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TO: ALL READERS JULY 17, 1984

FROM: DONN MILLER, HYDROLOGIST

SUBJECT: OPEN-FILE REPORT ENTITLED:

APPRAISAL OF GROUND WATER CONDITIONS IN THE FORT ROCK BASIN, LAKE COUNTY, OREGON.

The purpose of this report is to provide information to the public concerning technical reasons for the limitations placed on the appropriation of ground water in the Fort Rock Basin. It is noted as an open-file report which is subject to revision. U.S. Geological Survey Professional Paper 383-B is included as a supplement. A final report in the Oregon Water Resources Department Ground Water Report series is expected in early 1986. That report will supersede this report and will contain new data, some of which has not yet been collected.

Questions from the public are welcome. In addition, comments correcting errors in the report are encouraged. These questions and comments will help in the production of an accurate and understandable report in 1986.

State of Oregon

Water Resources Department

William H. Young

Director

Appraisal of Ground Water Conditions in the Fort Rock Basin, Lake County, Oregon

Donn W. Miller

July, 1984

Open-File Report
Subject to Revision

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ILLUSTRATIONS

DEFINITIONS OF TERMS

Acre-Foot (AF). -- The volume required to cover 1 acre to a depth of 1 foot. This is equal to 43,560 cubic feet or 325,851 gallons.

Aquifer. -- A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.

Confined ground water. -- Ground water that is under pressure greater than atmospheric. In a well that taps a confined ground water body, the static water level is above the top of the aquifer.

Critical Ground Water Area. -- An area in which an underlying ground water reservoir is specially controlled by order of the Oregon Water Resources Director due to certain current or pending water supply or quality considerations.

Drawdown. -- The lowering of the ground water level caused by well discharge. It is the difference between the static water level and the pumping or flowing water level in a well.

Evapotranspiration. -- Water transferred to the atmosphere by evaporation from water surfaces and moist soil by plant transpiration.

Full Appropriation. -- The level of ground water withdrawal through rights and entitlements which equals the present or future capturable portion of average recharge without injuring senior rights or entitlements.

Ground Water Reservoir. -- A designated body of standing or moving ground water having exterior boundaries which may be ascertained or reasonably inferred.

Hydraulic Conductivity. -- The volume of water that will move in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Hydraulic Gradient. -- The change in static head per unit of distance in a given direction. The direction generally is understood to be that of the maximum rate of decrease in head.

Interference. -- The drawdown in a well which is the result of the withdrawal of water from another well.

Perched Ground Water. -- Ground water separated from an underlying body of ground water by an unsaturated zone.

Permit. -- A document issued by the Oregon Water Resources Department which authorizes the diversion and beneficial use of public waters of the State.

Potentiometric Surface. -- A surface that represents the static head. In an aquifer it is defined by the levels at which water stands in tightly cased wells. The water table is a special kind of potentiometric surface. The static head (water level) in a well represents the average nonpumping water level of the water bearing materials open to the well bore.

Residual Drawdown. -- The distance during a recovery period that the water level in a well is found to be below the pre-pumping water level.

Specific Capacity. -- The rate of discharge of water from a well divided by the drawdown of water level within the well.

Storage Coefficient. -- The storage coefficient is the volume of water an aquifer releases from or takes into storage per unit area of aquifer per unit change in head.

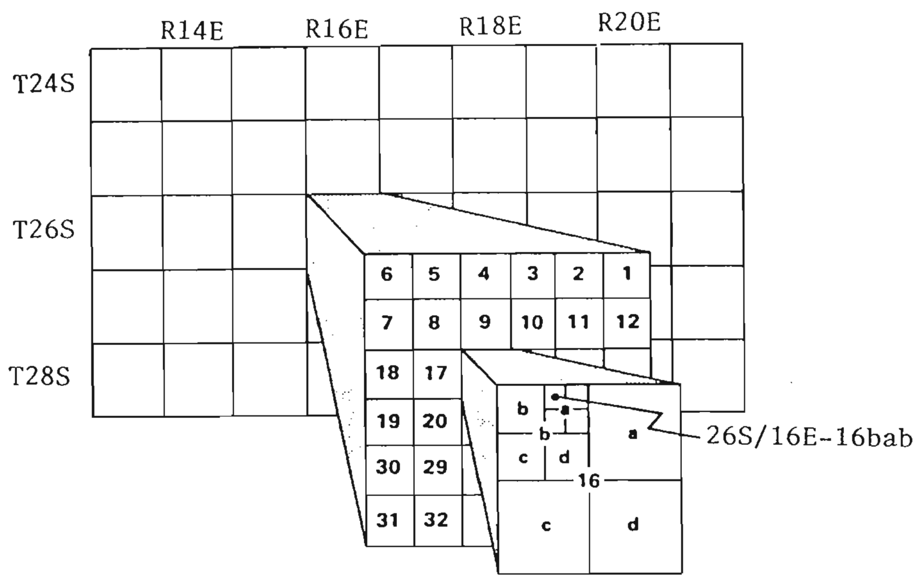
Transmissivity. -- The rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is equal to the average hydraulic conductivity times the saturated thickness of the aquifer.

Unconfined Ground Water. -- Ground water in an aquifer that has a water table.

Water Table. -- The water surface in an unconfined water body, at which the pressure is atmospheric.

WELL NUMBERING SYSTEM

Wells are numbered on the basis of their location according to the rectangular system for subdivision of public lands. Successively, the numerals represent the township, range, and section. For instance, well 26S/16E-16bab is located in Township 26 South, Range 16 East, Section 16. The letters following the section number indicate the location within the section. The first letter designates the quarter section (160 acres), the second letter the quarter-quarter section (40 acres), and the third letter the quarter- quarter-quarter section (10 acres).



Appraisal of Ground Water Conditions in the
Fort Rock Basin, Lake County, Oregon

ABSTRACT

The dominant use of ground water in the Fort Rock Basin is irrigated agriculture. Ground water withdrawals have increased sharply during the period 1976 through 1981 for this purpose in the region. Permitting has stabilized since that time, probably due to economic conditions. The potential for increased withdrawals is evidenced by the existence, but current nonuse, of dozens of irrigation wells on undeveloped lands. The additional development from these wells is uncertain, but probably exceeds 10,000 acres. Permitted use is currently estimated to exceed actual use by about 20,000 acres.

The volcanic and sedimentary rocks of the Fort Rock Basin provide excellent aquifers. A generally dry climate notwithstanding, significant local recharge occurs to these units. The high porosity and transmissivities of the materials serve to modulate changes in ground water levels in the basin. Under current climatic and water use conditions, water levels in wells will generally decline for many years to come, although at a small and decreasing rate. In addition, seasonal interference effects are expected to persist at levels greater than the rate of annual reservoir depletion.

The application of statistical methods to hydrograph, precipitation and streamflow records reveals much about the main ground water reservoir in the Fort Rock Basin. This rather potentiometrically flat reservoir may be generalized mathematically and analyzed for natural recharge/discharge effects. This analysis may then provide guidelines for appropriation from the reservoir.

Ground water conditions have been monitored in the Fort Rock Basin for over 50 years through an observation well system. This system expanded and contracted as the data need changed. Data prior to 1976 show the variations of a predominantly natural system. Data after that time record a blend of natural and artificial conditions. Analysis of these data suggest that there may be slightly more water pumped than recharged in the basin.

INTRODUCTION

Purpose and Scope of the Investigation

The current investigation commenced in 1980 as a result of concerns due to rapid increases in irrigated agriculture in the Fort Rock Basin. These increases have come solely from ground water development. In addition to this fact, there was reason to believe that future increases were probable due to releases of federally managed lands as well as expansion on undeveloped private lands. At present, approximately 400 irrigation wells withdraw water in the basin and about 100 more potential irrigation wells are in place. Thus, current as well as future demands on the ground water body in this high desert area are of major concern for the management of the resource.

The primary objective of this investigation is to determine the limits of ground water appropriation in the Fort Rock Basin. In order to make this determination, several hydrogeologic features require assessment. These include: 1) a qualitative understanding of the ground water flow regime, 2) a quantitative assessment of hydrogeologic equilibrium under natural and stressed conditions and 3) a program of on-going monitoring of ground water levels and pumping stress. A later, more complete report is anticipated in early 1986 which will expand further on these items.

This investigation was conducted by the Oregon Water Resources Department. Lake County and the North Lake County Water Users provided financial support for the well inventory. The Lakeview Office of the BLM and Oregon State University furnished aid in kind. Midstate Electric Co-op provided data on electric consumption for irrigation. In addition to on-going water level

monitoring by staff of the Water Resources Department, other temporary employees performed the irrigation well inventory to determine at site pumping conditions. These included Gary Crane and Kelly Archer during the summer of 1981 and Karmen Emery during the summer of 1982.

Location

The Fort Rock Basin is located in south-central Oregon (Figure 1a). It rests primarily in Northern Lake County, but also includes portions of Deschutes and Klamath Counties. The basin consists of three valleys: Silver Lake Valley, Fort Rock Valley and Christmas Valley. The Fort Rock Basin is a topographic basin of interior surface drainage with very low divides separating component valleys. Total area of the basin is approximately 2500 square miles of which approximately 100,000 acres are suitable for irrigation, according to state and federal studies.

Previous Investigations

In addition to several geologic reports on the basin, a number of ground water hydrologic studies have been prepared. Most have been conducted by the U.S. Geological Survey. However, one minor report prepared by a private consulting firm is also available, as is a preliminary report by the Oregon Water Resources Department.

Russell (1884) and Waring (1904) made early investigations of the general geology of the basin. Waring's report included interpretations of ground water flow in the basin as well as records of shallow well water levels and some chemical analyses of well waters.

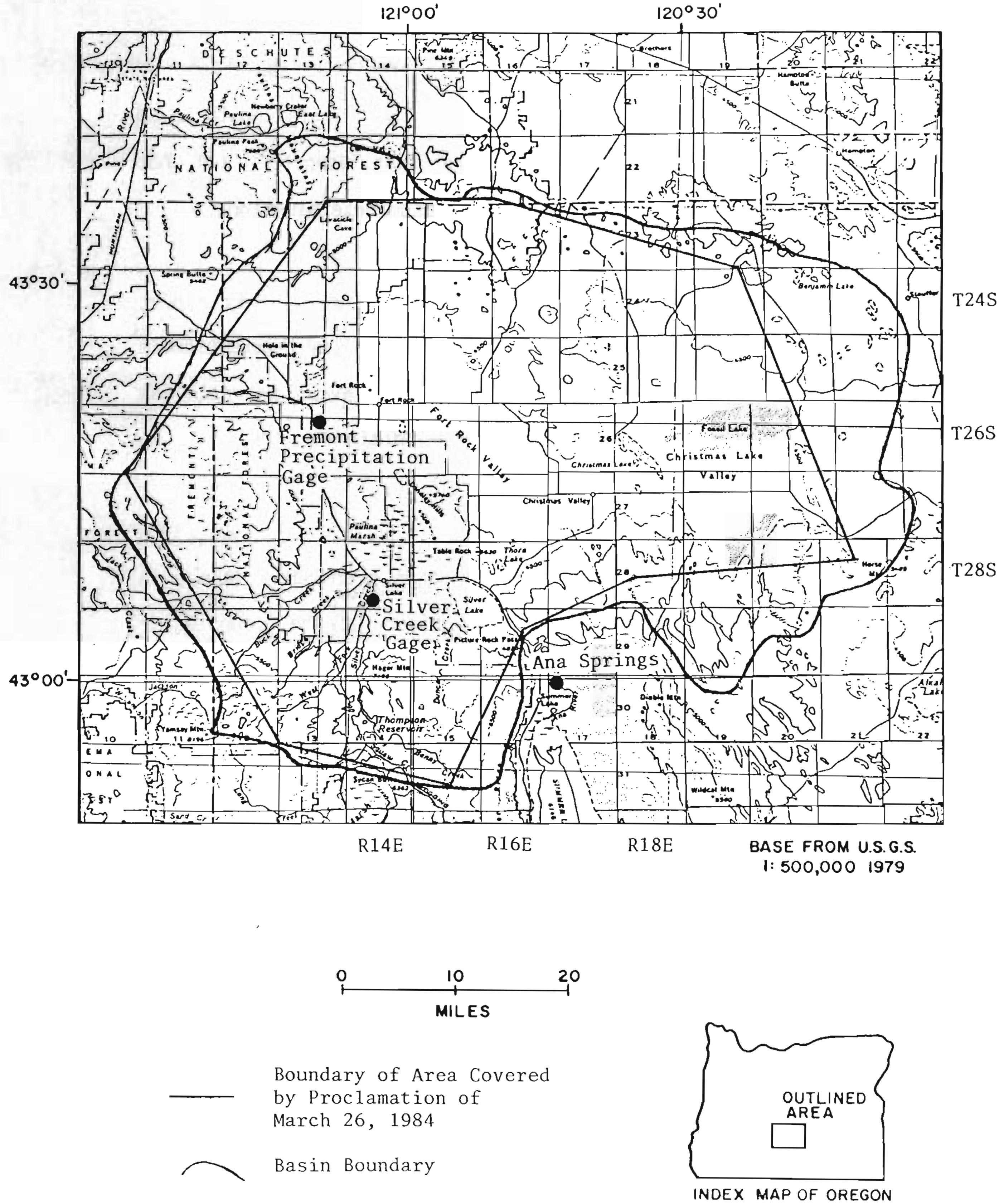
Trauger (1952) of the USGS made a non-interpretive tabulation of precipitation, well log, geologic, hydrographic and water chemistry data in an open-file report. A preliminary water table map was prepared, but not released, apparently due to inadequate wellhead elevation determinations.

R.C. Newcomb authored another USGS open-file report in 1953. This report estimated ground water recharge to the basin as well as available captureable recharge. A correlation between precipitation and water levels in wells was noted as was the purported existence of a subsurface drain for the basin in the vicinity of Hole-in-the-Ground.

The consulting firm of Warren O. Wagner and Associates prepared a report in 1963 for the purpose of determining the order of magnitude of the ground water resources in the basin. Estimates of ground water recharge were determined as a possible percentage of average annual precipitation in the basin. Admittedly, estimates were very rough by this methodology.

In 1964, E.R. Hampton authored USGS Professional Paper 383-B. This report delineates the various stratigraphic units in the basin as well as the effects of other geologic controls on ground water. As a result, he divided the basin into eight subareas.

In 1971, Philips and Van Denburgh published USGS Professional Paper 502-B. Their work investigated the hydrology and geochemistry of closed-basin lakes in south-central Oregon. Of particular interest to the current investigation



MAP SHOWING LOCATION AND GENERAL FEATURES OF THE FORT ROCK BASIN

Fig. 1a

is the suggestion that the bed of Silver Lake may leak and provide a source of water for the southward interbasin transfer of water to the Summer Lake Basin through Ana Springs.

In 1980, Miller of the Oregon Water Resources Department wrote a report on current and projected ground water conditions in the basin. This report examined various possible water rights and pumpage conditions. It estimated that some form of ground water control would probably be needed by 1985 if 'normal' growth proceeded on private lands alone.

Administrative Action

On March 26, 1984, the Oregon Water Resources Director signed a proclamation that will begin proceedings to determine if the Fort Rock Basin should be declared a critical ground water area. This action does not curtail permitted diversions of water from wells. However, it does halt the issuance of new permits for an indefinite period of time. A hearing to accept testimony from the public and the Oregon Water Resources Department is anticipated within 2 to 4 years of the signing before any final determination of a critical ground water area occurs. The area covered by the proclamation is outlined in Figure 1A, while the proclamation itself is given in Appendix VIII.

Climate

The basin has a variable climate, ranging from arid in the lowest valley deserts to humid in the higher mountain forests. In general, the climate is semi-arid with an average annual precipitation ranging from 12-15 inches. Diurnal temperature changes of up to 50°F are not uncommon in the area. Since the valley floor base level altitude is 4300 feet and the latitude is 43°N, frosts can occur any month of the year. This condition generally limits the growing season to about 100 days.

Culture and Industry

Approximately 1050 people reside in the Fort Rock Basin. The population centers for the region are the towns of Christmas Valley, Silver Lake and Fort Rock. Yet, most of the population lives outside of the towns. Much of the current population has migrated to the basin within the last 7 years.

Agriculture and related services constitute the principal industry of the basin. Livestock, hay and small grains are the main agricultural products. In addition, the logging and processing of timber is also important to the local economy. Other industries are the mining and processing of diatomite as well as tourism.

State Highway 31 traverses the basin from the northwest to the southeast. It provides access to the larger population centers of Bend to the northwest and Lakeview to the southeast. In recent years paved roads have been constructed to connect the towns within the basin. The area is further served by numerous gravel and dirt roads within the lowland farming areas.

Landforms and Drainage

The Fort Rock Basin lies within both the Basin and Range and High Lava Plains physiographic provinces. Landforms typical of the region are high fault scarps (rim rocks), block mountains and volcanic features such as shield volcanoes, cinder cones, tuff rings and flows. Undissected younger volcanic rocks, which are characteristic of the High Lava Plains physiographic province, dominate the northern and western edges of the basin.

The basin ranges in altitude from 4300 feet on the basin floor to more than 7000 feet in the mountains south of Silver Lake. Surface drainage is internal. Perennial streams consist of Silver, Buck and Bridge Creeks. Ephemeral drainage is common on the south, east and northeast upland areas of the basin. Such drainage is conspicuously rare on the west and northwest uplands. Where present, ephemeral stream channels generally terminate at the valley/upland break in slope.

GEOLOGY

General Description

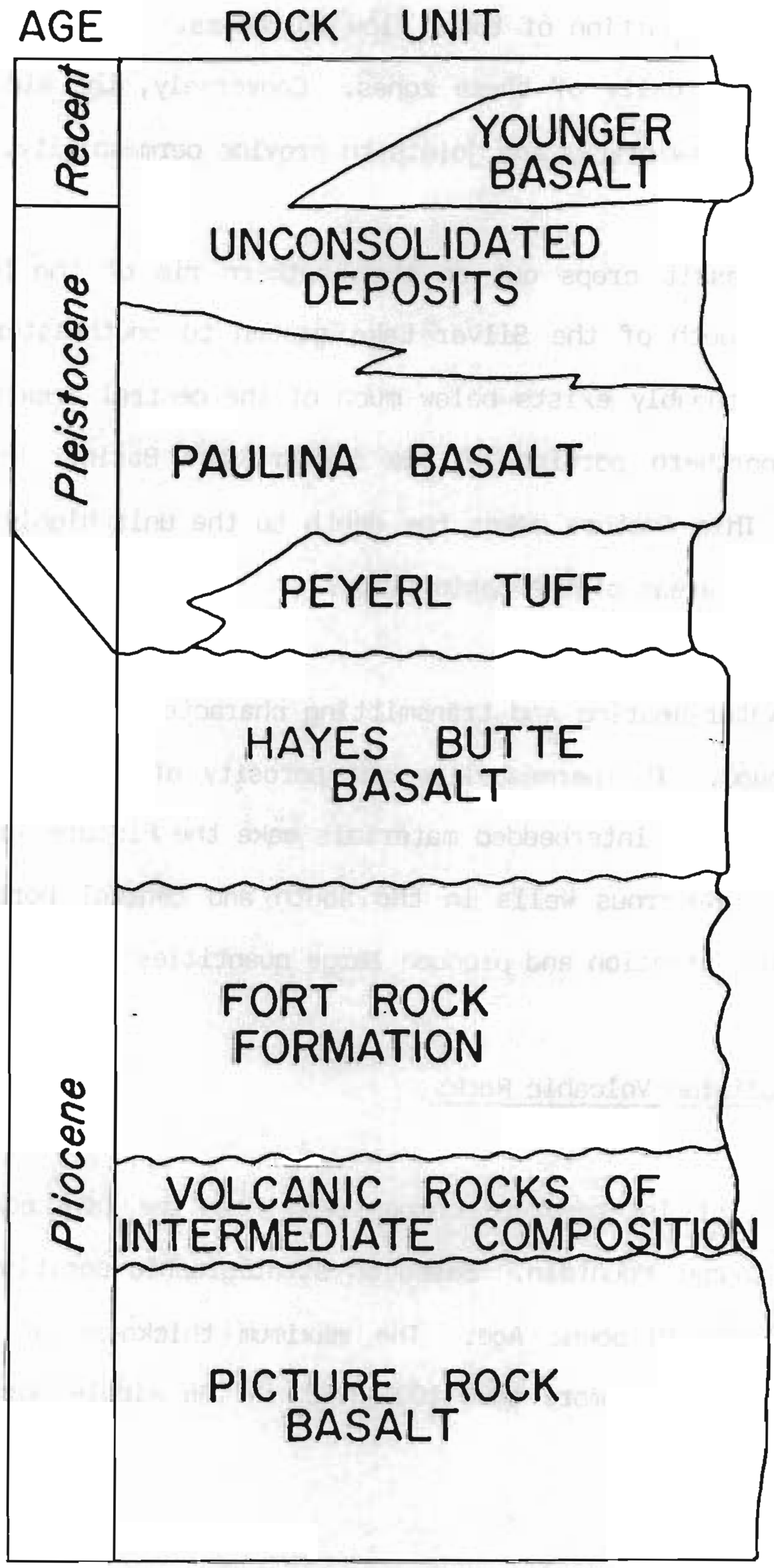
Hampton (1964) detailed the various rock units in the Fort Rock Basin. In addition to his formalization of the stratigraphic nomenclature, he also outlined the structural geology of the area and estimated the hydrogeologic potential of the rock units. Modifications on and additions to Hampton's work have been made by several more recent investigators. The abbreviated rock unit descriptions in this report are essentially those cited by Hampton. His work is recommended for a more in depth explanation.

The rock units of the Fort Rock Basin range in age from Pliocene to Recent. From oldest to youngest they are: Picture Rock Basalt, volcanic rocks of intermediate composition, Fort Rock Formation, Hayes Butte Basalt, Peyerl Tuff, Paulina Basalt, unconsolidated deposits and younger basalt. The stratigraphic sequence after Hampton is shown in Figure 1b and Plate 1.

TERTIARY ROCKS

Picture Rock Basalt

The Picture Rock Basalt is the oldest outcropping rock unit in the basin and is of Pliocene Age. It consists of a thick sequence of basaltic lava flows and interbedded pyroclastic and sedimentary materials. The maximum exposure of basalt is 700 feet while the maximum observed thickness of interbed material is 250 feet.



(Hampton, 1964)

STRATIGRAPHIC COLUMN IN THE FORT ROCK BASIN

Fig. 1b

Individual basalt flows are 10 to 50 feet thick with scoriaceous tops and bottoms. According to Hampton (1964), these scoriaceous zones are permeable and constitute a large portion of total flow thickness. Interbedded materials add further to the porosity of these zones. Conversely, the middle parts of flows are dense with few cracks and joints to provide permeability.

The Picture Rock Basalt crops out on the southern rim of the basin on the mountain arc from south of the Silver Lake graben to southeastern Christmas Valley. The unit probably exists below much of the central area of the basin as well as the northern portion of the Summer Lake Basin. Exposures are heavily faulted. This feature makes the depth to the unit highly variable in the alluvium covered areas of the basin floor.

In general, the water-bearing and transmitting characteristics of the Picture Rock Basalt are good. The permeability and porosity of the scoriaceous tops of flows as well as the interbedded materials make the Picture Rock Basalt an important aquifer. Numerous wells in the south and central portions of the basin penetrate the formation and produce large quantities of water.

Intermediate Composition Volcanic Rocks

The volcanic rocks of intermediate composition form the lava cone masses of Horning Bend and Cougar Mountain. Based on stratigraphic position, this unit is assigned a middle Pliocene Age. The maximum thickness of the unit is uncertain, but is probably more than 1000 feet in the middle portions of the two eruptive centers.

Horning Bend consists of a fine-grained, light blue gray to cream andesite while Cougar Mountain is composed of a fine-grained, dark pink to bluish-gray rhyodacite. Black and red streaked obsidian grade into rhyodacite on Cougar Mountain. Although these rocks are fractured and heavily eroded they have weathered to form only thin, rocky soils.

The unit unconformably overlies the Picture Rock Basalt, having issued from faults cutting the basement rock. The viscous lava formed rather high, isolated mountains of limited areal extent. Due to these factors no wells have been drilled into these rocks. Therefore, water yielding characteristics have not been determined.

Fort Rock Formation

Sedimentary and volcanic rocks of the Fort Rock Formation unconformably overly the Picture Rock Basalt and the intermediate composition volcanic rocks. The formation consists of tuff, diatomite, basaltic agglomerate and basaltic lava. Total thickness is highly variable with a maximum thickness in excess of 1000 feet. Diatomite alone may constitute more than 600 feet in certain areas.

The formation underlies much of the valley floor and crops out in irregular and scattered exposures. Important outcrops occur at Table Rock, Fandango Canyon, Seven Mile Ridge and the southeastern border of Christmas Valley. Numerous small exposures also occur on the western, northern and eastern margins of the valley floor. Based on stratigraphic and diatomite fossil evidence, the Fort Rock Formation is assigned a middle to late Pliocene Age.

The volcanic materials of the Fort Rock Formation were expelled from volcanic centers within the basin. These centers occurred along faults in the underlying Picture Rock Basalt from areas such as Table Rock and Fort Rock. The grain size of pyroclastic materials generally decreases while sorting increases with distance from these centers.

The various lithologies comprising the Fort Rock Formation offer differing water-producing characteristics. The diatomites and fine-grained tuffs are rather poor producers while the coarser basaltic agglomerates and lavas are often very good aquifers. The diatomite and fine-grained tuffs at shallow depths, particularly in the Thorn Lake/Christmas Valley areas, generally make shallow wells modest producers.

Hayes Butte Basalt

The Hayes Butte Basalt unconformably overlies the Fort Rock Formation and other older volcanic rocks. Due to its stratigraphic position, it is assigned a late Pliocene Age although early Pleistocene is possible. The unit consists of numerous flows, ranging in thickness from 10 to 30 feet. The maximum measured thickness exceeds 1300 feet at Hayes Butte.

Principal outcrops of the unit occur at Hayes Butte, Table Mountain, the eastern upland border of Christmas Valley and the area surrounding much of Paulina Marsh. Primary eruptive centers are the cones at Hager Mountain and Hayes Butte. Exposures reveal that individual flows consist of a thin scoriaceous base, a dense yet jointed center and a rubbly top. The basalt has undergone faulting. It is generally displaced less than 50 feet but exceeds 100 feet in certain places.

The water-bearing properties of the Hayes Butte Basalt appear to be very good. Several deep irrigation wells penetrate the unit in the Paulina Marsh area where they produce large quantities of water with little drawdown. In general, the formation occurs in areas where surface sources of water are available or soil conditions are not favorable for irrigation.

TERTIARY AND QUATERNARY ROCKS

Peyerl Tuff

The Peyerl Tuff unconformably overlies a portion of the Hayes Butte Basalt. This late Pliocene or early Pleistocene unit consists of a sequence of essentially undeformed tuffs, tuffaceous sandstones and pumice conglomerates. The maximum thickness of the formation may be 400 feet with individual layers being generally only a few feet.

The outcrop area is confined to a 10 square mile area on the western edge of the basin in what was once a small basin. These waterlain materials originated from eruptive centers located to the west of the outcrop area. In addition, a welded rhyolitic tuff at the top of the formation suggests deposition by a glowing cloud for that part of the formation.

The Peryerl Tuff appears to occur above the water table. Therefore, it is not an aquifer. Exposures suggest that, if the unit were saturated in places, it may be good water-producing material.

Paulina Basalt

The Paulina Basalt unconformably overlies the Peyerl Tuff and the Hayes Butte Basalt. This series of late Pliocene to Recent flows is the dominant lithologic unit along the northern border of the basin. Extrusion of this unit came from the numerous low shield volcanoes of the Paulina Mountains.

Individual flows of the Paulina Basalt are fairly thin, ranging in thickness from 5 to 20 feet. The total thickness of the formation is probably in excess of 1000 feet at eruptive centers. Typically, flows are slightly brecciated on the bottom, dense but jointed in the middle, and broken and scoriaceous on the top. Flows have undergone minor faulting with displacements usually less than 10 feet.

Exposures suggest that the water yielding character of the Paulina Basalt is very good. Scoriaceous material at flow contacts provides excellent horizontal permeability while jointing and faulting give good vertical permeability. The formation is an important aquifer in the northern part of the basin and The Sinks area in particular.

QUATERNARY ROCKS

Unconsolidated Deposits

A thin mantle of surficial material overlies the older sedimentary and volcanic rocks in the Fort Rock Basin. This cover is essentially limited to the valley floor and consists of lacustrine and deltaic deposits of Pleistocene age and streambed, playa and windblown deposits of Recent Age. The source of material for these deposits was the underlying sedimentary and volcanic rocks of the basin.

Pleistocene Fort Rock Lake occupied the present basin to a maximum elevation of 4500 feet. Varying lake stages deposited and reworked lacustrine deposits between that level and the present valley floor level at about 4300 feet. Lake bed deposits of fine-grained clay, silt, sand, volcanic detritus and diatomaceous earth cover much of the interval. Coarser-grained sand and gravel are the remnants of shoreline terraces, bars and spits. The finer-grained lacustrine deposits constitute the soil of the area.

Concurrent with lacustrine deposition at Fort Rock Lake, deltaic deposition occurred on the southwest shore where streams were present. The lower reaches of Silver, Bridge, Buck and Murdock Creeks display remnants of a delta in the form of bedded terraces. These deposits show a depositional range from gravel to clay layers.

Recent eolian transport of Pleistocene lakebed deposits has formed stabilized and moving sand dunes in the eastern portion of Christmas Valley. These dunes may serve as a good ground water infiltration medium since they are more permeable than nearby lakebed deposits. In a special case, perched ground water in dune material is the source of water for the trees of the Lost Forest.

Stream valley alluvium of Recent Age has accumulated along the lower reaches of the perennial and intermittent streams. This material consists of thin layers of gravel, sand, silt or clay. Where these materials occur near a perennial stream they may provide a modest source of water to shallow wells.

Younger Basalt

Unconformably overlying the Paulina Basalt in several areas on the northern slopes of the basin are younger basalts of Recent Age. This unit consists of virtually unweathered lava flows as well as cinder cones. Individual flows range in thickness from 5 to 50 feet. Total thickness at eruptive centers is as much as 200 feet.

The inflated granules of the cinder cones and the broken lava of the flows suggest that these basalts are an important ground water recharge inlet. The basalts lie above the saturated zone, so the unit is not an aquifer. Precipitation striking the basalt can be rapidly conveyed downward to the Paulina Basalt, thus escaping high losses due to evaporation and transpiration.

GEOLOGIC STRUCTURE

In addition to the stratigraphic units present, the geologic structure of these units will control the availability of ground water. Also, geologic structure influences the current topography and drainage in the basin. Therefore, a knowledge of the geologic structures in the basin will explain the occurrences and thicknesses of the rock units.

Folds

Hampton (1964) stated that of several major folds in the Fort Rock Basin, only one could be accurately mapped. The axis of the St. Patrick Anticline forms the crest of the southern basin boundary from Picture Rock Pass to Sheep Rock. The axis trend is arcuate, being east-northeast on the west, east at St. Patrick Mountain and southeast on the east. This anticline is asymmetrical with rock layers of the Picture Rock Basalt dipping 2° to 5° north on the north limb and 7° to 10° south on the south limb. This folding occurred basically during Pliocene time prior to Fort Rock Formation deposition.

The St. Patrick Anticline serves to depress the older Picture Rock Basalt below the valley floor due to its northerly dip. The presence of the Fort Rock Formation allows fine-grained material to act as confining layers above the more permeable Picture Rock Basalt. Wells in Christmas Valley often encounter very little water until the Fort Rock Formation is fully penetrated. Upon encountering underlying basalts, water levels rise to near land surface and yields increase greatly.

Colbath (1982) in his work on the diatomites of the upper Fort Rock Formation found that these beds have been systematically deformed and dip 0.5° to 5° to the west or northwest in the area of Thorn Lake. Truncation of the diatomite beds in this otherwise flat area suggests that an open drainage system operated in the basin, allowing for the erosion of tremendous quantities of diatomite. Such an open drainage probably would have occurred through an opening on the northwest border of the current basin. This gap could have been subsequently closed by flows of Paulina Basalt.

Faults

North-trending faults are the dominant faulting and structural features in the Fort Rock Basin. Movement along these normal faults occurred sporadically from the early Pliocene to Recent time. Displacements are greatest within the Picture Rock Basalt. Displacements in that unit may exceed 800 feet while those of younger units are generally less than 100 feet.

Deep faulting of the Picture Rock Basalt has resulted in the generation of horsts and grabens. These features control the thickness of overlying beds (generally Fort Rock Formation). In the Thorn Lake area graben filling has resulted in more than 1000 feet of sediment accumulation above the basalts. Visibly, the Silver Lake graben shows the severe downdropping of a block within the Picture Rock Basalt.

Faulting trends are also indicated by alignment of eruptive centers. These fault zones have locally controlled the distribution of volcanic units younger than the Picture Rock Basalt. Alignment of eruptive centers is particularly conspicuous in the areas of Paulina and younger basalt extrusion.

Though the principle normal faults are north-trending, a number of other normal faults intersect them at approximately right angles. These faults occur in the Picture Rock Pass area as well as adjacent areas of the Summer Lake Basin to the south. The displacement along these east-west trending faults is usually less than 50 feet but exceeds 100 feet in places.

In relation to ground water availability, the role of faulting is that of depressing or elevating the various significant water-bearing units. Contrary to being barriers to ground water movement, faulting may aid in this movement by producing greater vertical permeability.

Water Rights

Figure 2 illustrates the trend of permitted acreage for ground water withdrawals in the basin. Total acreage was very small until 1956. The sudden increase at that time corresponds with the introduction of electric power to the basin. That new level of permitted acreage was little changed until the mid-70's. From that time through 1981, permitting increased at a rapid pace. The reasons for this surge appear to involve generally favorable crop prices and yields, availability of arable land and irrigation water, advances in irrigation equipment and attractive interest rates. The abrupt halt to new application filings in late 1981 seems to be the result of rapidly rising interest rates and increased power costs. It appears that availability of new farm land has not generally been a limiting factor. It is believed that several tens of thousands of acres could yet be developed in the basin. Therefore, it is reasonable to believe that there is a pent-up demand to obtain permits for new acreage should other factors improve.

Irrigation Withdrawals

The estimated withdrawal of ground water reflects the permitted water rights for the basin (Figure 3). Since compliance with the water right process is generally met by irrigators, this similarity is not surprising. In addition, for a growth area such as the Fort Rock Basin, there should be few long-standing inactive permits.

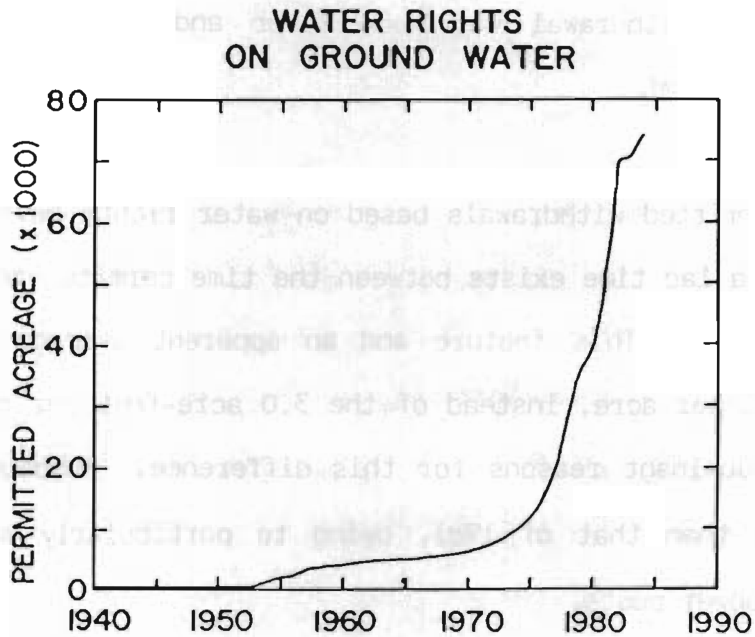

WATER RIGHTS
ON GROUND WATER
PERMITTED ACREAGE (x 1000)
80
60
40
20
0
1940
1950
1960
1970
1980
1990

Fig. 2

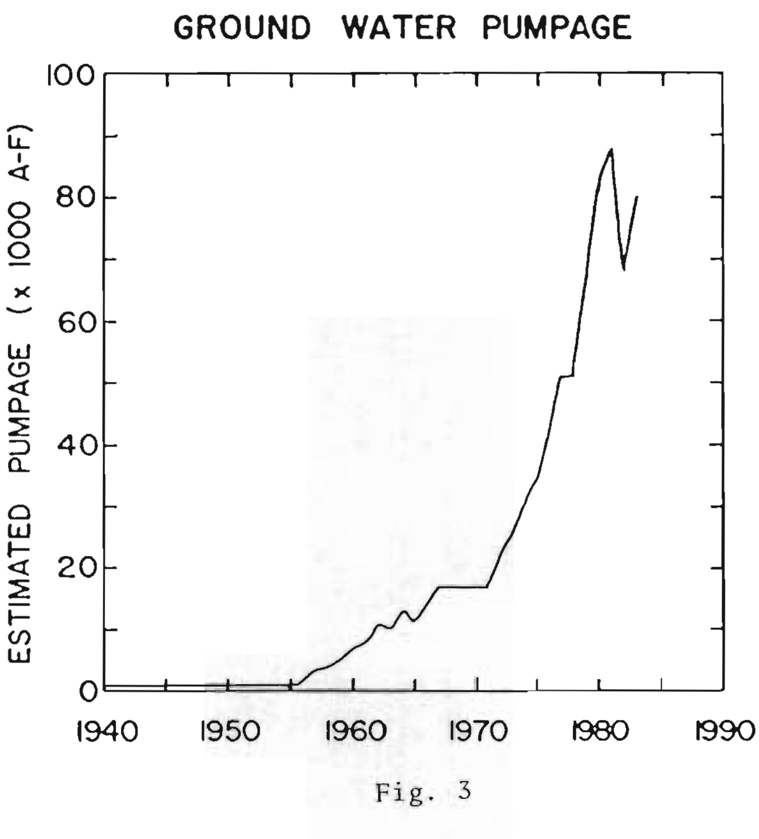

GROUND WATER PUMPAGE
ESTIMATED PUMPAGE (x 1000 A-F)
100
80
60
40
20
0
1940
1950
1960
1970
1980
1990

Fig. 3

Utilization of power records and field studies of water application rates in the basin have lead to estimates of ground water withdrawals since 1956. Prior to 1956, total withdrawal was much lower and estimates from past investigators were employed.

The theoretically permitted withdrawals based on water rights have never been pumped. In general, a lag time exists between the time permits are issued and development takes place. This feature and an apparent average application rate of 2.0 acre-feet per acre, instead of the 3.0 acre-feet per acre allowed by permit, are the dominant reasons for this difference. Pumpages for 1982 and 1983 were lower than that of 1981, owing to particularly strong water years and increased power costs.

GROUND WATER

Ground water in the Fort Rock Basin occurs under confined, unconfined and perched conditions. A dominant confined and unconfined ground water system can be viewed as a single flow system, reflecting local variations in permeability of overlying rocks. This system is herein referred to as the main ground water reservoir and consists of the aquifers of the Picture Rock Basalt, the Hayes Butte Basalt, the Paulina Basalt and the Fort Rock Formation excluding the diatomite dominated member and the eruptive center tuffs. Perched and/or quasi-perched conditions reflect a somewhat higher head system, generally showing low permeability of underlying material. These upper reservoirs are found in the diatomite dominated member and the eruptive center tuffs of the Fort Rock Formation as well as in the Quaternary unconsolidated deposits.

Recharge

Ground Water recharge in the Fort Rock Basin appears to originate from precipitation which falls within the basin. This relationship is confirmed by comparison of precipitation and well hydrograph records for the area. Regional dryness or wetness has correlated satisfactorily with water level drops or rises in wells. Precipitation enters the water table by downward infiltration in areas where rock permeability and water availability are sufficient. Hydrograph and precipitation data generally display a one-year lag time for full assimilation of precipitation into the reservoir to produce a water level rise. Likely areas of significant recharge are Paulina Marsh, exposures of younger basalt, the sand dunes and the basin flanks where perennial and ephemeral streams cross permeable lava outcrops. In addition, certain parts of the valley floor transmit water to the water table during periods of significant precipitation. Hydrograph and precipitation data indicate that the rate of recharge is highly variable. This variability is tied to the wide range in total precipitation in the basin as well as the distribution of precipitation. Since evaporation, transpiration and soil moisture demands are dynamic processes, similar periods and quantities of precipitation may have differing recharge potential. During years of very little or evenly distributed precipitation, recharge is only a small portion of its average rate. Most precipitation is evapotranspired from the surface and soil horizon before it can become ground water.

Discharge

Discharge of ground water occurs through two, or perhaps three, mechanisms in the Fort Rock Basin. These losses are pumpage by wells, evapotranspiration and possibly subsurface outflow. The precise magnitude of each is not fully known, but it is believed that pumpage is the largest possibly followed by subsurface outflow to the extent that it occurs and finally evapotranspiration as the smallest.

Pumpage through wells is probably the most significant source of ground water discharge in the Fort Rock Basin. In recent years water level changes have been generally downward in response to increases in irrigation withdrawals. This decline has occurred during above normal precipitation conditions.

Subsurface outflow may be the largest natural ground water discharge from the basin. Past investigators have suggested that outflow may occur to the Deschutes and Summer Lake Basins. Flow to the Deschutes Basin is difficult to substantiate from available data. Past water table mapping, which suggested that flow direction, has been found to be in error. However, inferred outflow to the Summer Lake Basin is suggested by several lines of evidence. Interbasin transfer from the Silver Lake Valley of the Fort Rock Basin to the northern portion of the Summer Lake Basin (principally through Ana Springs) is possible in light of the following points:

1. Potentiometrics: Heads are about 60 feet lower at Ana Springs and at associated flowing wells of the northern Summer Lake Basin than at the Fort Rock Basin,

2. Water Chemistry: A generally favorable water quality of springs and wells in the northern Summer Lake Basin is similar to that found in wells in the Fort Rock Basin,

3. Structural Geology: Fault patterns show that intense north/northwest trending normal faults extend from southern Silver Lake and Christmas Valleys through Picture Rock Pass and its associated mountains to northern Summer Lake Basin,

4. Geography: Strong flowing well and spring conditions exist along the northern portion of the Summer Lake Basin and much less so elsewhere in the Basin, even though land surface elevations elsewhere in the basin are similar to the northern portion,

5. Spring Flow: Constant flow and 66°F water temperature at Ana Springs suggest a deep, large and highly modulated flow system. The main ground water reservoir of the Fort Rock Basin contains these elements and a general water temperature of about 52°F. A deep flow path could easily increase temperatures by 14°.

6. Spring Hydraulics: The most widely known artesian flow in the northern Summer Lake Basin is Ana Springs, which has a specific capacity of about 1.4 cfs per foot (Brown, 1956). The total average spring flow of about 86 cfs represents a steady state drawdown of about 63 feet in the aquifer. This drawdown is the approximate potentiometric difference from the main ground water reservoir in the Fort Rock Basin to Ana Springs.

7. Water Level Changes: The water level in the observation well at 30S/R16-1cbb near Ana Reservoir shows a decline of 1.6 feet from 1976 to 1984 and no decline in the previous record from 1963 to 1976. In addition, the estimated flow from the springs which feed the reservoir has been slightly less in recent years than in the past. This is noted by decreasing flow from the reservoir.

Existing data do not prove that interbasin ground water transfer occurs. Cited evidence, however, suggests that the possibility of this transfer is greater than mere speculation. Reports by past investigators of a subsurface drain near Hole-in-the-Ground are not substantiated by data. Nevertheless, flow from Ana Springs continues. The source area for Ana Springs may be the southeast highlands of the Fort Rock Basin at Silver Lake Valley rather than the entire basin. Continued water level collection in these areas will help clarify this issue.

Evapotranspiration is a large source of ground water discharge in the Fort Rock Basin, but is probably less than pumpage, and perhaps, subsurface outflow. In the Paulina Marsh area, evapotranspiration is a powerful discharge from the upper ground water reservoir. The marsh loses water by way of transpiration through its rich vegetal cover as well as direct evaporation of free standing water. Based upon an estimated area of 400 square miles where the depth to water in the main ground water reservoir is 50 feet or less and assuming that a transpiration rate of 0.2 foot of water per year occurs, estimated phreatophyte withdrawals are 50,000 AF per year. Phreatophyte studies indicate that these parameters are reasonable yet variable. Evaporation from minor springs occurs at Alkali Flat (Langdon Spring) and the sand dunes (Sand and Mound Springs) appears to represent discharge from the main ground water body.

Chemical Quality

The chemical quality of ground water in the Fort Rock Basin is generally good to excellent for most purposes. Hampton (1964) presented nine analyses. In addition, twenty-one analyses are on file in the Water Resources Department in connection with irrigation lending through the Water Development Loan Fund and the Department of Veteran's Affairs (Appendix I). These latter analyses were typically determined from samples taken under less controlled conditions. In some instances the location of the sampled well can only be approximated. As such, the reliability of the sampling procedure for the analyses cannot be assured. This lack of control notwithstanding, the general quality of these analyses is probably good.

Boron is a chemical constituent of particular concern since its occurrence in concentrations greater than 3.75 ppm is toxic to even the most tolerant crop. Boron levels are within acceptable limits in all but three samples. It appears that sampling or testing errors have produced the unacceptable concentrations and not actual concentrations in natural waters.

An interesting feature of the several analyses concerns well depths. Newer analyses have come from wells which are usually deeper than those Hampton sampled, i.e. greater than 400 feet. Yet, the quality of the water in these rather shallowly cased deep wells is comparable to that of the shallower wells. Although the contribution percentage of deep zones to total well yield is uncertain, the possibility exists that a significant part comes from depth. This mixing does not appear to produce deleterious effects on water quality.

