Fruit Crops
6. " " " " " " - Forage Crops
7. Example - Use of Crop Tolerance Tables.
8. Boron in Irrigation Waters.
9. Tolerance of Ornamental Shrubs and Ground Covers to Salinity in Irrigation Water.
10. Recommended Maximum Concentrations of Trace Elements in Irrigation Waters.
11. Guide to Use of Saline Waters for Livestock and Poultry.
12. Guidelines To Levels of Toxic Substances in Drinking Water For Livestock.
13. Tables for Calculating pHc Values of Waters.

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GUIDELINES FOR INTERPRETATION OF QUALITY OF WATER FOR IRRIGATION

Interpretations are based on possible effects of constituents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation.

PROBLEM AND RELATED CONSTITUENT	WATER QUALITY GUIDELINES		
	No Problem	Increasing Problems	Severe Problems
Salinity[1/]			
EC_w of irrigation water, in millimhos/cm	<0.75	0.75 - 3.0	>3.0
Permeability			
EC_w of irrigation water, in mmho/cm	>0.5	<0.5	<0.2
adj.SAR[2/]	<6.0	6.0 - 9.0	>9.0
Specific Ion Toxicity[3/]			
from ROOT absorption			
Sodium (evaluate by adj.SAR)	<3	3.0 - 9.0	>9.0
Chloride (me/l)	<4	4.0 - 10	>10
(mg/l or ppm)	<142	142 - 355	>355
Boron (mg/l or ppm)	<0.5	0.5 - 2.0	2.0 - 10.0
from FOLIAR absorption[4/] (sprinklers)			
Sodium (me/l)	<3.0	>3.0	----
(mg/l or ppm)	<69	>69	----
Chloride (me/l)	<3.0	>3.0	----
(mg/l or ppm)	<106	>106	----
Miscellaneous[5/]			
NH_4-N, NO_3-N (mg/l or ppm) for sensitive crops	<5	5 - 30	>30
HCO_3 (me/l) [only with overhead sprinklers]	<1.5	1.5 - 8.5	>8.5
(mg/l or ppm)	<90	90 - 520	>520
pH	normal range = 6.5 - 8.4		----

1/ Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity. Refer to tables for crop tolerance and LR. (mmho/cmX640= approximate total dissolved solids (TDS) in mg/l or ppm; mmhoX1000= micromhos)

2/ adj.SAR (Adjusted Sodium Adsorption Ratio) is calculated from a modified equation developed by U.S. Salinity Laboratory to include added effects of precipitation or dissolution of calcium in soils and related to CO_3 + HCO_3 concentrations.

To evaluate sodium (permeability) hazard: $\text{adj.SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \left[1 + (8.4 - pHc) \right]$

pHc is a calculated value based on total cations, Ca+Mg, and CO_3+HCO_3. Calculating and reporting will be done by reporting laboratory. NOTE: Na, Ca+Mg, CO_3+HCO_3 should be in me/l.

Permeability problems, related to low EC or high adj.SAR of water, can be reduced if necessary by adding gypsum. Usual application rate per acre foot of applied water is from 200 to about 1000 lbs. (234 lbs. of 100% gypsum added to 1 acre foot of water will supply 1 me/l of calcium and raise the ECw about 0.1 mmho). In many cases a soil application may be needed.

3/ Most tree crops and woody ornamentals are sensitive to sodium and chloride (use values shown). Most annual crops are not sensitive (use salinity tolerance tables). For boron sensitivity, refer to boron tolerance tables.

4/ Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride absorption under low-humidity, high-evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.)

5/ Excess N may affect production or quality of certain crops, e.g. sugar beets, citrus, avocados, apricots, grapes etc.
(1 mg/l NO_3-N = 2.72 lbs. N/acre foot of applied water).
HCO_3 with overhead sprinkler irrigation may cause a white carbonate deposit to form on fruit and leaves.

Symbol	Name
EC_w	Electrical Conductivity of water
mmho/cm	millimho per centimeter
<	less than
>	more than
mg/l	milligrams per liter
ppm	parts per million
LR	Leaching Requirement
me/l	milliequivalents per liter
TDS	Total Dissolved Solids

Symbol	Name	Equiv. wt.
Na	Sodium	23.00
Ca	Calcium	20.04
Mg	Magnesium	12.16
CO_3	Carbonate	30.00
HCO_3	Bicarbonate	61.00
NO_3-N	Nitrate-nitrogen	14.00
Cl	Chloride	35.45

17.1 ppm = 1 grain per gallon

UC-Coop. Extension
December 1, 1974

Assumptions and Comments on Guidelines for Interpretation of Quality of Water for Irrigation Developed by UC-Committee of Consultants.

1. These "guidelines" are flexible and intended for use in estimating the potential hazards to crop production associated with long term use of the particular water being evaluated. "Guidelines" should be modified when warranted by local experience and special conditions of crop, soil, method of irrigation or level of soil-water-crop management. Changes of 10 to 20 percent above or below an indicated guideline value may have little significance if considered in proper perspective along with all other variables that enter into a yield of crop.