Although no analytic tests have been run, hydrogen sulfide with its rotten egg smell is found in some areas. This sulfur odor represents a discernible chemical difference from most well waters in the basin. In quantitative terms, the concentration of H_2S in the more odorous waters is probably less than 1 mg/l. The anaerobic reduction of sulfate in conjunction with the oxidation of buried organic matter is the probable source of this dissolved gas. Localized areas of hydrogen sulfide occurrence, low concentrations of the gas, probable dilution within a larger reservoir and potentiometric flatness serve to suggest that sulfur waters are part of the main ground water reservoir.

A typical ground water temperature found on water well reports in the Fort Rock Basin is 52°F. Temperatures increase with depth in the earth at the rate of about 1°F per 100 feet. Variable well depths not withstanding, a distinct thermal anomaly exists on the north flank of the Connley Hills. Water temperatures of 76° and 90°F are reported from wells near 26S/15E-31. Several other nearby wells have water temperatures of about 60°F. This localized hot spot may be coincident with waters which are a bit more mineralized than those of the basin generally, but not with a discernible potentiometric rise.

High concentration of sodium salts develops alkali soils in which little or no vegetation will occur. However, soil clays which carry a good excess of calcium or magnesium ions tills easily and has good permeability. Irrigation waters need a favorable ratio of sodium to calcium and magnesium in order to maintain good soil characteristics. The sodium-adsorption ratio is a measure of the suitability of irrigation water and is expressed in equivalents per million as:

$$SAR = \frac{Sodium^{+}}{\sqrt{\dfrac{Calcium^{++} + Magnesium^{++}}{2}}}$$

Ratios greater than 18 are high; ratios of 10 to 18 are medium; values below 10 are low and offer little danger of creating a sodium problem. Reported ratios in the Fort Rock Basin range of 0.3 to 2.1. Most values are less than 4.

Total dissolved solids (TDS) is a measure of the dissolved minerals in water. For irrigation, a TDS less than 500 parts per million is generally good for all uses while 3000 is poor. TDS is more easily estimated by measuring the specific conductance of a water sample. This measure of the ability of a water to conduct an electric current is reported in micromhos. For most natural waters, the specific conductance multiplied by a factor between 0.55 and 0.75 will give a good estimate of the dissolved solids. This empirical relationship is a function of the dissolved minerals which are involved.

The presence of "salty" water in certain wells in the Fort Rock Basin may be due to borehole penetration of localized alkali beds in the shallow lacustrine sediments. In general, this is not a problem. The range of calculated TDS values from waters in Fort Rock Basin wells is about 130 to 700 ppm.

Water Level Fluctuations - General Features

Well hydrographs are charts displaying depths to water over time. These graphs are among the most diagnostic sources of hydrogeologic information. Long-term records can provide good indications of the ultimate yield of a ground water body as well as the apparent recharge rate. In addition, short-term records can give valuable information on the hydraulic properties of hydrogeologic units as well as the relationship of the aquifer to atmospheric pressure changes.

Causes of water level fluctuations can be classified into four basic types:

1. changes in ground water storage,

2. changes of atmospheric pressure in contact with the water surface in wells,

3. deformation of aquifers, and

4. disturbances within wells.

In the Fort Rock Basin, the dominant source of water level fluctuations is changes in ground water storage. This includes the natural changes due to climatic variations as well as seasonal and residual pumping effects. With regard to other possible factors, no meaningful fluctuations due to atmospheric pressure changes have been observed in this highly modulated reservoir. Also, fluctuations due to aquifer deformation from such sources as earthquakes, explosions, tidal loading and earth tides are either insignificant or lacking in the basin. Finally, disturbances within wells such as leaking pipes, animals falling into wells and gas bubbling through the water are not significant or identifiable causes for water level changes in the Fort Rock Basin.

Observation Wells

Approximately 90 wells have been monitored as observation wells in the Fort

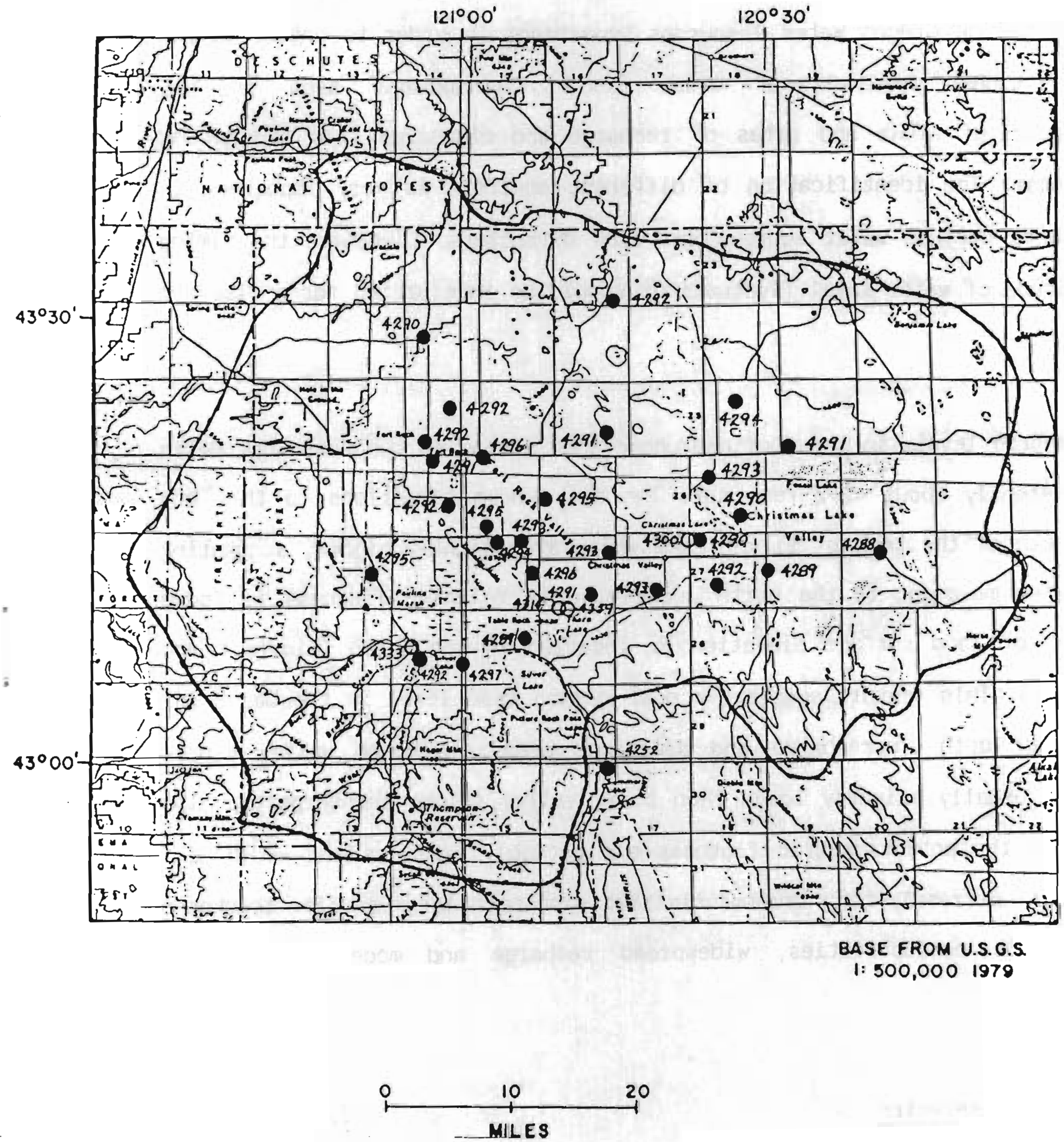
Rock Basin. The Oregon Water Resources Department (formerly the State Engineer's Office and the Water Resources Board) and the U.S. Geological Survey have collected varying lengths of record on these wells. Observations began in 1932 on a few wells. Subsequent expansions of irrigation resulted in the addition of new wells. A reduction in the number of wells in the network later occurred as duplication became apparent. At present, 31 wells are monitored at least three times per year over a broad area of the basin. The records that the various wells provide serve greatly in the interpretation of recharge and discharge effects (Appendix II).

The continuation of the current network will document the effects of the current climate and ground water use regime. Spot measurements of depth to water in wells which are near the inferred ground water boundaries of the basin (topographic boundaries) will aid in the more precise determination of such boundaries. Lack of topographic maps along the southeastern border of the basin may delay local examination in that area.

Potentiometric Levels

Ground water moves from areas of higher energy (or potential) to areas of lower energy. The energy of the water in a well may be measured as the elevation of the water level in the well. This measure is that of the potentiometric level at the well and is dependent on the construction of the well which may allow the effective integration of water-bearing zones of various individual potentials and transmissivities.

Examination of the potentiometric levels permits the discovery of the



● OBSERVATION WELL
MAIN GROUND WATER RESERVOIR

⊙ OBSERVATION WELL
UPPER GROUND WATER RESERVOIR

MARCH, 1984 POTENTIOMETRIC LEVELS AT CURRENT OBSERVATION WELLS
IN FEET ABOVE SEA LEVEL

Fig. 4

directions of ground water flow and, often, the separation of different aquifers. The construction of a potentiometric surface map is in progress at this time by the Oregon Water Resources Department in order to better define flow directions. Analysis of water level fluctuations aids in the determination of areas and rates of recharge and discharge from the ground water system. The identification of different aquifers is very important in order not to confuse water sources and flow directions. Likewise, the timing and amplitude of water level fluctuations should be interpreted for a discrete source.

Potentiometric levels in the confined/unconfined system in the Fort Rock Basin are consistently about 4292 feet msl. The only known exceptions to this are levels south of the town of Silver Lake which are slightly higher, suggesting ground water movement to the north locally. This relative flatness is found regardless of land surface elevation or location in the basin (Figure 4 and Appendix II). This feature suggests a near common base level in the basin for ground water both in recharge and discharge areas, although valley center levels are usually slightly lower than their valley fringe counterparts. The reasons for the potentiometric flatness are probably numerous and would seem to include: extremely high transmissivities with both large aquifer thickness and hydraulic conductivities, widespread recharge and modest topographic relief.

Ground Water Reservoirs

In the Fort Rock Basin, there are two principal ground water bodies. These are herein termed the main ground water reservoir and the upper ground water reservoirs. The upper reservoirs appear to have a scattered occurrence in the

Basin. Hydrograph justification for the basin reservoir separation will be presented in the next section.

The main ground water reservoir has several diagnostic features. First, the reservoir is highly modulated, showing natural water level changes of less than 1.5 feet annually. Water levels which are free of pumping effects do not change appreciably during the year. The wettest years on record show natural rises of just over one foot annually while the driest years display natural declines of no more than one-half foot. Annually, natural water level fluctuations are very sluggish.

Second, the potentiometric surface of the reservoir is approximately 4292 feet msl basinwide. The only exception noted to this empirical determination is found south of the town of Silver Lake where a potential of about 4297 feet occurs. Levels in other irrigation wells which are not regularly monitored suggest that those slightly higher levels occur from the area of the town of Silver Lake eastward and including the Silver Lake graben. This gradient may reflect an area of significant ground water movement (recharge) from the south to the essentially flat potentiometric main body of the reservoir.

Third, the reservoir consists of numerous water producing zones in several formations. These zones have an essentially common potentiometric level and generally are very transmissive. It appears that the high transmissivities of these zones result in the nearly flat potentiometric surface. Finally, the extraction of water for irrigation and other large scale uses comes from this widespread reservoir.

The upper ground water reservoirs are volumetrically much smaller than the main ground water reservoir and exhibit several distinguishing features. The upper ground water reservoirs reflect in general a shallower system, usually showing water level fluctuations of several feet annually. This feature is particularly evident in the Silver Lake area where recharge from surface sources is significant. Elsewhere, on the plains of Fort Rock and Christmas Valleys, shallow wells suggest that these large annual changes occur only during very wet years. Annual changes on the plains are variable and reflect variations in water availability and local geology.

Near Table Rock, the observation wells at 27S/16E-32bd (1020 feet deep) and -32ca (545 feet deep) show that deep wells (1000+ feet) into the eruptive center tuffs of the Fort Rock Formation can be in the upper reservoir. The potentiometric levels of the upper ground water reservoirs are generally greater than those of the main ground water reservoir in an area. This feature reflects the upper reservoirs' role as a shallow water body which may serve to provide "trickle-down" water to the main reservoir. The potentiometric levels range from about 4295 to more than 4400 feet. The highest levels are reflected in the shallow streambed deposits in the uplands south of Silver Lake.

Transmissivities of the upper reservoirs are much lower than those of the main reservoir. Vertical flow is weak due to the prevalence of clay or diatomite units which often retard percolation to the main reservoir. No irrigation wells are known to collect water from the upper reservoirs. This fact is due to the poor hydraulic character and "patchy" occurrence of these upper reservoirs. In low areas of the valley floor, this reservoir may not be truly perched, but simply overlies the main ground water reservoir. This source produces some domestic and stock supplies.

The areal extent of both major reservoirs is assumed to be that of the topographically closed drainage of the Fort Rock Basin. Boundaries are assumed to be the divides between the Basin and adjacent watersheds. This premise is consistent with investigations elsewhere. Future work may indicate that the ground water basin differs from the topographic boundaries.

Well Hydraulics

Examination of hydrographs with an understanding of nearby pumping conditions reveals much about the specific capacities, transmissivities, and specific yield of the system. Detailed aquifer tests have not been conducted in the basin. These would allow the most controlled determination of hydraulic characteristics. Pumping discharge measurements at irrigation wells reveal that specific capacities are high with a range of about 25 to 200 gpm per foot of drawdown in most irrigation wells. Field studies suggest that pumping drawdowns at irrigation wells vary little after about 30 minutes of pumping at a constant rate. On that basis, estimated transmissivities generally lie in a range from 7,000 to 60,000 ft^2 per day. Since transmissivity is the product of two components, estimated values reflect differences in hydraulic conductivity of rock materials as well as borehole depth. A general estimate of specific yield based on the limited decline response of long term water levels to pumping is 10 percent.

Hydrograph Analysis

Since well hydrographs reveal the results of ground water recharge and discharge conditions, the analysis of these hydrographs is very important to the quantitative management of the resource. The variety of well depths, constructions, areal distribution and long term records as well as the diversity of recharge/discharge conditions aid the analysis greatly. Water level data are available to reflect baseline or natural conditions and man-induced or modified conditions at the same wells.

The main ground water reservoir is the dominant ground water body in the basin. It occurs throughout the valley area of the basin and is not restricted to a single rock formation. The water level changes with time at various points in the reservoir show that fairly similar conditions exist throughout the basin. For reference to these potentiometric and water level fluctuation similarities, please note the following representative hydrographs: T25S/R14E-15bc for Fort Rock Valley, T27S/R18E-6db for Christmas Valley and T28S/R14E-25bba for Silver Lake Valley.

The period prior to 1976 is herein considered to reflect a time of natural ground water conditions in the basin. The assumption is based on the record of permitted and actual use which was noted earlier and the divergence of water level trends from previously observed conditions. Conversely, the period from 1976 to the present reflects modified conditions which are influenced by recent ground water development.

The following conclusions from hydrograph analysis of the main ground water reservoir are made for natural conditions in the main ground water reservoir unless otherwise noted:

1. The system is highly modulated in regard to water level change,
2. Potentiometric relief is slight throughout the basin,
3. The largest annual water level rise of record is 1.1 feet,
4. The largest annual water level decline of record is 0.5 feet,
5. Water year precipitation and streamflow correlate closely to calendar year water level changes,
6. The common potentiometric base level suggests a highly transmissive reservoir without major hydraulic barriers to lateral flow.
7. The amplitude of water level fluctuations is apparently less in the eastern portion of Christmas Valley (the driest part of the basin) and the largest at Silver Lake Valley (the wettest part of the basin).
8. Certain shallow wells or shallowly cased wells react quickly to nearby streamflow, lake stage or precipitation.

Under modified conditions the following conclusions are made:

1. The main ground water reservoir is declining in response to irrigation pumping,
2. Seasonal fluctuations due to modest well interference are widespread,
3. Some wells show a temporary recharge effect which corresponds to recharge by excess irrigation water.
4. Residual drawdown effects can persist for several months after the cessation of irrigation pumpage.

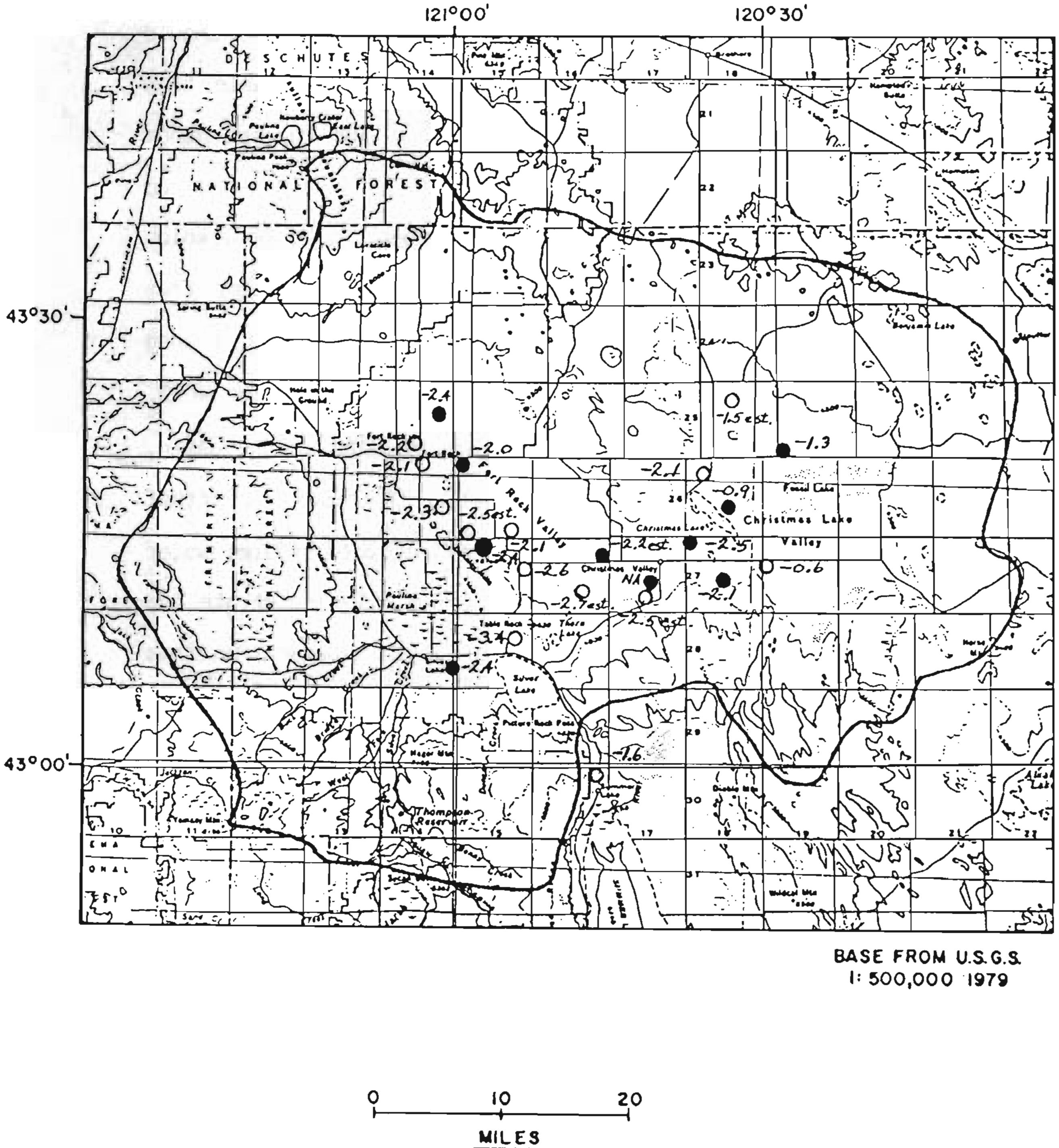
Integration of hydrograph, precipitation and streamflow data appears to provide a valuable technical tool for ground water appropriation assessment in the basin. An abundance of data and a seemingly uniform ground water environment are important ingredients for such an integration. The correlation by statistical methods and analysis of several cause and effect relationships are developed in the following discussions.

Parks Well - A Key Well

No single well can totally describe changes in ground water storage throughout a large basin. However, certain features of the main ground water reservoir in the Fort Rock Basin make such estimates from a single source more practical for this purpose than might be the case in other basins. The most significant factor in this regard is the widespread flatness of the potentiometric surface. Observation wells generally display a water level elevation of approximately 4292 feet in the main ground water reservoir. This level has been found in wells where land surface elevations range from 4300 to 4700 feet. The apparent lack of intrabasin topographic control on the potentiometric surface suggests that transmissivities are very high. Further, hydrograph response suggests that recharge is a widespread phenomenon. Estimated transmissivities in excess of 15,000 ft^2 per day would allow the effects of pumping to be equalized over large areas. In addition, the highly modulated condition in the main ground water reservoir produces changes of less than two feet in water level between very wet and very dry years. This modulation makes water level changes less difficult to precisely monitor in the reservoir.

Since the concept of a key well appears plausible for the basin, there should be certain characteristics of a key well which make it more valuable than other wells in the area. The 257 feet deep Parks well at The Poplars Ranch (27S/15E-4aca) (Appendix III) is selected as the best candidate based on several criteria. First, this well intercepts the main ground water body which is utilized for irrigation and other purposes. The well diverts water from cinder beds and possibly basalt of the Fort Rock Formation. Second, a long data base of 50 years of water level measurements is available for the well. This particular well has the most comprehensive volume of data in the basin, including many years of monthly measurements. Third, the well is rather centrally located in the basin and, as such, should effectively reflect water levels in an area of use. Fourth, other observation wells which penetrate the main ground water body display rather similar water level changes. On this point, Hampton (1964) stated that this well reflected the general long-term trend found in other long-term hydrographs in the basin. Although water level declines since 1976 are sensitive to proximity of pumping centers, the Parks Well has a water level decline that is roughly equivalent to the average decline observed in other wells in the basin (Figure 5).

Based on the preceding explanation, it appears reasonable that water level changes at the Parks well are fairly representative of basin-wide changes. Since water levels provide a barometer of ground water storage, the annual changes at this key well are used in the forthcoming statistical models. Therefore, Parks well data supply the 'effect' of the recharge/discharge balance.



● PARKS WELL

⊙ OTHER OBSERVATION WELLS

● OTHER REGRESSION WELLS

WATER LEVEL CHANGES (FT) AT OBSERVATION WELLS (APRIL, 1976 TO MARCH, 1984)

Fig. 5

Model Development

It is assumed that a natural, quasi-equilibrium ground water system was operative in the Fort Rock Basin prior to 1976. With that assumption, a description of the recharge/discharge relationship of the natural system and modified system is possible, based on current data. A set of linear regressions of recharge related factors (local precipitation or streamflow) and ground water storage changes is developed. These comparisons suggest the cause and effect relationships in the main ground water body and offer theoretical target objectives for limits on ground water appropriation.

Precipitation Models

These models correlate precipitation at the Fremont Station (26S/13E-10b) with water level changes at the Parks well. The Fremont Station is the only long term (about 60 years) precipitation gaging station in the basin (Figure 6 and Appendix IV). Annual values are compared for years of record in which both precipitation and water level changes can be acccurately defined. If precipitation data were lacking or partial, then that specific year was not used in the regression. Likewise, if water levels were not collected so as to reasonably indicate a change, then that year was not used. Water level changes during calendar years are the increments which are used for all models.

Total Calendar Year Precipitation Model

This model (Figures 6, 7, 8 and 9) incorporates total calendar year

TOTAL PRECIPITATION FOR CALENDAR YEAR AT FREMONT, LAKE CO.
(1919-23, 1925-35, 1937-43, 1945-47, 1950-51, 1954-56, 1958-69, 1971-81)

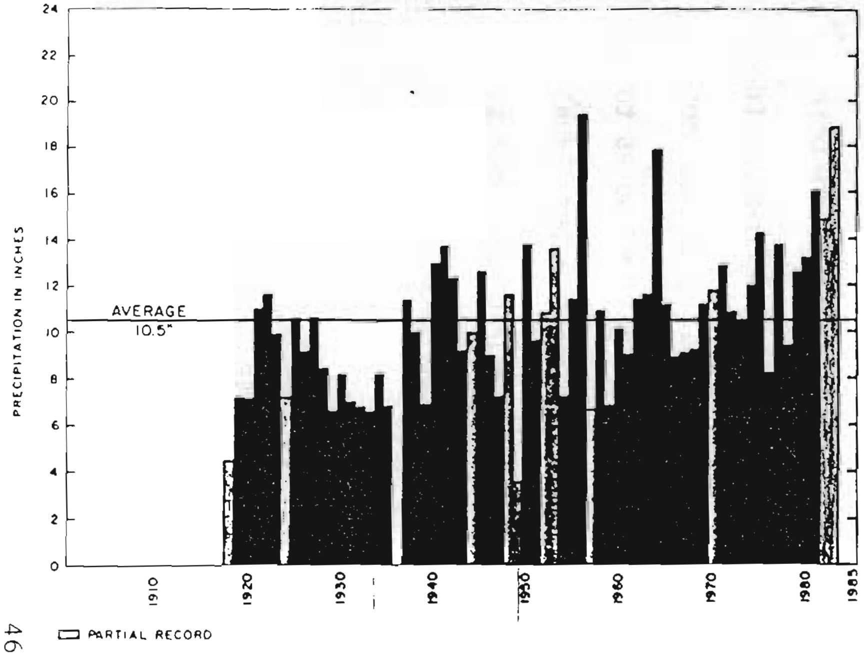


Fig. 6

CUMULATIVE DEPARTURE

OF CALENDAR YEAR PRECIPITATION AT FREMONT, LAKE CO.

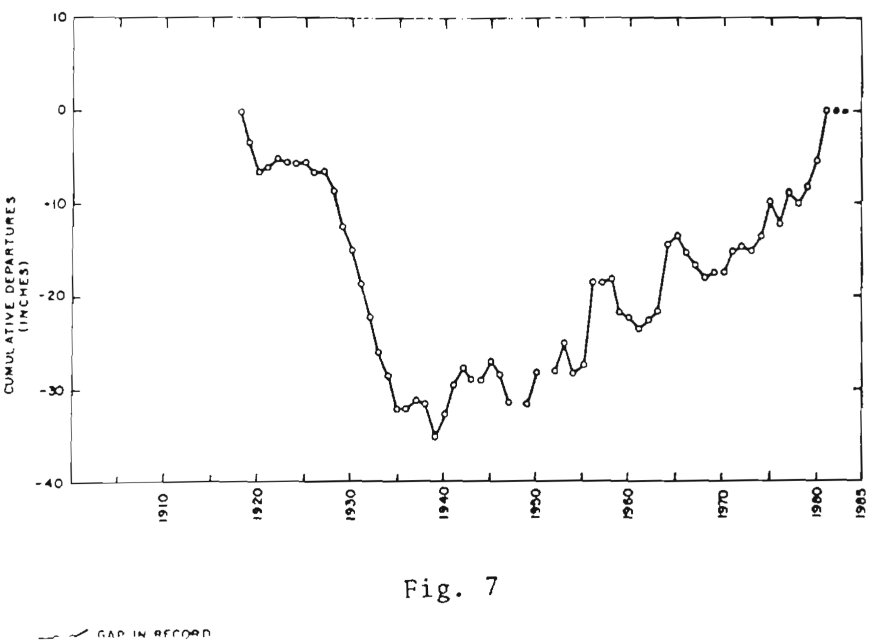


Fig. 7

PARKS WELL WATER LEVEL CHANGE vs TOTAL ANNUAL PRECIPITATION
(1939-43, 1946-47, 1950, 1954-56, 1959-69, 1971-75)

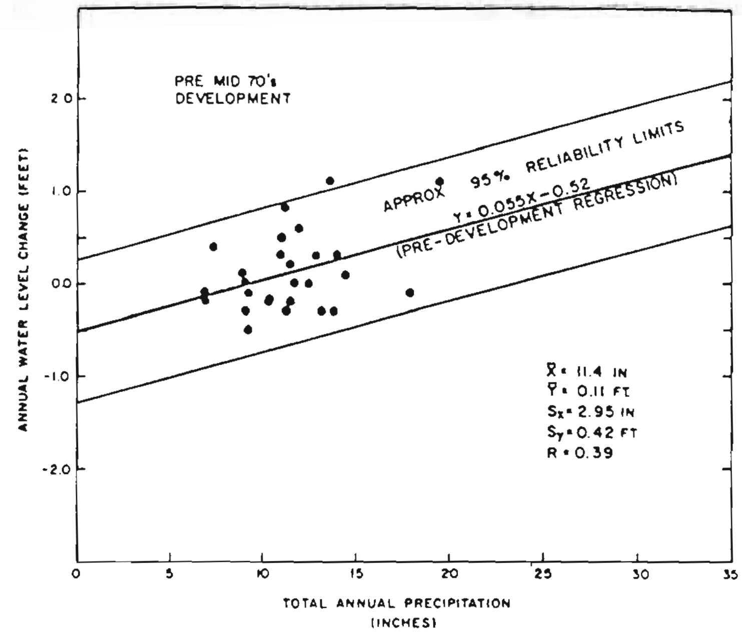


Fig. 8

PARKS WELL WATER LEVEL CHANGE vs TOTAL ANNUAL PRECIPITATION
(1976-1983)

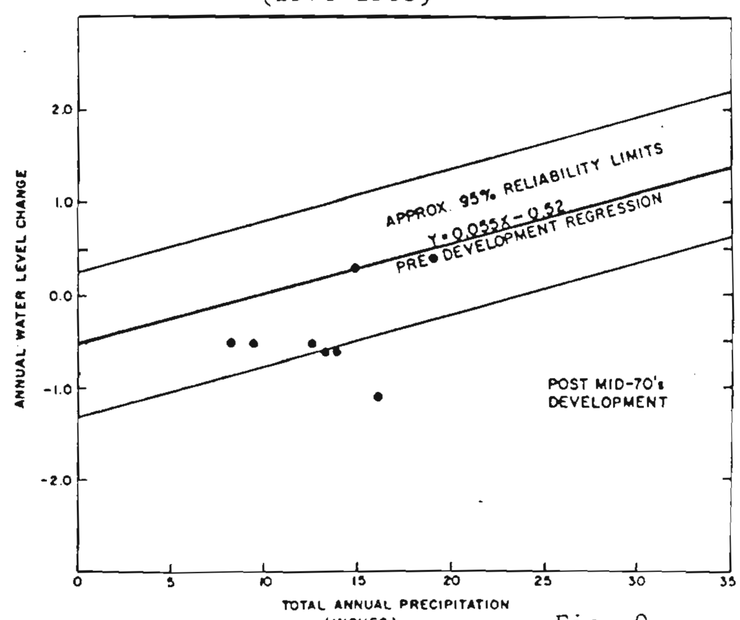


Fig. 9

precipitation at Fremont (X or independent variable) versus annual water level change at the Parks well (Y or dependent variable). In all, 26 data points were used to form the regression equations. These data have a mean precipitation (X) of 11.4 inches with a standard error (S_x) of 2.95 inches. Standard error is a measure of the variability of the data sample about the mean. The mean plus or minus one standard error includes about 67 percent of all data values while the mean plus or minus two standard errors includes about 95 percent of all data values. In addition, the mean water level change was +0.11 foot with a standard error (S_y) of 0.42 foot. The Y- intercept of -0.52 foot represents the estimated water level change during a zero precipitation year. This water level decline is, therefore, the approximate effect of natural discharges alone in the otherwise steady state, natural ground water regime. Likewise, on the average, +0.52 foot of head change will be the mean effect of ground water recharge. In contrast to the natural condition regression, data since 1976 (Figure 9) have shown water level declines.

The basic regression for this model is weak, having a correlation coefficient of 0.39. To illustrate scale, a correlation coefficient of 0.0 is no correlation, +1.00 is a perfect correlation and -1.00 is a perfect inverse correlation.

The weaknesses of this basic regression are largely conceptual and not measurement error. No lag was utilized in this model, meaning that precipitation just prior to the water level change period was not considered while that at the end of the period was too strongly considered. Also, total precipitation will contain seasonal quantities which are not readily available for recharge. For example, summer rains probably contribute little or no water for recharge. Hydrograph inspection suggests that a lag time of about one year exists between precipitation and full water level response (see hydrographs for 25/14-15bc, 27/18-6db and 28/14-25bb). This fact is best represented by the water level response to the December, 1964, precipiation. At that time, essentially a single precipitation event provided a normal year's quantity, offering an excellent examination of the basin's recharge character.

Discrete data point locations suggest other perturbing factors to a perfect correlation. Precipitation at one station cannot perfectly reflect regional precipitation availability for recharge. As previously noted, a single well will not perfectly reflect the response of an entire watershed to basinwide recharge.

Total Water Year Precipitation Model

This model utilizes the total water year precipitation as the independent variable and the annual calendar year water level change as the dependent variable (Figures 10, 11, 12 and 13). The regression equation used 25 data points which have a mean precipitation of 10.9 inches and a mean water level change of +0.08 foot per year. The standard error of precipitation is 4.11 inches while that of the water level change is 0.42 foot. The Y- intercept of -0.60 foot suggests that water level will decline 0.60 foot under zero precipitation conditions. Similarly, average annual recharge will result in a water level rise of 0.60 foot. Again, a long-term ground water storage balance is assumed for the current climatic conditions, i.e., natural conditions are

TOTAL WATER YEAR PRECIPITATION AT FREMONT, LAKE CO.
(1919-23, 1925-35, 1938-43, 1946-47, 1950, 1953-1956, 1959-70, 1972-81)

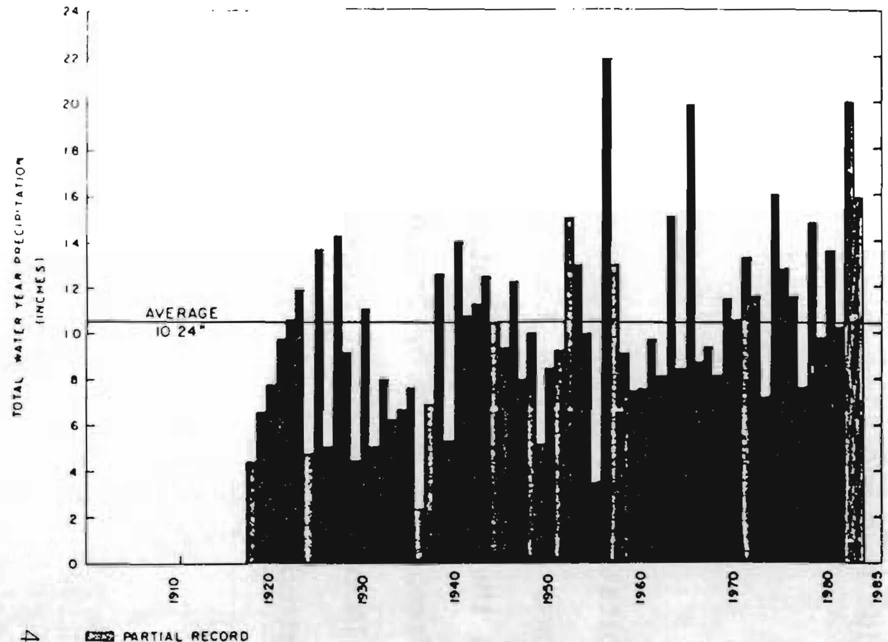


Fig. 10

CUMULATIVE DEPARTURE OF
TOTAL WATER YEAR PRECIPITATION AT FREMONT, LAKE CO.

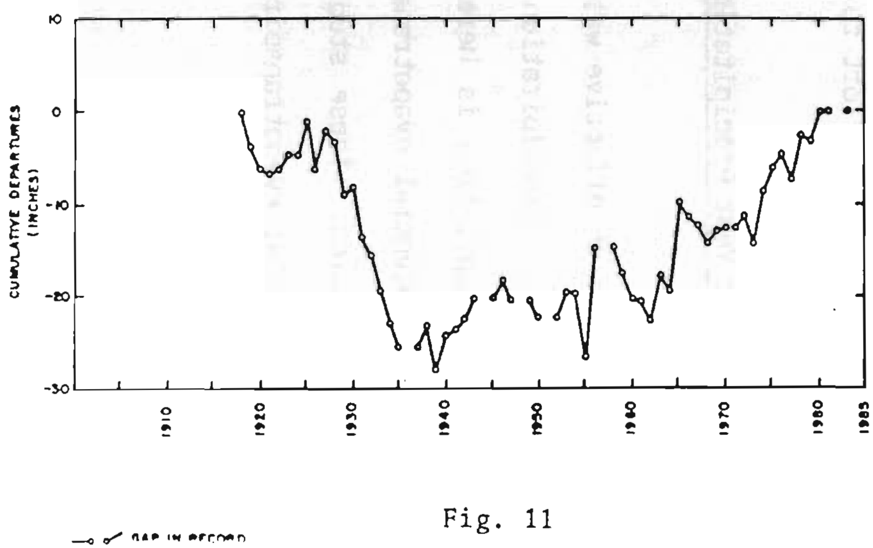


Fig. 11

PARKS WELL WATER LEVEL CHANGE vs. TOTAL WATER YEAR PRECIPITATION
(1939-43, 1950, 1953-56, 1959-69, 1972-76)

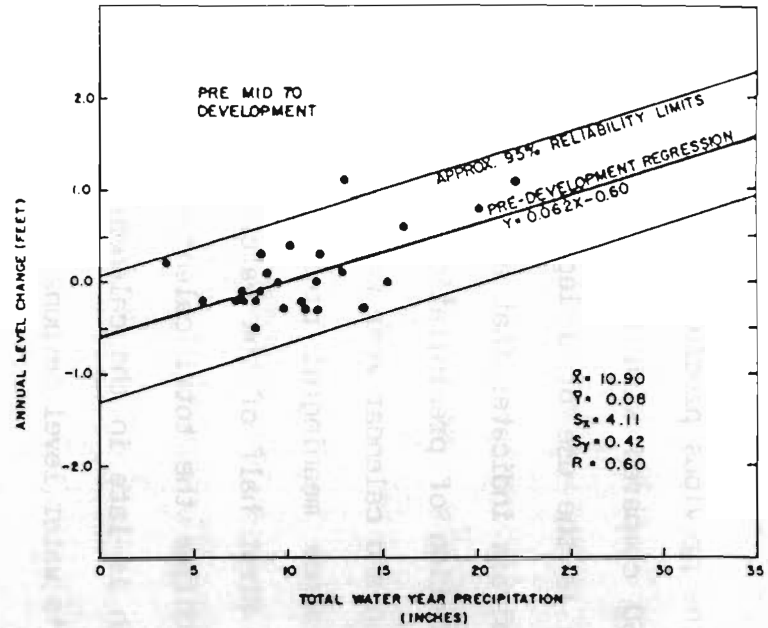


Fig. 12

PARKS WELL WATER LEVEL CHANGE vs TOTAL WATER YEAR PRECIPITATION
(1976-1983)

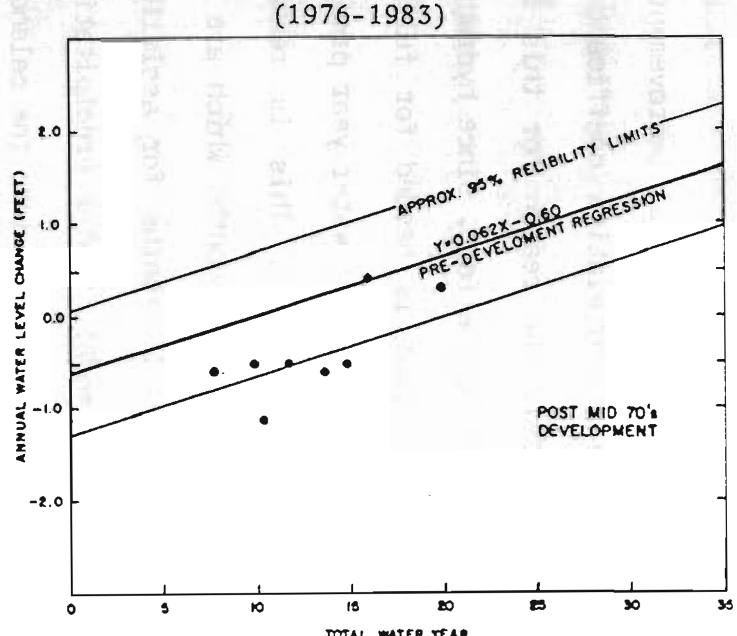


Fig. 13

observable and in equilibrium.

This model is a statistical improvement over the previous precipitation model as noted by a correlation coefficent of 0.60 compared with 0.39 for the previous model. The reason for this increase is the use of a lag time in relating cause and effect. Since hydrograph analysis indicates that a lag time of about one year is needed for full assimilation of precipitation to the water table, the use of water year precipitation and calendar year water level changes is reasonable. This is reasonable since meaningful precipitation occurs in the winter months which are in the first half of the water year, allowing 10 to 13 months for assimilation. Unlike the total calendar year precipitation model, winter precipitation which is late in the calendar year will not be incorporated into the calendar year's water level response.

Like the previous model, this one has no seasonal filter to eliminate immediate, evapotranspiration-susceptible precipitaton. As before, this model contains the discrete point problem of relating a single precipitation station to a single well in an effort to detail basinwide features.

Effective Water Year Precipitation Model

This model uses an effective water year precipitation which is the sum of each month's effective precipitation (Figure 14 and Appendix V). Each month's effective precipitation is herein defined as the monthly precipitation less the average potential evapotranspiration at Fremont as noted by Oregon State University studies. These studies used the Thornthwaite-Mather procedure to estimate potential evapotranspiration. The method assumes that with complete

EFFECTIVE PRECIPITATION FOR WATER YEAR AT FREMONT, LAKE CO.
(1919-23, 1925-35, 1938-43, 1946-47, 1950, 1953-56, 1959-70, 1972-81)

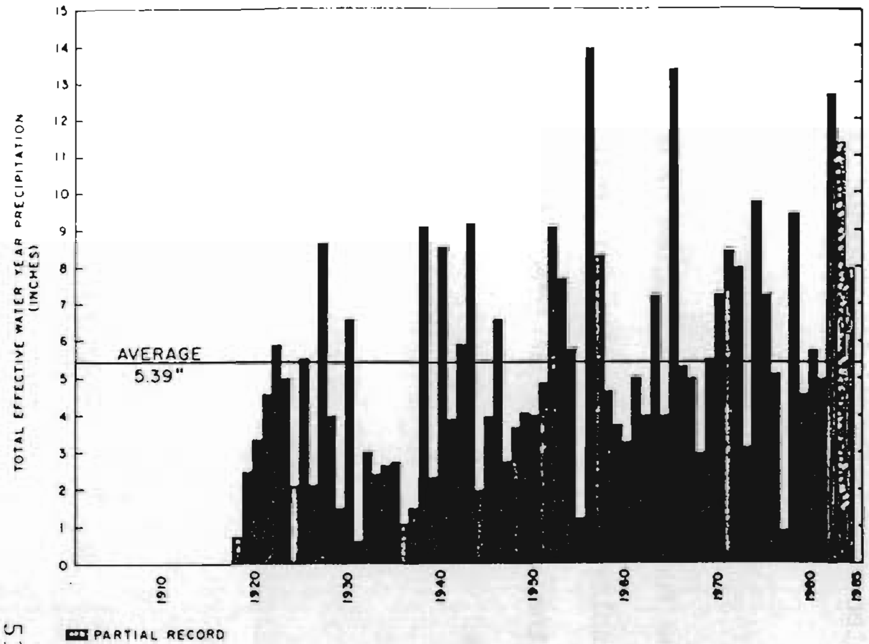


Fig. 14

CUMULATIVE DEPARTURE OF
EFFECTIVE PRECIPITATION FOR WATER YEAR AT FREMONT, LAKE CO.