2. It is assumed that the water will be used under average conditions - soil texture, internal drainage, total water use, climate, and salt tolerance of crop. Large deviations from the average might make it unsafe to use water which under average conditions, would be good, or might make it safe to use water, which under average conditions, would be of doubtful quality.

3. The divisions into "No problem - Increasing problem - Severe problem" is more-or-less arbitrary but based on large numbers of field studies and observations, as well as carefully controlled greenhouse and small plot research conducted by various researchers over the past 40 years or more. Guidelines of one sort or another have been proposed by U.S. Geological Survey, University of California, U.S. Salinity Laboratory and many others starting as early as 1911. As new research and observations have developed additional information for assessing water quality,guidelines have been modified.

4. These "guidelines" apply to surface irrigation methods such as furrow, flood, basin, sprinklers, or any other which applies water on an "as-needed" basis and which allows for an extended dry-down period between irrigations during which the crop uses up a considerable portion of the available stored water.

5. The guidelines incorporate some of the newer concepts in soil-plant-water relationships as recently developed at U.S. Salinity Laboratory. Uptake of water occurs mostly from the upper two-thirds of the rooting depth of crop (the "more-active" part of the root zone). Each irrigation normally will leach this upper soil area and maintain it at relatively low salinity. Salts applied in the irrigation water under reasonable irrigation management concentrate in the soil water in this active root zone to about three times the concentration of the applied irrigation water and the salinity of this root area is representative of the salinity levels to which the plant responds. The salinity of the lower root zone is of less importance as long as plants are reasonably well supplied with moisture in the upper, "more-active", root zone.

These guidelines represent the 1974 consensus of the UC-Committee of Consultants. It is recognized they are not perfect and it is expected they will be modified from time to time as further knowledge and experience dictate.

CROP TOLERANCE [illegible]BLES[1/] - FIELD CROPS

CROP	Expected Yield Reduction[2/] at EC_e or EC_w indicated: 0% ECe[3/]	0% ECw[4/]	0% LR[5/]	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw[6/]
Barley[7/] (Hordeum vulgare)	8.0[7/]	5.3	10%	10	6.7	12%	13	8.7	15%	18	12	21%	56
Cotton (Gossypium hirsutum)	7.7	5.1	10%	9.6	6.4	12%	13	8.3	15%	17	12	21%	54
Sugarbeet (Beta vulgaris)	7.0[7/]	4.7	10%	8.7	5.8	12%	11	7.5	16%	15	10	21%	48
Wheat[7/ 8/] (Triticum aestivum)	6.0[7/]	4.0	10%	7.4	4.9	12%	9.5	6.4	16%	13	8.7	22%	40
Safflower (Carthamus tinctorius)	5.3	3.5	12%	6.2	4.1	14%	7.6	5.0	17%	9.9	6.6	23%	29
Soybean (Glycine max)	5.0	3.3	17%	5.5	3.7	18%	6.2	4.2	21%	7.5	5.0	25%	20
Sorghum (Sorghum bicolor)	4.0	2.7	7%	5.1	3.4	9%	7.2	4.8	13%	11	7.2	20%	36
Groundnut (Arachis hypogaea)	3.2	2.1	16%	3.5	2.4	18%	4.1	2.7	21%	4.9	3.3	25%	13
Rice (paddy) (Ozyza sativa)	3.0	2.0	9%	3.8	2.6	11%	5.1	3.4	15%	7.2	4.8	21%	23
Sesbania (Sesbania macrocarpa)	2.3	1.5	6%	3.7	2.5	8%	5.9	3.9	12%	9.4	6.3	19%	33
Corn (grain) (Zea mays)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Flax (Linum usitatissimum)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
[illegible] (Vicia faba)	1.6	[illegible]	4%	2.6	1.8	7%	4.2	2.0	12%	6.8	4.5	19%	24
[illegible] (Vigna sinensis)	1.3	[illegible]	5%	2.0	1.3	8%	3.1	2.1	12%	4.9	3.2	19%	17
[illegible] (field)	[illegible]	0.7	[illegible]	1.5	1.0	8%	2.3	1.5	12%	3.6	2.4	19%	13

VEGETABLE CROPS

CROP	Expected Yield Reduction[2/] at EC_e or EC_w indicated: 0% ECe	0% ECw	0% LR	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw
Beets[7/] (Beta vulgaris)	4.0	2.7	9%	5.1	3.4	11%	6.8	4.5	15%	9.6	6.4	21%	30
Broccoli (Brassica italica)	2.8	1.9	7%	3.9	2.6	10%	5.5	3.7	14%	8.2	5.5	20%	27
Tomato (Lycopersicon esculentum)	2.5	1.7	7%	3.5	2.3	9%	5.0	3.4	13%	7.6	5.0	20%	25
Cucumber (Cucumis sativus)	2.5	1.7	8%	3.3	2.2	11%	4.4	2.9	15%	6.3	4.2	21%	20
Cantaloupe (Cucumis melo)	2.2	1.5	5%	3.6	2.4	7%	5.7	3.8	12%	9.1	6.1	19%	32
Spinach (spinacia oleracea)	2.0	1.3	4%	3.3	2.2	7%	5.3	3.5	12%	8.6	5.7	19%	30
Cabbage (Brassica oleracea capitata)	1.8	1.2	5%	2.8	1.9	8%	4.4	2.9	12%	7.0	4.6	19%	24
Potato (Solanum tuberosum)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Sweet corn (Zea mays)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Sweet potato (Ipomea batatas)	1.5	1.0	5%	2.4	1.6	8%	3.8	2.5	12%	6.0	4.0	19%	21
Pepper (Capsicum frutescens)	1.5	1.0	6%	2.2	1.5	9%	3.3	2.2	13%	5.1	3.4	20%	17
Lettuce (Lactuca sativa)	1.3	0.9	5%	2.1	1.4	8%	3.2	2.1	12%	5.2	3.4	19%	18
Radish (Raphanus sativas)	1.2	0.8	4%	2.0	1.3	7%	3.1	2.1	12%	5.0	3.4	19%	18
Onion (Allium cepa)	1.2	0.8	5%	1.8	1.2	8%	2.8	1.8	12%	4.3	2.9	19%	15
Carrot (Daucus carota)	1.0	0.7	4%	1.7	1.1	7%	2.8	1.9	12%	4.6	3.1	19%	16
Beans (Phaseolus vulgaris)	1.0	0.7	6%	1.5	1.0	8%	2.3	1.5	12%	3.6	2.4	19%	12.5

FRUIT CROPS

CROP	Expected Yield Reduction[2/] at EC_e or EC_w indicated: 0% ECe	0% ECw	0% LR	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw
Date palm (Phoenix dactylifera)	4.0	2.7	4%	6.8	4.5	7%	10.9	7.3	11%	17.9	12	19%	64
Fig (Ficus carica) Olive (Olea europaea) Pomegranate (Puncia granatum)	2.7	1.8	6%	3.8	2.6	9%	5.5	3.7	13%	8.4	5.6	20%	28
Grapefruit (Citrus paradisi)	1.8	1.2	8%	2.4	1.6	10%	3.4	2.2	14%	4.9	3.3	21%	16
Orange (Citrus sinensis)	1.7	1.1	7%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Lemon (Citrus limenea)	1.7	1.1	7%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Apple (Pyrus malus) Pear (Pyrus communis)	1.7	1.0	6%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Walnut (Juglans regia)	1.7	1.1	7%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Peach (Prunus persica)	1.7	1.1	9%	2.2	1.4	11%	2.9	1.9	15%	4.1	2.7	21%	13
Apricot (Pyrus armeniaca)	1.6	1.1	9%	2.0	1.3	11%	2.6	1.8	15%	3.7	2.5	20%	12
Grape (Vitis spp.)	1.5	1.0	4%	2.5	1.7	7%	4.1	2.7	11%	6.7	4.5	19%	24
Almond (Prunus amygdalus)	1.5	1.0	7%	2.0	1.4	10%	2.8	1.9	13%	4.1	2.7	20%	14
Plum (Prunus domestica)	1.5	1.0	7%	2.1	1.4	10%	2.9	1.9	14%	4.3	2.8	20%	14
Blackberry (Rubus spp.)	1.5	1.0	8%	2.0	1.3	11%	2.6	1.8	15%	*3.8	2.5	21%	12
Boysenberry (Rubus spp.)	1.5	1.0	8%	2.0	1.3	11%	2.6	1.8	15%	3.8	2.5	21%	12
[illegible]	1.3	0.9	7%	1.6	1.2	10%	2.5	1.7	15%	3.7	2.4	20%	12
[illegible]	1.0	0.7	6%	1.4	1.0	9%	2.1	1.4	13%	3.2	2.1	19%	11
[illegible]	1.0	0.7	5%	1.3	0.9	10%	[illegible]	1.2	15%	2.5	1.7	21%	8