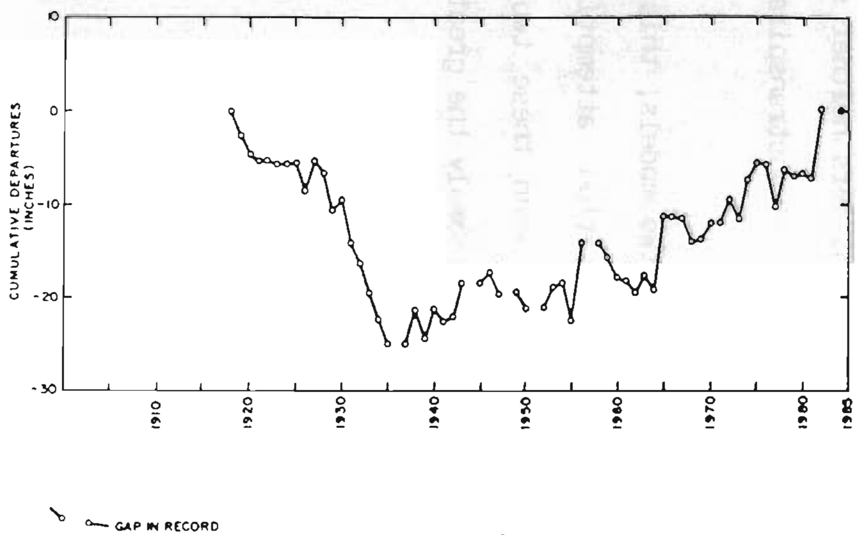


Fig. 15

PARKS WELL WATER LEVEL CHANGE vs EFFECTIVE WATER YEAR PRECIPITATION
(1939-42, 1950, 1953-56, 1959-70, 1972-75)

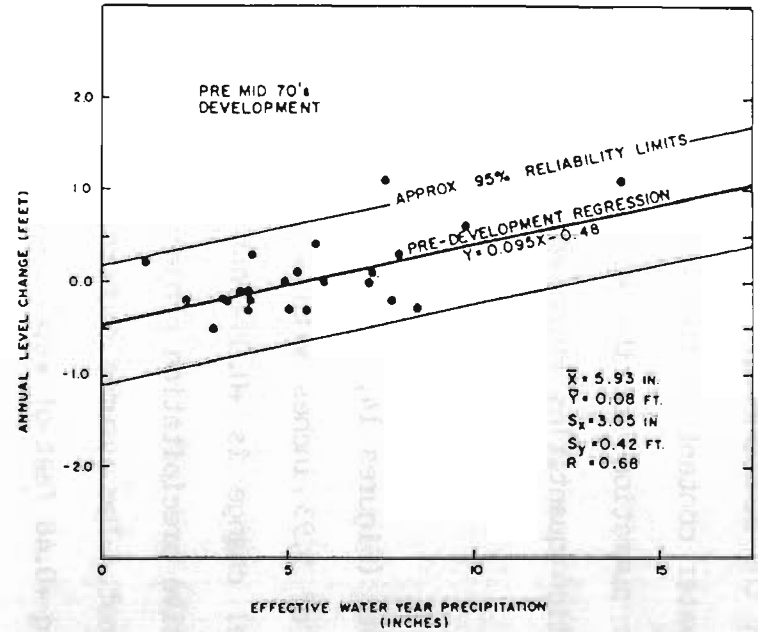


Fig. 16

PARKS WELL WATER LEVEL CHANGE vs EFFECTIVE WATER YEAR PRECIPITATION
(1976-1984)

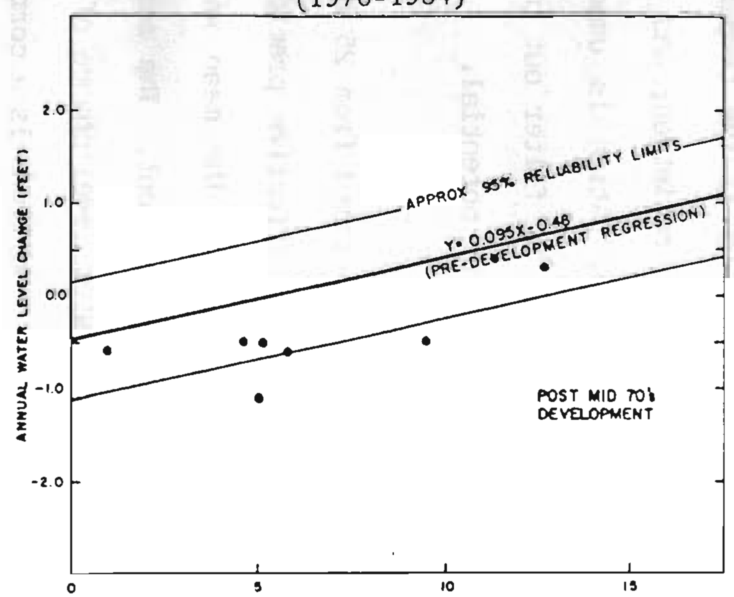


Fig. 17

vegetative cover the evaporation and transpiration from an area will be controlled primarily by 1) the temperature of the atmosphere; 2) day length, as an index of solar radiation; and 3) the water content of the soil. Only excess monthly precipitation is used in the summation for the water year. This technique seeks to filter out precipitation quantities which would seem to have little recharge potential.

This regression was formed from 25 data points (Figures 14, 15, 16 and 17). The set has a mean effective precipitation of 5.93 inches with a standard error of 3.05 inches. The mean water level change is +0.08 foot with a standard error of 0.42 foot. The zero effective precipitation projection (Y-intercept) is a water level change of -0.48 foot. The assumed recharge effect under equilibrium conditions is a corresponding +0.48 feet of water level rise.

Statistically, this is the best precipitation model with a correlation coefficient of 0.68. It incorporates both a lag time factor and extraneous precipitation filter. Although the evapotranspiration filter is an improvement, it considers neither specific antecedent soil moisture conditions nor specific monthly evapotranspiration.

Like the previous two models, this one has the fundamental data problem of one well and one station attempting to display basin cause and effect relationships. Between these two factors, the variability of precipitation over the area is probably the greater weakness.

Streamflow Model

This model correlates streamflow in Silver Creek at the gaging stations south of the town of Silver Lake with water level changes at the Parks well. This flow consists of combined live and diverted flow. Silver Creek is the only long-term gaged stream in the basin and drains a largely forested area of about 180 square miles (Appendix VI). Regulation of Silver Creek flow above the gages has existed since 1922 at Thompson Valley Reservoir (capacity 17,400 AF) and the Diversion Reservoir (capacity 800 AF) south of the town of Silver Lake. Carryover storage is generally small compared to total annual flow volume as noted by the 19 years of available storage data at Thompson Valley Reservoir. Carryover storage at the Diversion Reservoir is not recorded. As with the precipitation models, both the streamflow and corresponding water level change had to be accurately defined before they became a useable data set for the regression. As previously, calendar year water level changes are the data increments for the model.

Total Water Year Streamflow Model

This model was developed by correlating the total water year streamflow (X) against the calendar year water level change (Y) (Figures 18, 19, 20 and 21). The equation for this relationship is $Y=2.23 \times 10^{-5}X - 0.43$. In all, 30 data points served as input to the regression equation. The mean streamflow is 26,632 acre-feet per year with a standard error of 15,356 acre-feet per year. The mean water level change for the set is +0.16 foot with a standard error of 0.43 foot. The projected zero streamflow displays a water level change of -0.43 foot. Therefore, at equilibrium, the effect of average annual

SILVER CREEK FLOW
(LIVE FLOW AND DIVERSIONS UNLESS NOTED)
1906, 1910-27, 1930-41, 1944-83

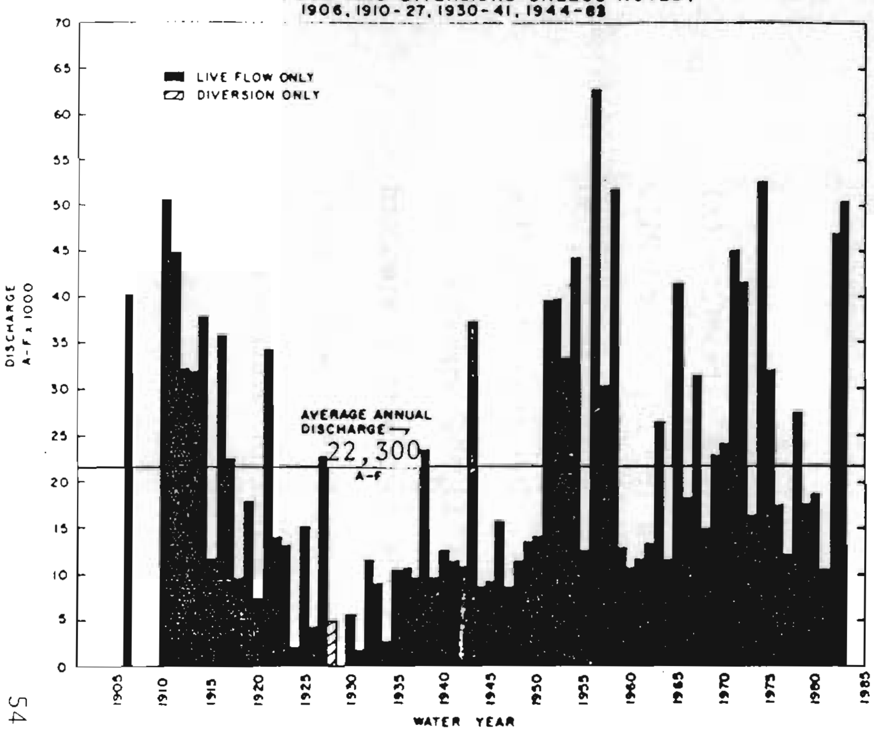


Fig. 18

CUMULATIVE DEPARTURE OF SILVER CREEK FLOW
(LIVE FLOW AND DIVERSIONS)

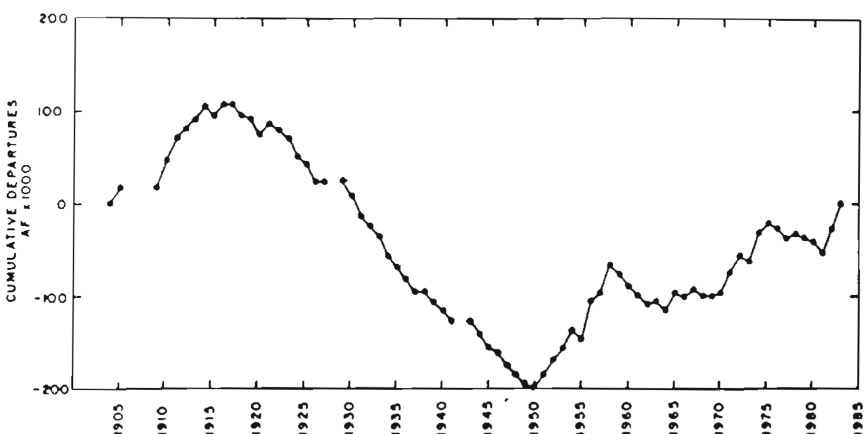


Fig. 19

—o o— GAP IN RECORD

PARKS WELL WATER LEVEL CHANGE vs SILVER CREEK DISCHARGE
1939-41, 1949-75

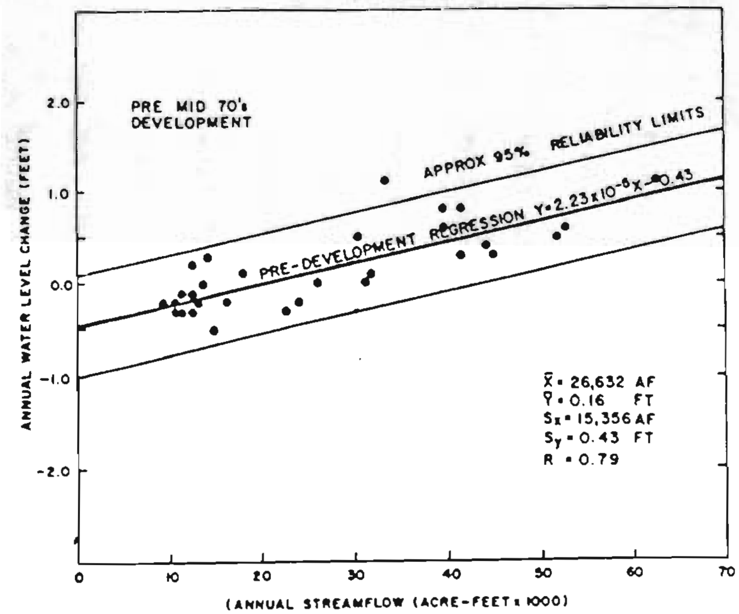


Fig. 20

PARKS WELL WATER LEVEL CHANGE vs SILVER CREEK FLOW
1976-1983

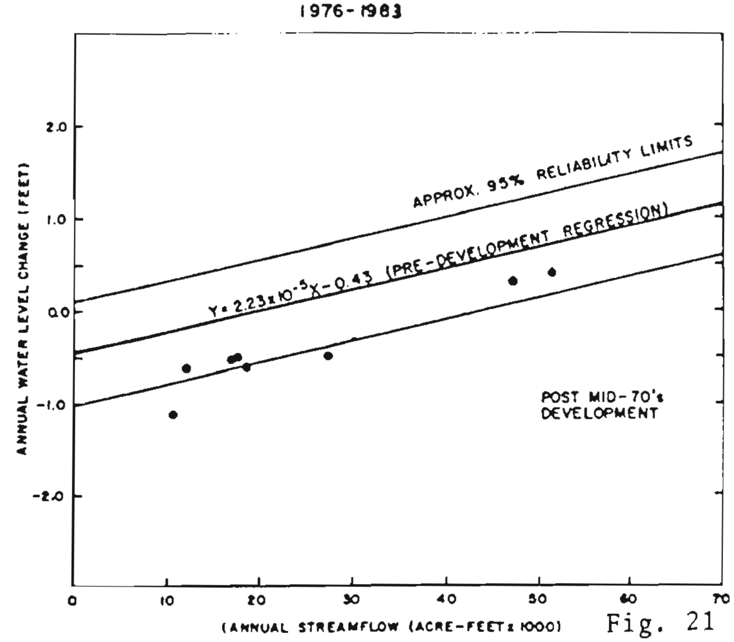


Fig. 21

recharge to the system is calculated to produce a 0.43 foot rise in water level. This value is quite similar to the best precipitation model (Effective Water Year Precipitation Model) which indicated that recharge was 0.48 foot.

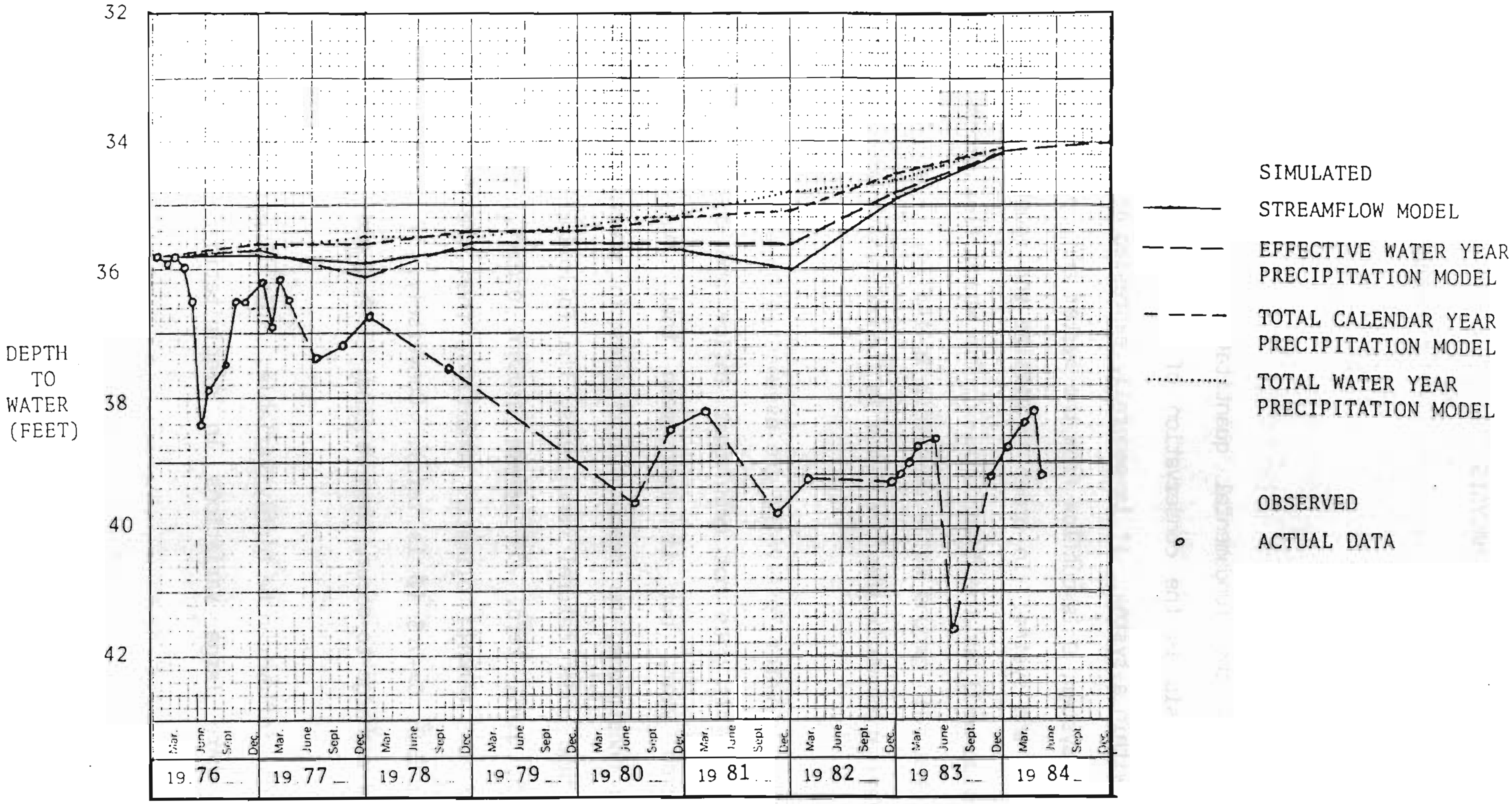
Statistically, this model is the most powerful since its regression has a correlation coefficient of 0.79. This compares with 0.68 for the best precipitation model and 0.39 for the weakest model. The time period for the data provides for lag time effect. In addition, a seasonal evapotranspiration filter is inherent in the generation of streamflow since it results from the site specific ground conditions in the watershed. Also, the watershed acts to integrate precipitation from a large area. This feature helps to render an average water yielding character. The integrated streamflow from a substantial watershed within a basin is more likely to reflect basin water availability conditions than is precipitation from a single precipitation station. The "cause" side of this model is strong, as is the overall correlation, yet, the possible single well problem remains on the "effect" side.

Model Conclusions

The streamflow model demonstrates a reasonably good statistical correlation between total water year flow on Silver Creek and calendar year water level change at the Parks well for natural recharge/discharge conditions. Small measurement errors alone will preclude a perfect correlation as will the assumption that purely natural conditions existed before 1976. The former seems to be the case for the water level rise for 1953 which is an outlier in each model. In addition, the lack of more complete data on reservoir storage in the Silver Creek drainage modifies streamflow and probably reduces the correlation.

Hydrograph analysis and water level changes since 1976 (modified conditions) suggest that the Parks well acts much like other wells in the basin where the main ground water body is penetrated. Appendix VII shows the water level fluctuation similarities of other wells in the basin with the Parks well. The existence of modified ground water conditions is demonstrated by all four Parks well models as water level changes after 1976 have consistently fallen below their respective pre-development regression lines. In addition, the utilization of the various models to simulate nondevelopment water levels since 1976 shows a clear contrast with actual levels (Figure 22).

The inclusion of lag time, evapotranspiration and precipitation integration factors have progressively improved the correlation of the regression equations. The streamflow model appears to be sufficiently reliable to serve as a basis for helping to balance the system under modified conditions. Modification of the streamflow equation in a subseqent section will lead to a target equation designed to result in a future equilibrium.



SIMULATED WATER LEVELS AT THE PARKS WELL USING STATISTICAL MODELS
FROM A JANUARY 1, 1976 BRANCH POINT

Fig. 22

Continuity Equation

The continuity equation is the fundamental quantitative expression for hydrologic systems. Its basis is the conservation of mass, relating mass changes into, from and within a system. It is generally expressed as $I-O=\Delta S$, where I is inflow to the system, O is outflow from the system and ΔS is the change in storage within the system. In order to utilize the equation, one must define the system as well as the time interval for which flow occurs. For current purposes, the main ground water reservoir in the Fort Rock Basin is the system under examination while the time frame is the calendar year.

Prior to development, ground water reservoirs are assumed to be approximately at dynamic equilibrium. This does not mean that inflow and outflow are perfectly balanced each year, but it does mean that under current long-standing climatic conditions, no meaningful changes in storage occur. Therefore, on the average under natural conditions, the following equations apply: $I=O$ and $\Delta S=\emptyset$, i.e., zero. If severe drought occurs, which is plausible and part of the general climatic condition, then the following equation is operative: $I=\emptyset$, $O=-\Delta S$ ($\emptyset$ is zero). Conversely, if conditions permit abnormally large recharge to occur, then we find: $I > O$ and $\Delta S>\emptyset$.

Under natural conditions, inflow can be highly variable. This is particularly so in drier areas where large variations in precipitation may occur year-to-year.

Outflow, however, appears to be fairly constant on an annual basis in the Fort Rock Basin due to the modulated nature of the ground water body. Since the depth to water has varied little over observable time, it appears that severe climatic or geologic changes are required to alter the evapotranspiration outflow mechanism. Also, the fairly constant discharge of large springs is indicative of ground water storage levels which change little.

Development Stages

As ground water development occurs, new stress is placed on a natural system. The goal for development of the resource for a sustained yield is to modify the system such that otherwise wasted water is salvaged for a beneficial use. A prime objective of sustained yield is to produce a ground water condition in which artificial outflow never exceeds average recharge to the system. Commonly, this requires a permanent depletion of some water from storage in order to reduce natural outflow from the system. This depletion is part of a transition process which results in progressively less natural outflow. In some areas, this depletion allows for increased inflow of formerly rejected recharge. However, for the Fort Rock Basin, the general lack of surface water would seem to preclude a significant inflow augmentation by this mechanism. Subsequent equations for various development stages will utilize the following variable subscripts in order to express this transition: N for natural, A for artificial and T for Total.

Pre-Development

Pre-development or natural conditions are expressed as:

$$I_N - O_N = \Delta S = \emptyset.$$

As noted earlier, this condition formed over geologic time and displays a balance between geologic and climatic conditions. Both natural outflow and storage are at maximum levels and will appear highly modulated. Natural inflow will change greatly each year depending on annual climatic conditions.

Early Development

Early development at full appropriation (complete salvage) is a modified system which may be expressed as:

$$I_N-(O_N+O_A) = \Delta S.$$

This period is one of general storage depletion. Losses from storage will, on the average, be larger early in the period and decrease later in the period as natural outflow decreases. O_A is equal to O_N early in the period and a discharge equal to double natural outflow exists. ΔS on the average is equal to $-O_N$. The average natural inflow is noted as $\overline{I}_N$. For complete salvage, I_N is equal to O_A on the average. I_N is variable year-to-year but would range from Ø under severe drought to several times $\overline{I}_N$ during very wet years. Early in this period, $O_T=O_N+O_A=2(O_N)=2(\overline{I}_N)$. The expression $2(O_N)$ is the double outflow notation and reflects the maximum discharge from the system. For this period, storage changes rest, by definition in this discussion, within the average boundaries: $-1/2(\overline{I}_N) \geq \Delta S \geq -(\overline{I}_N)$. In other words, this period is one in which there are declines which are generally reflecting more than 1/2 the average annual inflow but less than the full average annual inflow ($\overline{I}_N$).

Late Development

Late development at full appropriation is a further modification of the system which may be expressed as:

$$(I_N+I_A)-(O_N+O_A) = \Delta S.$$

This period is one of lessening storage depletion as well as reduced natural outflow. O_N is less than O_A. Also, a very small quantity of induced recharge occurs through I_A, however, $\bar{I}_N$ remains much greater than I_A. ΔS on the average is still negative but more than $-1/2(\bar{I}_N)$ and approaches $\emptyset$ later in the period. For this period storage changes rest, by definition, within the range: $\emptyset \geq \Delta S \geq -1/2\ (\bar{I}_N)$. This means that the period experiences declines which are slowing to $\emptyset$ from a value of about 1/2 the average annual inflow $(\bar{I}_N)$.

Full Transitional Development

Full transitional development at full appropriation is complete modification of the system and is expressed as:

$$(I_N+I_A)-O_A = \Delta S = \emptyset.$$

Again, I_A is probably negligible in the Fort Rock Basin. Therefore, the only significant change from the pre-development period is the replacement of O_A for O_N. Continuing storage changes are nil. However, the quantity of storage depletion necessary to arrive at this point may be several tens of times the average annual inflow (recharge). If such a condition is obtained, water levels will lie consistently below the root zone of phreatic plants, below the capillary fringe of bare soil and just below the orifice level of springs and seeps. For orderly development to exist in accordance with the listed equations, artificial outflow can not persist at levels which exceed the average annual inflow.

Fort Rock Basin Development

Hydrograph data suggest that development of the main ground water reservoir of the Fort Rock Basin has moved from essentially a pre-development stage (pre-1976) to an early development stage. Statistical analysis of the pre-development system suggests that recharge alone is comparable to a water level change of 0.43 foot at the Parks Well. This value and the general equation for early development provide a graphical solution to estimate the limits of full appropriation at this time (Figure 23). On the basis of the streamflow model equation ($Y=2.23\times10^{-5}(X)-0.43$), the average outflow ($O_N$) is shown to effect a head change of 0.43 foot. Since $O_N=O_A$ in early development at full appropriation, total outflow, O_T, equals O_N+O_A which equals $2(O_N)$. Since O_N is responsible for -0.43 foot of head change in the reservoir, $2(O_N)$ is equivalent to -0.86 foot of head change. This double outflow principle yields the current target equation:

$$Y = 2.23 \times 10^{-5}(X)-0.86,$$

where X is water year streamflow on Silver Creek (AF) and Y is the calendar year water level change at the Parks Well (Ft). The data since 1976 indicate that the actual trend of ground water conditions falls, in general, slightly below this target (Figure 24). Calendar year 1982 was the first year since 1976 in which an annual water level rise occurred. This resulted from the abnormally high precipitation during the water year. On the average, water levels will fall about 0.43 foot per year at full appropriation at the beginning of the early development period. Current information suggests that the system is fully developed or slightly overdrafted under present pumping and historical climatic conditions.

At full appropriation a progression of anticipated equations will occur. Using the logic cited in this section, the following are expected.

Pre-Development	$Y = 2.23 \times 10^{-5}(X)-0.43$
Early Development	$Y = 2.23 \times 10^{-5}(X)-0.86$ to $Y = 2.23 \times 10^{-5}(X)-0.65$
Late Development	$Y = 2.23 \times 10^{-5}(X)-0.65$ to $Y = 2.23 \times 10^{-5}(X)-0.44$
Full Transitional Development	$Y = 2.23 \times 10^{-5}(X)-0.43$

The data on Figures 21 and 24 do not represent a single population for statistical correlation. This is based on the fact that irrigation withdrawals have varied greatly since 1976. The data does represent water level changes during various streamflow conditions over a time since essentially artificial conditions began. The 1982 and 1983 data points are the only ones which are above the target equation while all others are at or below the target. Since the data prior to 1982 show such a decided decline bias, it appears that the reverse in 1982 and 1983 represent statistically high values. Continued pumping at 1981/1982 diversion rates is expected to produce changes near the target equation in the future.

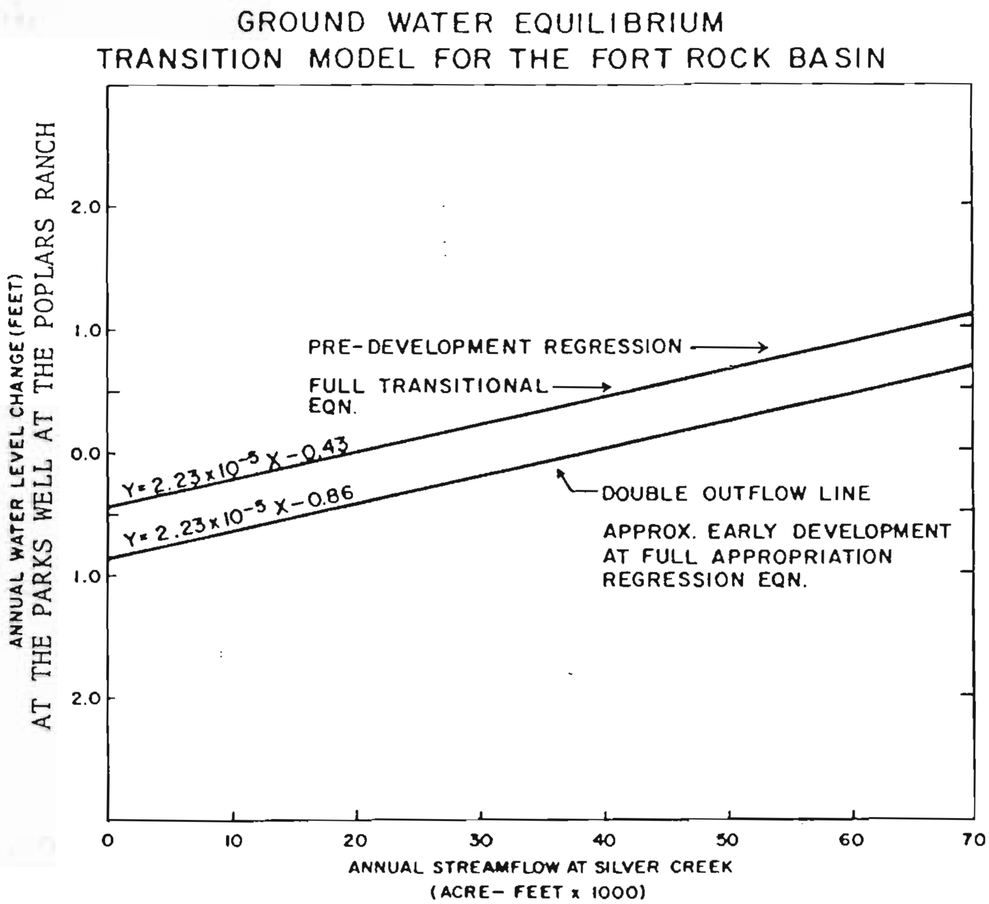

GROUND WATER EQUILIBRIUM
TRANSITION MODEL FOR THE FORT ROCK BASIN
ANNUAL WATER LEVEL CHANGE (FEET)
AT THE PARKS WELL AT THE POPLARS RANCH
2.0
1.0
0.0
1.0
2.0
PRE-DEVELOPMENT REGRESSION
FULL TRANSITIONAL EQN.
Y= 2.23 x 10-5 X - 0.43
Y= 2.23 x 10-5 X - 0.86
DOUBLE OUTFLOW LINE
APPROX. EARLY DEVELOPMENT AT FULL APPROPRIATION REGRESSION EQN.
0
10
20
30
40
50
60
70
ANNUAL STREAMFLOW AT SILVER CREEK
(ACRE- FEET x 1000)

Fig. 23

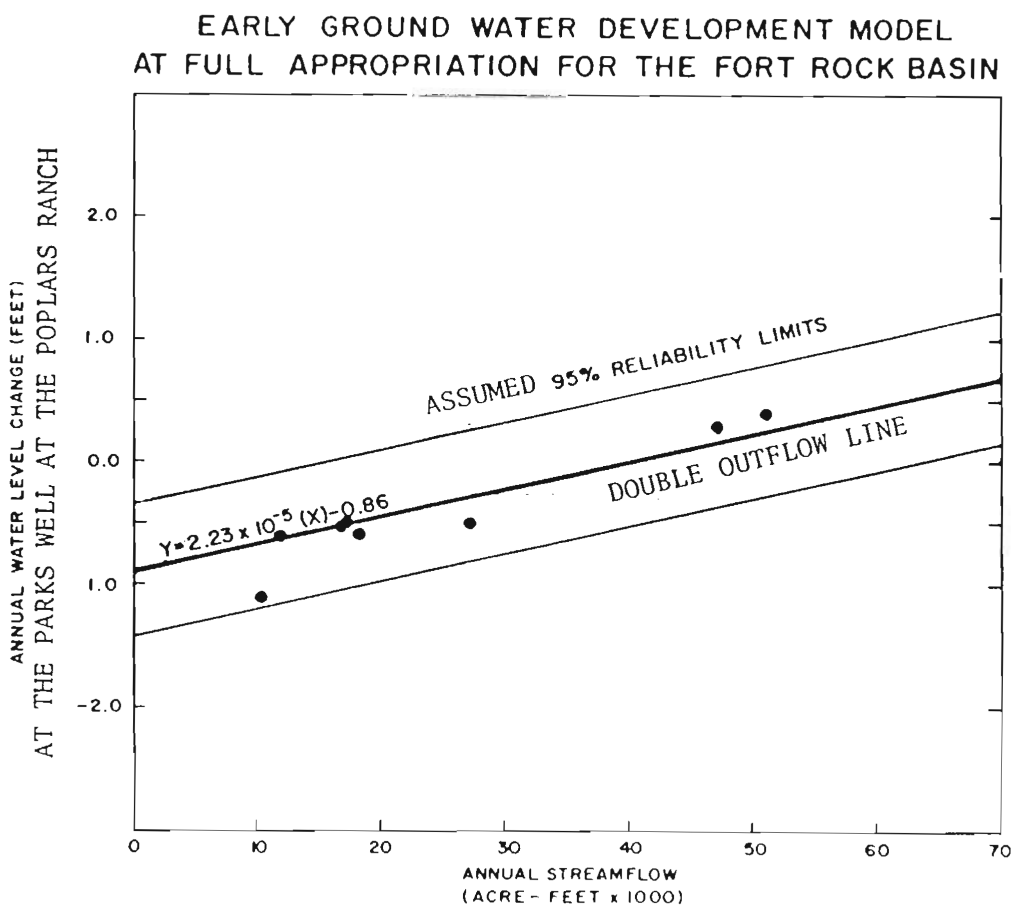

EARLY GROUND WATER DEVELOPMENT MODEL
AT FULL APPROPRIATION FOR THE FORT ROCK BASIN
ANNUAL WATER LEVEL CHANGE (FEET)
AT THE PARKS WELL AT THE POPLARS RANCH
2.0
1.0
0.0
1.0
-2.0
ASSUMED 95% RELIABILITY LIMITS
DOUBLE OUTFLOW LINE
Y=2.23 x 10-5 (X)-0.86
0
10
20
30
40
50
60
70
ANNUAL STREAMFLOW
(ACRE- FEET x 1000)

Fig. 24

The total potentiometric drop which is necessary in order to practicably prevent natural losses is uncertain. Continuing the withdrawal rates of recent years would seem to lead ultimately to that level. It would appear that a drop of 50 feet would arrest phreatophyte consumption from the main ground water reservoir in the basin. This lowering would place the water table below the deepest portions of the root zone. If Fort Rock Basin water flows to the Summer Lake Basin, a total drop of 70 feet would seem to halt discharge to Ana Springs. On this basis it appears that a total water level drop of 70 feet would serve to arrest natural losses from the main ground water reservoir in the Fort Rock Basin.

SUMMARY

A water level decline of about 2.5 feet has occurred in the main ground water reservoir of the Fort Rock Basin during the last eight years. This decline has taken place during a period in which precipitation has been more than 110 percent of normal and in which water levels would have risen 1.6 feet if development of the reservoir were at pre-1976 intensity. Withdrawal from wells has increased sharply to about 68,000 acre-feet per year for the period. On the basis of these facts, a small but definite water level decline is taking place in response to pumping for irrigation.

The main ground water reservoir consists of water in the basalts, basaltic agglomerates, cinders, sands and gravels of the Picture Rock Basalt, Fort Rock Formation, Hayes Butte Basalt and the Paulina Basalt. Available data suggests that recharge to these units is the result of precipitation which occurs in the basin. This water requires about one year to become fully assimilated into the reservoir in the central parts of the basin. Most irrigation wells in the reservoir have very high specific capacities. Water levels in the reservoir are highly modulated and displayed a water level elevation of about 4292 feet msl.

Although water level changes are small on an annual basis in the main ground water reservoir, this reservoir appears to be fully appropriated at this time. The water level rises in response to abundant water availability in 1982 and 1983 have been less than one would expect had irrigation not reached current levels. Assuming that pumpage from wells continues at present rates in the future and generally normal water availability occurs, water levels should decline at a rate less than one foot per year through this century.

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Appendix 1

Chemical Analyses of Well Water In the Fort Rock Basin

Well	Owner	Use	Depth	Principal Aquifer	Date of Collection	Temp. (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) cromhos at 25°C)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron	Sodium Adsorption ((Na)) / ((1/2 (Ca +Mg)) 1/2)	Dissolved Solids Calculated	Dissolved Solids Residue at 180°C	Hardness As Ca CO_3	Hardness Non Carb.	Specific Conductance as Ca CO_3	pH (ml
25/15-33a[3]	A. Roberts	Irr	280	Fort Rock Fm	04-09-80[8]	--	--	--	--	16	8.3	38	--	--	--	--	--	--	0.2	2.0	--	--	--	--	270	--
25/18-4b[3]	V. Houston	Irr	346	Picture Rock Bas	10-03-80[8]	--	--	--	--	21	16	32	--	121	--	--	--	--	0.16	1.3	--	--	--	--	360	7.1
25/18-4c[3]	V. Houston	Irr	440	Picture Rock Bas	10-03-80[8]	--	--	--	--	12	11	30	--	85	--	--	--	--	0.12	1.5	--	--	--	--	240	7.7
25/18-21a[3]	W. Brown	Irr	202	Paulina Basalt	07-13-80[8]	--	--	--	--	37	18	56	--	--	--	--	--	--	0.38	1.8	--	--	--	--	720	--
26/14-1a[3]	J. Rust	Irr	350	Fort Rock Fm	06-04-80[8]	--	--	--	--	25	12	365	--	--	--	--	--	--	4.2	15.0	--	--	--	--	1500	--
26/14-12b[3]	K. Hanna	Irr	200+	Fort Rock Fm	09-08-80[8]	--	--	--	--	22	9.8	57	--	--	--	--	--	--	1.6	2.6	--	--	--	--	530	--
26/15-22b(?)[3]	T. Tiahrt	Irr	262	Fort Rock Fm	02-23-79[8]	--	--	--	--	20	10	41	--	--	--	--	--	--	--	1.9	--	--	--	--	----	--
26/15-23c(?)[3]	T. Tiahrt	Irr	365	Fort Rock Fm	02-23-79[8]	--	--	--	--	8.4	6.8	40	--	--	--	--	--	--	0.6	2.4	--	--	--	--	210	--
26/15-28d[3]	A. Parks	Irr	660	Fort Rock Fm	05-12-80[8]	--	--	0.42	.05	24.6	1.5	46	5.2	--	34	57	--	--	.02	2.4	--	--	--	--	----	--
26/15-33g[1]	M. Parks	Irr	200	Fort Rock Fm	04-26-61	--	45	--	--	36	19	84	7.9	191	103	68	0.4	0.2	2.1	2.0	460	468	170	14	725	7.6
26/16-6d[3]	W. Brown	Irr	900	Fort Rock Fm (?)	07-09-80[8]	--	--	--	--	19	9.8	32	--	--	--	--	--	--	0.46	1.5	--	--	--	--	310	--
26/16-27c[3]	D. Gallogly	Irr	906	Fort Rock Fm	11-16-81[8]	--	--	--	--	5.7	11	26	--	--	--	--	--	--	0.49	1.4	--	--	--	--	462	--
26/16-28d[3]	D. Gallogly	Irr	894	Fort Rock Fm	10-19-81[8]	--	--	--	--	5.2	11	53	--	--	--	--	--	--	0.32	3.0	--	--	--	--	460	--
26/16-30d[4]	G. Hanson	Irr	650	Fort Rock Fm	10-15-81	--	--	--	--	5	6	20	--	--	1	--	--	--	17	1	--	90	20	--	175	8.0
26/18-5a[3]	W. Brown	Irr	350	Paulina Basalt	07-09-80[8]	--	--	--	--	42	16	42	--	--	--	--	--	--	0.46	1.4	--	--	--	--	580	--
26/18-29/30[7]	L. Grassman	Irr	400+	Fort Rock Fm	05-08-80[8]	--	--	--	--	8	3.5	50.1	--	(1.96)	16.4	--	--	--	0.82	3.7	--	--	--	--	255	8.3
26/18-31[7]	M. Morse	Irr	350+	Fort Rock Fm	05-08-80[8]	--	--	--	--	30.4	0.32	35.2	--	(.91)	18.3	--	--	--	0.21	1.7	--	--	--	--	240	10.3
26/18-31[7]	M. Morse	Irr	350+	Fort Rock Fm	05-08-80[8]	--	--	--	--	4.7	1.46	43.6	--	89.6	17.3	--	--	--	0.67	4.5	--	--	--	--	200	7.2
27/14-35c[1]	M. Kittridge	D,S	61	Fort Rock Fm (?)	02-18-50	50	51	0.72	0.00	17	17	20	5.6	184	1	1	.2	3.2	.01	0.8	207	188	112	0	285	7.5
27/15-4a[1]	M. Parks	I,D,S	257	Fort Rock Fm	10-24-48	62	56	.04	.2	31	21	176	15	330	115	121	.6	4.3	.8	6.0	701	690	164	0	1100	8.1
27/15-24c[1]	R. Webber	Irr	351	Fort Rock Fm	12-03-48	50	45	.52	.4	8.4	5.7	16	1.9	92	2.9	2.2	.2	.2	.02	1.0	128	125	44	0	145	8.1
27/16-27b[3]	M. Blevins	Irr	980	Picture Rock Bas	04-16-80[8]	--	--	--	--	1	2	14	--	--	--	--	--	--	0.1	1.8	--	--	--	--	72	--
27/17-1c[3]	J. Hall	Irr	265	Fort Rock Fm	04-10-80[8]	--	--	--	--	105	230	501	--	--	--	--	--	--	1.6	11	--	--	--	--	2100	--
27/17-5b[1]	Chewaucan Land and Cattle Co.	S	206	Fort Rock Fm	10-12-48[8]	52	44	.29	.2	9.4	14	92	7.7	210	90	12	.4	8.5	.06	4.4	382	368	81	0	555	7.5
27/17-19a[3]	T. Champion	Irr	608	Picture Rock Bas	11-07-80[8]	--	--	--	--	3.5	3.3	17	--	--	--	--	--	--	0.36	1.6	--	--	--	--	121	--
27/17-21[2]	H. Mehlhoff	Irr	400+	Picture Rock Bas	06-00-80	--	--	--	--	(34.05)	(34.05)	1150		(3.28)	--	--	--	--	2.96	--	--	--	--	--	6250	7.3
27/17-21a[2]	H. Mehlhoff	Irr	412	Picture Rock Bas	02-02-77	--	--	--	--	(.65)	(.65)	53	--	(2.92)	--	--	--	--	0.6	4.0	--	--	--	--	280	8.6
27/17-21b[2]	H. Mehlhoff	Irr	500	Picture Rock Bas	02-02-77	--	--	--	--	(.75)	(.75)	62	--	(1.76)	--	--	--	--	0.34	2.9	--	--	--	--	280	8.2
27/17-21c[2]	H. Mehlhoff	Irr	412	Picture Rock Bas	02-02-77	--	--	--	--	(.75)	(.75)	4.6	--	(1.64)	--	--	--	--	0.58	0.3	--	--	--	--	280	8.2
27/17-22[2]	T. Puckett	Irr	250+	Fort Rock Fm Picture Rock Bas	06-00-80	--	--	--	--	(9.8)	(9.8)	87	--	(2.36)	--	--	--	--	0.62	1.7	--	--	--	--	1200	8.2
27/17-22b[3]	E. Gustafson	Irr	385	Picture Rock Bas	03-28-80[8]	--	--	--	--	291	168	1800	--	--	--	--	--	--	8.0	21	--	--	--	--	8200	--
27/17-22b[3]	E. Corwin	Irr	385	Picture Rock Bas	05-21-80[8]	--	--	--	--	335	165	1842	--	--	--	--	--	--	9.2	21	--	--	--	--	8300	--
27/17-22b[2]	E. Corwin	Irr	385	Picture Rock Bas	06-00-80[8]	--	--	--	--	(5.35)	(5.35)	268	--	(1.95)	--	--	--	--	1.5	7.1	--	--	--	--	1750	7.5
27/17-27c[6]	H. Wahl	Irr	220	Picture Rock Bas	01-10-52	--	16	.80	--	15	9.7	35	--	140	24	11	--	--	.10	1.2	180	--	78	0	----	7.0
27/18-18b[1]	R. Hardin	S	45	Fort Rock Fm	10-19-48	--	53	1.3	.2	45	40	120	14	194	302	54	.3	5.4	.08	3.1	729	736	277	118	1070	7.3
27/18-21d[3]	Wm. Schmidt	Irr	500	Picture Rock Bas	08-25-81[8]	--	--	--	--	11	6.9	23	--	--	--	--	--	--	0.31	1.3	--	--	--	--	253	--
28/14-21d[1]	U.S. Forest Service	D,PS	240	Fort Rock Fm	12-12-58	--	43	.07	--	14	7.7	10	2.8	107	4.4	1.5	.1	.5	--	0.5	137	133	66	0	177	8.2
28/14-22c[1]	R. Hohstadt	D	36	Unconsolidated deposits	02-18-50	48	53	.95	.00	13	9.8	13	4.8	94	9	8	.2	8.8	.00	0.7	166	160	73	0	210	7.4

[Use D, domestic; Irr, Irrigation; PS, public supply; S, stock. Results are given in milligrams per liter in samples after 1976 and parts per million before 1976 unless otherwise noted.]

1. Analysis by USGS.
2. Analysis by Oregon State University, Corvallis, Oregon.
3. Analysis by Century Testing Laboratories, Bend, Oregon.
4. Analysis by Water Analysis and Consulting, Incorporated, Eugene, Oregon.
5. Analysis by Northwest Testing Laboratories, Portland, Oregon.
6. Analysis by Twining Laboratories, Fresno, California.
7. Analysis by CH_2M Hill Laboratories, Corvallis, Oregon.
8. Date of sample submission.

( ) Combined me/l, Mg and Ca or bicarbonate and carbonate.

APPENDIX II
Current Fort Rock Basin
Observation Wells

Well number: See page viii for description of well-numbering system.
Type of well: Dr, drilled; Dv, driven; Dg, dug; B, bored.
Finish: B, open bottom (not perforated or screened); Sc, screened; P, perforated.
Altitude: Altitude of land surface at well, in feet above mean sea level, interpolated from topographic maps or surveyed.(*)
Water level: Depths to water given in feet.
Potentiometric level: Altitude of water level in feet above mean sea level (see Figure 4).

Type of Pump: S, submersible; P, piston; T, turbine; N, none.
Well performance: Yield in gallons per minute, and drawdown in feet below nondischarging water level, reported by owner, operator, driller, pump company or state.
Use: D, domestic; Ir, irrigation; S, stock; T, test; N, none.
Remarks: A, air tested; P or B, pumped or bailed, for the indicated number of hours, when drawdown was measured. Remarks on well structure are reported by drillers or state.