FORAGE CROPS

CROP	Expected Yield Reduction 2/ at EC_e or EC_w indicated: 0% ECe	0% ECw	0% LR	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw
Tall wheat grass (Agropyron elongatum)	7.5	5.0	8%	9.9	6.6	10%	13.3	9.0	14%	19.4	13	21%	63
Wheat grass (fairway) (Agropyron elongatum)	7.5	5.0	11%	9.0	6.0	14%	11	7.4	17%	15	9.8	22%	44
Bermuda grass 9/ (Cynodon dactylon)	6.9	4.6	10%	8.5	5.7	13%	10.8	7.2	16%	14.7	9.8	22%	45
Barley (hay) 7/ (Hordeum vulgare)	6.0	4.0	10%	7.4	4.9	11%	9.5	6.3	16%	13.0	8.7	22%	40
Perennial rye grass (Lolium perenne)	5.6	3.7	10%	6.9	4.6	12%	8.9	5.9	16%	12.2	8.1	21%	38
Trefoil, birdsfoot 10/ narrow leaf (L. corniculatus tenuifolius)	5.0	3.3	11%	6.0	4.0	13%	7.5	5.0	17%	10	6.7	22%	30
Harding grass (Phalaris tuberosa)	4.6	3.1	9%	5.9	3.9	11%	7.9	5.3	15%	11.1	7.4	21%	36
Tall fescue (Festula elatior)	3.9	2.6	6%	5.8	3.9	8%	8.6	5.7	12%	13.3	8.9	19%	46
Crested Wh. grass (Agropyron desertorum)	3.5	2.3	4%	6.0	4.0	7%	9.8	6.5	11%	16	11	19%	57
Vetch (Vicia sativa)	3.0	2.0	8%	3.9	2.6	11%	5.3	3.5	15%	7.6	5.0	21%	24
Sudan grass (Sorghum sudanense)	2.8	1.9	4%	5.1	3.4	7%	8.6	5.7	11%	14.4	9.6	18%	52
[illegible]drye, beardless ([illegible] triticoides)	2.7	1.8	5%	4.4	2.9	7%	6.9	4.6	12%	11.0	7.4	19%	39
[illegible], big ([illegible])	2.3	1.5	10%	2.8	1.9	13%	3.6	2.4	16%	4.9	3.3	22%	15
Alfalfa ([illegible] sativa)	2.0	1.3	4%	3.4	2.2	7%	5.4	3.6	12%	8.8	5.9	19%	31
[illegible] 7/	[illegible]	[illegible]	5%	[illegible]	2.1	8%	5.0	3.3	12%	8.0	5.3	19%	28

FORAGE CROPS (continued)

CROP	Expected Yield Reduction[2] at EC_e or EC_w indicated: 0% ECe	0% ECw	0% LR	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw
Corn (forage) (zea mays)	1.8	1.2	4%	3.2	2.1	7%	5.2	3.5	11%	8.6	5.7	18%	31
Clover, berseem (Trifolium alexandrinum)	1.5	1.0	3%	3.2	2.2	6%	5.9	3.9	10%	10.3	6.8	18%	38
Orchard grass (Dactylis glomerata)	1.5	1.0	3%	3.1	2.1	6%	5.5	3.7	11%	9.6	6.4	18%	35
Meadow Foxtail (Alopecurus pratensis)	1.5	1.0	4%	2.5	1.7	7%	4.1	2.7	11%	6.7	4.5	19%	24
Clover, alsike, ladino, red, strawberry (trifolium spp.)	1.5	1.0	5.5	2.3	1.6	8%	3.6	2.4	12%	5.7	3.8	19%	20

CROP TOLERANCE TABLES[1]

1/ Based on data as reported by MAAS and Hoffman (in press); Bernstein ( ), and University of California Committee of Consultants ( ).

2/ Expected yield reduction for the particular crop due to indicated salinity of soil or salinity of irrigation water.

3/ ECe means electrical conductivity of the saturation extract of the soil ( ) reported in millimhos per centimeter at 25°C. Values reported are from MAAS and Hoffman ( ) and Bernstein ( ).

4/ ECw means electrical conductivity of the irrigation water in millimhos per centimeter at 25°C. This assumes a 15 to 20% leaching fraction and an average salinity of soil water equal to about [illegible] that of the irrigation water applied (EC_{sw}= 3 EC_w) or about twice that of the soil saturation extract (EC_{sw}= 2 EC_e). From the above, EC_e= 1.5 EC_w.

CROP TOLERANCE TABLES[1/] (continued)

5/ LR means leaching requirement or the minimum leaching fraction that can be relied upon to control salts within the tolerance of the particular crop grown and considering the quality of water used. LR is determined from the equation LR= EC_w/EC_{dw}[6/].

6/ Maximum ECdw is the maximum salinity of the percolating water draining from the root zone that can result due to removal of water by the particular crop to meet its water requirement for growth (if all the root zone soil water were at this maximum ECdw, yield reduction would be 100% since the crop would be unable to extract water from the very salty soil water). This is the value used as ECdw in the LR calculation (LR= EC_w/EDdw). For the given crop and quality of water indicated, application of irrigation water to exactly meet the evapotranspiration demand of crop plus the LR to control salt should result in maximum efficiency of water use. At this efficiency, percolating water draining from the root zone would be minimal as to quantity but at a maximum as to salinity and should approach the maximum EC_{dw} as shown on these crop tolerance tables.

7/ Barley, wheat, sugar beets and several other crops are less tolerant of salts during germination and early seedling growth. For germination of beets, salinity of soil in the seed area should not exceed EC_e= 3 mmhos/cm; for barley and wheat, EC_e should not exceed EC_e= 4 or 5 mmhos/cm.

8/ Tolerance data may not apply to semi-dwarf varieties of wheat. These are often more tolerant.

9/ An average of Bermuda grass varieties. Suwanee and Coastal are about 20% more tolerant; common and Greenfield are about 20% less tolerant.

10/ Average of Boer, Wilman, Sand, and Weeping Lovegrass. Lehman appears about 50% more tolerant.

11/ Broad-leaf birdsfoot trefoil appears to be less tolerant than narrow leaf.

EXAMPLE - Use of Crop Tolerance Tables

Crop = Alfalfa

Max. EC_{dw} = 31

$$LR\% = \frac{EC_w}{EC_{dw}} \times 100$$

(Applied water (needed to supply ET+LR) $= \frac{ET}{1-LR}$)

Max. EC_w - From Tables

for 0 yield loss	= 1.3 mmho,	LR = 4%
10% " "	= 2.2 " ,	LR = 7%
25% " "	= 3.6 " ,	LR = 12%
50% " "	= 5.9 " ,	LR = 19%

**** 0 yield loss expected with $EC_w < 1.3$

EC_w = 0.2 mmho, LR = $\frac{0.2}{31}$ X 100 = .6%

EC_w = 0.5 "	LR = 1.6%
EC_w = 0.75 "	LR = 2.4%
EC_w = 1.00 "	LR = 3.2%
EC_w = 1.30 "	LR = 4.2%

**** From 0-10% yield loss expected with EC_w = 1.3-2.2 mmho

EC_w = 1.3 mmho,	LR = 4.2%
EC_w = 1.5 "	LR = 4.8%
EC_w = 1.75 "	LR = 5.6%
EC_w = 2.0 "	LR = 6.5%
EC_w = 2.2 "	LR = 7.0%

**** From 10-25% yield loss expected with EC_w = 2.2-3.6 mmho

EC_w = 2.2 mmho,	LR = 7.1%
EC_w = 2.35 "	LR = 7.6%
EC_w = 2.50 "	LR = 8.1%
EC_w = 2.75 "	LR = 8.9%
EC_w = 3.00 "	LR = 9.7%
EC_w = 3.30 "	LR = 10.6%
EC_w = 3.6 "	LR = 11.6%

**** From 25-50% yield loss expected with EC_w = 3.6-5.9 mmho

EC_w = 3.6 mmho,	LR = 11.6%
EC_w = 3.80 "	LR = 12.3%
EC_w = 4.00 "	LR = 12.9%
EC_w = 4.50 "	LR = 14.5%
EC_w = 5.0 "	LR = 16.1%
EC_w = 5.3 "	LR = 17.1%
EC_w = 5.9 "	LR = 19.0%

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BORON IN IRRIGATION WATERS

Boron toxicity in many areas is traceable to use of irrigation waters with boron content in excess of 1 ppm. The UC Ag. Extension laboratories are using the following interpretation as regards boron content of irrigation water:

Below 0.5 mg/l	Satisfactory for all crops.
0.5 - 1.0 mg/l	Satisfactory for most crops; sensitive crops may show injury (may show leaf injury but yields may not be affected).
1.0 - 2.0 mg/l	Satisfactory for semi-tolerant crops. Sensitive crops are usually reduced in yield and vigor.
2.0 -10.0 mg/l	Only tolerant crops produce satisfactory yields.

There is no economically feasible method of removing boron from irrigation water. Similarly, there is at present no chemical or soil amendment which can economically be added to the soil to render the boron nontoxic. However, growers in some areas are learning to live with marginal boron and salinity conditions by: 1) Maintaining fertility levels slightly above the usual "optimum," and 2) By irrigating a little more frequently than "normal."

RELATIVE TOLERANCE OF PLANTS TO BORON

(In each group the plants first named are considered as being more sensitive and the last named more tolerant)

SENSITIVE	SEMI-TOLERANT	TOLERANT
0.5 mg/l	1 mg/l	2 mg/l
Lemon	Lima Bean	Carrot
Grapefruit	Sweet Potato	Lettuce
Avocado	Bell Pepper	Cabbage
Orange	Tomato	Turnip
Thornless Blackberry	Pumpkin	Onion
Apricot	Zinnia	Broad Bean
Peach	Oat	Gladiolus
Cherry	Milo	Alfalfa
Persimmon	Corn	Garden Beet
Kadota Fig	Wheat	Mangel
Grape (Sultanina & Malaga)	Barley	Sugar Beet
Apple	Olive	Palm (Phoenix Canariensis)
Pear	Ragged Robin Rose	Date Palm (Phoenix Dactylifera)
Plum	Field Pea	Asparagus
American Elm	Radish	Athel (Tamarix Aphylla)
Navy Bean	Sweet Pea	10 mg/l
Jerusalem Artichoke	Pima Cotton	
rsian (English) Walnut	Acala Cotton	
Black Walnut	Potato	
Pecan	Sunflower (Native)	
1.0 mg/l	2 mg/l	

Adopted from
USDA Tech. Bull. No. 448

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TOLERANCE OF ORNAMENTAL SHRUBS AND GROUND COVERS TO SALINITY IN IRRIGATION WATER 1/

SENSITIVE 2/

(ECw=.75-1.50 3/)

Star jasmine
(Trachelospermum jasminoides)