Well Number	Owner	Type of well	Year completed	Depth of well	Casing Diameter (in.)	Casing Depth (feet)	Finish	Water-bearing zone(s) Depth to top (feet)	Thickness (feet)	Character of material	Altitude (feet)	Water level Feet below datum	Date	Potentiometric Level	Type of pump	Well performance Yield (gpm)	Drawdown (feet)	Use	Remarks
									T23S, R16E										
35cd	BLM	Dr	1976	505	6	498	P,418- 498	435 470	35 28	Red cinders sand and gravel	4726	434.26	3-18-84	4292	S	25	0	S	P 4 hr.
									T24S, R14E										
17da	U.S. Forest Service	Dr	1940	330	8	-	-	234.6 328	0.4 2	Lava Red cinders	4515	224.80	3-20-84	4290	S	-	-	D	
									T25S, R14E										
15bc	LeRoy Surcamp	Dr	1923	256	18	-	-	-	-	-	4337	45.44	3-18-84	4292	T,S	500+	4	Ir	P
29da	Banfield Vet. Hospital	Dr	1956	310	14	86	B	48	32	Black sand	4336	44.08	3-19-84	4292	T	550	22	Ir	P
									T25S, R16E										
26bc	Maurice Ward	Dr	-	278	6	6	B	-	-	-	4506	214.81	3-18-84	4291	P	-	-	S	-
									T25S/R18E										
9cc	Alfred Prevost	Dr	1963	260	12	18	B	90	3	gravel	4329	34.90	3-17-84	4294	N	1500	56	N	P 30 hrs
									T25S/R14E										
31dc	O.E. White	Dr	1963	225	12	20	B	222	3	gravel	4306	15.29	3-17-84	4291	T	2375	6	Ir	P 6 hrs
									T26S, R14E										
3bb	Dick Fritts	Dr	-	60	6	-	-	-	-	-	4325	33.65	3-20-84	4291	N	-	-	N	-
23bb	BLM	Dr	-	121	8	-	-	-	-	-	4326	34.18	3-16-84	4292	S	20	5	S	P
									T26S, R15E										
6ab	Jack Kittredge	Dr	1955	317	16	119	B	-	-	-	4329	33.43	3-18-84	4296	T	800	41	Ir	P 6 hrs
32bc	Robert Tuttle	Dr	1954	235	15	-	-	-	-	-	4329	34.00	3-21-84	4295	T	-	-	Ir	
									T26S, R16e										
19bb	Roy Forman	Dr	1978	500	14	107	B	324	46	Pumice	4317	22.00	3-16-84	4295	N	1000	-	N	A 1 hr
									T26S, R18E										
8ad	Wayne Maki	Dr	1964	220	8	20.5	B	135 197 218	- 21 2	Green clay Black sand sand and gravel	4354	61.14	3-17-84	4293	S	20	2	D	B 1 hr
26ab	Bob Bothern (well caved in to 81 feet prior to 1-18-66)	Dr	1960	(225)	18	8	B	-	-	-	4311	20.82	3-17-84	4290	N	1200 1600	51 56	N	P 28 hrs P 22 hrs

									T27S, R13E										
23db	Jim Crofoot	Dr	1980	350	14	25	B	290 315	25 10	Lava Gravel	4475	179.65	3-22-84	4295	T	1000±	-	Ir	A 21 hrs
									T27S, R15E										
2ad	Ernest Porter	Dr	1950	255	18	1	B	167 174	3 13	Cinders Cinders	4314	20.84	3-22-84	4293	T	-	-	Ir	-
4ac	Merritt Parks	Dr	1922	257	16	14	B	-	-	Agglom- erate	4332	38.34	3-16-84	4294	T	1100	3.45	Ir	P 50 min
13bb	Loma Vista Farms	Dr	1949	181	15	15	B	-	-	-	4319	23.05	3-16-84	4296	T	1600	55	Ir	P
	(Deepening)		1975	245	14	30	B	243	2	Cinders	-	-	-	-	T	2800	24	Ir	P 3 hrs
									T27S, R16E										
13ab	Richard Morehouse	Dr	1955	560	12	6	B	-	-	-	4313	19.61	3-18-84	4293	T	1000	60	Ir	P 3 hrs
26cd	Mark Bedinger	Dr	1963	755	14	60	B	-	-	-	4315	24.13	3-18-84	4291	T	2000	100	Ir	P
32bd	Dick Lucas	Dr	1956	848	12	32	B	55 795	15 39	Pumice Cinders	4335	21.34	3-18-84	4314	N	60	-	N	P 4 hrs
	(Deepening)	Dr	-	1020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32ca	Jim Lancaster	Dr	-	545	12	-	-	-	-	-	4415	56.30	3-18-84	4359	T	-	-	N	-
									T27S, R17E										
27ca	Dave Seibel	Dr	1952	220	16	77	B	130 139 176	9 2 6	Lava Sand Lava	4332*	39.10	3-18-84	4293	T	3200	-	Ir	P
									T27S, R18E										
6bc	Terry Nofziger (well caved in to 39 feet by 1983)	Dr	-	(83)	8	10	B	-	-	-	4316	16.40	3-17-84	4300	N	-	-	N	-
6db	Clint Carrico	Dr	1956	244	14	70	B	134	15	Pumice	4312	21.52	3-17-84	4290	T	1000	19	Ir	P
21aa	BLM	Dr	1950	635	6	366	-	-	-	-	4321*	29.05	3-17-84	4292	N	-	-	T	
									T27S, R19E										
18cc	View Point Ranch	Dr	1954	255	16	20	B	-	-	-	4340*	50.51	3-17-84	4289	T	900	5	Ir	P
									T27S, R20E										
8dd	ZX Ranch	Dr	1943	154	8	-	-	-	-	-	4320*	31.60	3-14-84	4288	P	10	7	S	P
									T28S, R14E										
20ab	Lawrence Iverson	Dr	1960	155	14	20	B	-	-	-	4380	46.60	3-22-84	4333	S	15	10	S	-
21db	U.S. Forest Service	Dr	1958	240	8	240	P, 180-240	220	20	Cinders	4370	77.95	3-22-84	4292	S	154	11	D	P 4 hrs
25bb	ZX Ranch	Dr	1963	300	-	76	B	122	-	Cinders	4363*	65.60	3-22-84	4297	N	500	-	N	A 2 hrs
	(Deepening)	Dr	1964	521	-	-	-	-	-	-	-	-	-	-	-	1500	43	-	P 8 hrs
	(Deepening)	Dr	1966	560	-	-	-	-	-	-	-	-	-	-	-	20	0	-	B 2 hrs
									T28S, R15E										
14ad	View Point Ranch	Dr	1955	520	16	342	B	495	4	Red Lava	4340	50.64	3-22-84	4289	T	-	-	Ir	-
								T29S, R16E (Summer Lake Basin)											
1bd	Oregon State Game Commission	Dr	-	339	6	-	-	-	-	Red Sand	4290	38.12	3-22-84	4252	N	-	-	N	-

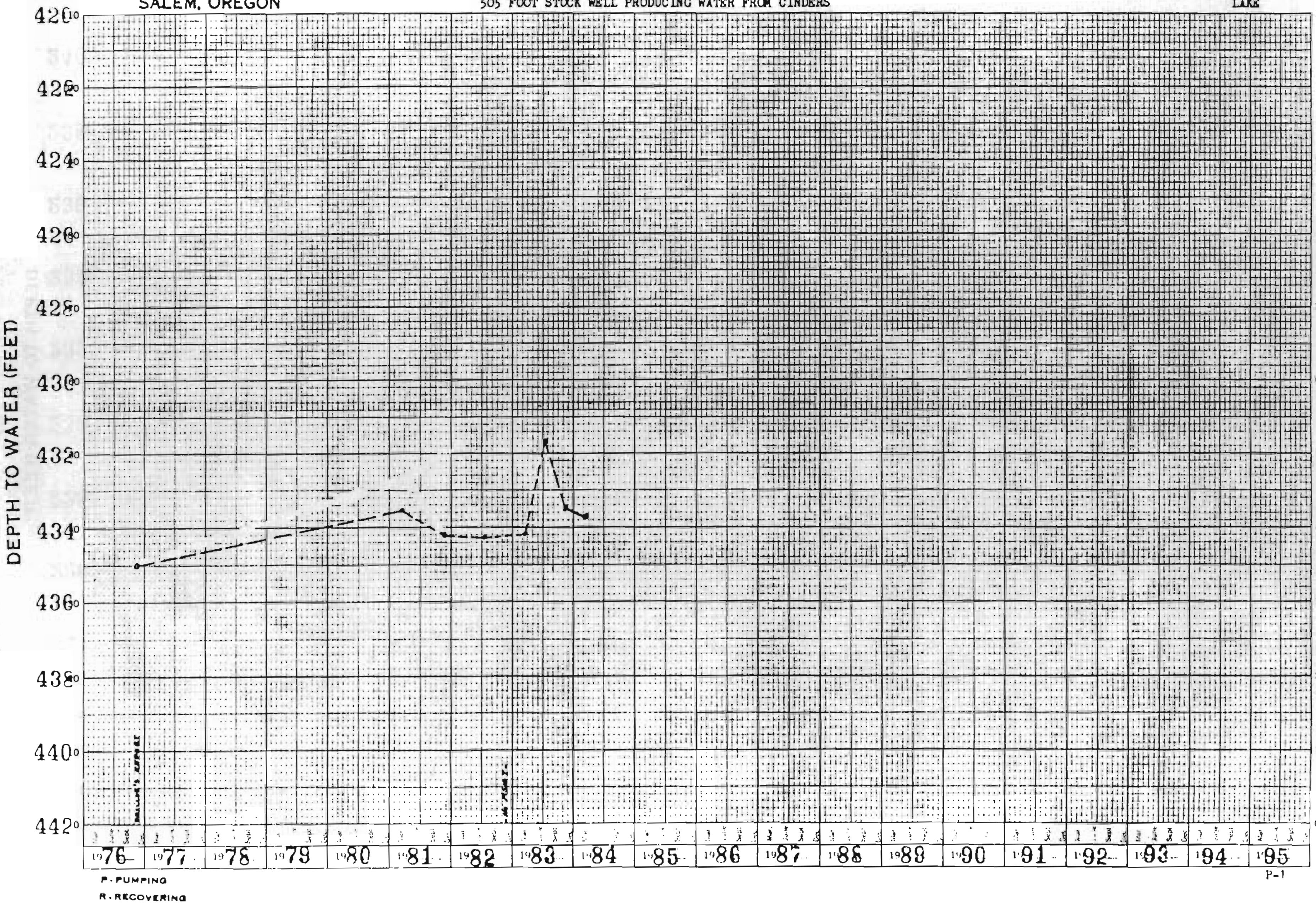
APPENDIX III

Well Hydrographs

WATER RESOURCES DEPT
SALEM, OREGON

505 FOOT STOCK WELL PRODUCING WATER FROM CINDERS

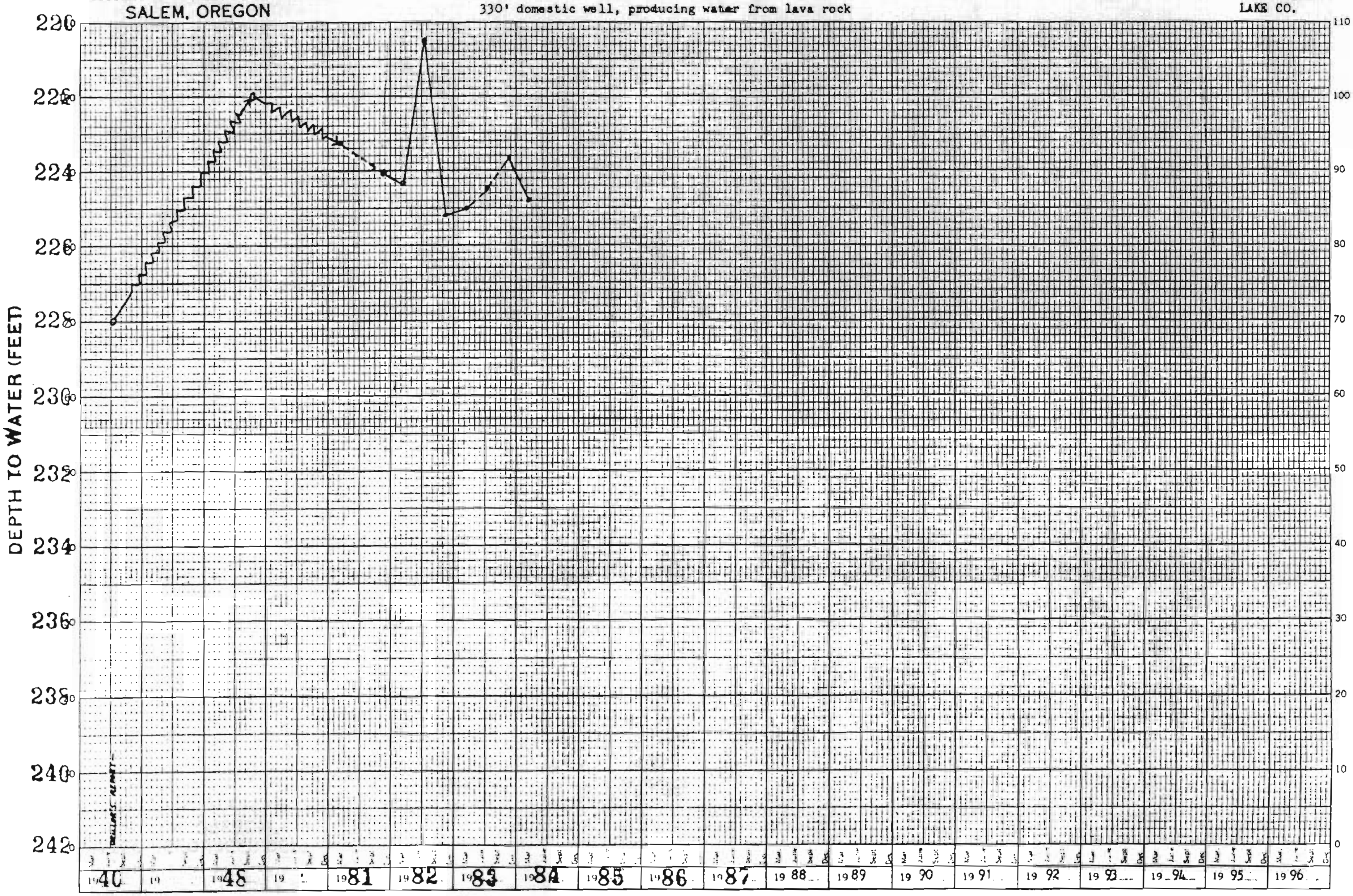
23/16-35cd
LAKE



WATER RESOURCES DEPT
SALEM, OREGON

330' domestic well, producing water from lava rock

24/14-17aa da
LAKE CO.



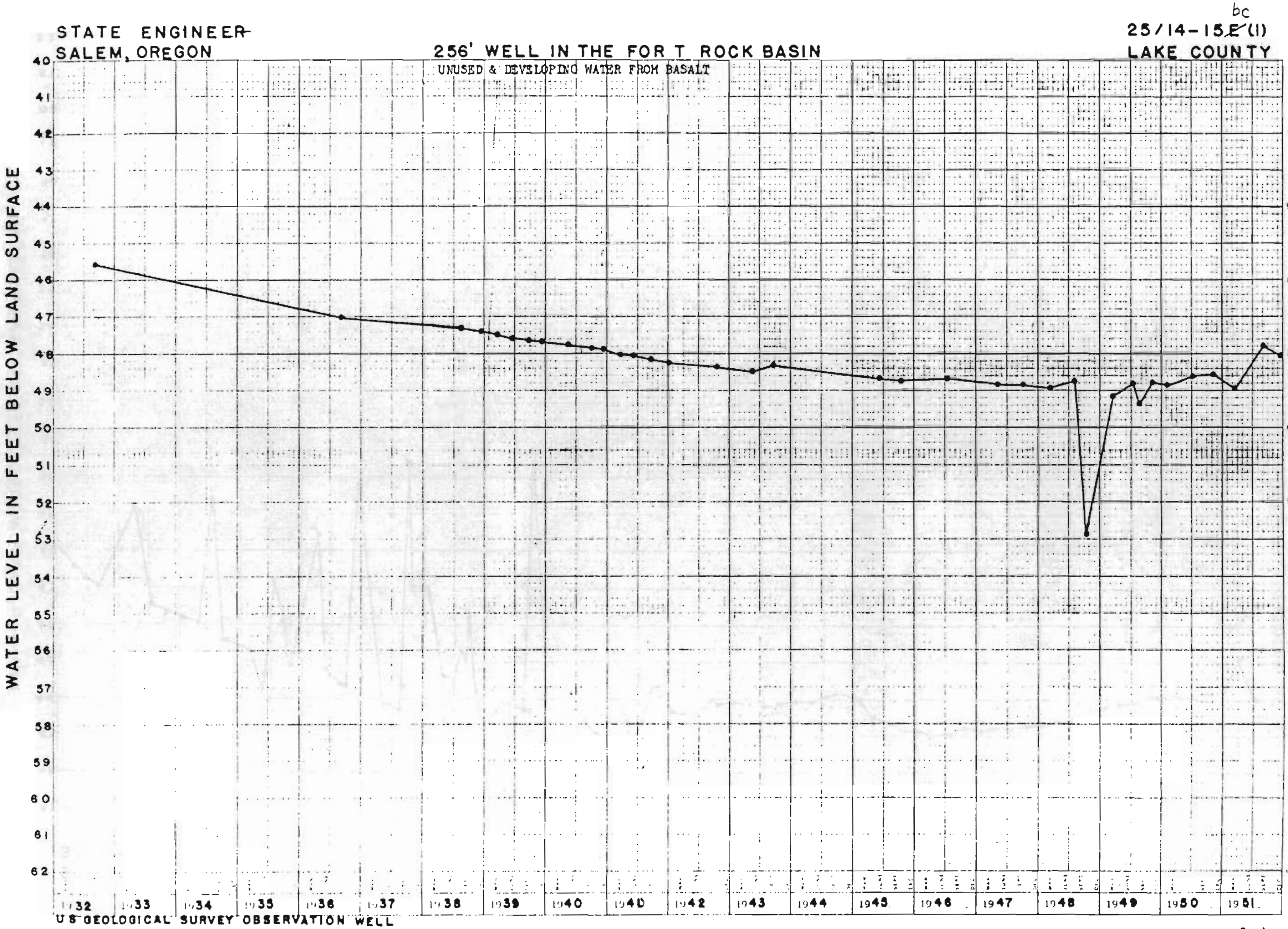
P-PUMPING
R-RECOVERING

P-1

K·E 2½ YEARS BY MONTHS X 110 DIVISIONS

74

47 3853


STATE ENGINEER
SALEM, OREGON
256' WELL IN THE FORT ROCK BASIN
UNUSED & DEVELOPING WATER FROM BASALT
25/14-15bc(1)
LAKE COUNTY
WATER LEVEL IN FEET BELOW LAND SURFACE
40
41
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1932
1933
1934
1935
1936
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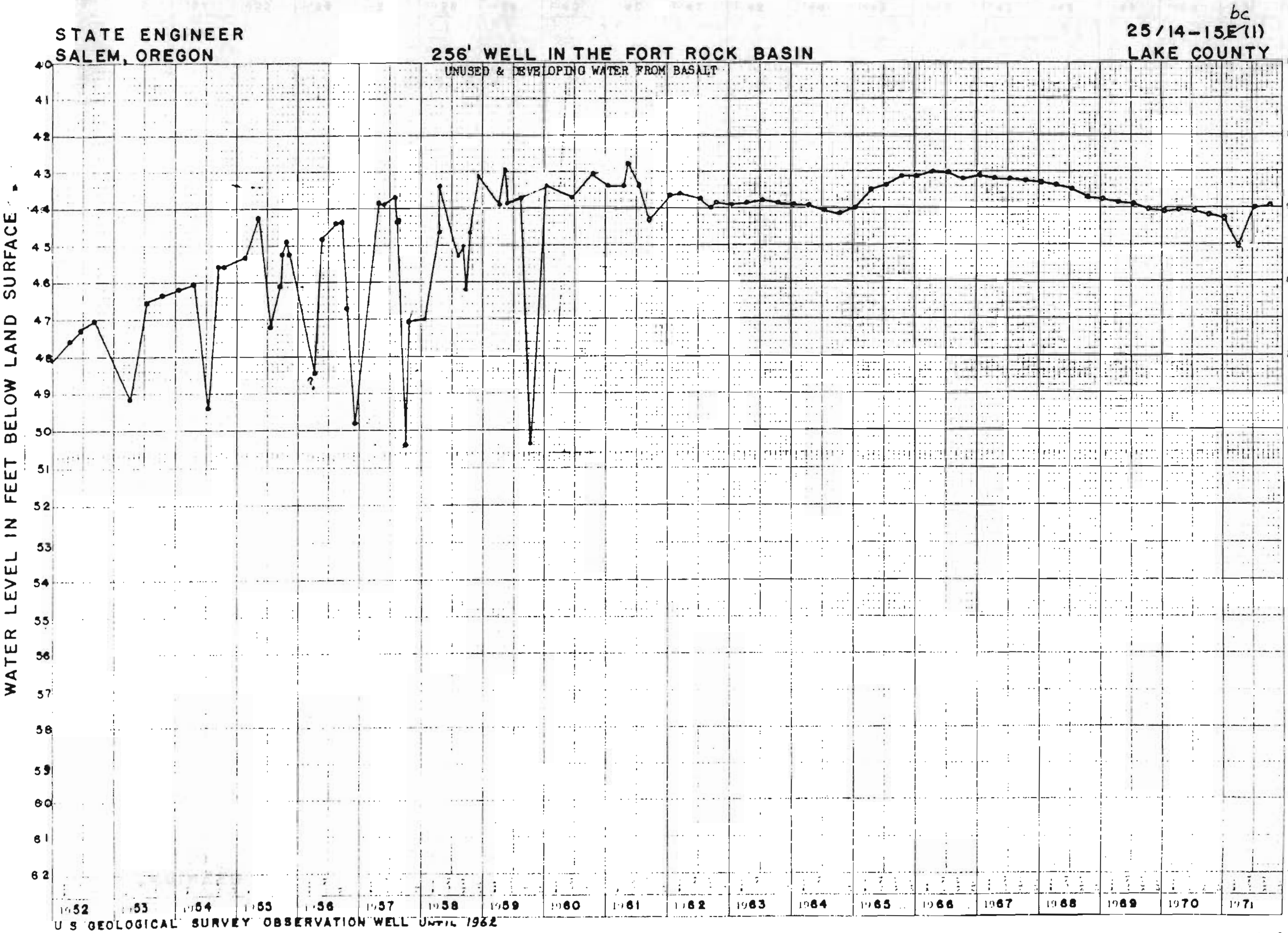
1951
US GEOLOGICAL SURVEY OBSERVATION WELL

p-1


STATE ENGINEER
SALEM, OREGON
256' WELL IN THE FORT ROCK BASIN
UNUSED & DEVELOPING WATER FROM BASALT
bc
25/14-15E(1)
LAKE COUNTY
WATER LEVEL IN FEET BELOW LAND SURFACE
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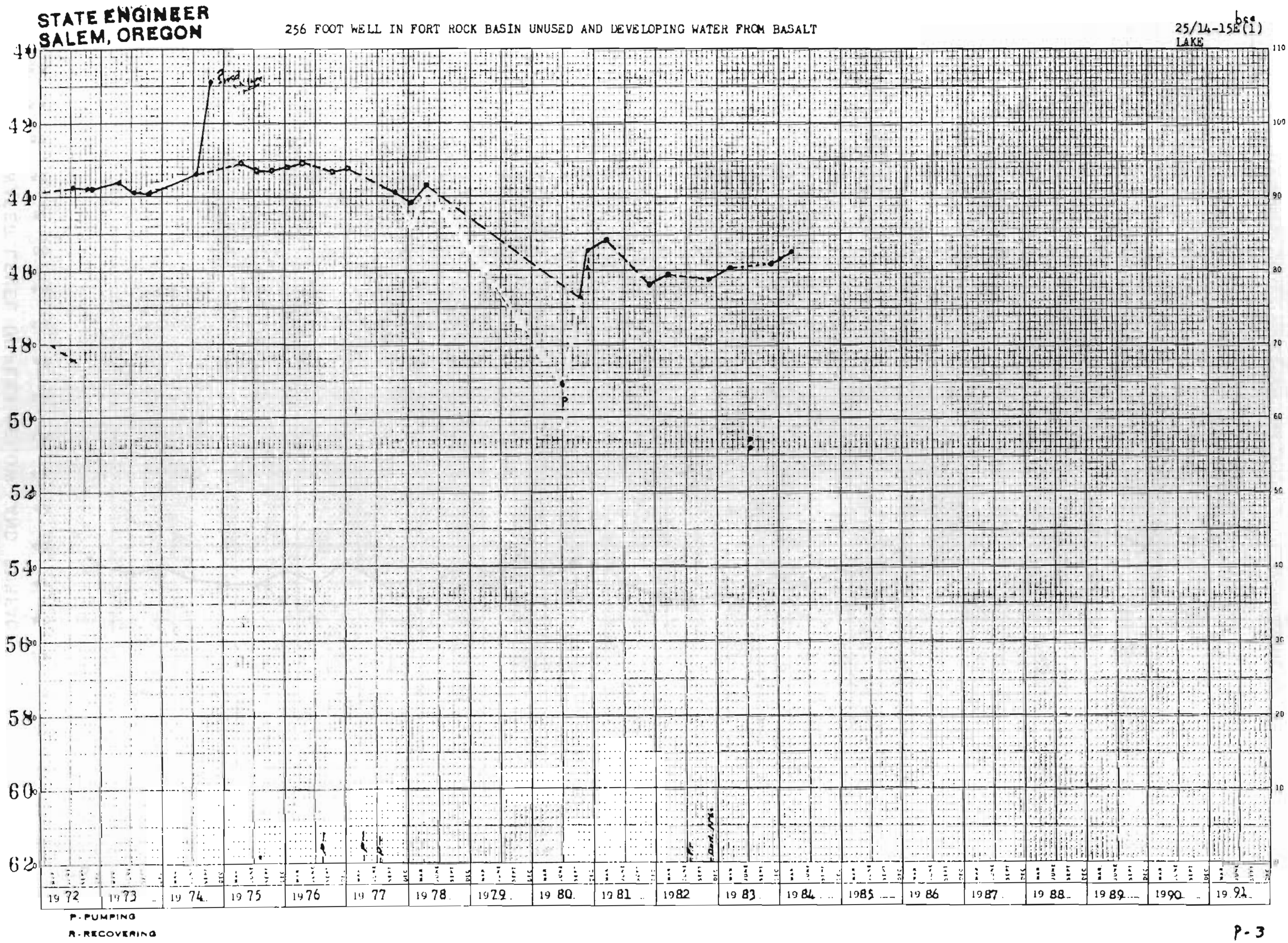
U S GEOLOGICAL SURVEY OBSERVATION WELL UNTIL 1962

76


STATE ENGINEER
SALEM, OREGON
256 FOOT WELL IN FORT ROCK BASIN UNUSED AND DEVELOPING WATER FROM BASALT
25/14-15E(1)
LAKE
DEPTH TO WATER (FEET)
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1972
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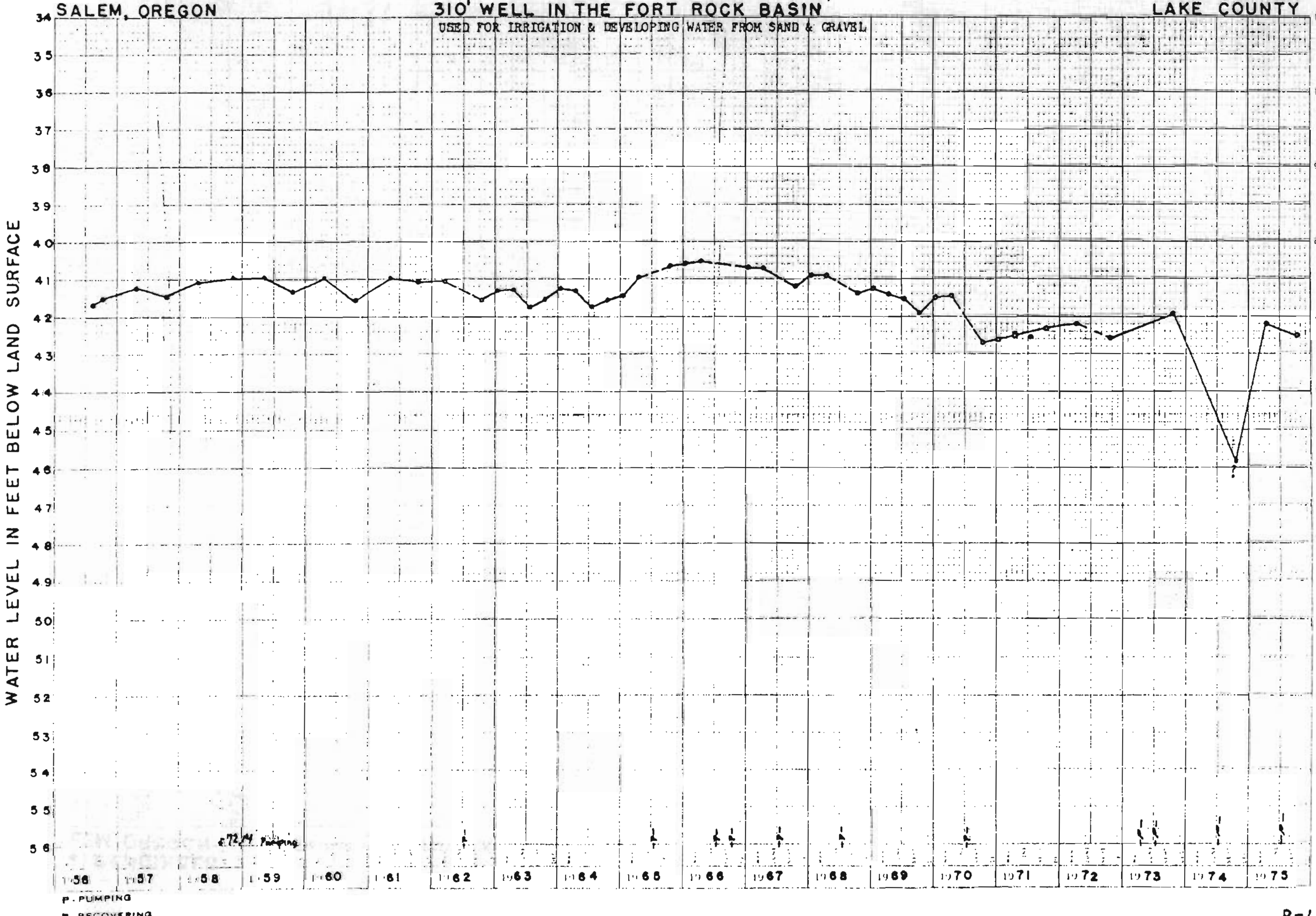
1990
1991
P - PUMPING
R - RECOVERING

P-3

STATE ENGINEER
SALEM, OREGON

25/14-29da(1)
LAKE COUNTY



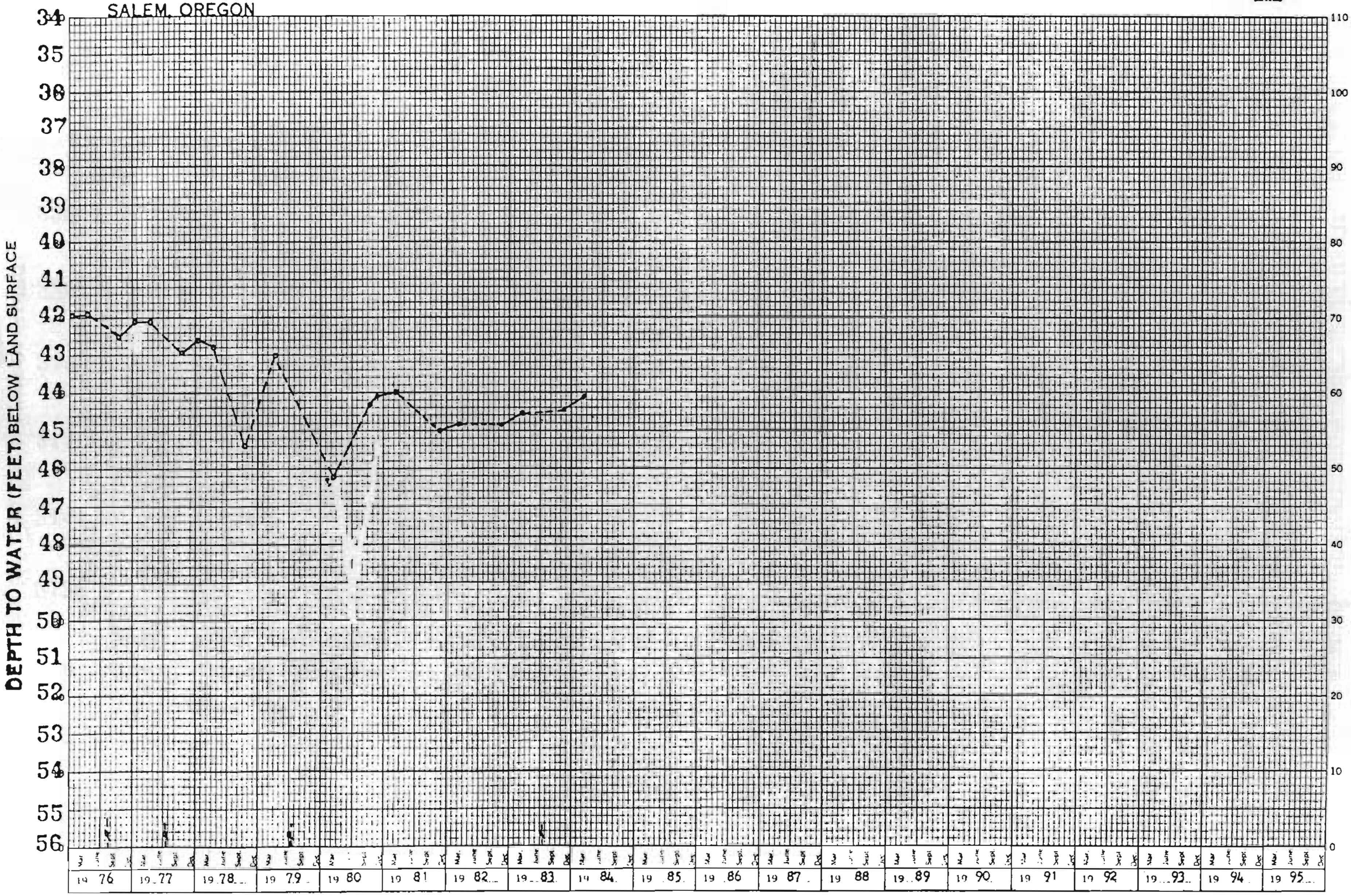
78

P-1

WATER RESOURCES DEPT
SALEM, OREGON

310 FOOT IRRIGATION WELL IN FORT ROCK BASIN DEVELOPING WATER FROM SAND AND GRAVEL

25/14-29da
LAKE



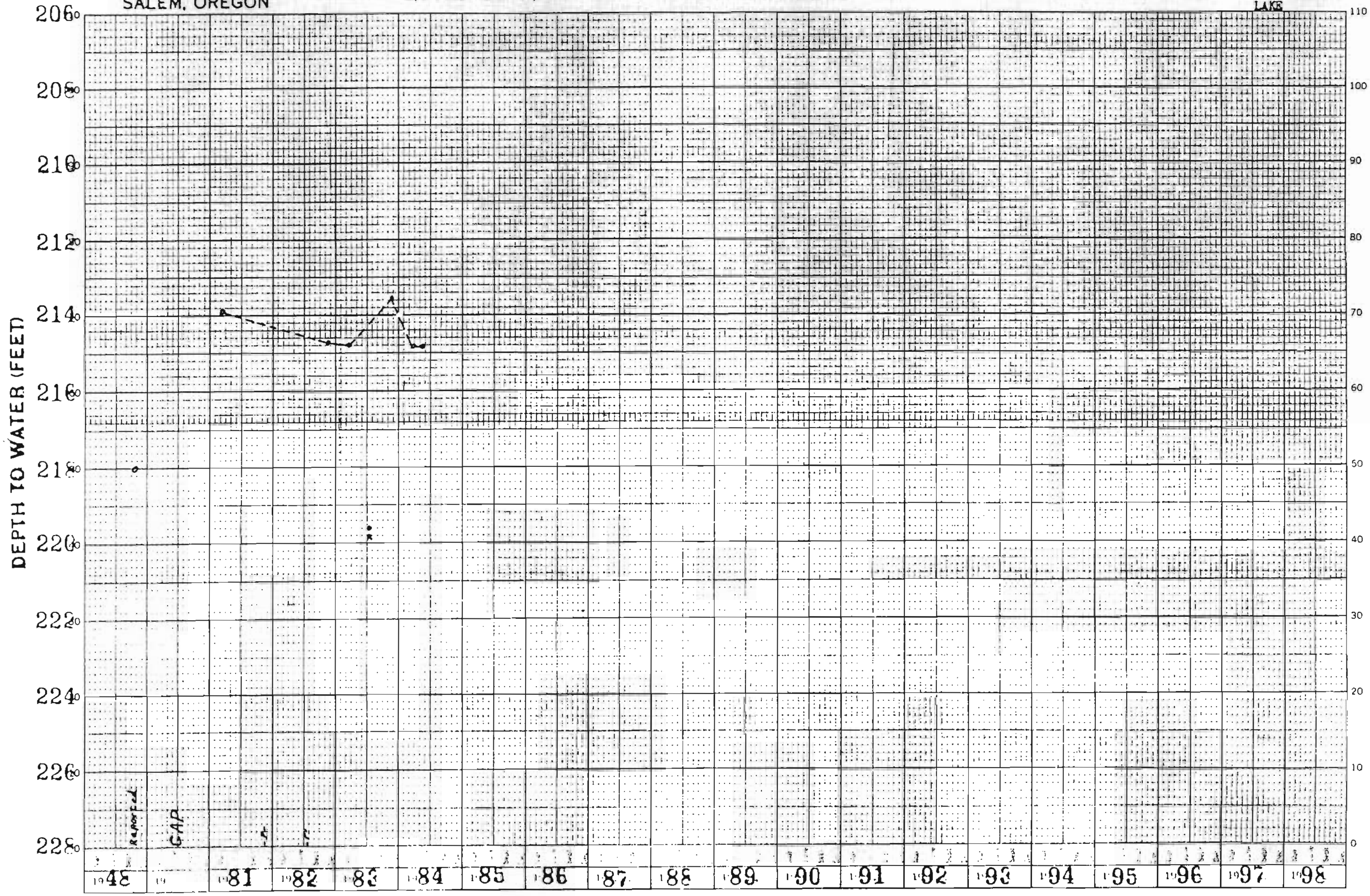
P - PUMPING
R - RECOVERING

p-2

WATER RESOURCES DEPT
SALEM, OREGON

278 FOOT DOMESTIC/STOCK WELL PRODUCING WATER FROM QUICKSAND

25/16-26bcb
LAKE



P - PUMPING
R - RECOVERING

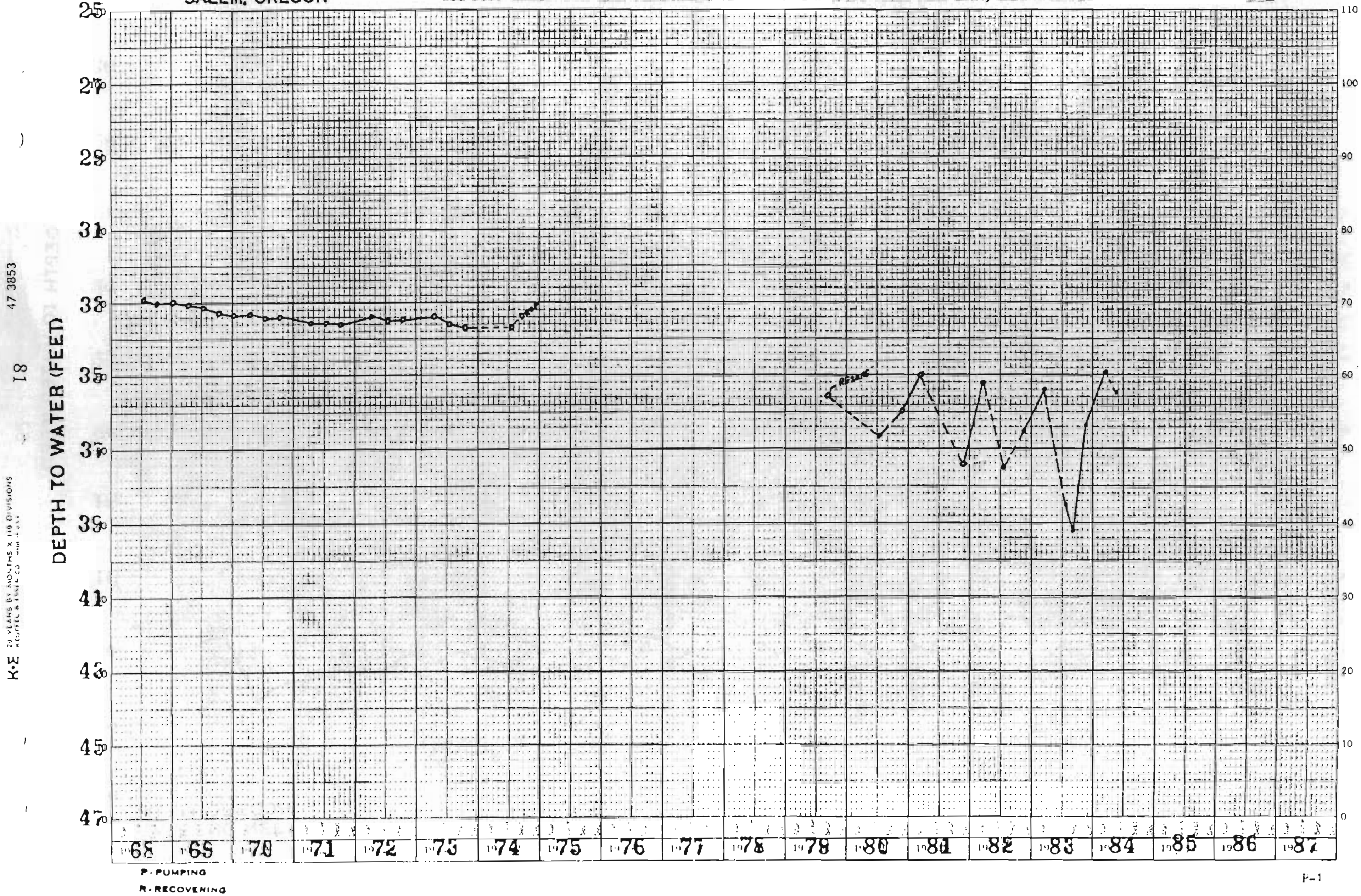
P-1

K·E 47 3853

WATER RESOURCES DEPT
SALEM, OREGON

260 FOOT UNUSED WELL NEAR CHRISTMAS LAKE VALLEY DEVELOPING WATER FROM LAVA, SAND & GRAVEL

25/18-9cc
LAKE

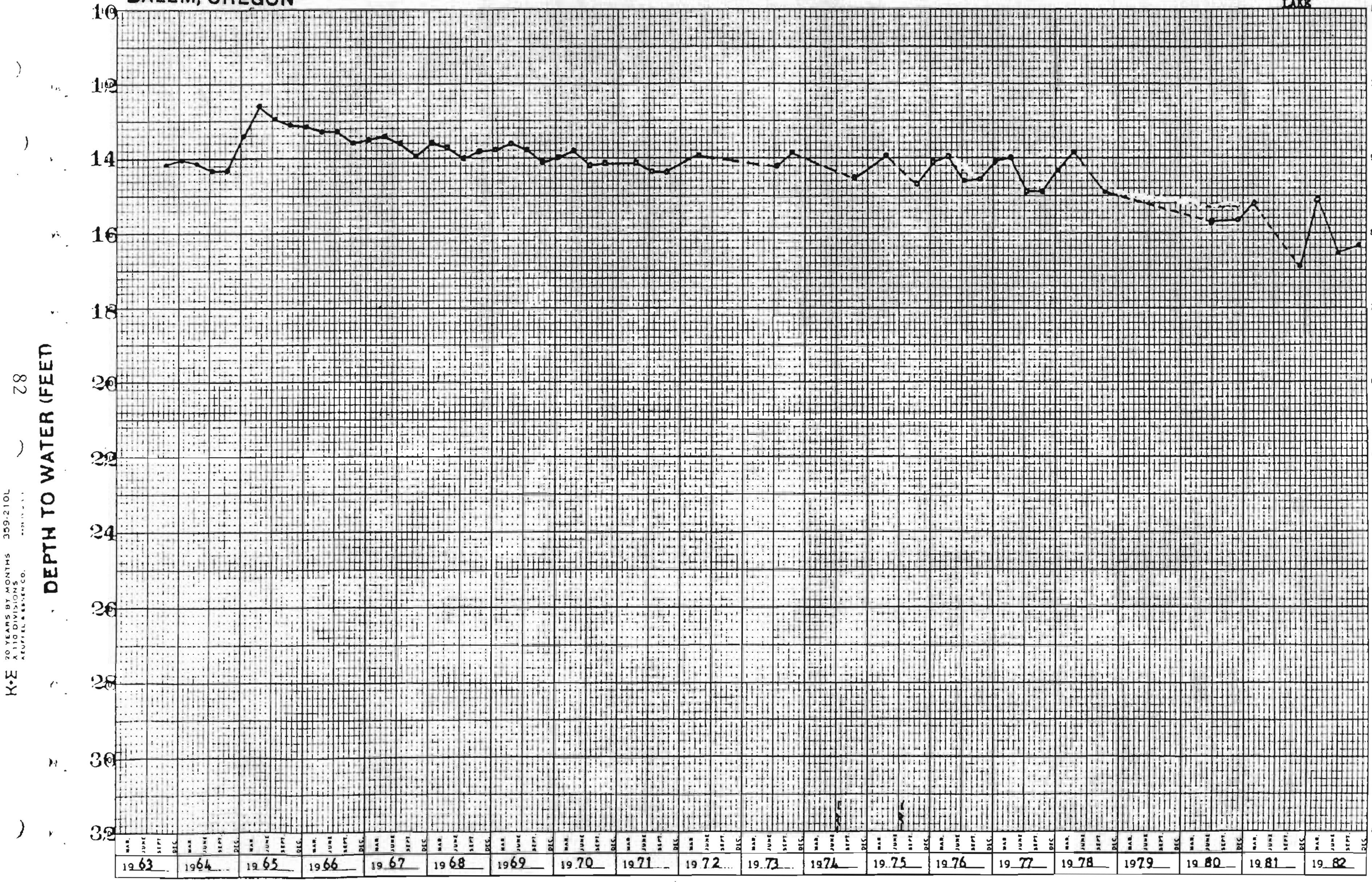


F-1

STATE ENGINEER
SALEM, OREGON

225 FOOT IRRIGATION WELL NEAR CHRISTMAS LAKE VALLEY DEVELOPING WATER FROM HARD GRAVEL

25/19-31Q(1) dc
LAKE



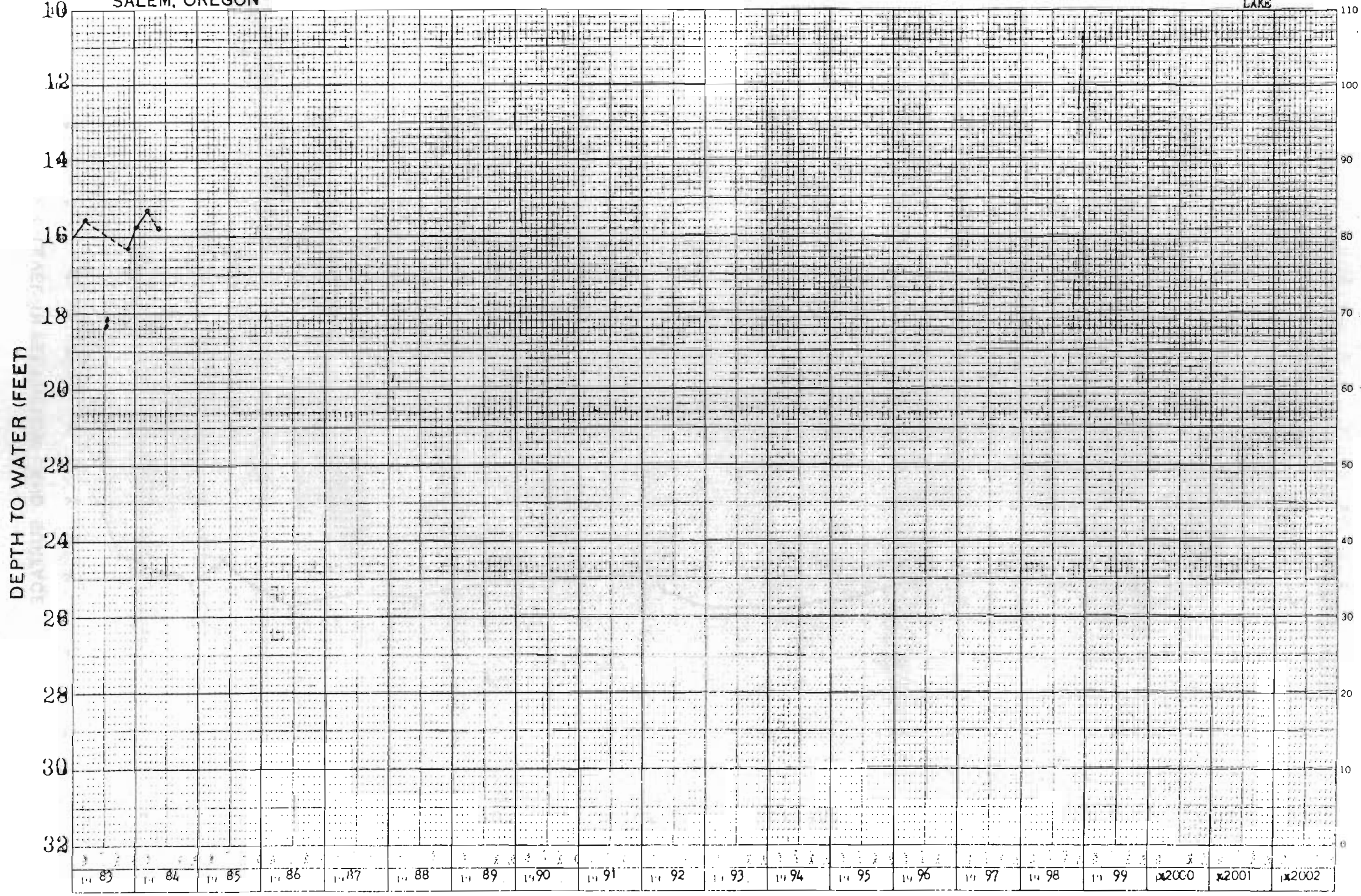
P. PUMPING
R. RECOVERING

p-1

WATER RESOURCES DEPT
SALEM, OREGON

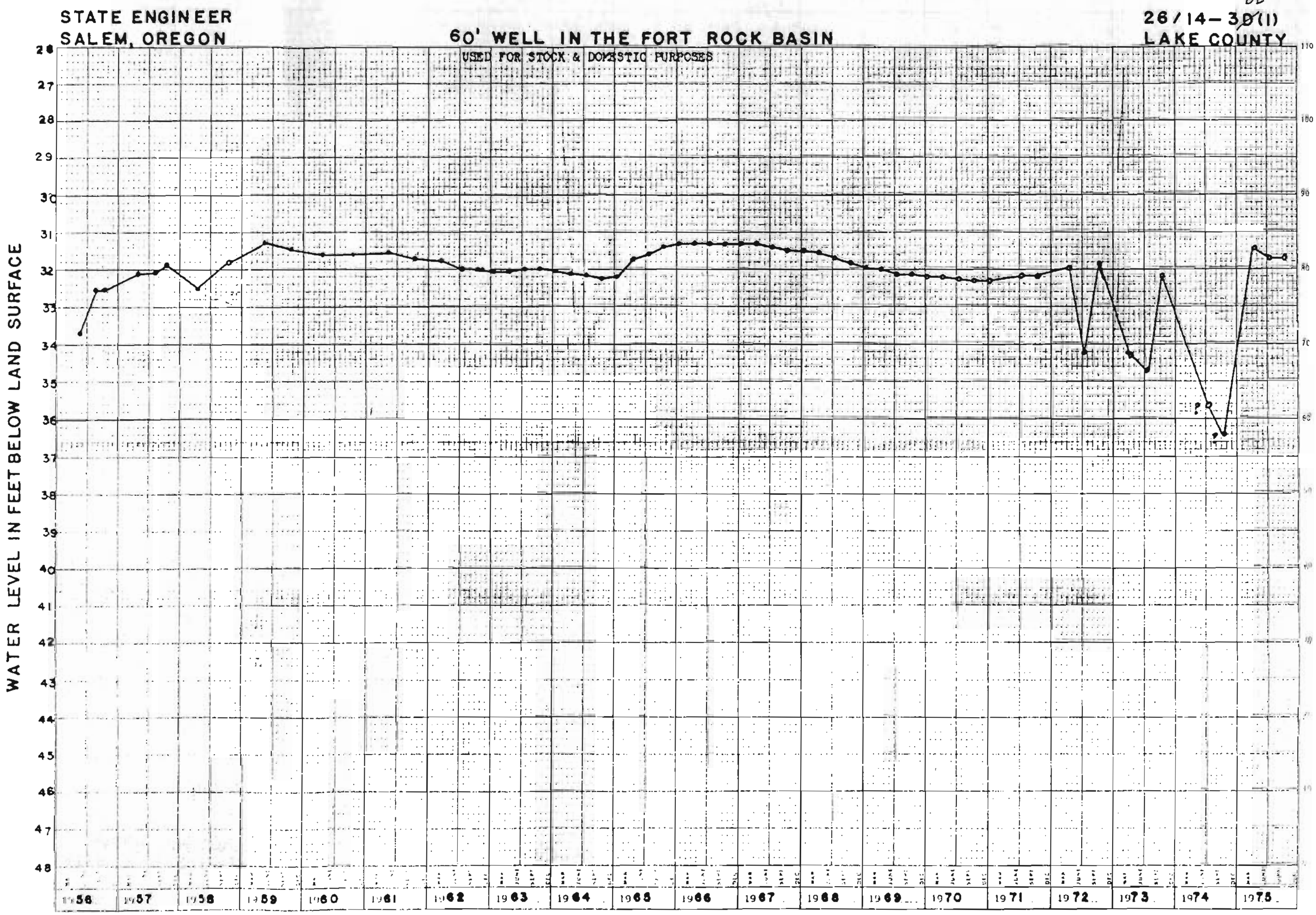
225 FOOT IRRIGATION WELL NEAR CHRISTMAS LAKE VALLEY DEVELOPING WATER FROM HARD GRAVEL

25S/19E-dc (Q1)
LAKE



P-PUMPING
R-RECOVERING

P-2



STATE ENGINEER
SALEM, OREGON
60' WELL IN THE FORT ROCK BASIN
USED FOR STOCK & DOMESTIC PURPOSES
26/14-3bb(1)
LAKE COUNTY
WATER LEVEL IN FEET BELOW LAND SURFACE
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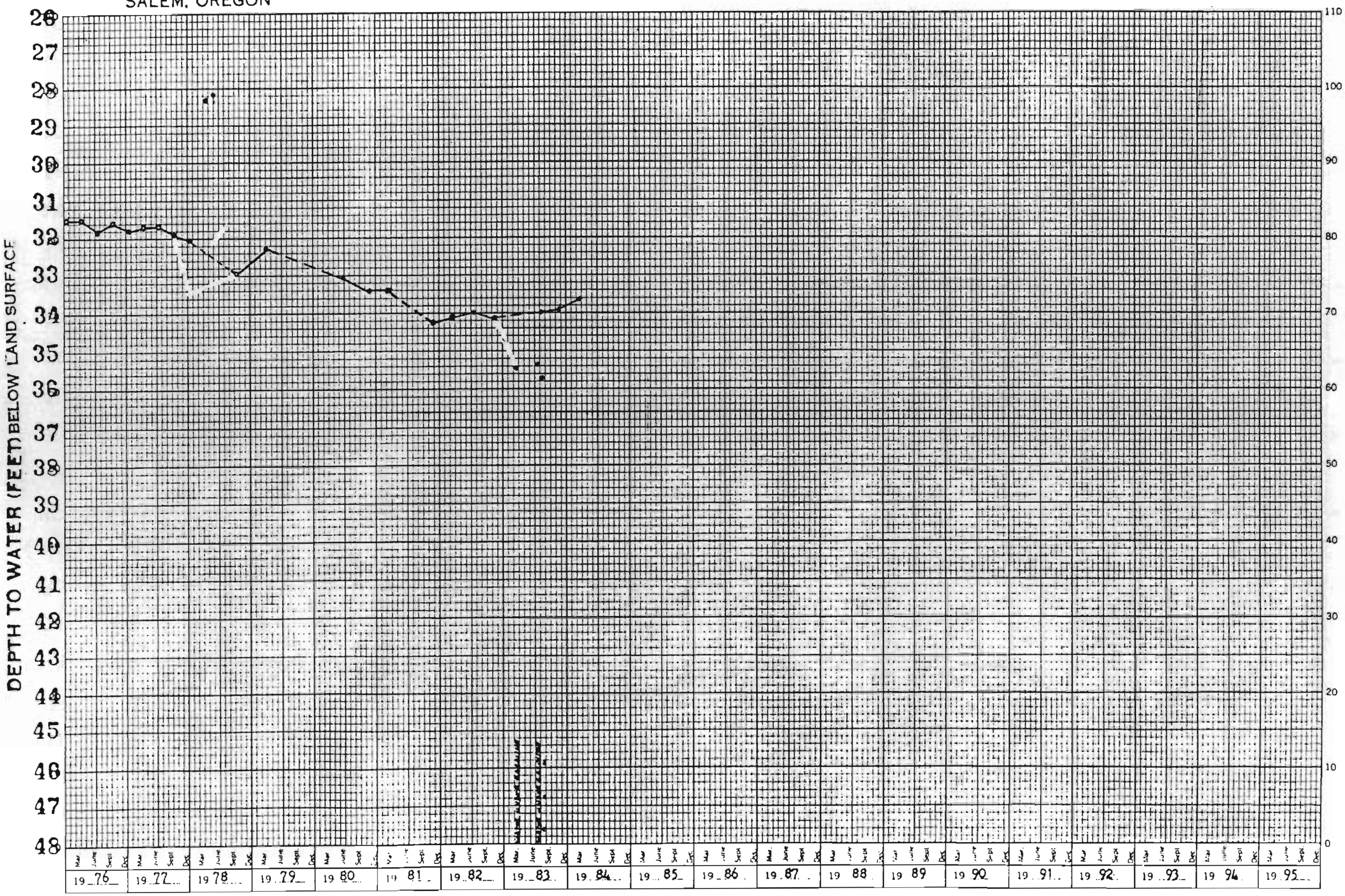
P-1

WATER RESOURCES DEPT
SALEM, OREGON

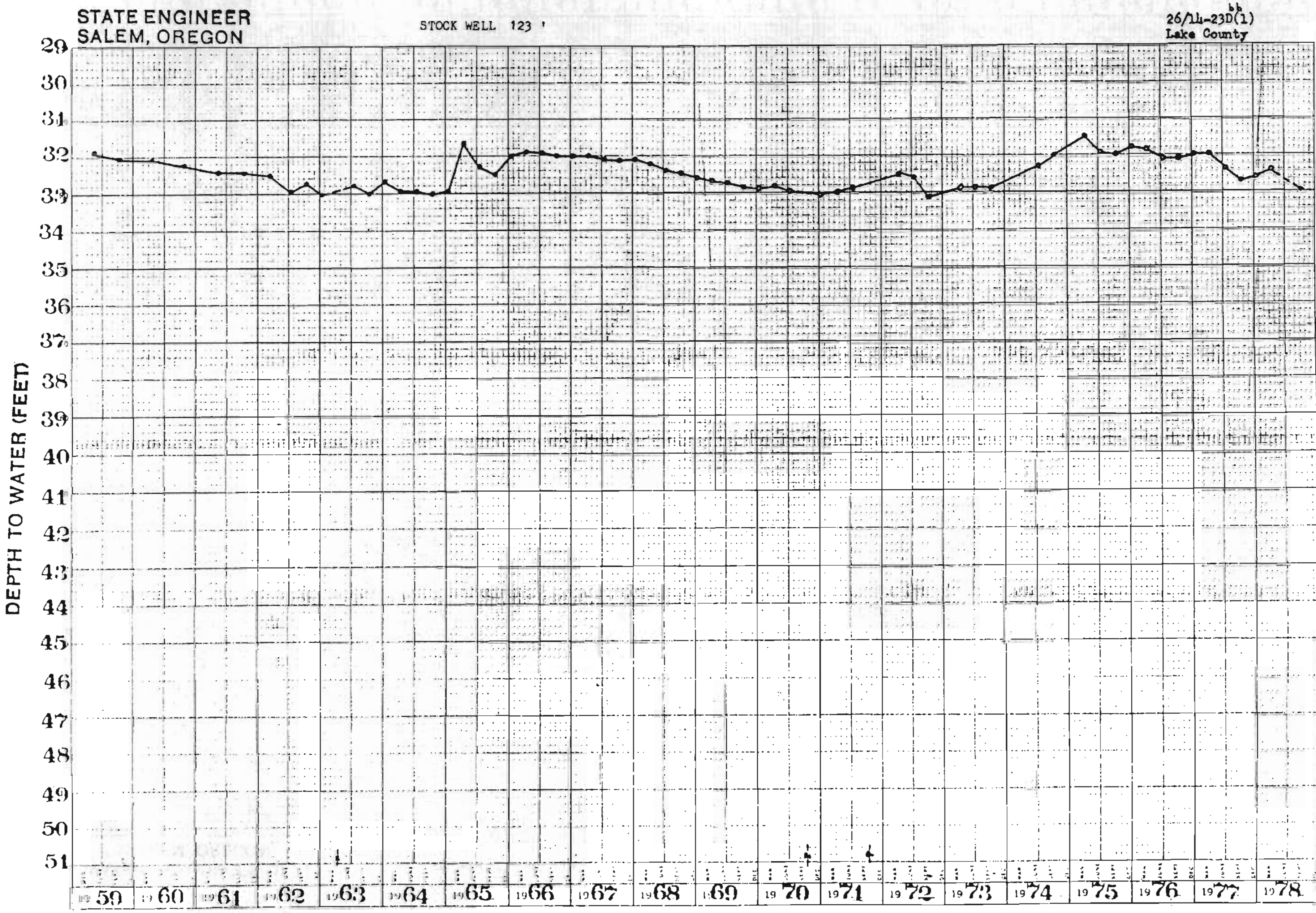
60 FOOT DOMESTIC WELL IN FORT ROCK BASIN

26/14-3bb (D1)
LAKE



P - PUMPING
R - RECOVERING

P-2



STATE ENGINEER
SALEM, OREGON
STOCK WELL 123 '
26/14-23D(1)
Lake County
DEPTH TO WATER (FEET)
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1978

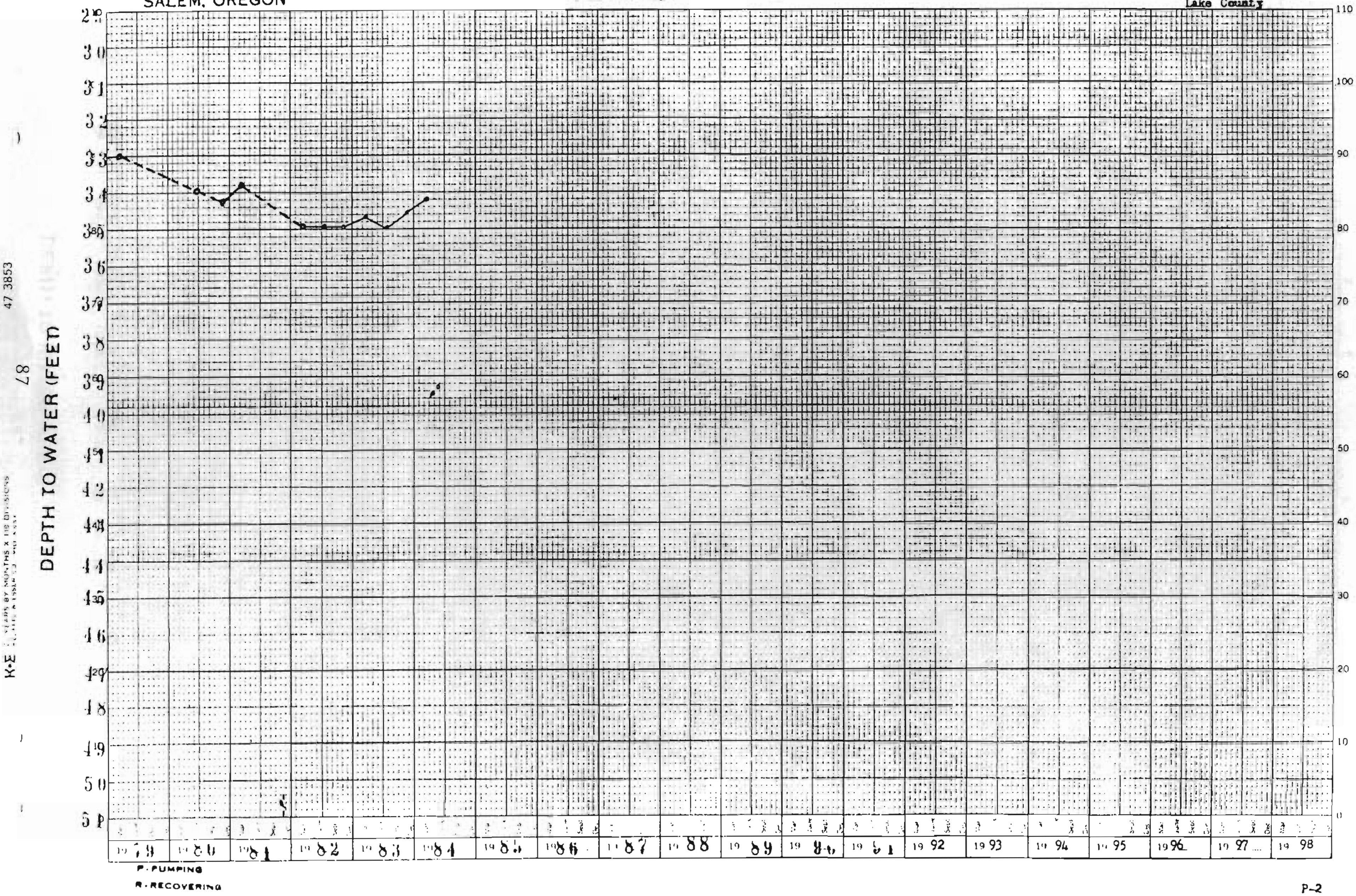
98

P-1

WATER RESOURCES DEPT
SALEM, OREGON

STOCK WELL 123'

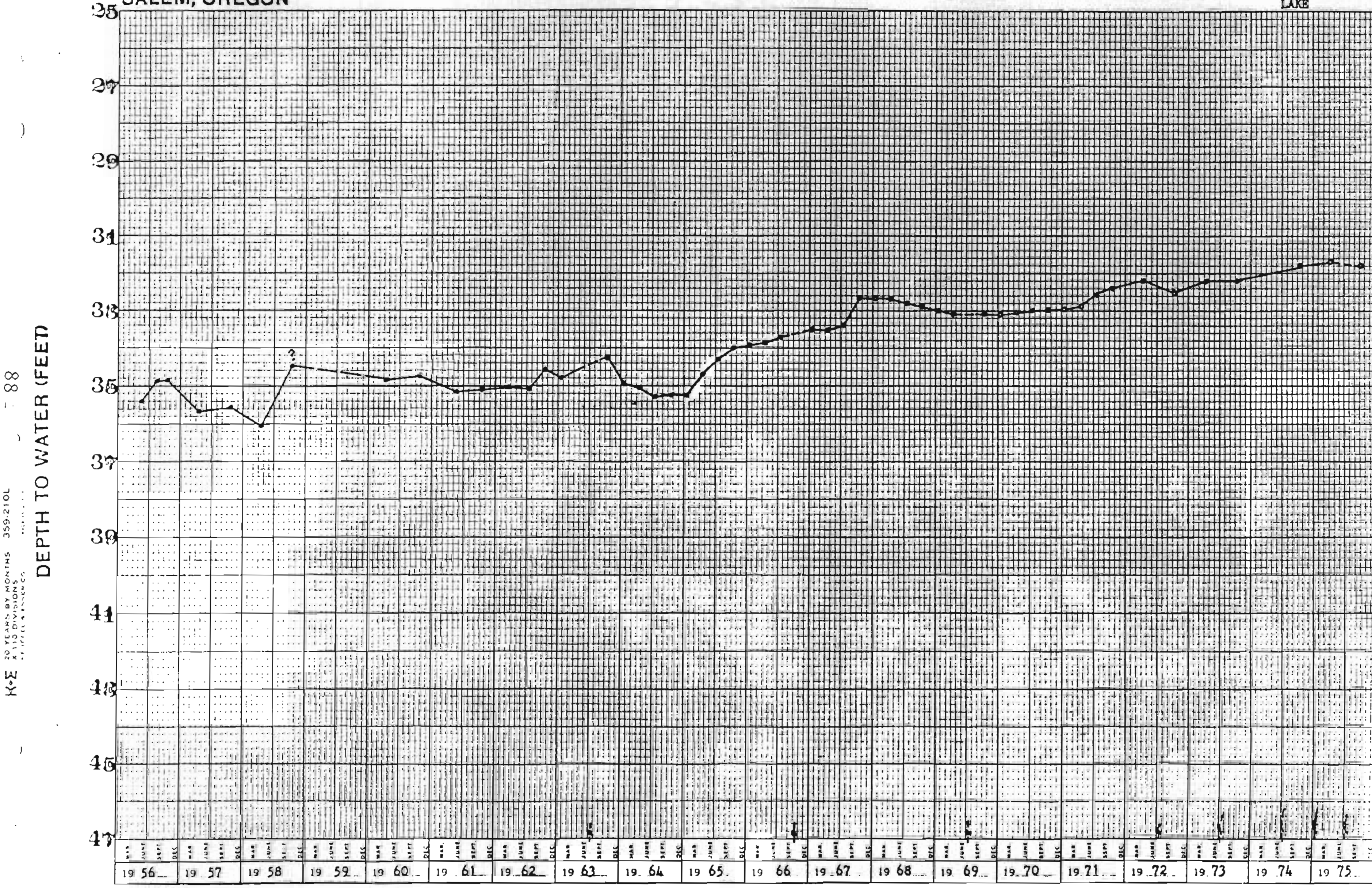
26/14-23bb
Lake County



STATE ENGINEER
SALEM, OREGON

317 FOOT IRRIGATION WELL ABOUT 3½ MILES EAST OF FORT ROCK DEVELOPING WATER FROM TUFF, SAND & GRAVEL

26/15-6ab(1)
LAKE



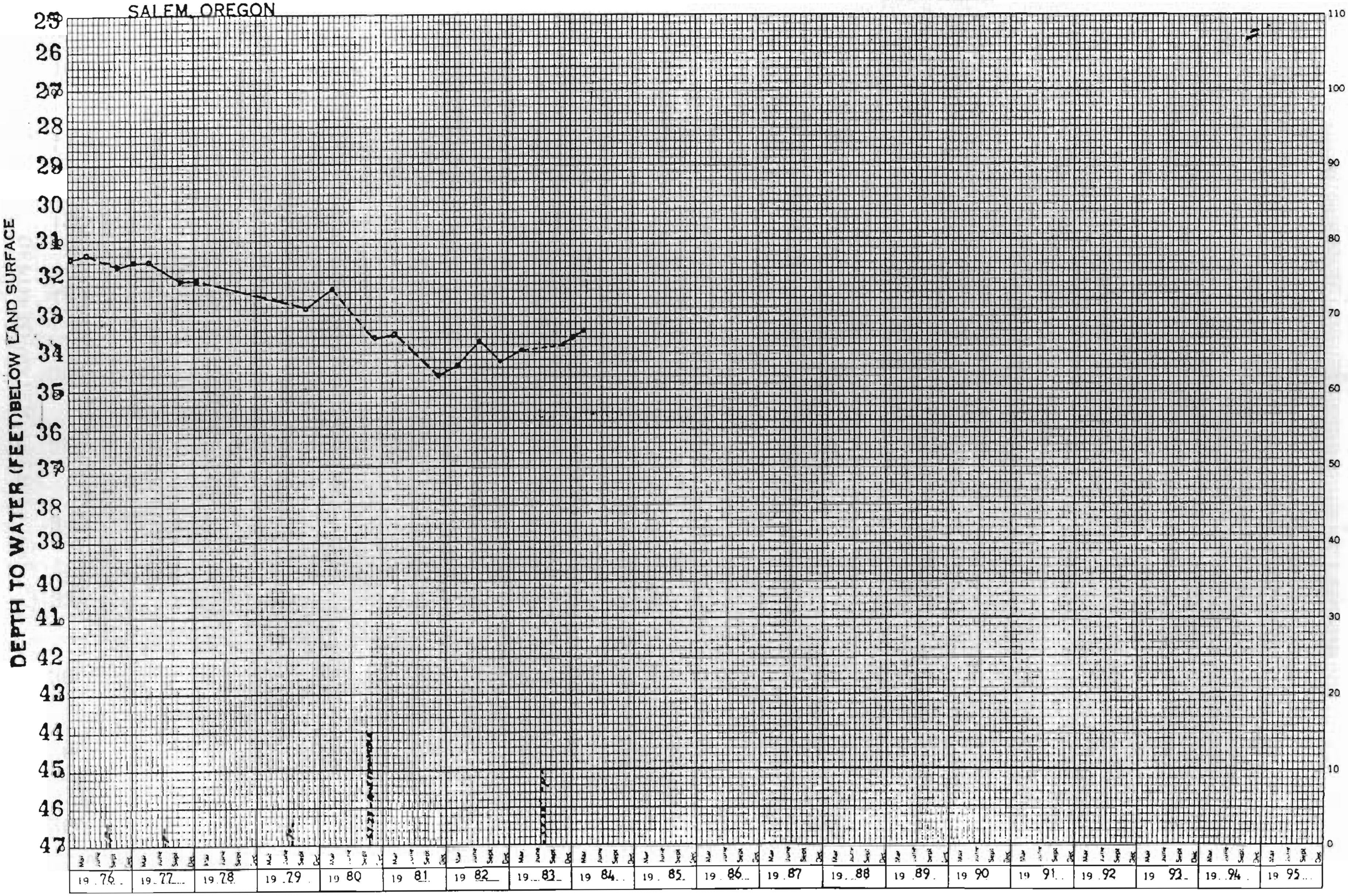
P - PUMPING
R - RECOVERING

P-1

WATER RESOURCES DEPT
SALEM, OREGON

317 FOOT IRRIGATION WELL ABOUT 3½ MILES EAST OF FORT ROCK DEVELOPING WATER FROM TUFF, SAND & GRAVEL

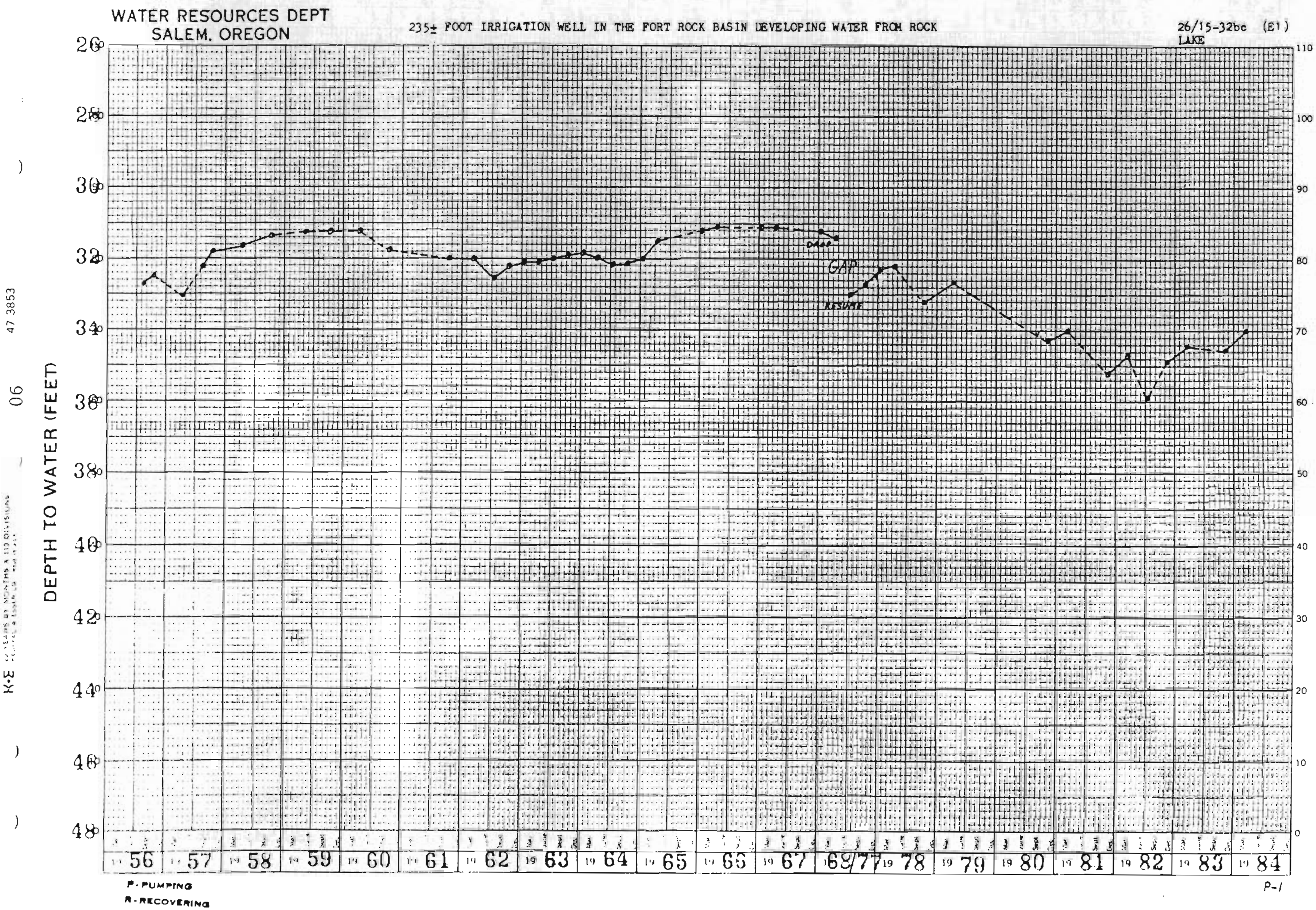
26/15-6ab (81)
LAKE



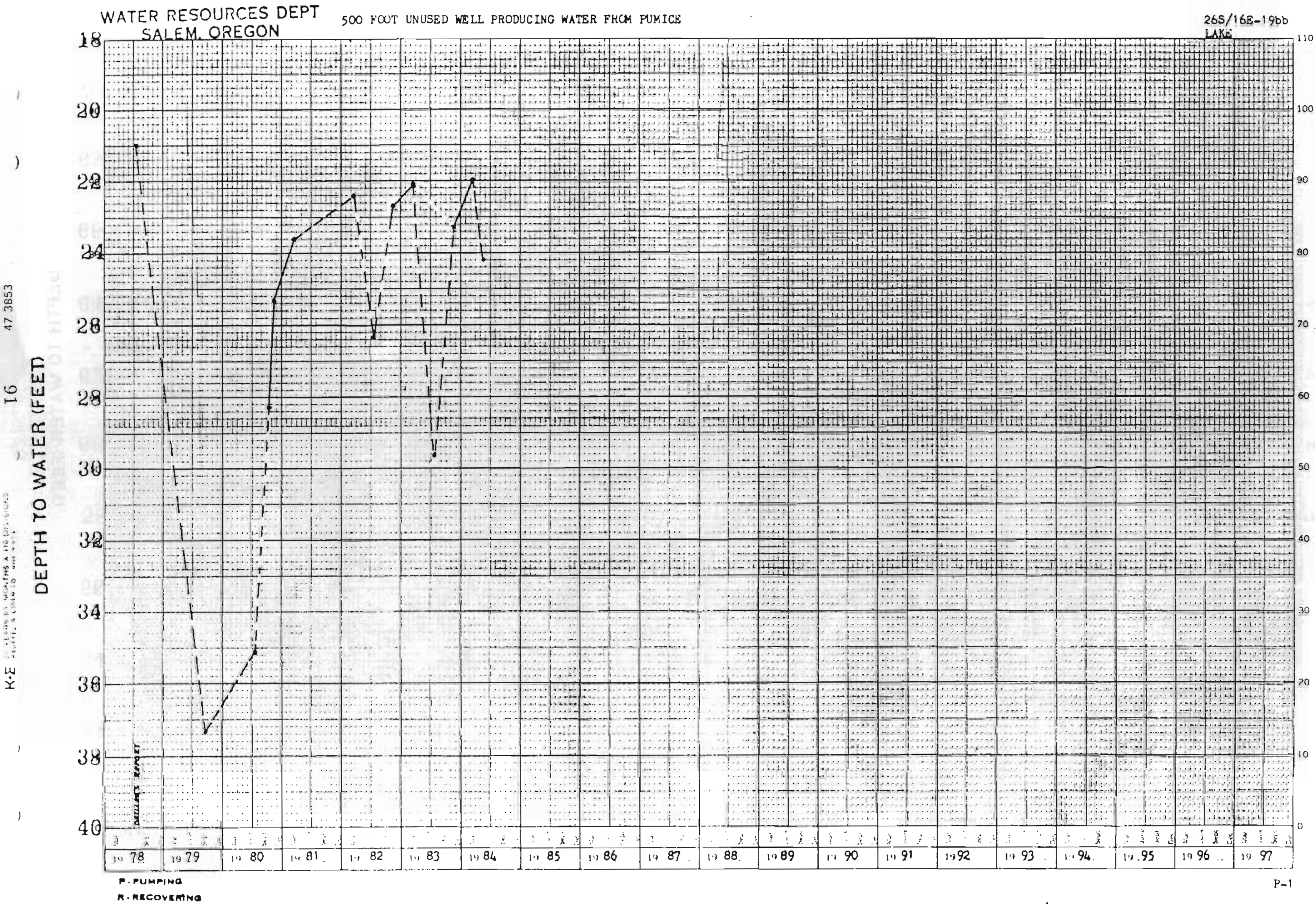
P-PUMPING
R-RECOVERING

K·E 20 YEARS BY MONTHS X 110 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 47 3853

P-2



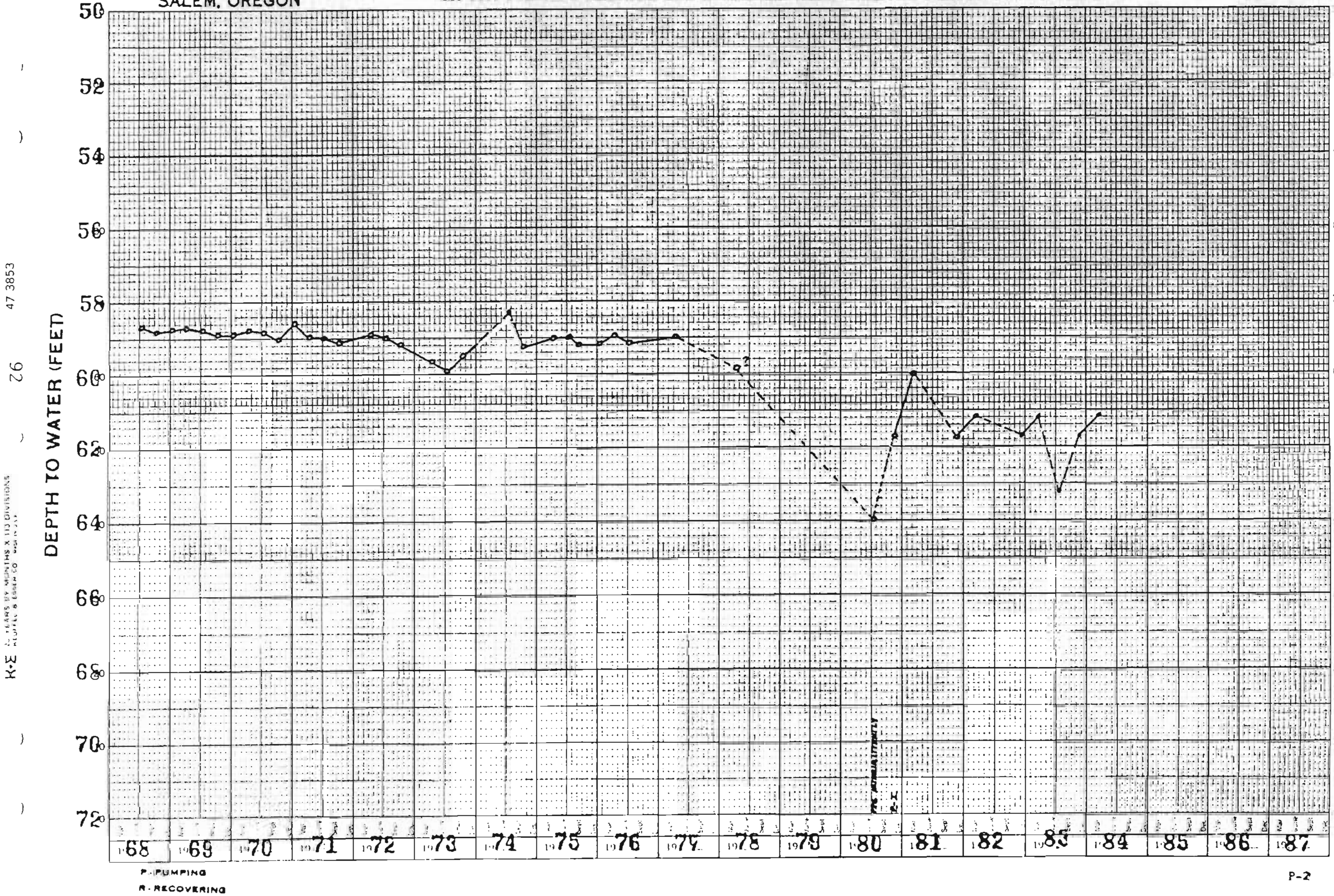
WATER RESOURCES DEPT
SALEM, OREGON
235± FOOT IRRIGATION WELL IN THE FORT ROCK BASIN DEVELOPING WATER FROM ROCK
26/15-32bc (E1)
LAKE
DEPTH TO WATER (FEET)
26
28
30
32
34
36
38
40
42
44
46
48
110
100
90
80
70
60
50
40
30
20
10
0
GAP
RESUME
56
57
58
59
60
61
62
63
64
65
66
67
69/77
78
79
80
81
82
83
84
P-PUMPING
R-RECOVERING
P-1


WATER RESOURCES DEPT
SALEM, OREGON
500 FOOT UNUSED WELL PRODUCING WATER FROM PUMICE
26S/16E-19bb
LAKE
DEPTH TO WATER (FEET)
18
20
22
24
26
28
30
32
34
36
38
40
110
100
90
80
70
60
50
40
30
20
10
0
DRILLER'S REPORT
19 78
19 79
19 80
19 81
19 82
19 83
19 84
19 85
19 86
19 87
19 88
19 89
19 90
19 91
19 92
19 93
19 94
19 95
19 96
19 97
P - PUMPING
R - RECOVERING
P-1
K·E 47 3853

WATER RESOURCES DEPT
SALEM, OREGON

220 FOOT DOMESTIC & IRRIGATION WELL IN CHRISTMAS VALLEY DEVELOPING WATER FROM SAND & GRAVEL

26/18-8ad
LAKE

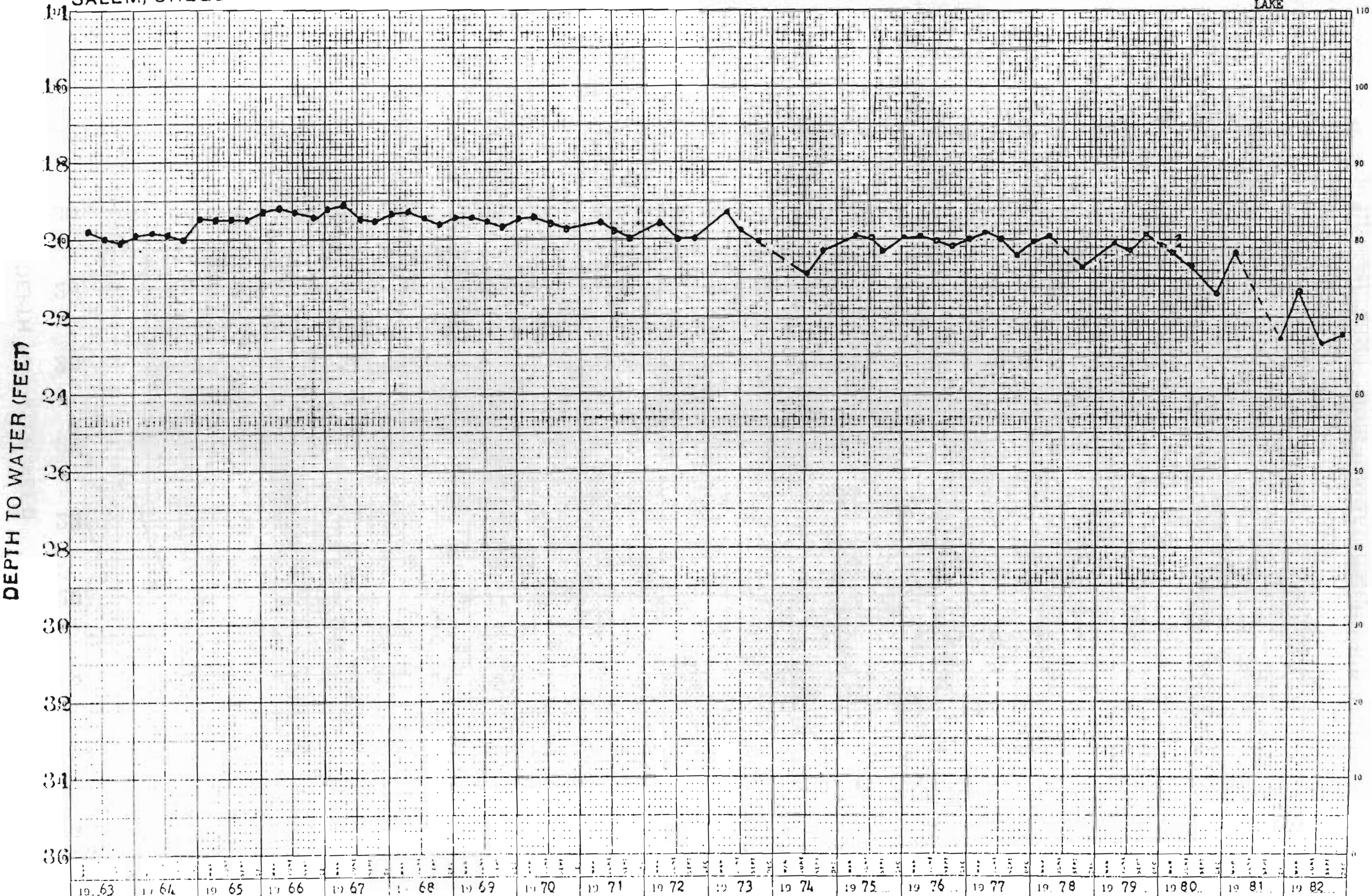


P-2

STATE ENGINEER
SALEM, OREGON

*275 FOOT IRRIGATION WELL IN CHRISTMAS VALLEY DEVELOPING WATER FROM LAKE SEDIMENTS.