Pineapple guava
(Feijoa sellowiana)

Burford holly
(Ilex cornuta Burford)

Rose
(Rosa sp.var.Grenoble on Dr. Huey root)

Algerian ivy
(Hedera canariensis)

Hibiscus
(H. rosa-sinensis cv. Brilliante)

Heavenly bamboo
(Nandina domestica)

MODERATELY TOLERANT

(ECw=1.50-3.0)

Pittosporum
(P. tobira)

Viburnum
(V.tinus v.robustum)

Texas privet
(Ligustrum lucidum)

Lantana
(L. camara)

Boxwood
(Buxus microphylla v. japonica)

Xylosma
(X senticosa)

Arborvitae
(Thuja orientalis)

Dodonea
(D. viscosa v. atropurpurea)

Silverberry
(Elaegnus pungens)

Spreading juniper
(Juniperus chinensis)

Bottlebrush
(Callistemon viminalis)

TOLERANT

(more than ECw=3.0)

Oleander
(Nerium oleander)

Pyracantha
(P. graeberi)

Rosemary
(Rosmarinus lockwoodi)

Dracaena
(D. endivisa)

Euonymus
(E. japonica v. grandiflora)

Natal plum
(Carissa grandiflora)

Bougainvillea
(B. spectabilis)

1/ Source: L. Bernstein; L.E. Francois; R.A. Clark - 1972: Salt Tolerance of Ornamental Shrubs and Ground Covers, J. Amer. Soc. Hort. Sci. 97(4): 550-556

2/ Listed in decreasing order of sensitivity. ECw values shown are associated with generally satisfactory appearance and up to 25% decrease in top growth.

3/ ECw means electrical conductivity of irrigation water (in mmho/cm).
Assumptions include the following:
ECe X 2 = ECsw, ECe = Electrical conductivity of soil saturation extract, representative of the more active part of the root zone.

ECsw=Electrical conductivity of soil water; ECwX3=ECsw, 1/2ECsw=EC [illegible]

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATERS [a]

ELEMENT	FOR WATERS USED CONTINUOUSLY ON ALL SOIL mg/l	FOR USE UP TO 20 YEARS ON FINE TEXTURED SOILS OF pH 6.0 TO 8.5 mg/l
Aluminum	5.0	20.0
Arsenic	0.10	2.0
Beryllium	0.10	0.50
Boron	0.75	2.0
Cadmium	0.010	0.050
Chromium	.10	1.0
Cobalt	.050	5.0
Copper	0.20	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5 [b]	2.5 [b]
Manganese	0.20	10.0
Molybdenum	0.010	0.050 [c]
Nickel	0.20	2.0
Selenium	0.020	0.020
Vanadium	0.10	1.0
Zinc	2.0	10.0

[a] These levels will normally not adversely affect plants or soils. No data available for Mercury, Silver, Tin, Titanium, Tungsten.

[b] Recommended maximum concentration for irrigating citrus is 0.075 mg/l.

[c] For only acid fine textured soils or acid soils with relatively high iron oxide contents.

Source: Above data based on Environmental Studies Board, Nat. Acad. of Sci. - Nat. Acad. of Eng. Water Quality Criteria 1972 (U.S. Gov't. Print. Office, Wash. D.C. 20402) p. 339.

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GUIDE TO THE USE OF SALINE WATERS FOR LIVESTOCK AND POULTRY[1/]

Total Soluble Salt Content of Waters (mg/1)	
Less than 1,000 mg/1 (EC less than 1.5)[2/]	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
1,000-2,999 (EC=1.5-5)	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them or watery droppings in poultry.
3,000-4,999 (EC=5-8)	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing water feces, increased mortality and decreased growth, especially in turkeys.
5,000-6,999 (EC=8-11)	Can be used with reasonable safety for dairy and beef cattle, for sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
7,000-10,000 (EC=11-16)	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although older ruminants, hors poultry, and swine may subsist on them under certain conditions.
Over 10,000 (EC over 16)	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

1/ Environmental Studies Board, Nat. Acad. of Sci. - Nat. Acad. of Eng. Water Quality Criteria 1972 (U.S. Gov't. Print. Office, Wash. D.C. 20402) p. 308.

2/ EC values shown are reported as mmho/cm and are only approximations based on rough conversion of given mg/1 to EC by mg/1 ÷ 640= EC.