26/18-26B(1) ab
LAKE

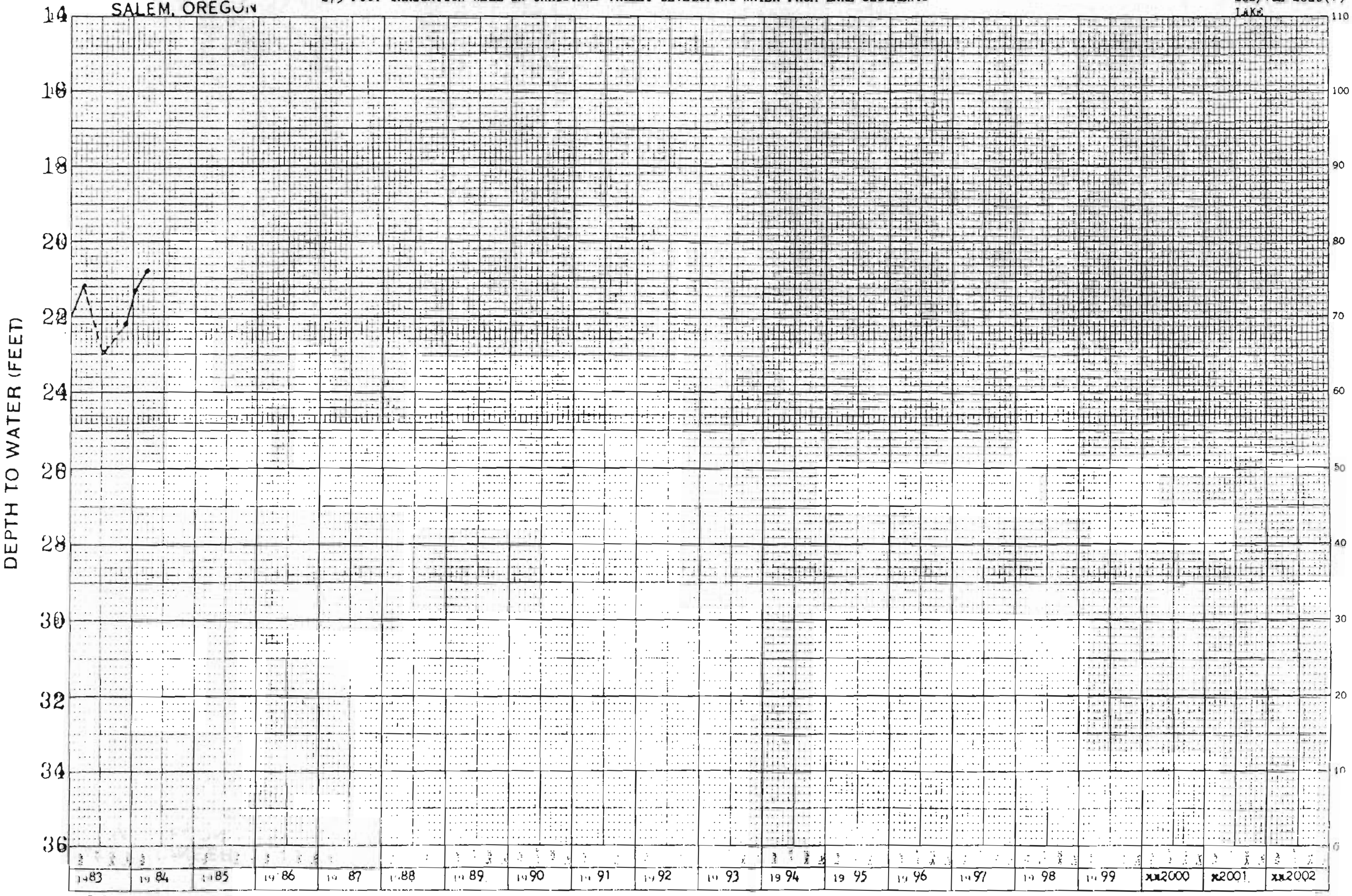


*- CAVED IN TO ± 81' (1-18-66)

WATER RESOURCES DEPT
SALEM, OREGON

*275 FOOT IRRIGATION WELL IN CHRISTMAS VALLEY DEVELOPING WATER FROM LAKE SEDIMENTS

26S/18E-26ab(1)
LAKE



P-PUMPING
R-RECOVERING

+ CAVED IN TO ± 81' (1-16-66)

P-2

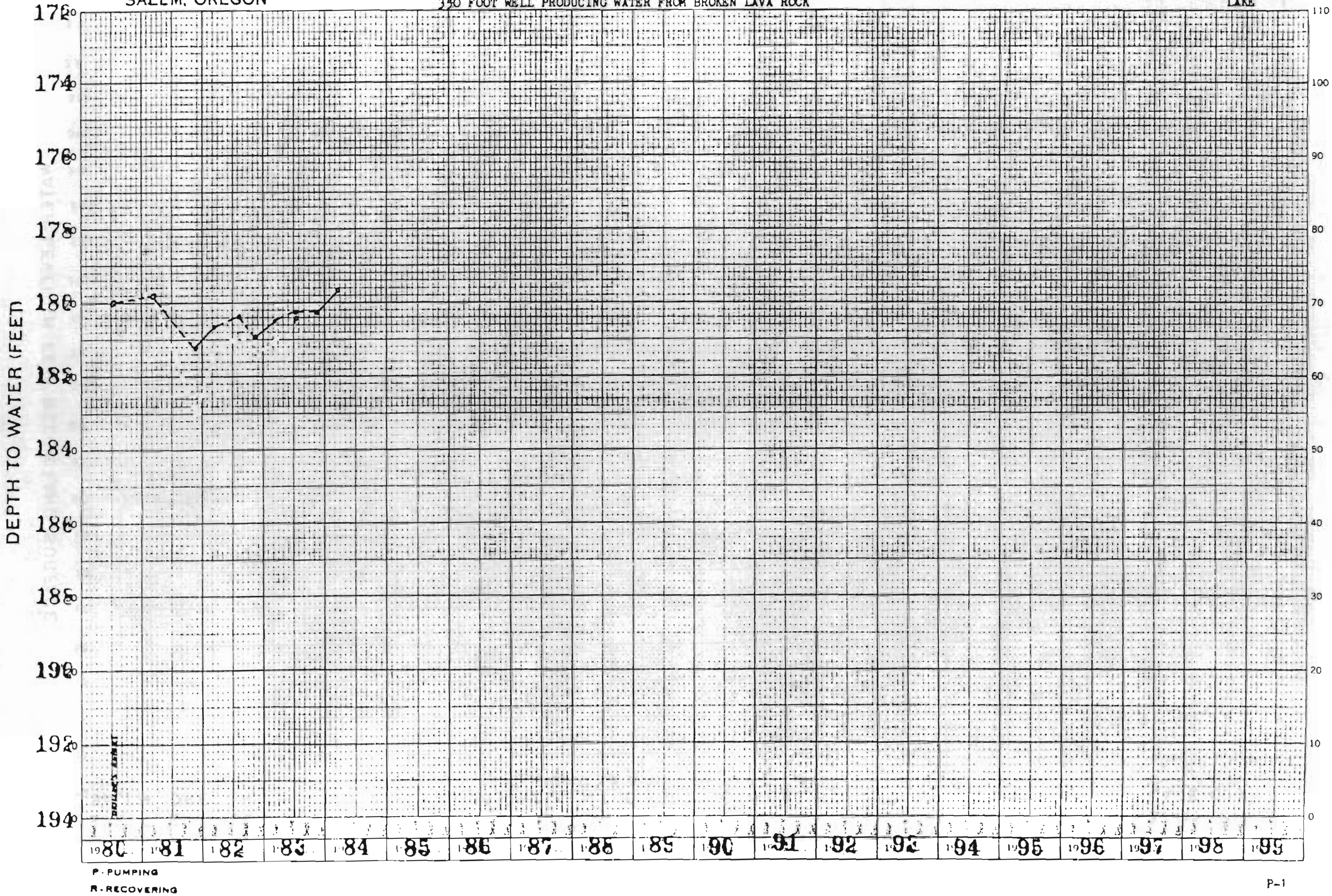
47 3853

94

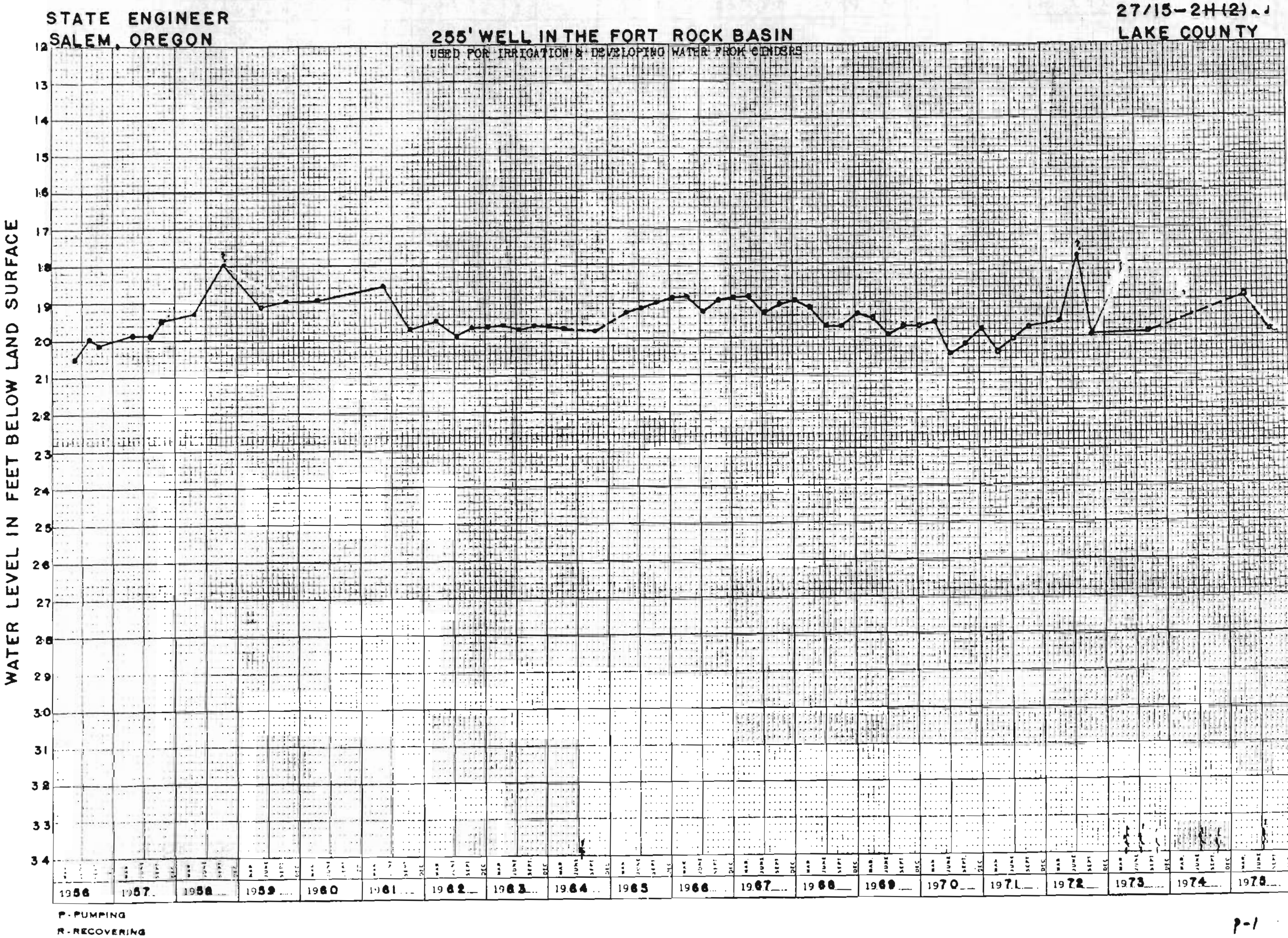
WATER RESOURCES DEPT
SALEM, OREGON

350 FOOT WELL PRODUCING WATER FROM BROKEN LAVA ROCK

27/13-23ac
LAKE



P-1



STATE ENGINEER
SALEM, OREGON
27/15-2H(2)
LAKE COUNTY
255' WELL IN THE FORT ROCK BASIN
USED FOR IRRIGATION & DEVELOPING WATER FROM CINDERS
WATER LEVEL IN FEET BELOW LAND SURFACE
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
P-PUMPING
R-RECOVERING

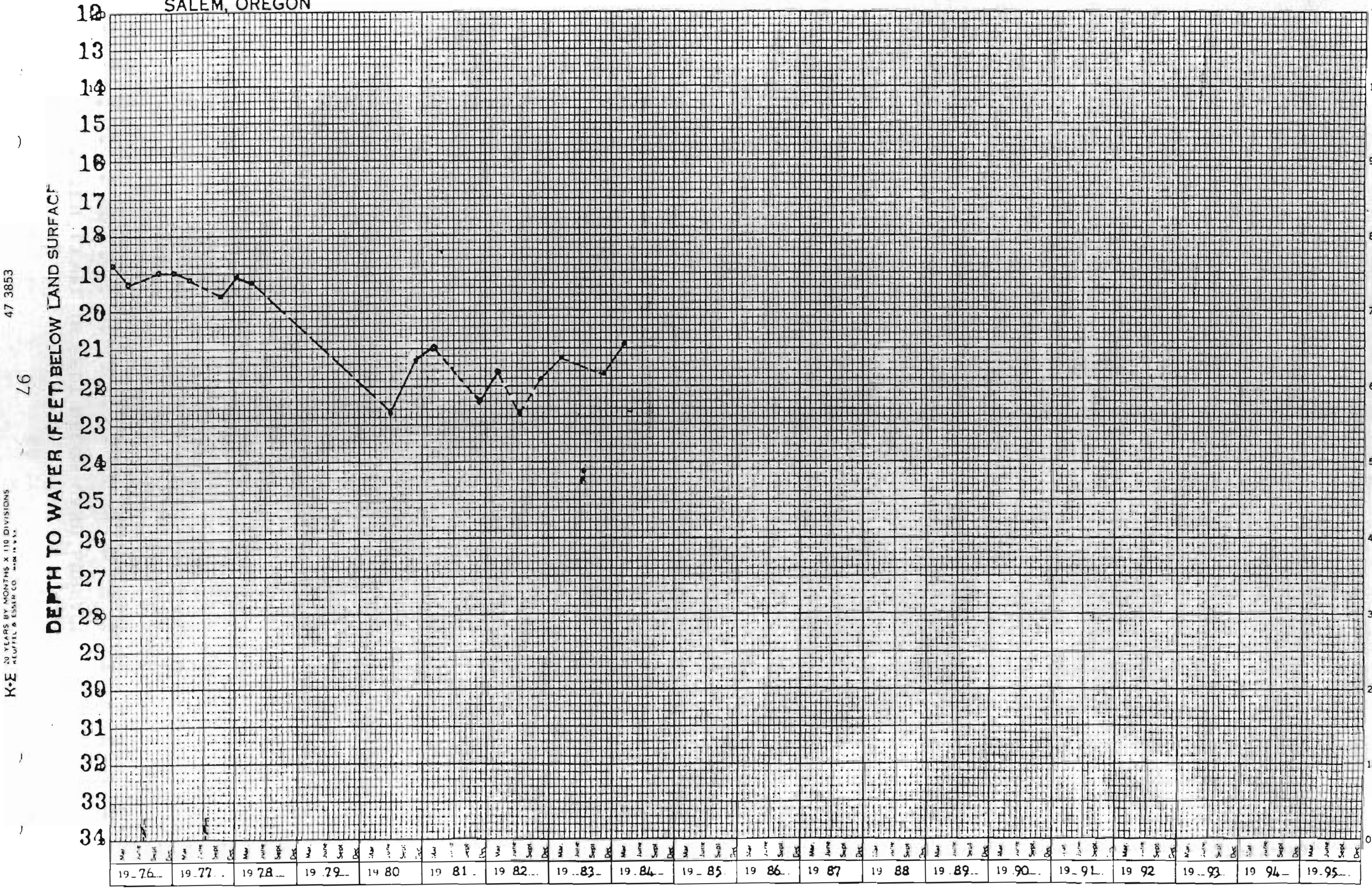
96

P-1

WATER RESOURCES DEPT
SALEM, OREGON

255 FOOT IRRIGATION WELL IN FORT ROCK BASIN DEVELOPING WATER FROM CINDERS

27/15-2ad
LAKE



P-PUMPING
R-RECOVERING

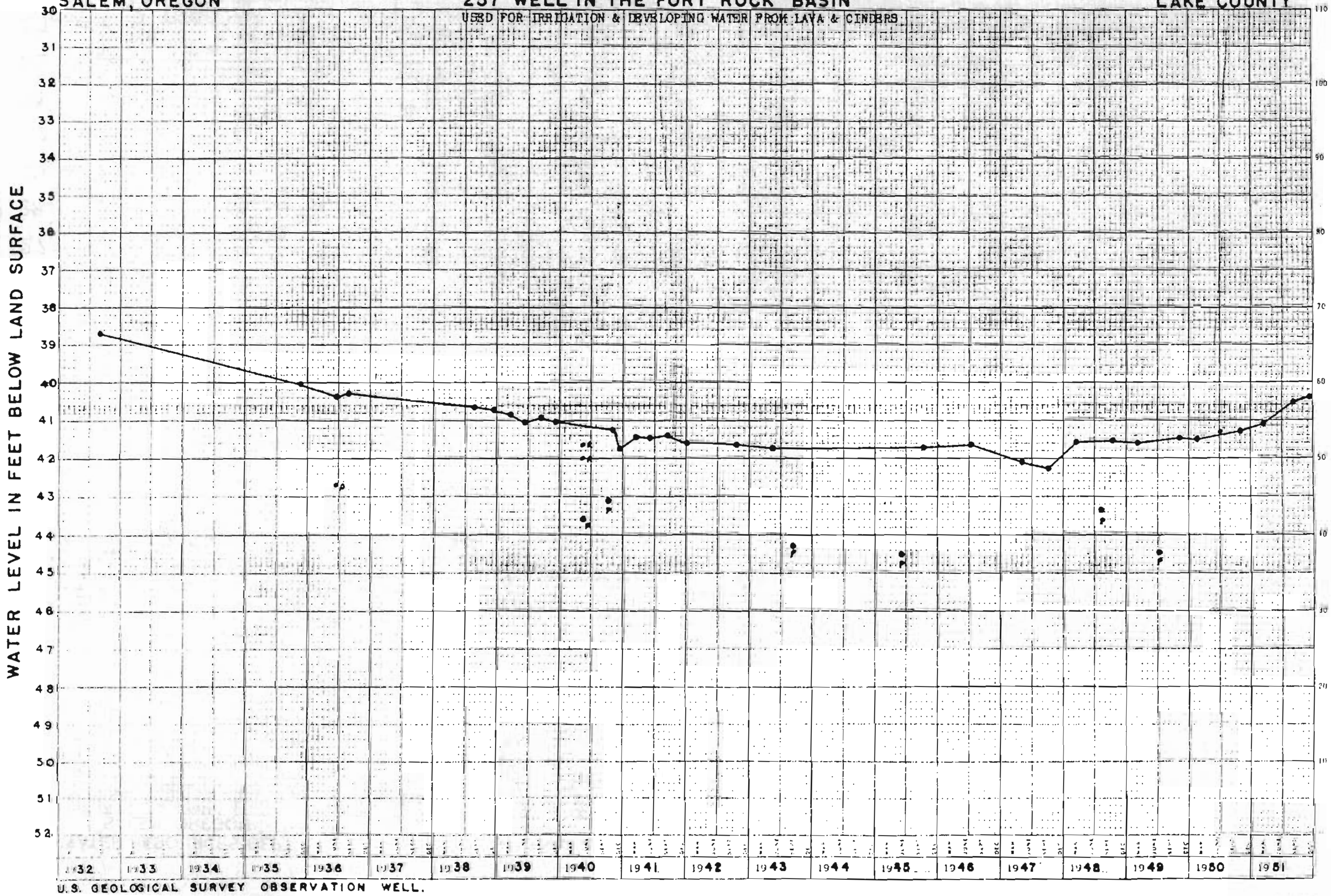
p-2

STATE ENGINEER
SALEM, OREGON

257' WELL IN THE FORT ROCK BASIN

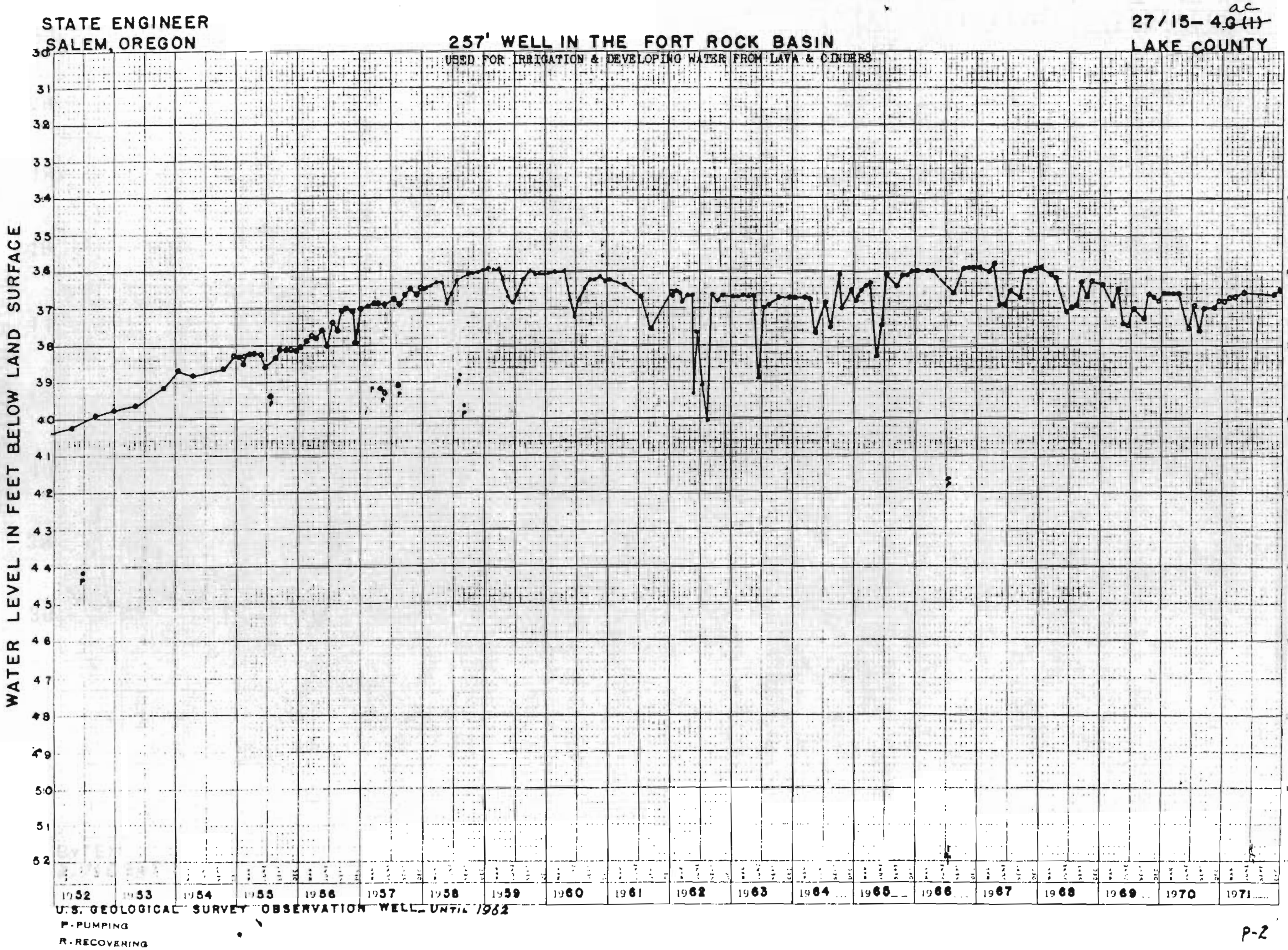
27/15-4G (1) ac
LAKE COUNTY

USED FOR IRRIGATION & DEVELOPING WATER FROM LAVA & CINDERS



U.S. GEOLOGICAL SURVEY OBSERVATION WELL.
P - PUMPING
R - RECOVERING

P-1

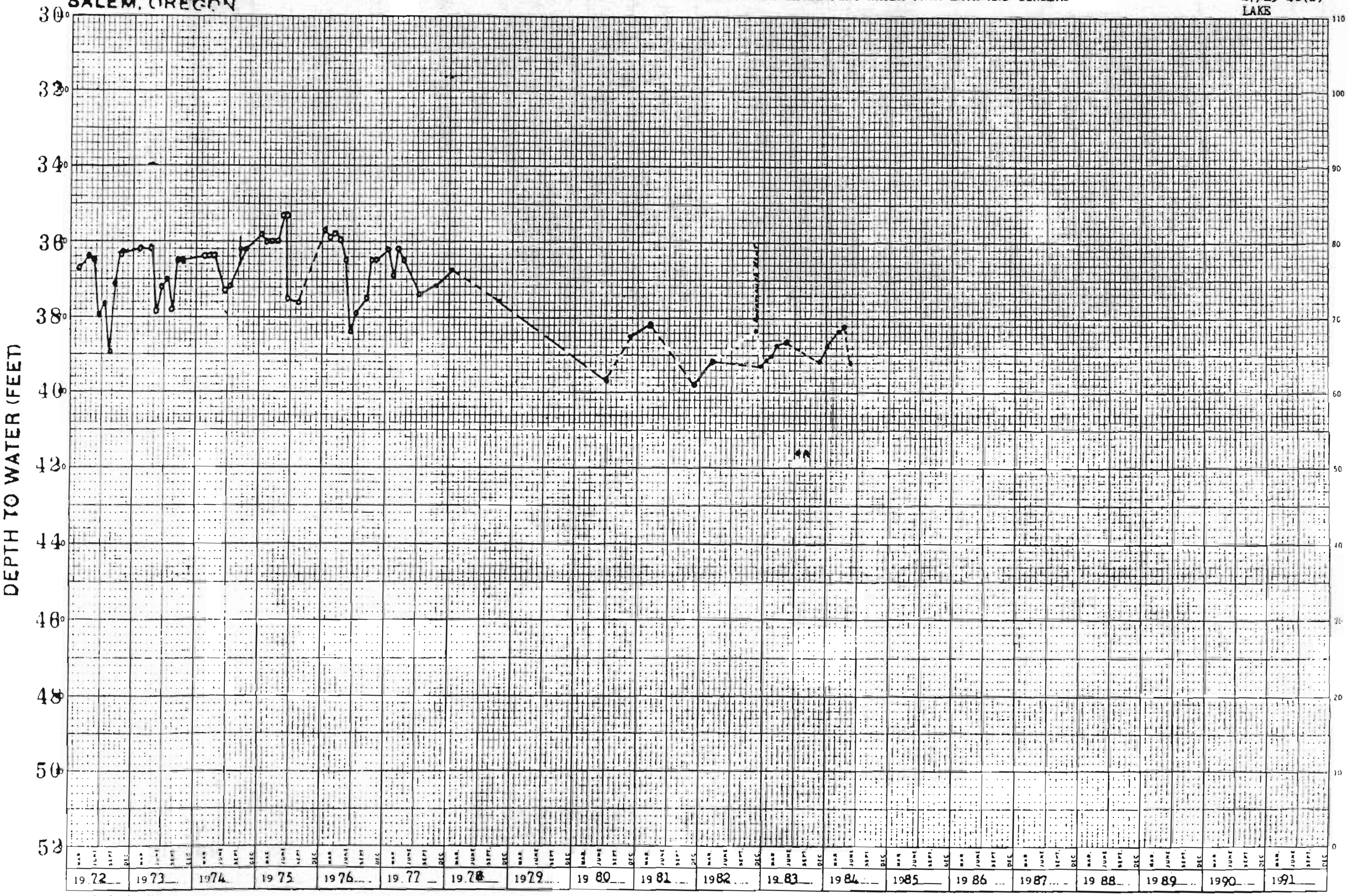


STATE ENGINEER
SALEM, OREGON
257' WELL IN THE FORT ROCK BASIN
USED FOR IRRIGATION & DEVELOPING WATER FROM LAVA & CINDERS
27/15-4ac
LAKE COUNTY
WATER LEVEL IN FEET BELOW LAND SURFACE
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
U.S. GEOLOGICAL SURVEY OBSERVATION WELL - UNTIL 1962
P - PUMPING
R - RECOVERING

STATE ENGINEER
SALEM, OREGON

257 FOOT WELL IN THE FORT ROCK BASIN USED FOR IRRIGATION AND DEVELOPING WATER FROM LAVA AND CINDERS

27/15-4C(1) acq
LAKE

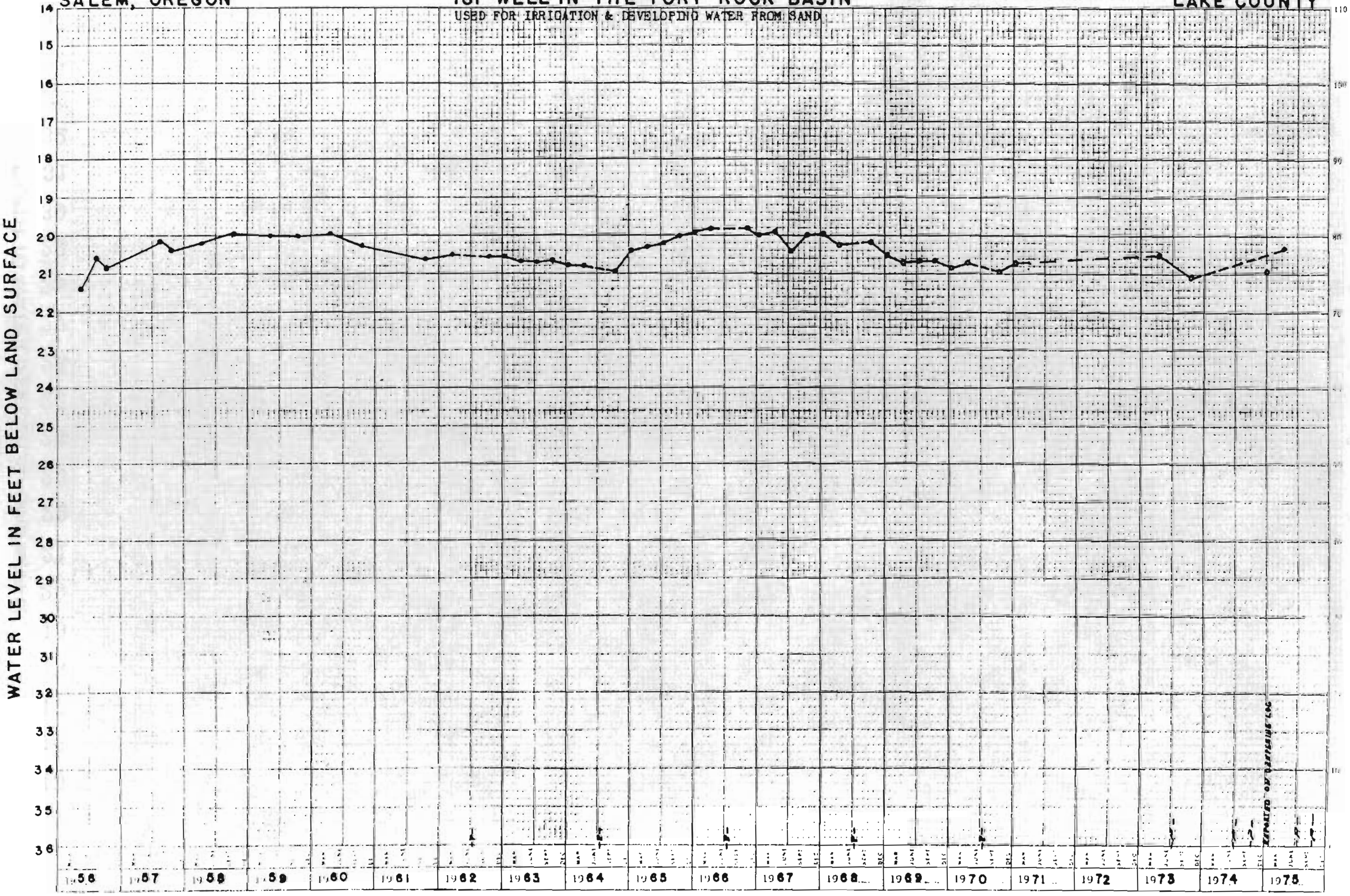


P - PUMPING
R - RECOVERING

STATE ENGINEER
SALEM, OREGON

181' WELL IN THE FORT ROCK BASIN

27/15-13bb ~~D (1)~~
LAKE COUNTY



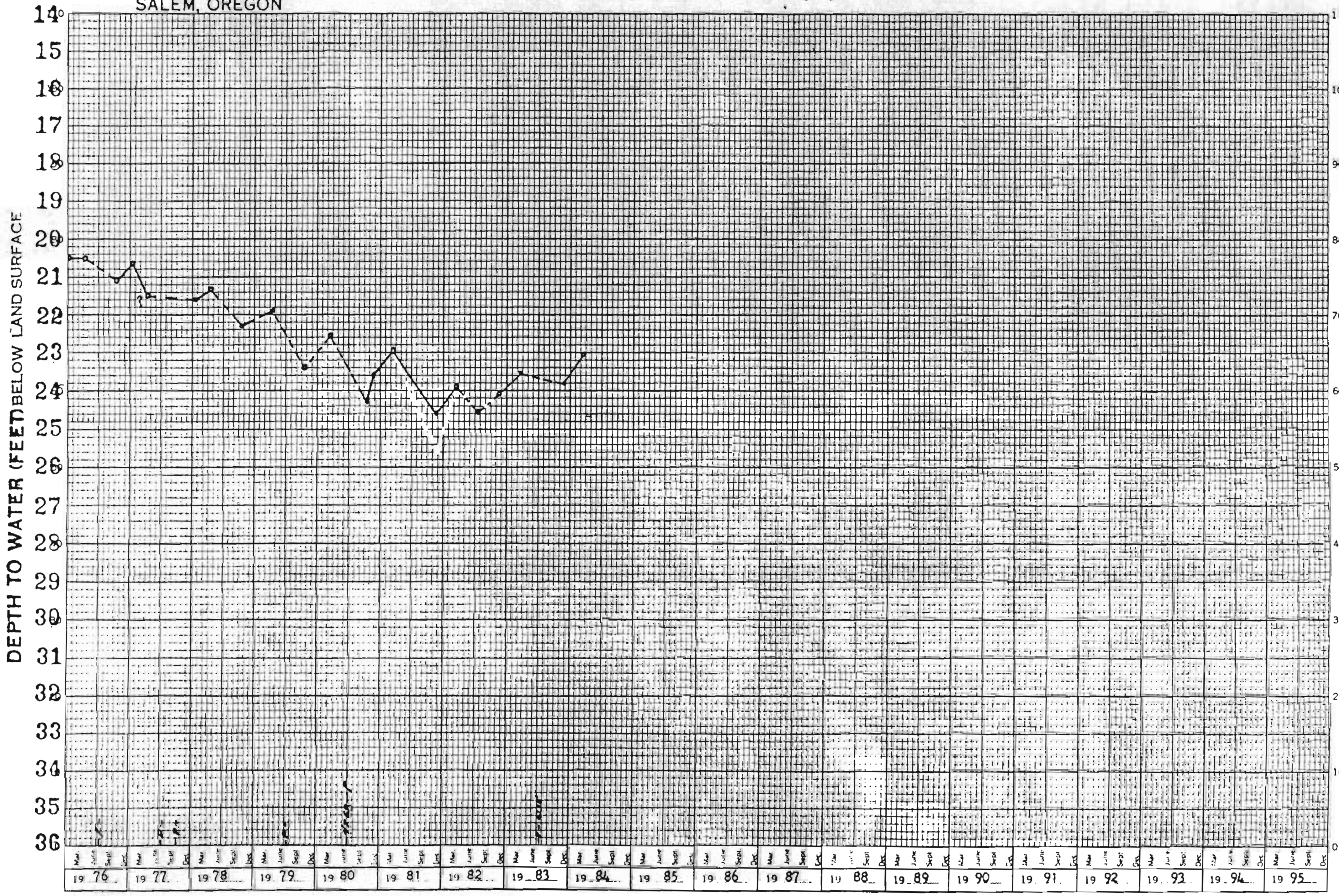
P - PUMPING
R - RECOVERING
* DEEPENED TO 246' (1/75)