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GUIDELINES TO LEVELS OF TOXIC SUBSTANCES IN DRINKING WATER FOR LIVESTOCK [1/]

Constituent	Upper Limit
Aluminum (Al)	5 mg/l
Arsenic (As)	0.2 mg/l
Beryllium (Be)	no data
Boron (B)	5.0 mg/l
Cadmium (Cd)	.05 mg/l
Chromium (Cr)	1.0 mg/l
Cobalt (Co)	1.0 mg/l
Copper (Cu)	0.5 mg/l
Fluoride (F)	2.0 mg/l
Iron (Fe)	no data
Lead (Pb)	0.1 mg/l [2/]
Manganese (Mn)	no data
Mercury (Hg)	.01 mg/l
Molybdenum (Mo)	0.5 mg/l
Nitrate + Nitrite (NO_3-N+NO_2-N)	100 mg/l
Nitrite (NO_2-N)	10 mg/l
Selenium (Se)	0.05 mg/l
Vanadium (Va)	0.10 mg/l
Zinc (Zn)	25 mg/l
Total Dissolved (TDS) Solids	10,000 mg/l [3/]

1/ Based primarily on Environmental Studies Board, Nat. Acd. of Sci. - Nat. Acad. of Eng. Water Quality Criteria 1972 (U.S. Gov't Print. Office, Wash. D.C. 20402) p. 30?-317.

2/ Lead is accumulative and problems may begin at threshold value = 0.05 mg/l.

3/ See "Guide to Use of Saline Waters For Livestock and

January 15, 1975

TABLES FOR CALCULATING pHc VALUES OF WATERS

pHc can be calculated, using the table below; pHc= $(pK'_2 - pK'_c)$ + p (Ca+Mg) + pAlk where $pK'_2 - pK'_c$ is obtained from Ca+Mg+Na
p (Ca+Mg) " " " Ca+Mg
pAlk " " " CO_3+HCO_3

Tables for Calculation pHc

Conct. Ca+Mg+Na (me/l)	$p(K'_2-K'_c)$	Conct. Ca+Mg (me/l)	p(Ca+Mg)	Conct. CO_3+HCO_3 (me/l)	pAlk
.5	2.11	.05	4.60	.05	4.30
.7	2.12	.10	4.30	.10	4.00
.9	2.13	.15	4.12	.15	3.82
1.2	2.14	.2	4.00	.20	3.70
1.6	2.15	.25	3.90	.25	3.60
1.9	2.16	.32	3.80	.31	3.51
2.4	2.17	.39	3.70	.40	3.40
2.8	2.18	.50	3.60	.50	3.30
3.3	2.19	.63	3.50	.63	3.20
3.9	2.20	.79	3.40	.79	3.10
4.5	2.21	1.00	3.30	.99	3.00
5.1	2.22	1.25	3.20	1.25	2.90
5.8	2.23	1.58	3.10	1.57	2.80
6.6	2.24	1.98	3.00	1.98	2.70
7.4	2.25	2.49	2.90	2.49	2.60
8.3	2.26	3.14	2.80	3.13	2.50
9.2	2.27	3.90	2.70	4.0	2.40
11	2.28	4.97	2.60	5.0	2.30
13	2.30	6.30	2.50	6.3	2.20
15	2.32	7.90	2.40	7.9	2.10
18	2.34	10.00	2.30	9.9	2.00
22	2.36	12.50	2.20	12.5	1.90
25	2.38	15.80	2.10	15.7	1.80
29	2.40	19.80	2.00	19.8	1.70
34	2.42				
39	2.44				
45	2.46				
51	2.48				
59	2.50				
67	2.52				
.76	2.54				

Example: To calculate adj.SAR of water from

$$adj.SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \left[1+(8.4-pHc)\right].$$

With report of water analysis
Na = 3.5 me/l
Ca+Mg = 1.0 me/l
Ca+Mg+Na = 4.5 me/l
CO_3+HCO_3 = 3.0 me/l

pHc= 2.21+3.30+2.5= 8.01 (from tables)

$$adj.SAR = \frac{3.5}{\sqrt{1/2}} \left[1+(8.4-8.01)\right] = 4.95\ (1+.39)$$

adj.SAR= 6.88

NOTE: Values of pHc above 8.4 indicate tendency to dissolve lime from soil through which the water moves; values below 8.4 indicate tendency to precipitate lime from waters applied.

(ref: L.V. Wilcox, U.S. Salinity Laboratory, mimeo Dec. 30, 1966)

APPENDIX F

CALIFORNIA DOMESTIC WATER QUALITY AND MONITORING REGULATIONS

CALIFORNIA DOMESTIC WATER QUALITY AND MONITORING REGULATIONS

Excerpts from the

California Health and Safety Code

and the

California Administrative Code
Title 22

1977

STATE OF CALIFORNIA

DEPARTMENT OF HEALTH
SANITARY ENGINEERING SECTION
2151 Berkeley Way
Berkeley, California 94704

17 4 5 405

(d) The Department may require a water supplier to make such additional tests as is judged to be warranted.

(e) Acceptable data from the provider wholesaling agency may be used to satisfy these requirements.

64433. Types of Analyses. (a) As a minimum, analyses shall be made for the following constituents:

(1) General mineral analyses for bicarbonate, carbonate, and hydroxide alkalinity, calcium, chloride, copper, foaming agents (MBAS), iron, magnesium, manganese, pH, sodium, sulfate, specific conductance, total dissolved solids, total hardness and zinc.

(2) General physical analyses for color, odor and turbidity.

(3) Inorganic chemical analyses for arsenic, barium, cadmium, chromium, lead, mercury, nitrate (as NO_3), selenium silver and fluoride.

(4) Organic chemical analyses for endrin, lindane, methoxychlor, toxaphene and chlorophenoxys 2, 4—D and 2, 4, 5—TP Silvex.

64435. Maximum Contaminant Levels. (a) Water containing contaminants exceeding the maximum contanimant levels shown on Tables 2, 3 and 4 presents a risk to the health of humans when continually used for drinking or culinary purposes.

Table 2

Maximum Contaminant Levels
Inorganic Chemicals

Constituent	*Maximum Contaminant Level, mg/l*
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as NO_3)	45.
Selenium	0.01
Silver	0.05

Table 3

Maximum Contaminant Levels
Organic Chemicals

Constituent	*Maximum Contaminant Level, mg/l*
(a) Chlorinated Hydrocarbons	
Endrin	0.002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
(b) Chlorophenoxys	
2, 4—D	0.1
2,4,5—TP Silvex	0.01

Table 4

Limiting Concentrations for Fluoride

Annual Average of Maximum Daily Air Temperature		*Fluoride Concentration, mg/l*			
Degrees Fahrenheit	*Degrees Celsius*	*lower*	*optimum*	*upper*	*Maximum Contaminant Level*
53.7 and below	12.0 and below	0.9	1.2	1.7	2.4
53.8 to 58.3	12.1 to 14.6	0.8	1.1	1.5	2.2
58.4 to 63.8	14.7 to 17.6	0.8	1.0	1.3	2.0
63.9 to 70.6	17.7 to 21.4	0.7	0.9	1.2	1.8
70.7 to 79.2	21.5 to 26.2	0.7	0.8	1.0	1.6
79.3 to 90.5	26.3 to 32.5	0.6	0.7	0.8	1.4

(b) The annual average of maximum daily air temperatures in Table 4 shall be obtained for a minimum of five years. The average concentration of fluoride during any month, if added, shall not exceed the upper concentration. Naturally occurring fluoride concentration shall not exceed the maximum contaminant level.

(c) The maximum contaminant level for nitrate shall be applicable to all public water systems. The maximum contaminant levels for the other inorganic chemical shall apply only to community and state small water systems.

(d) If any organic or inorganic chemical, except for nitrate, exceeds the maximum contaminant level, the water supplier shall:

(1) Inform the Department within seven days from the receipt of the analysis.

(2) Collect three additional samples within one month for analysis to confirm the result. If the average of the four samples collected exceeds the maximum contaminant level, this information shall be reported to the Department within 48 hours.

(e) If a single nitrate sample exceeds the maximum contaminant level, the water supplier shall:

(1) Collect another sample within 24 hours from the receipt of the original analysis.

(2) Analyze the new sample and inform the Department within seven days from the receipt of the original analysis.

(3) Average the two nitrate samples. Any average which exceeds the maximum contaminant level shall be reported to the Department within 48 hours.

(f) Surface waters exposed to significant sewage hazards or significant recreational use shall receive, as a minimum, pretreatment, filtration and disinfection. The filtered water turbidity, measured daily, shall be less than 0.5 turbidity units on a monthly average for an acceptable level of public health protection.

(1) The Department shall designate those public water systems subject to the requirements of this subsection.

Article 8. Secondary Drinking Water Standards

64471. Applicability. (a) The secondary drinking water standards in this article shall be maintained to protect the public welfare, and to assure a supply of pure, wholesome and potable water. These standards specify maximum contaminant levels:

(1) At the point of delivery to the consumer which may adversely affect the taste, odor or appearance of drinking water.

(2) Which, if exceeded, may cause a substantial number of persons served by the community water system to discontinue its use.

(b) The local health officer shall ensure compliance with the requirements of this article by community water systems with less than 200 service connections and state small water systems.

64473. Maximum Contaminant Levels. (a) Distribution system water containing substances exceeding the maximum contaminant levels shown in Table 6 and 7 may be objectionable to an appreciable number of people, but is not generally hazardous to health.

Table 6

Consumer Acceptance Limits—Secondary Drinking Water Standards

Constituents	*Maximum Contaminant Levels*
Color	15 Units
Copper	1.0 mg/l
Corrosivity	Relatively low
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor—Threshold	3 Units
Foaming Agents (MBAS)	0.5 mg/l
Turbidity	5 Units
Zinc	5.0 mg/l

Table 7

Mineralization—Secondary Drinking Water Standards

	Maximum Contaminant Levels		
Constituent, Units	*Recommended*	*Upper*	*Short Term*
Total Dissolved Solids, mg/l	500	1,000	1,500
or			
Specific Conductance, micromhos	900	1,600	2,200
Chloride, mg/l	250	500	600
Sulfate, mg/l	250	500	600

(b) The maximum contaminant levels listed in Table 6:

(1) Shall not be exceeded in:

(A) New community water systems.

(B) New sources developed for existing community water systems.

(2) Shall not be exceeded in existing community water systems. The distribution system water shall be free from significant amounts of particulate matter in all public water systems.