P-1

WATER RESOURCES DEPT
SALEM, OREGON

~~181~~ 245 foot irrigation well in Fort Rock basin developing water from sand

27/15-13bb
Lake



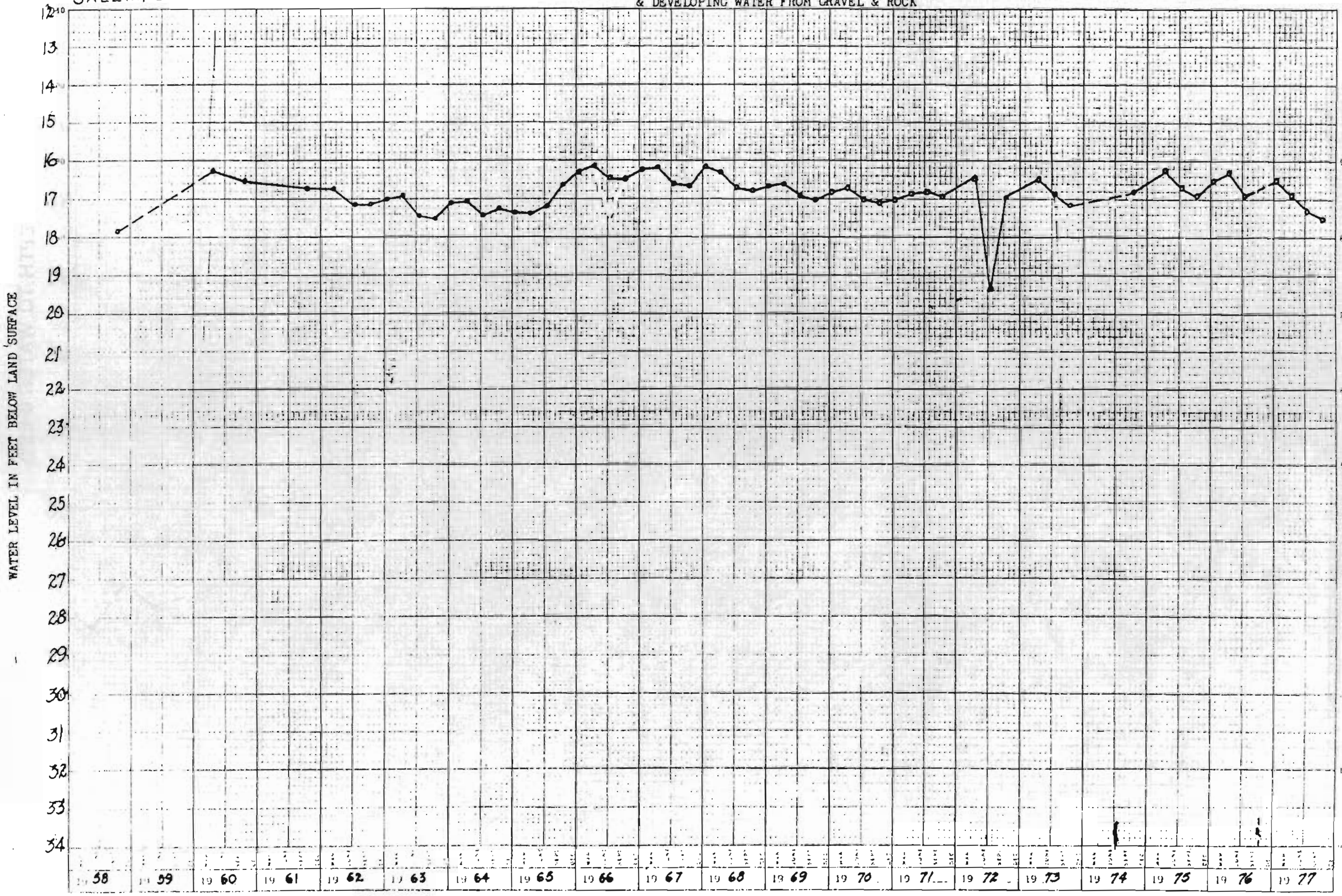
P. PUMPING
R. RECOVERING

P-2

STATE ENGINEER
SALEM, OREGON

A 560-FOOT WELL IN FORT ROCK BASIN USED FOR IRRIGATION
& DEVELOPING WATER FROM GRAVEL & ROCK

27/16-13B(1) abb
LAKE COUNTY



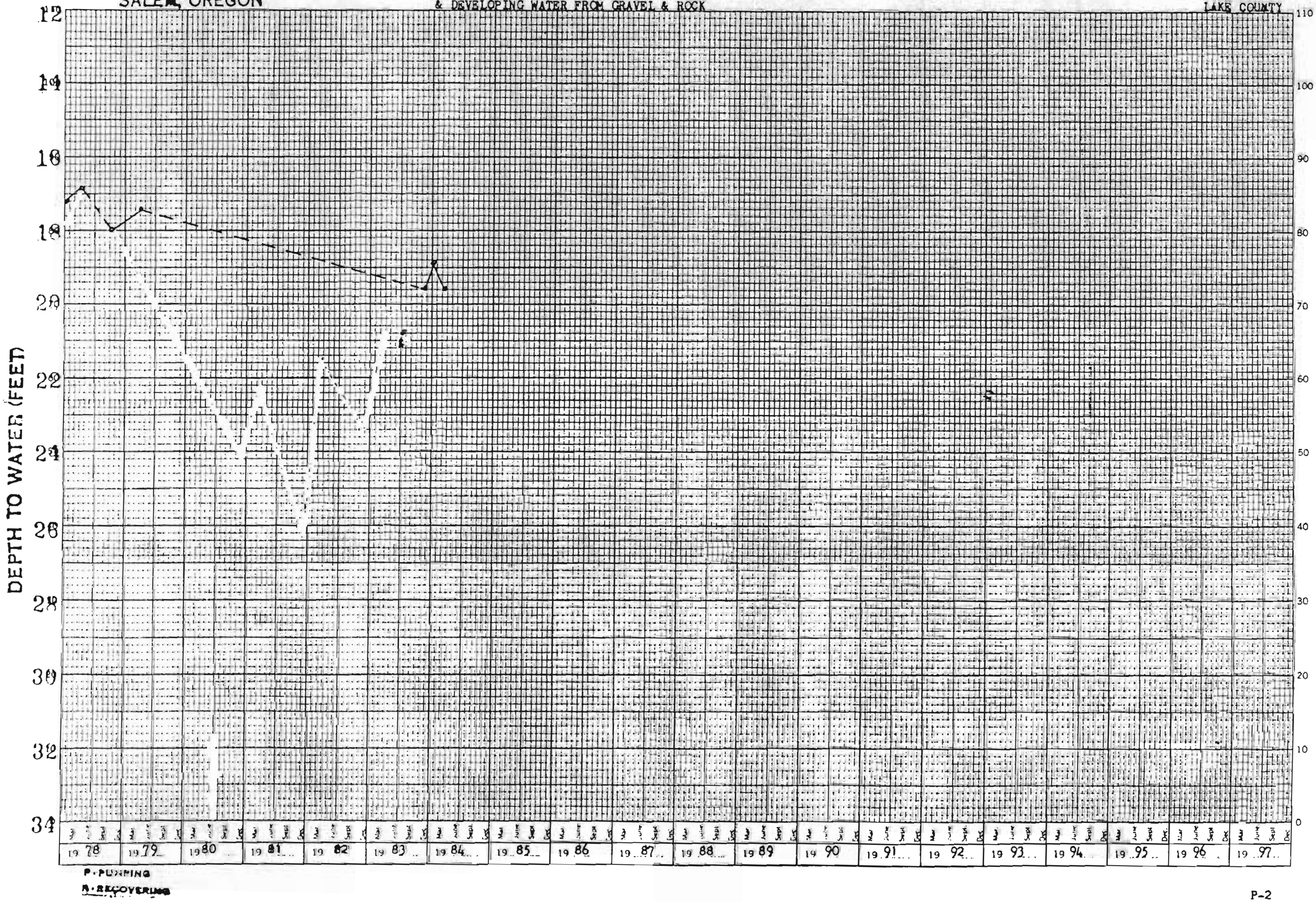
103

P-1

WATER RESOURCES DEPT
SALEM, OREGON

560 FOOT WELL IN THE FORT ROCK BASIN USED FOR IRRIGATION
& DEVELOPING WATER FROM GRAVEL & ROCK

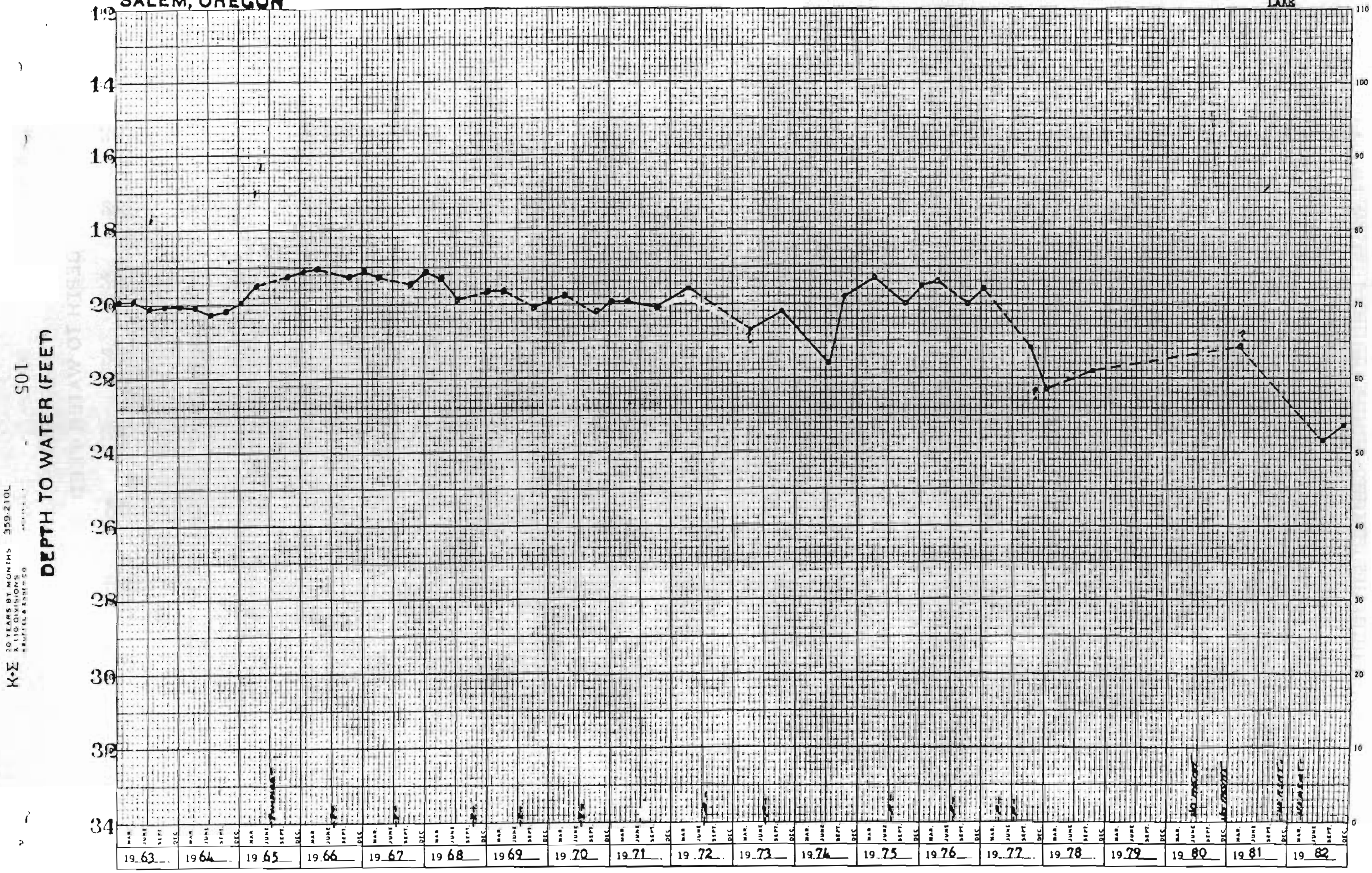
27/16-13abb (B1)
LAKE COUNTY



STATE ENGINEER
SALEM, OREGON

755 FOOT IRRIGATION WELL NEAR CHRISTMAS LAKE VALLEY DEVELOPING WATER FROM BASALT

27/16-26P(1) cd
LAKE



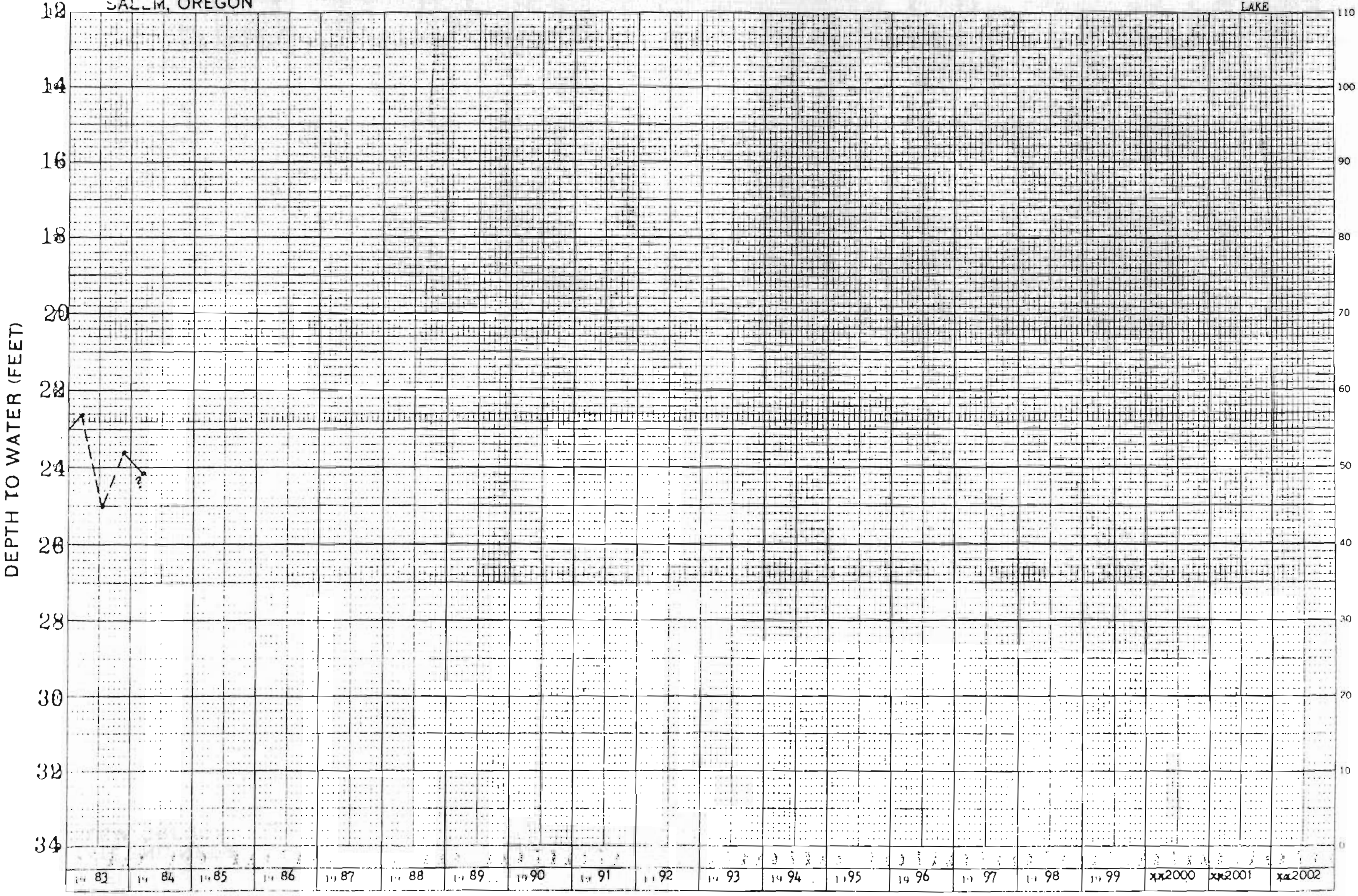
P-PUMPING
R-RECOVERING

P-1

WATER RESOURCES DEPT
SALEM, OREGON

755 FOOT IRRIGATION WELL NEAR CHRISTMAS VALLEY DEVELOPING WATER FROM BASALT

27S/16E-26cd(1)
LAKE



P-PUMPING
R-RECOVERING

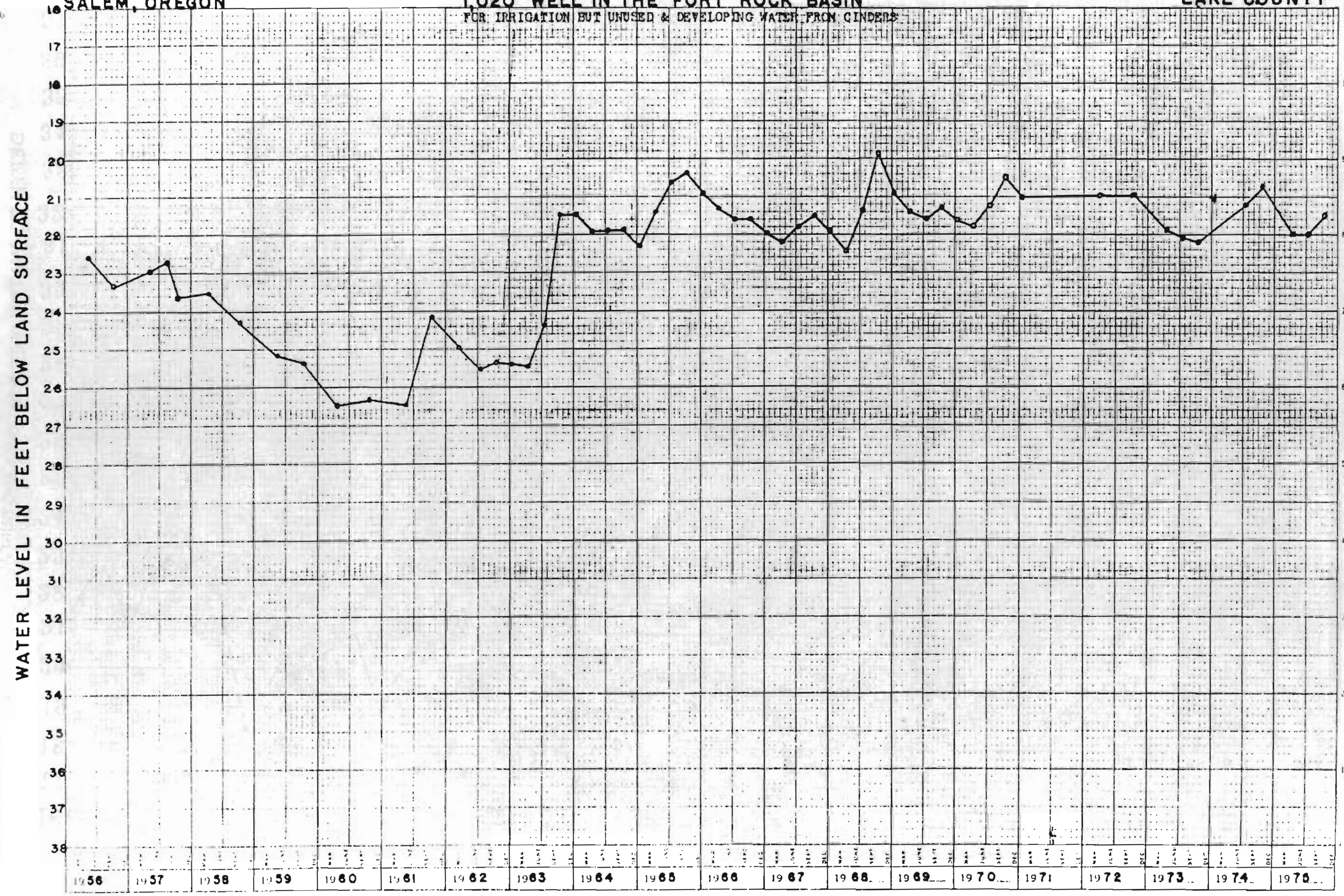
P-2

STATE ENGINEER
SALEM, OREGON

1,020' WELL IN THE FORT ROCK BASIN

FOR IRRIGATION BUT UNUSED & DEVELOPING WATER FROM CINDERS

27/16-32bd
LAKE COUNTY



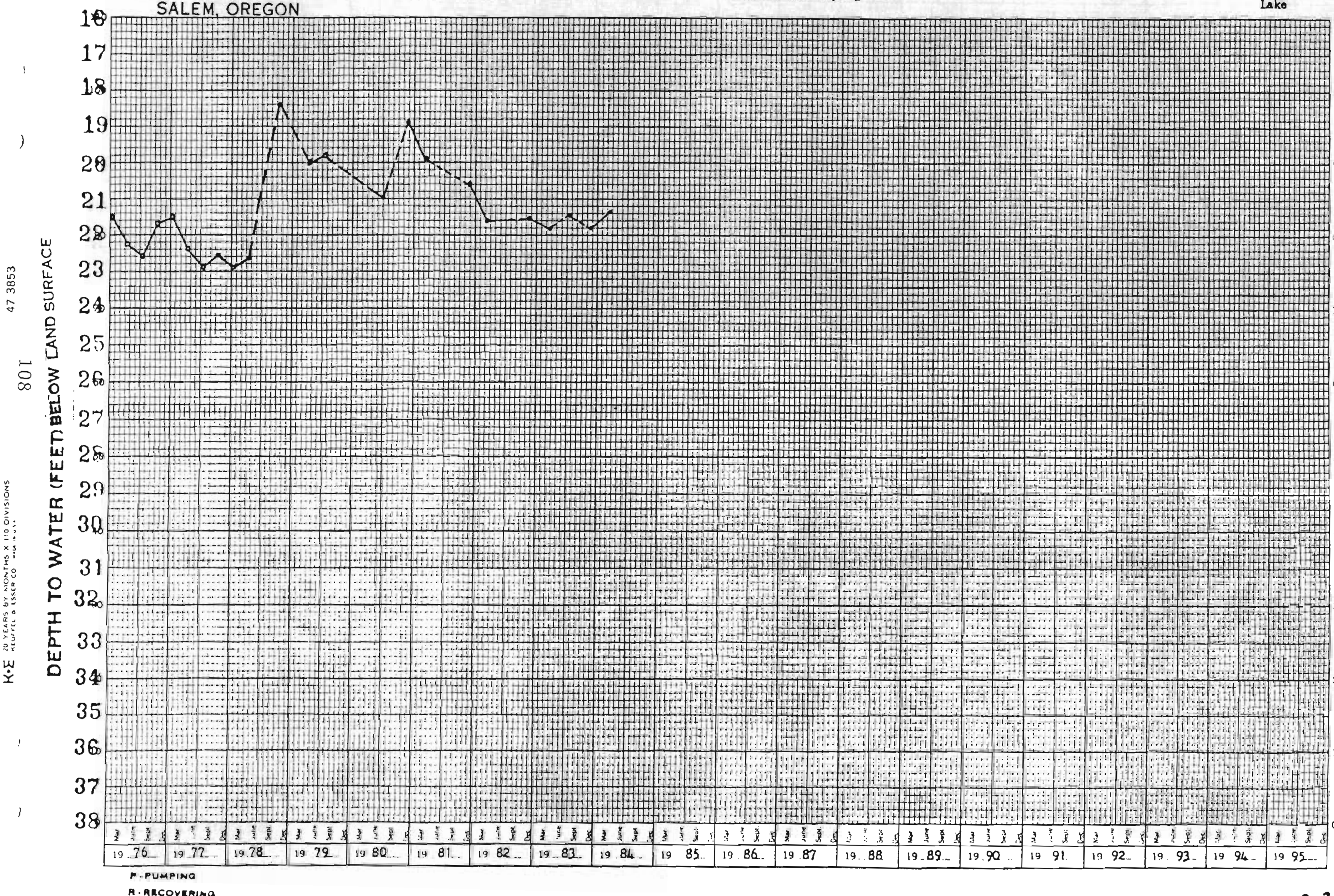
107

p-1

WATER RESOURCES DEPT
SALEM, OREGON

1,020 foot irrigation well in Fort Rock basin (unused) developing water from cinders

27/16-32bd
Lake

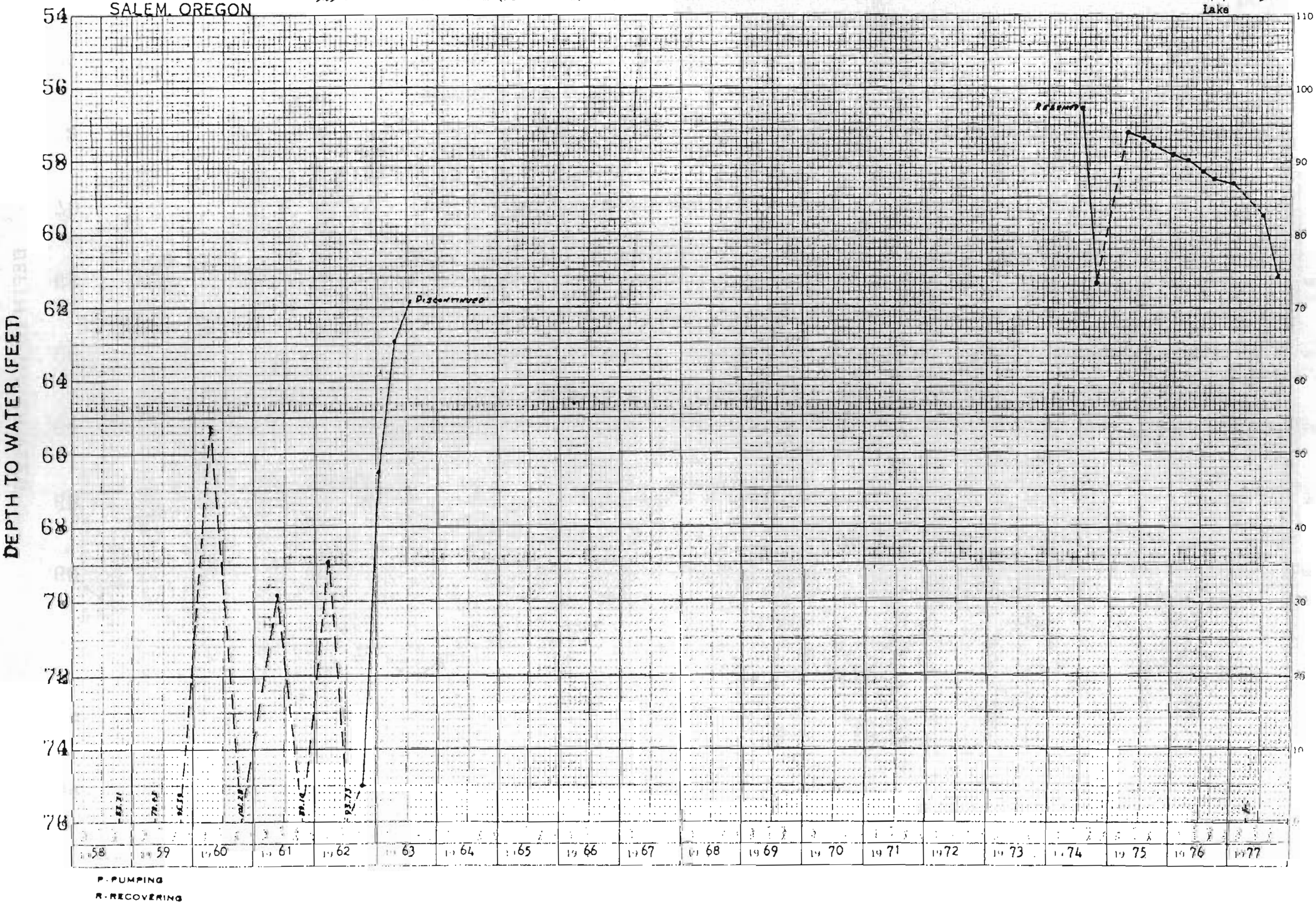


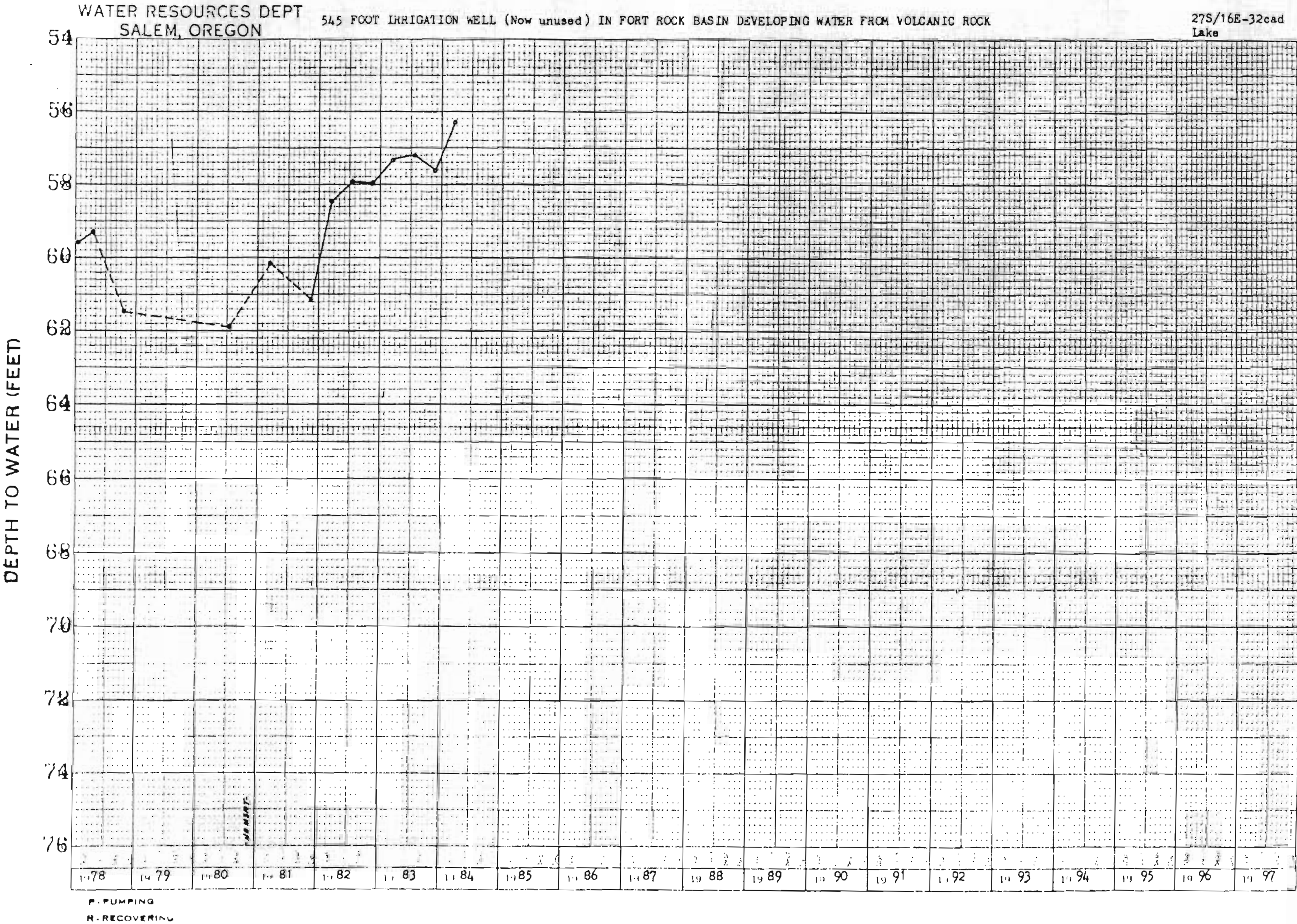
p-2

WATER RESOURCES DEPT
SALEM, OREGON

545 FOOT IRRIGATION WELL (Now unused) IN FORT ROCK BASIN DEVELOPING WATER FROM VOLCANIC ROCK

27S/16E-32cad
Lake



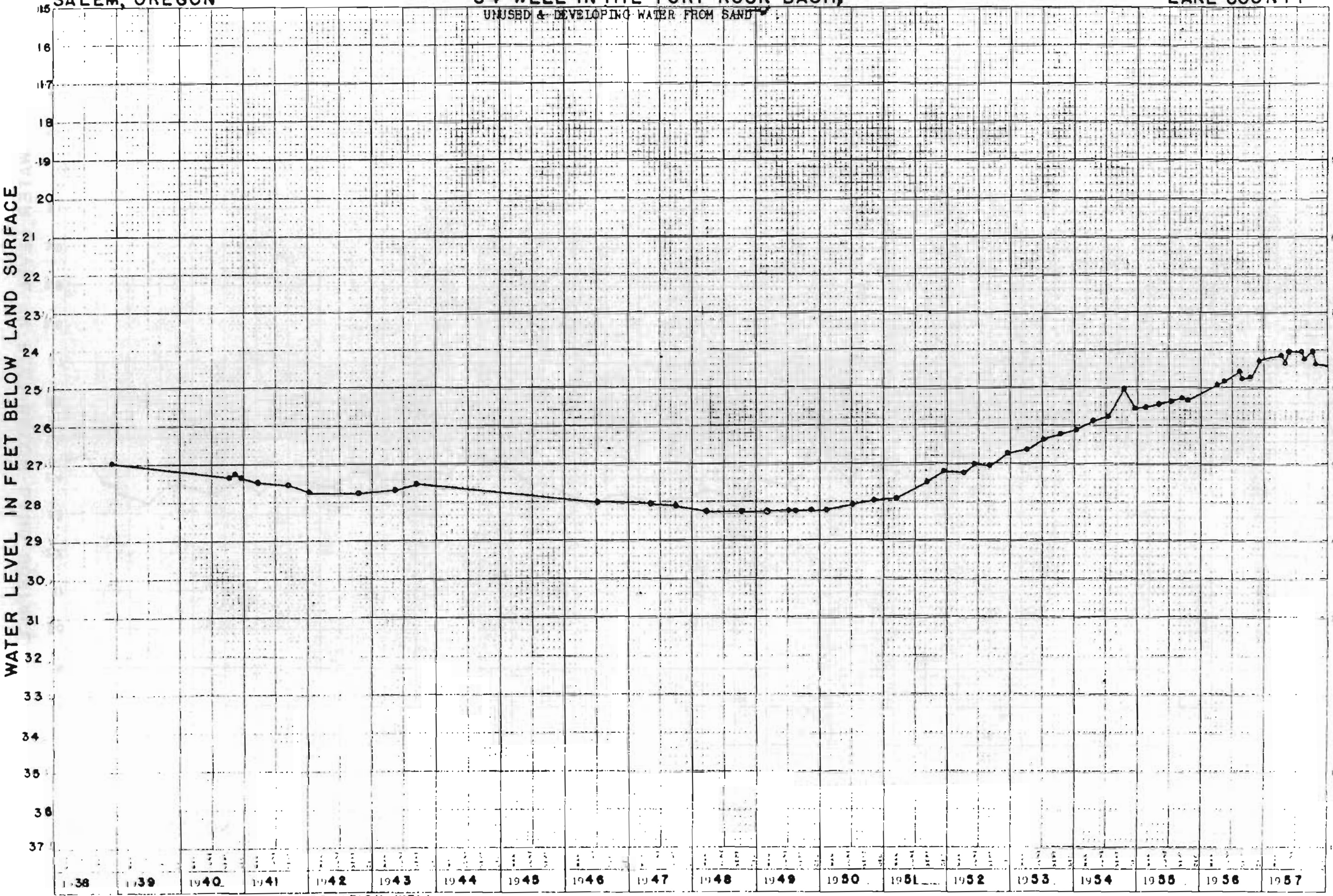


WATER RESOURCES DEPT
SALEM, OREGON
545 FOOT IRRIGATION WELL (Now unused) IN FORT ROCK BASIN DEVELOPING WATER FROM VOLCANIC ROCK
27S/16E-32cad
Lake
DEPTH TO WATER (FEET)
54
56
58
60
62
64
66
68
70
72
74
76
110
100
90
80
70
60
50
40
30
20
10
0
NO MEAS.
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
P. PUMPING
R. RECOVERING

STATE ENGINEER
SALEM, OREGON

dd
27/17-22 ~~R (2)~~
LAKE COUNTY

54' WELL IN THE FORT ROCK BASIN



U.S. GEOLOGICAL SURVEY OBSERVATION WELL.

359-210L

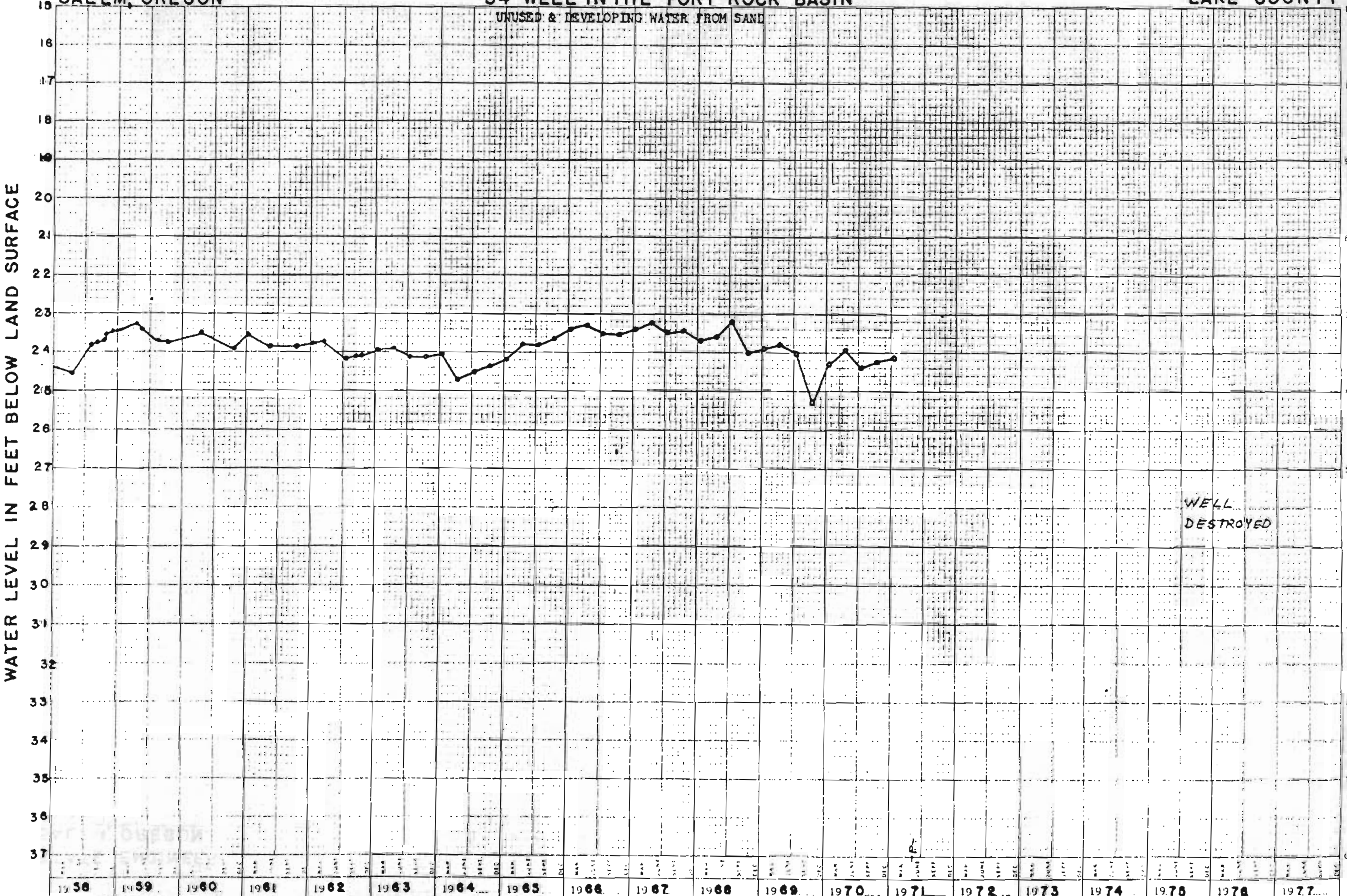
111

STATE ENGINEER
SALEM, OREGON

54' WELL IN THE FORT ROCK BASIN

27/17-22 dd

LAKE COUNTY

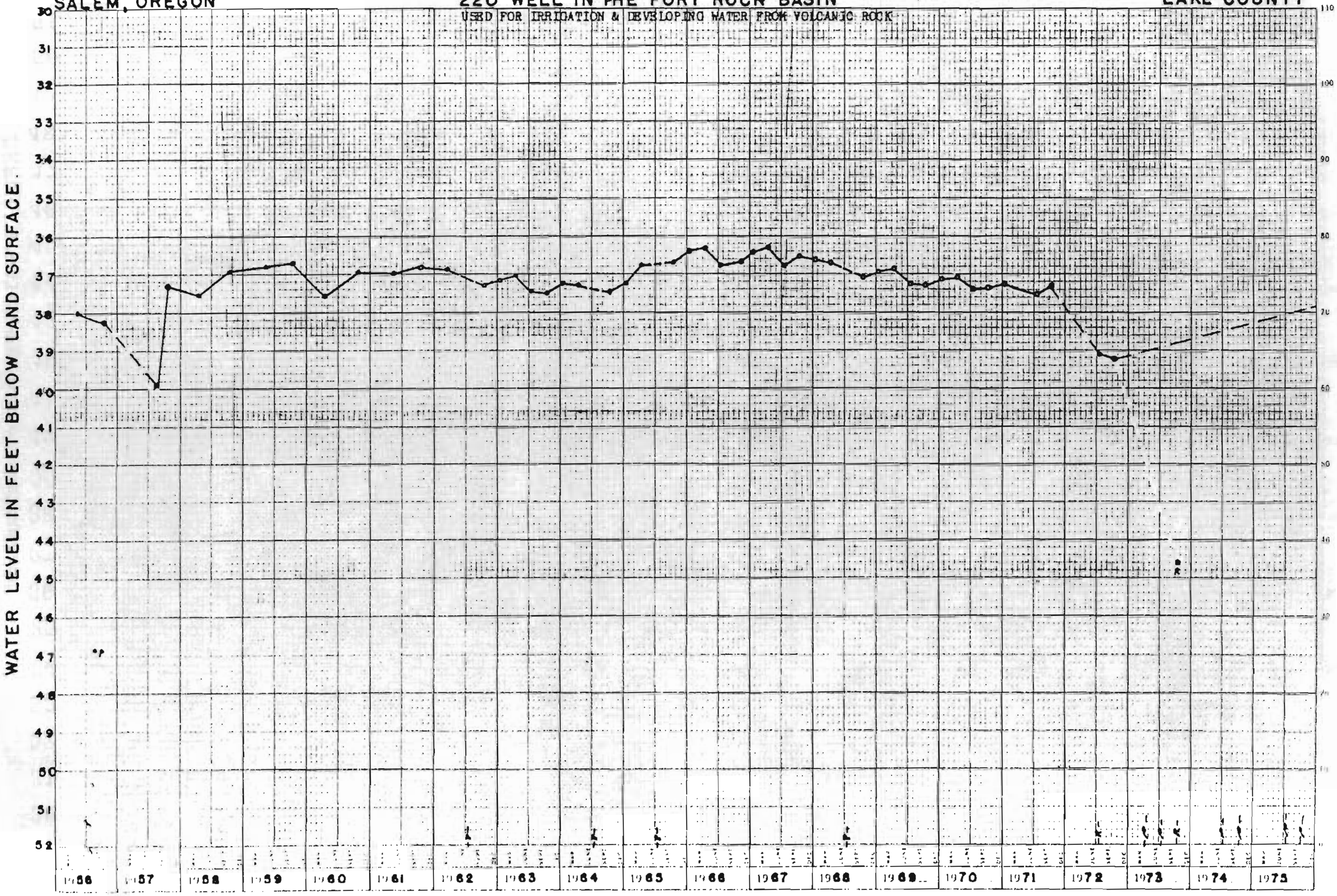


U.S. GEOLOGICAL SURVEY OBSERVATION WELL - UNTIL 1962

STATE ENGINEER
SALEM, OREGON

Caa
27/17-27L(1)
LAKE COUNTY

220' WELL IN THE FORT ROCK BASIN



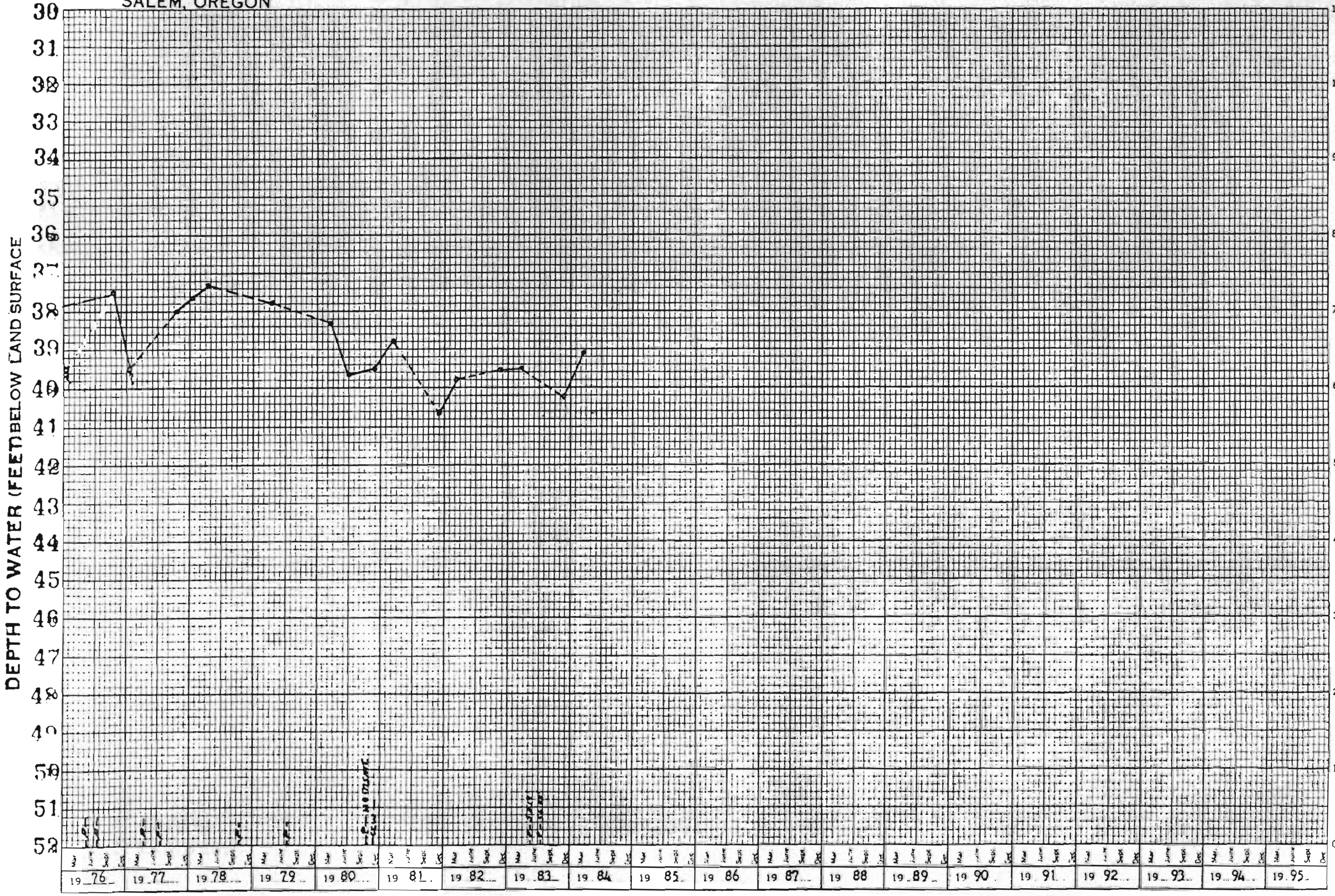
P-PUMPING
R-RECOVERING

p-1

WATER RESOURCES DEPT
SALEM, OREGON

220 foot Irrigation well 2 miles South of Christmas Valley developing water from volcanic rock

27/17-27ddb Cas Lake

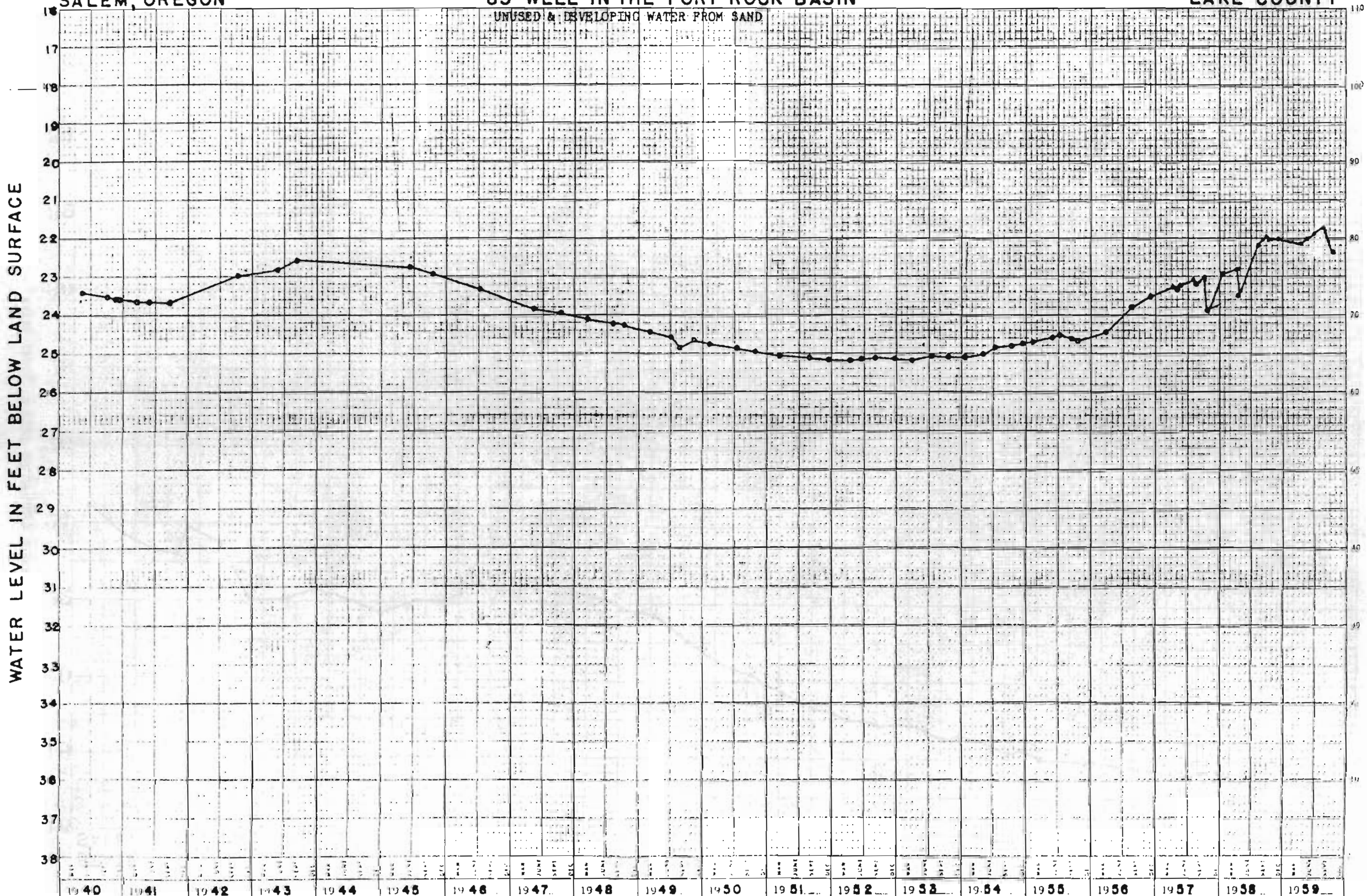


P - PUMPING
R - RECOVERING

STATE ENGINEER
SALEM, OREGON

83' WELL IN THE FORT ROCK BASIN

27/18-6E ~~(2)~~ bcb
LAKE COUNTY



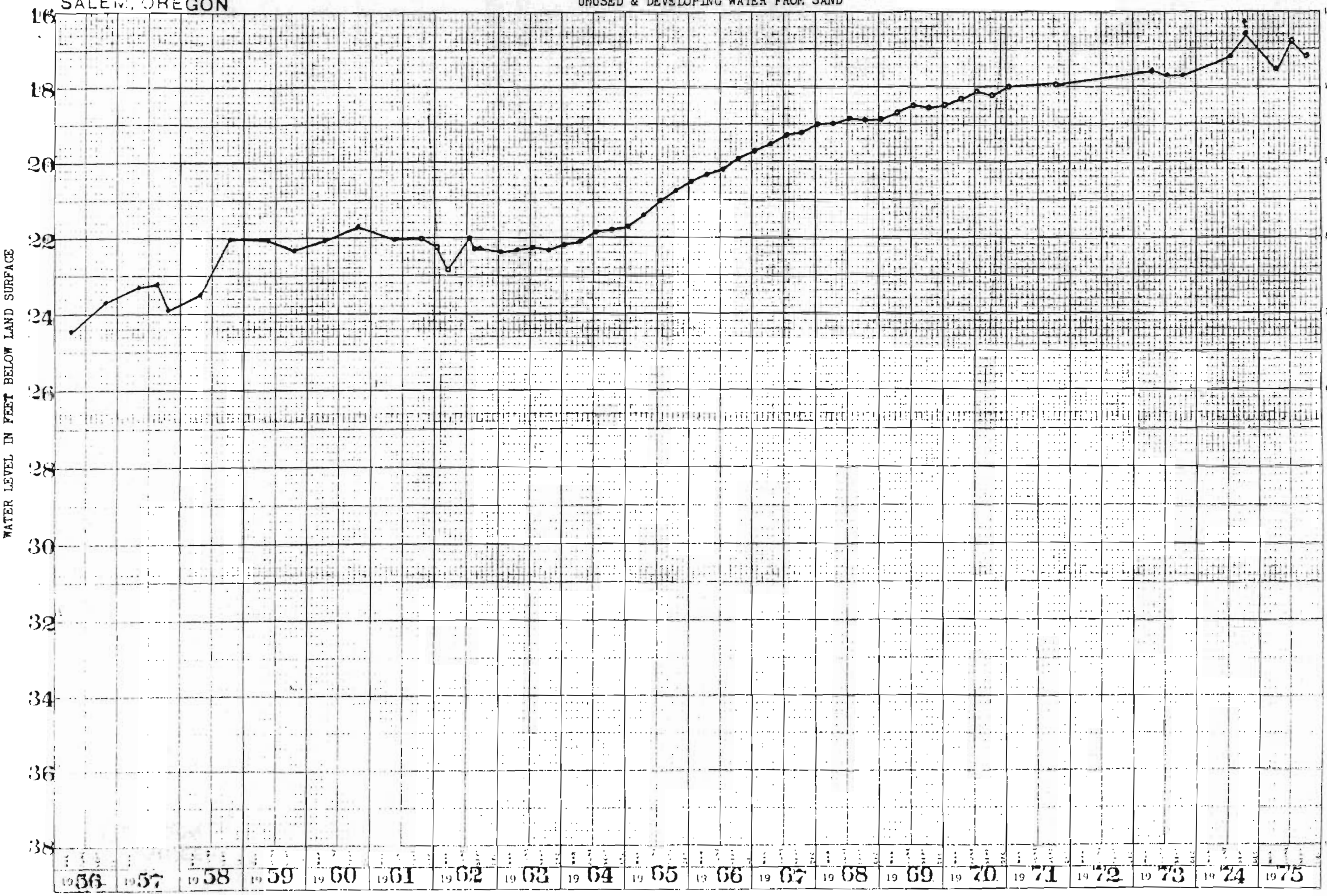
U. S. GEOLOGICAL SURVEY OBSERVATION WELL.

P-1

STATE ENGINEER
SALEM, OREGON

A 834-FOOT WELL IN THE FORT ROCK BASIN
UNUSED & DEVELOPING WATER FROM SAND

27/18-6B(2) bcb
LAKE COUNTY



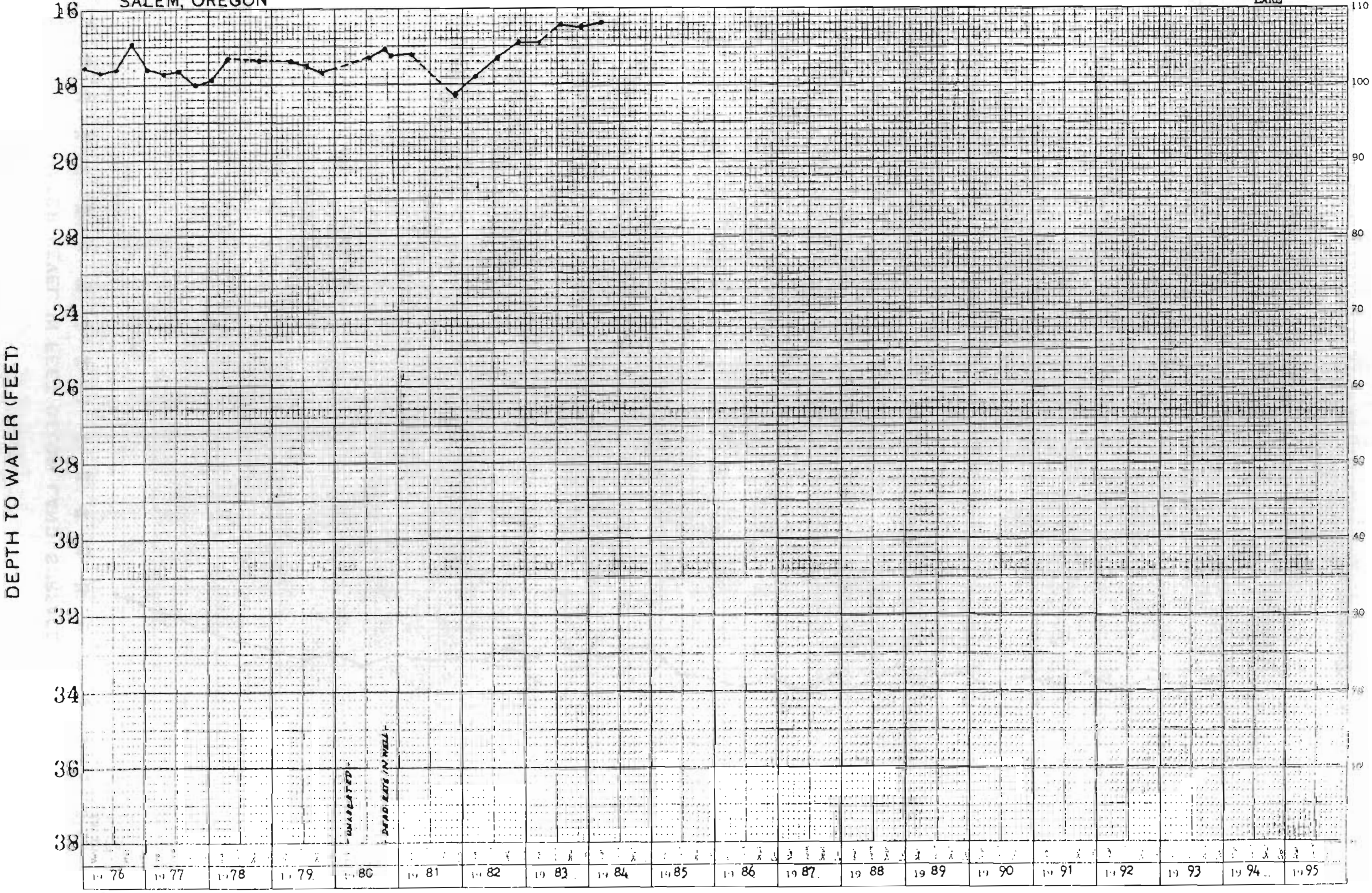
116

P-2

WATER RESOURCES DEPT
SALEM, OREGON

83 FOOT UNUSED WELL IN FORT ROCK BASIN DEVELOPING WATER FROM SAND

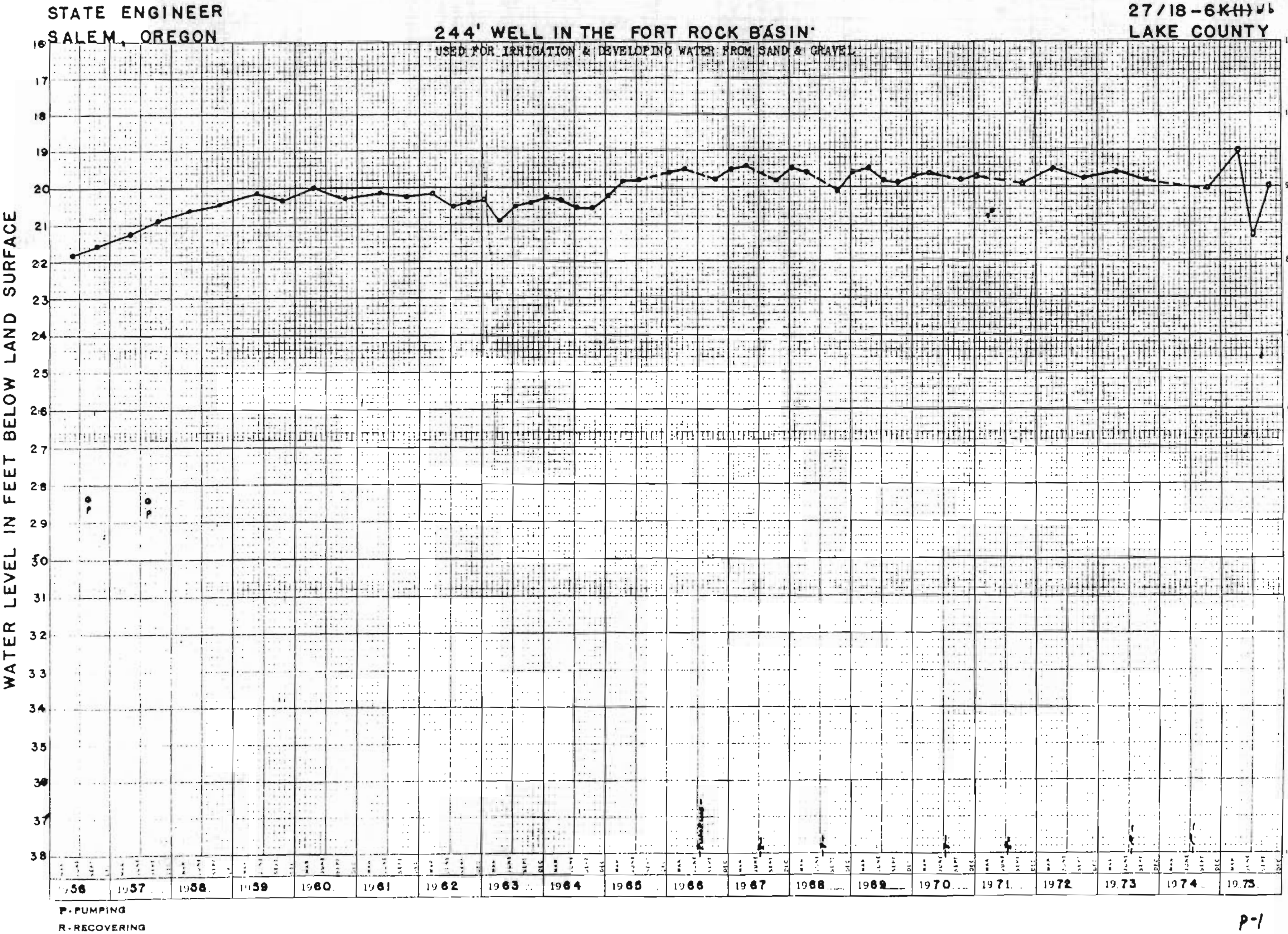
27S/18E-6bcb(2)
LAKE



P-PUMPING
R-RECOVERING

P-3

47 3853
117
K·E



STATE ENGINEER
SALEM, OREGON
244' WELL IN THE FORT ROCK BASIN
USED FOR IRRIGATION & DEVELOPING WATER FROM SAND & GRAVEL
27/18-6K(1)
LAKE COUNTY
WATER LEVEL IN FEET BELOW LAND SURFACE
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
P-PUMPING
R-RECOVERING
P-1

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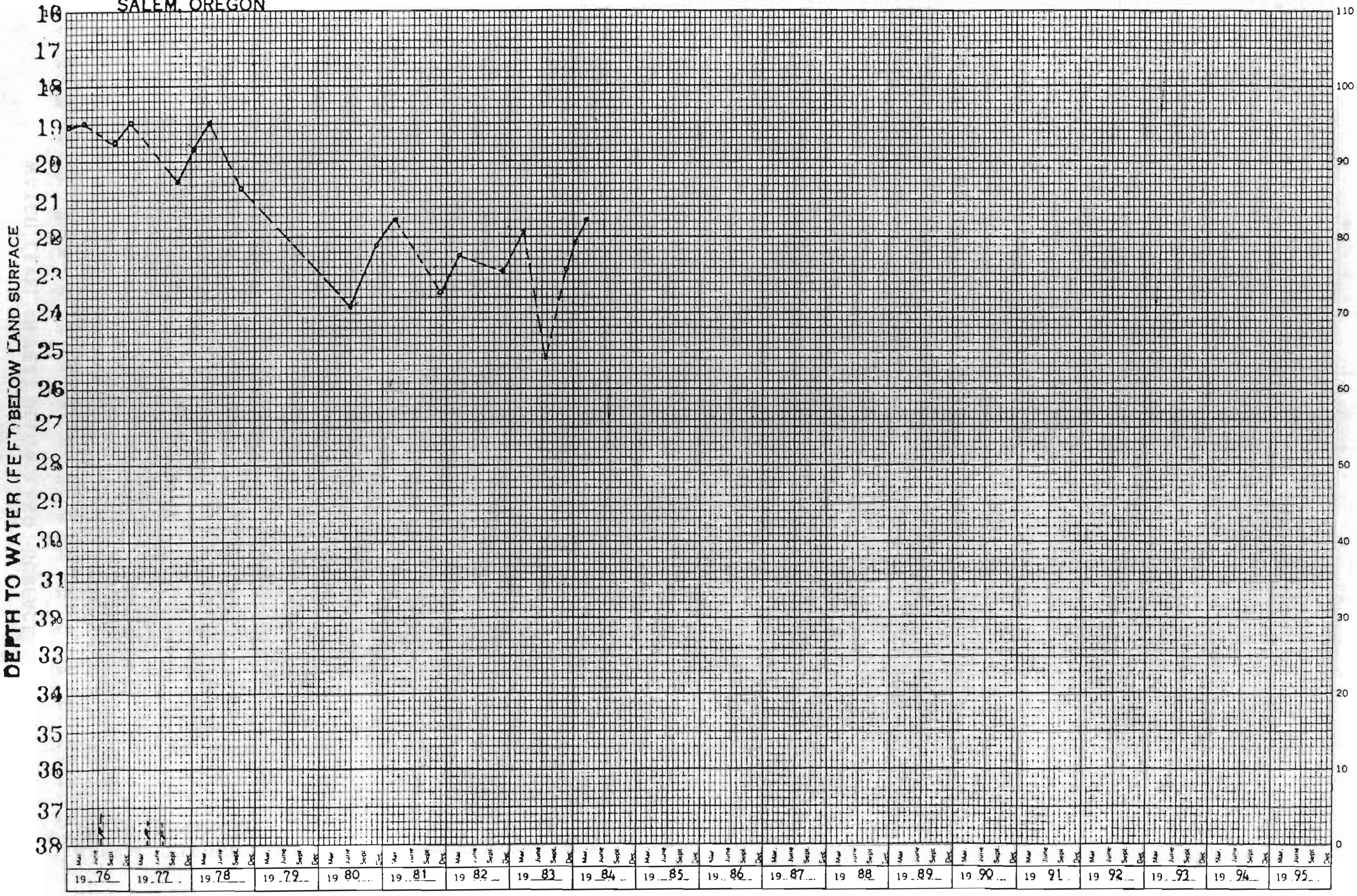
WATER RESOURCES DEPT
SALEM, OREGON

244 foot irrigation well in Fort Rock basin developing water from sand and gravel

27/18-6db
Lake



P - PUMPING
R - RECOVERING

K-E 20 YEARS BY MONTHS X 110 DIVISIONS
KEUFFEL & ESSER CO.

47 3853

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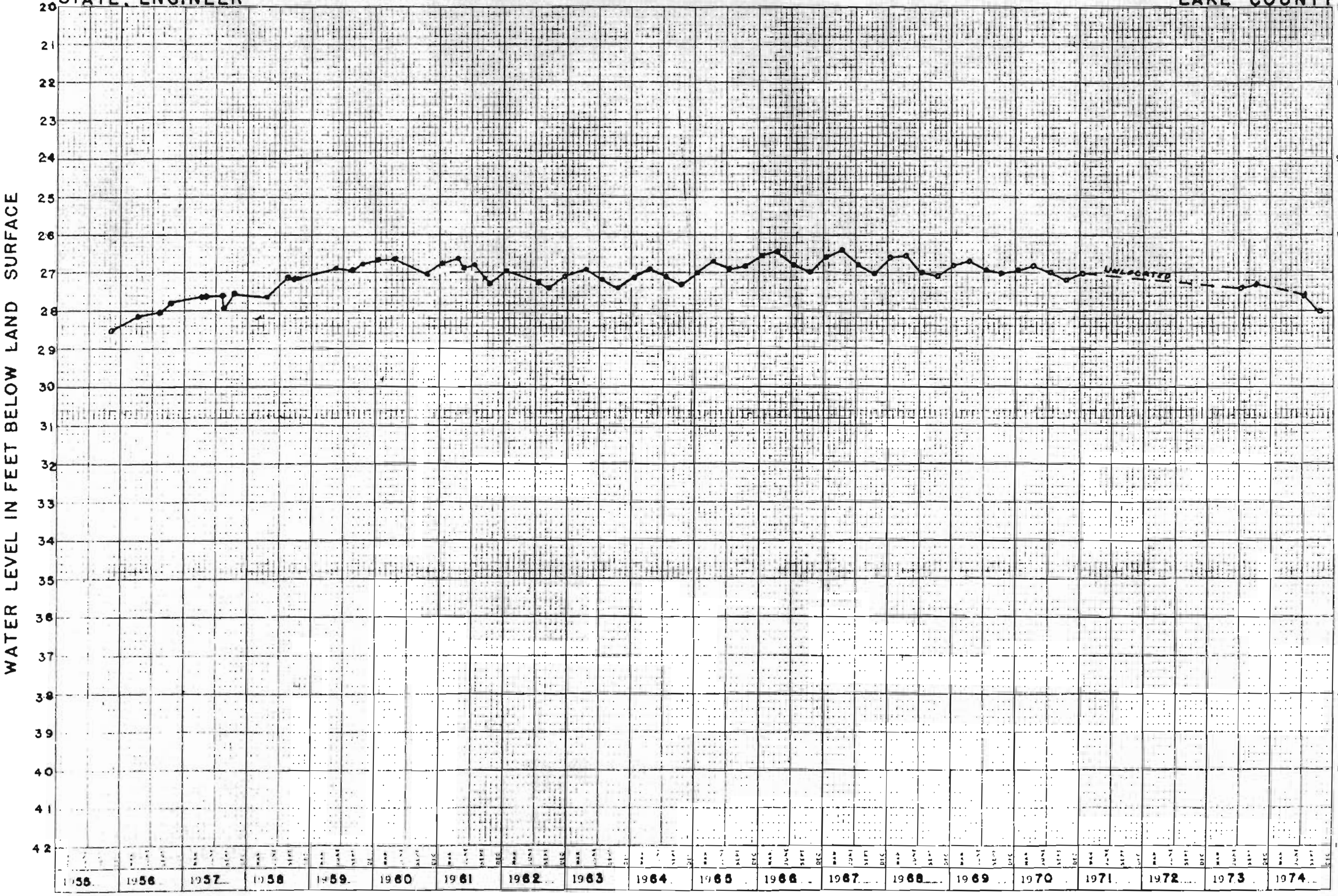
P-2

SALEM, OREGON
STATE ENGINEER

635 FOOT UNUSED WELL IN CHRISTMAS VALLEY

27/18-21 A (1)
LAKE COUNTY



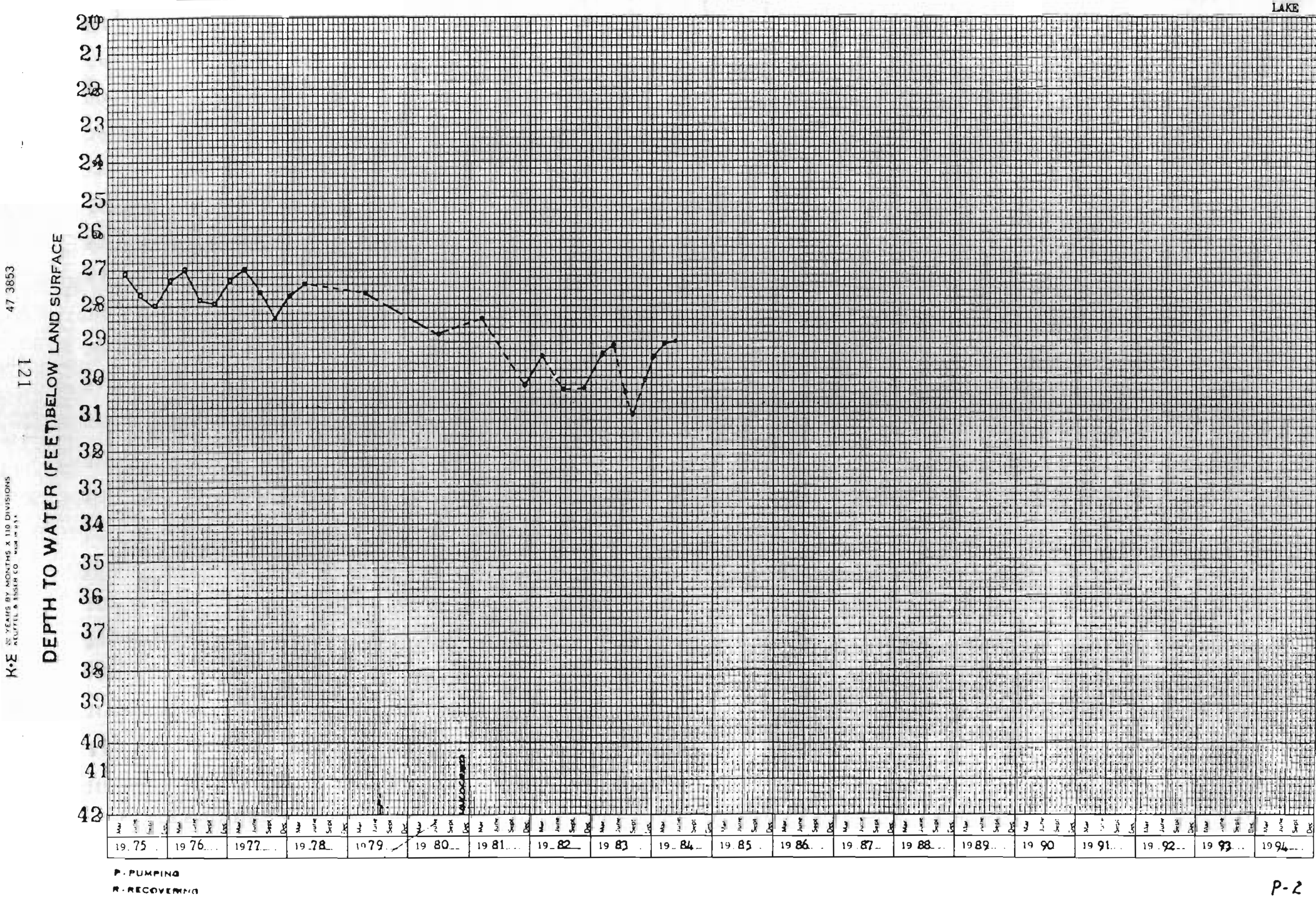
120

P-1

WATER RESOURCES

635 UNUSED WELL IN CHRISTMAS VALLEY

27/18-21aaa (A-1)
LAKE

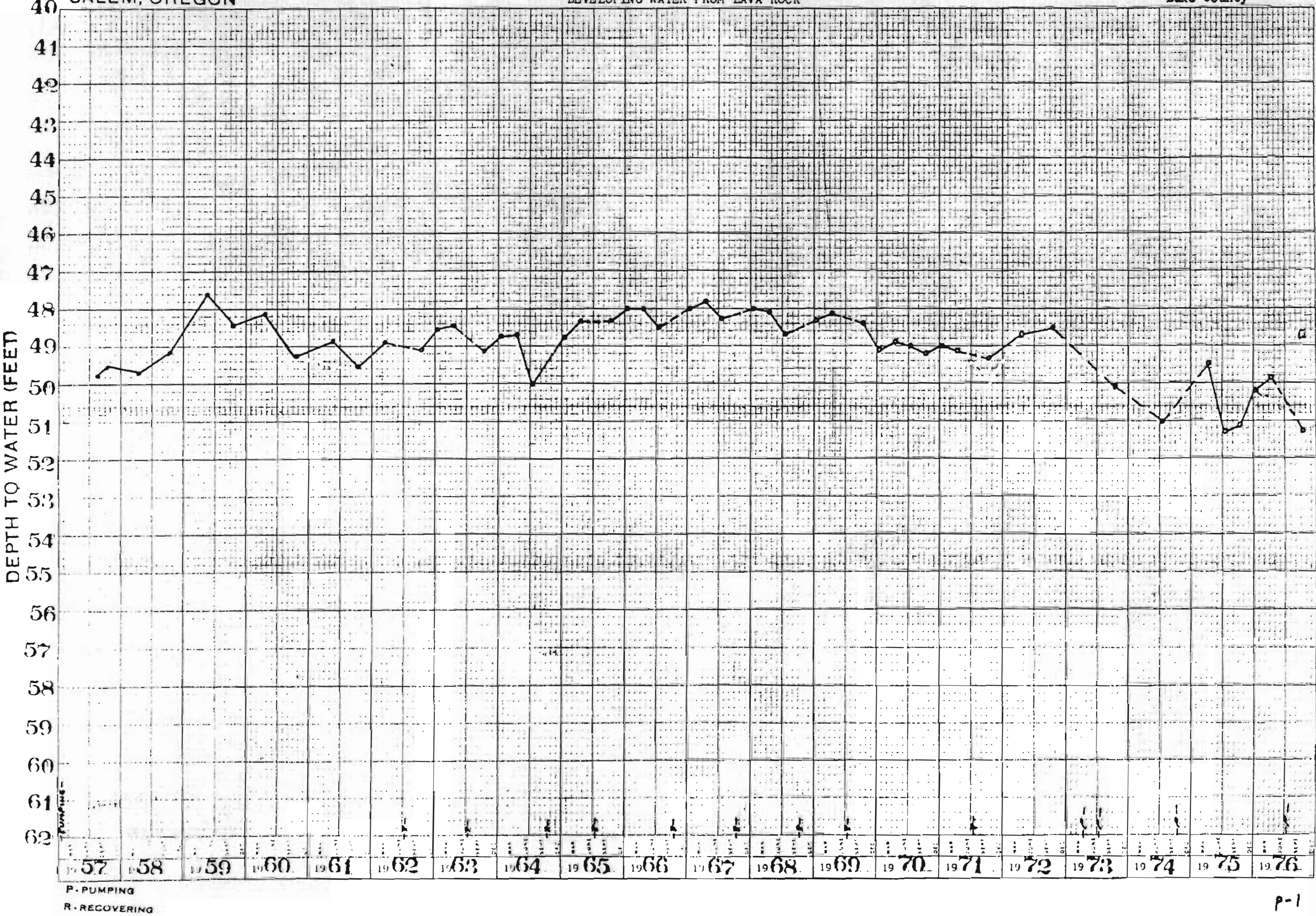


P-2

STATE ENGINEER
SALEM, OREGON

255-foot well in the Fort Rock Basin USED FOR IRRIGATION
DEVELOPING WATER FROM LAVA ROCK

27/19-18N(1) cc
Lake County



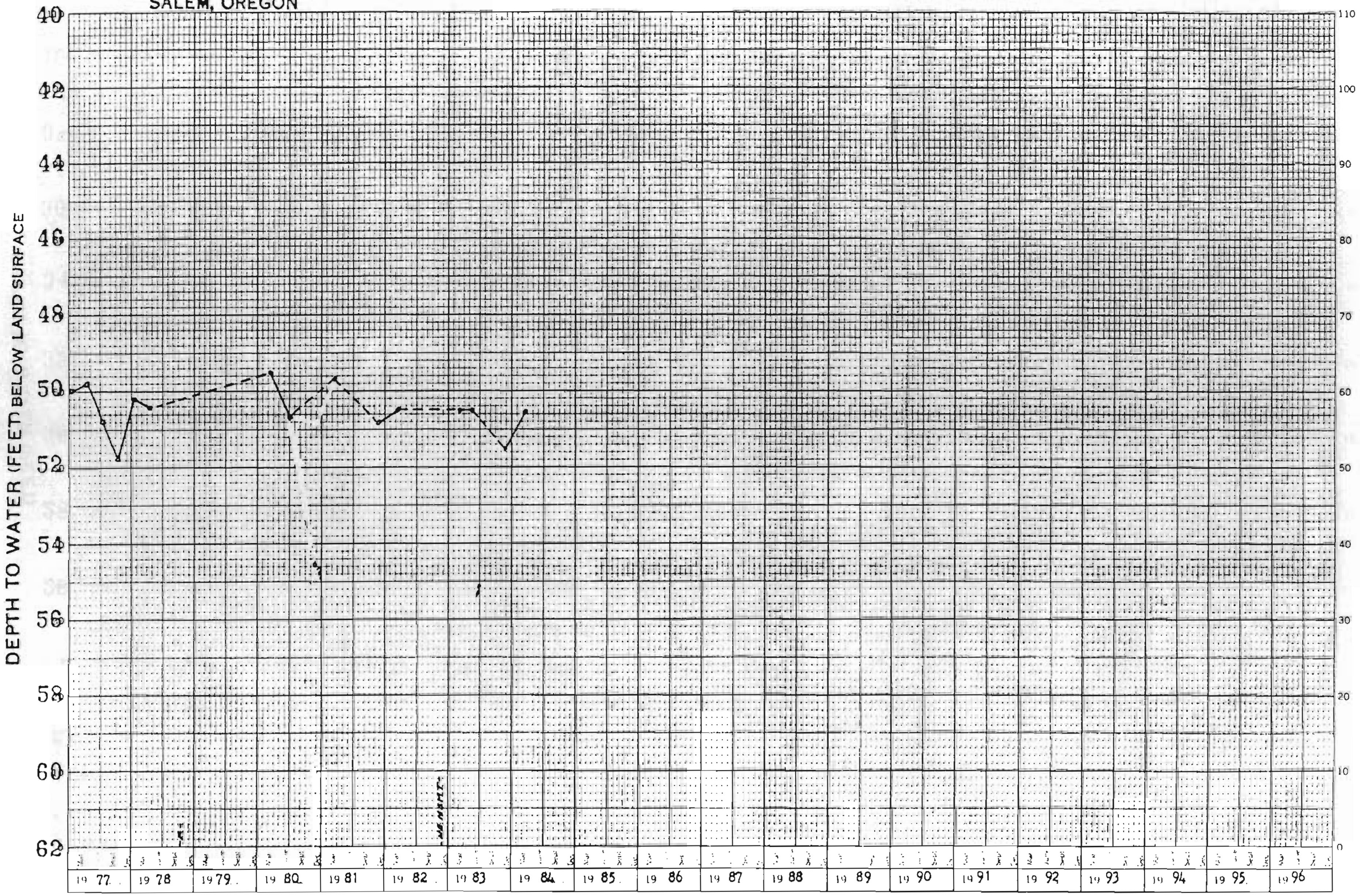
122

p-1

WATER RESOURCES DEPT
SALEM, OREGON

255 foot irrigation well in Fort Rock Basin developing water from lava rock

27S/19E-18cc
Lake



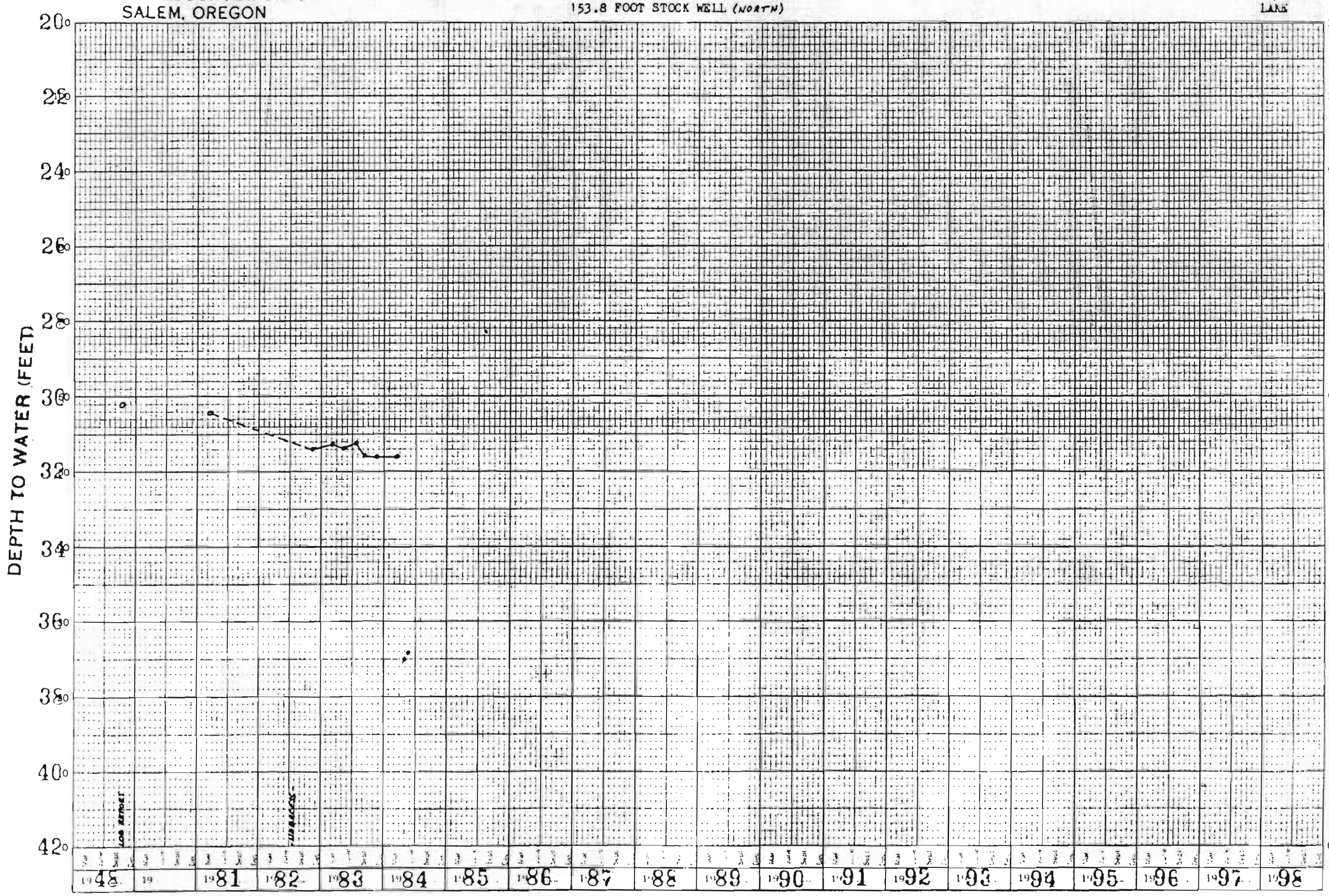
P-PUMPING
R-RECOVERING

P-2

WATER RESOURCES DEPT
SALEM, OREGON

153.8 FOOT STOCK WELL (NORTH)

27/20-8dda
LAKE



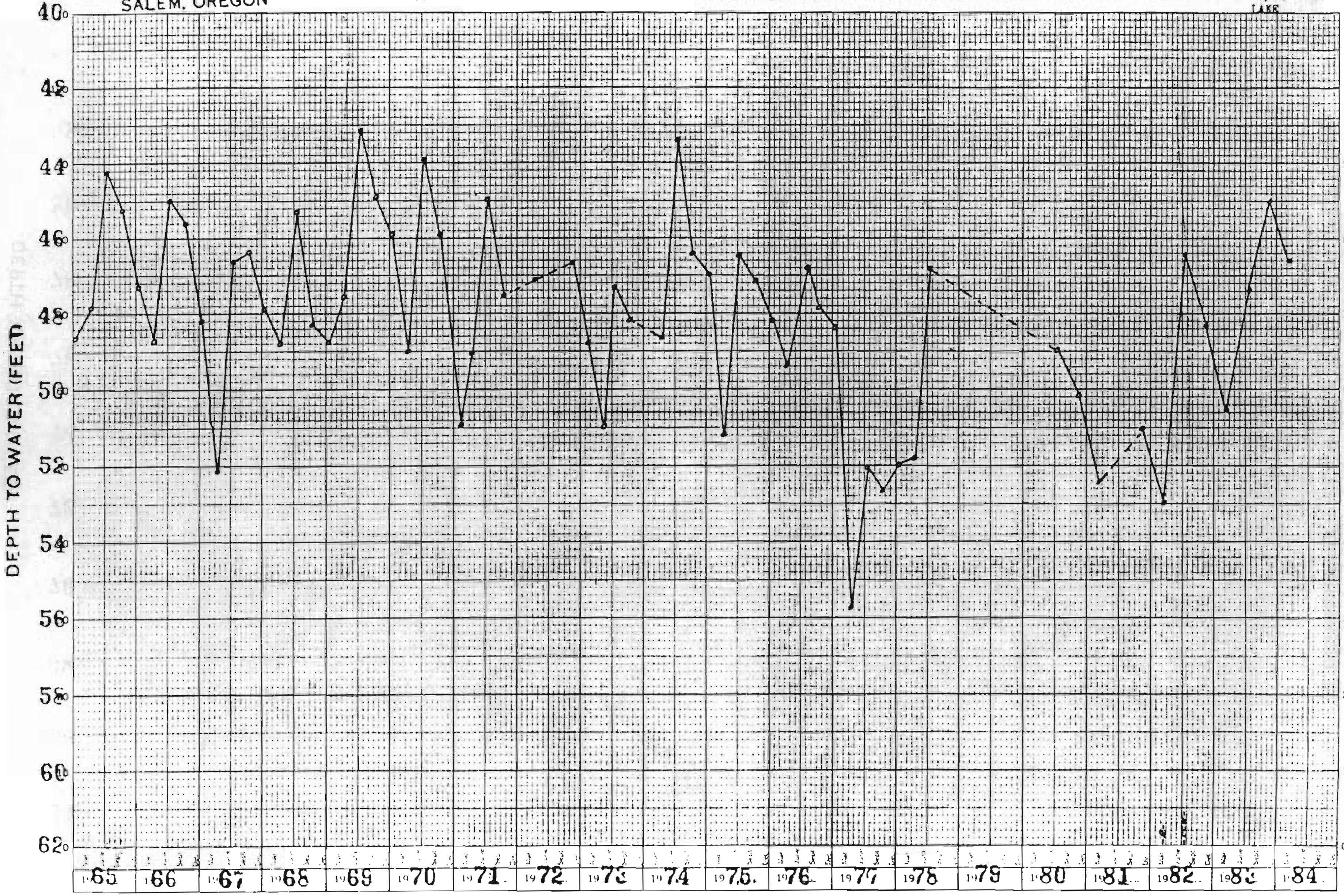
P - PUMPING
R - RECOVERING

P-1

WATER RESOURCES DEPT
SALEM, OREGON

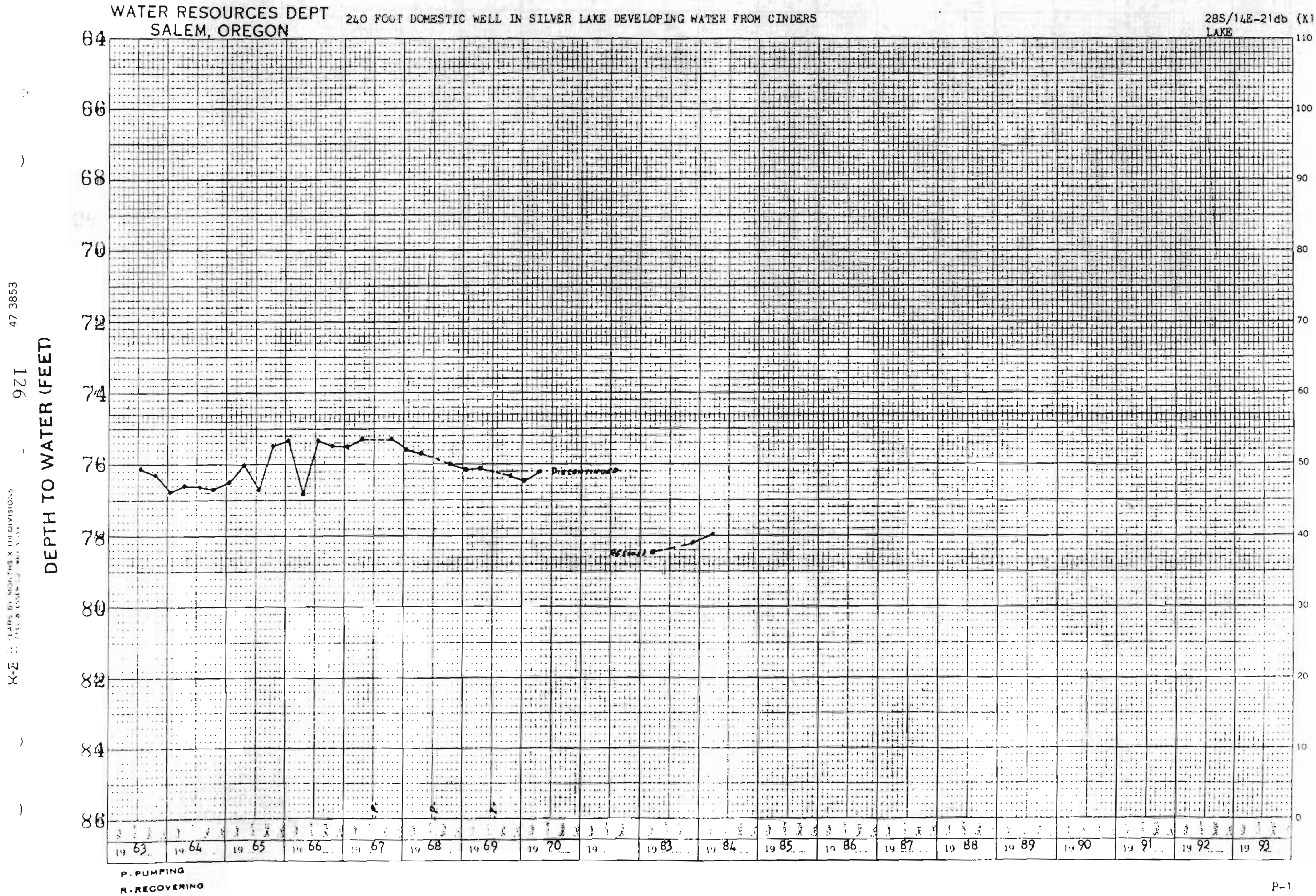
155 FOOT STOCK WELL ABOUT 1 MILE WEST OF SILVER LAKE DEVELOPING WATER FROM GRAVEL

28/14-20aba
LAKE



P - PUMPING
R - RECOVERING

P-1

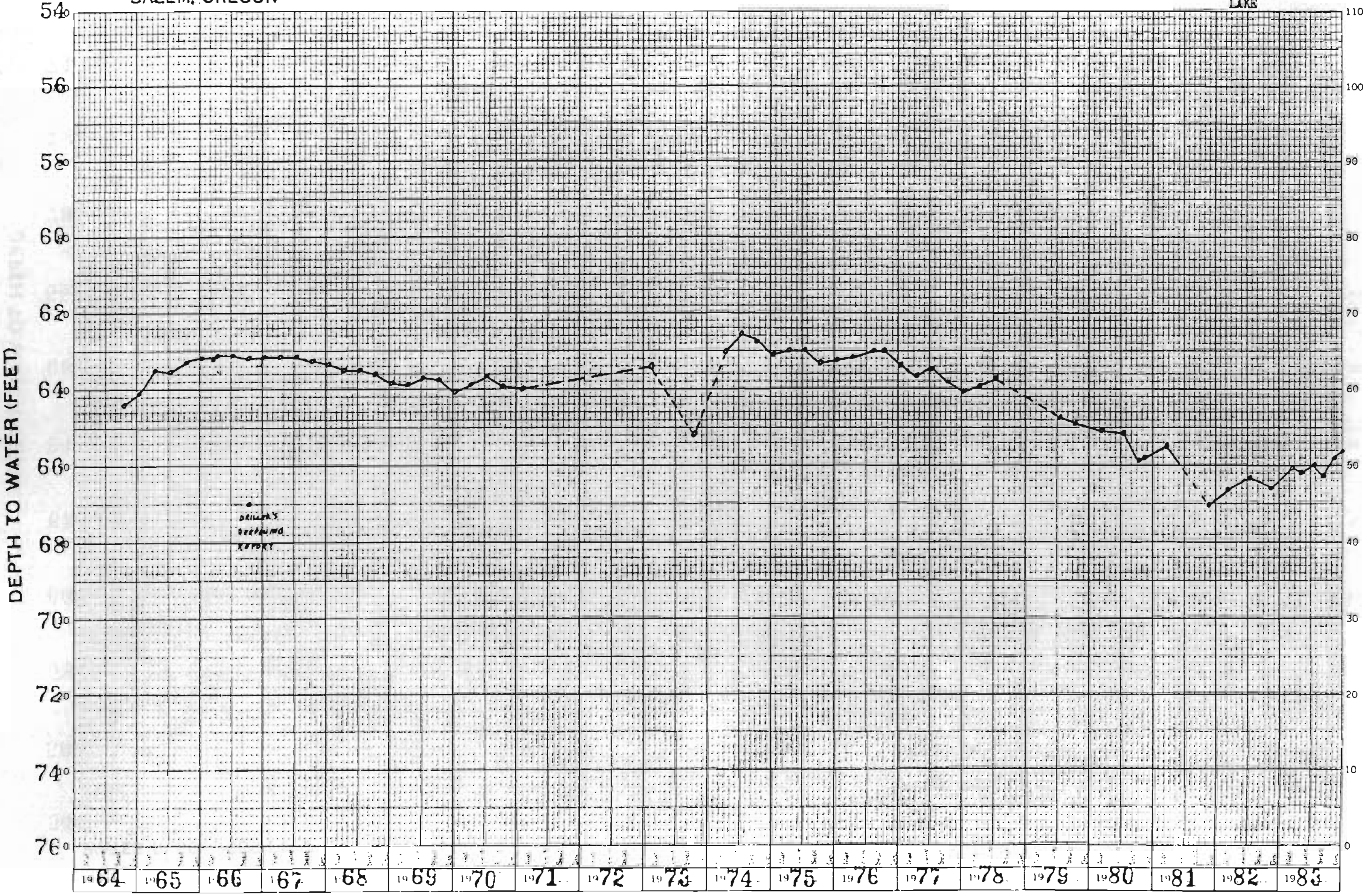

WATER RESOURCES DEPT
SALEM, OREGON
240 FOOT DOMESTIC WELL IN SILVER LAKE DEVELOPING WATER FROM CINDERS
28S/14E-21db (K1)
LAKE
DEPTH TO WATER (FEET)
64
66
68
70
72
74
76
78
80
82
84
86
110
100
90
80
70
60
50
40
30
20
10
0
Discontinued
Resumed
19 63
19 64
19 65
19 66
19 67
19 68
19 69
19 70
19
19 83
19 84
19 85
19 86
19 87
19 88
19 89
19 90
19 91
19 92
19 93
P. PUMPING
R. RECOVERING

P-1

WATER RESOURCES DEPT
SALEM, OREGON

521*FOOT IRRIGATION WELL ABOUT 3 MILES WEST OF SILVER LAKE DEVELOPING WATER FROM BASALT

28/14-25bba
LAKE



*DEEPENED TO 560' ON 10-1-66

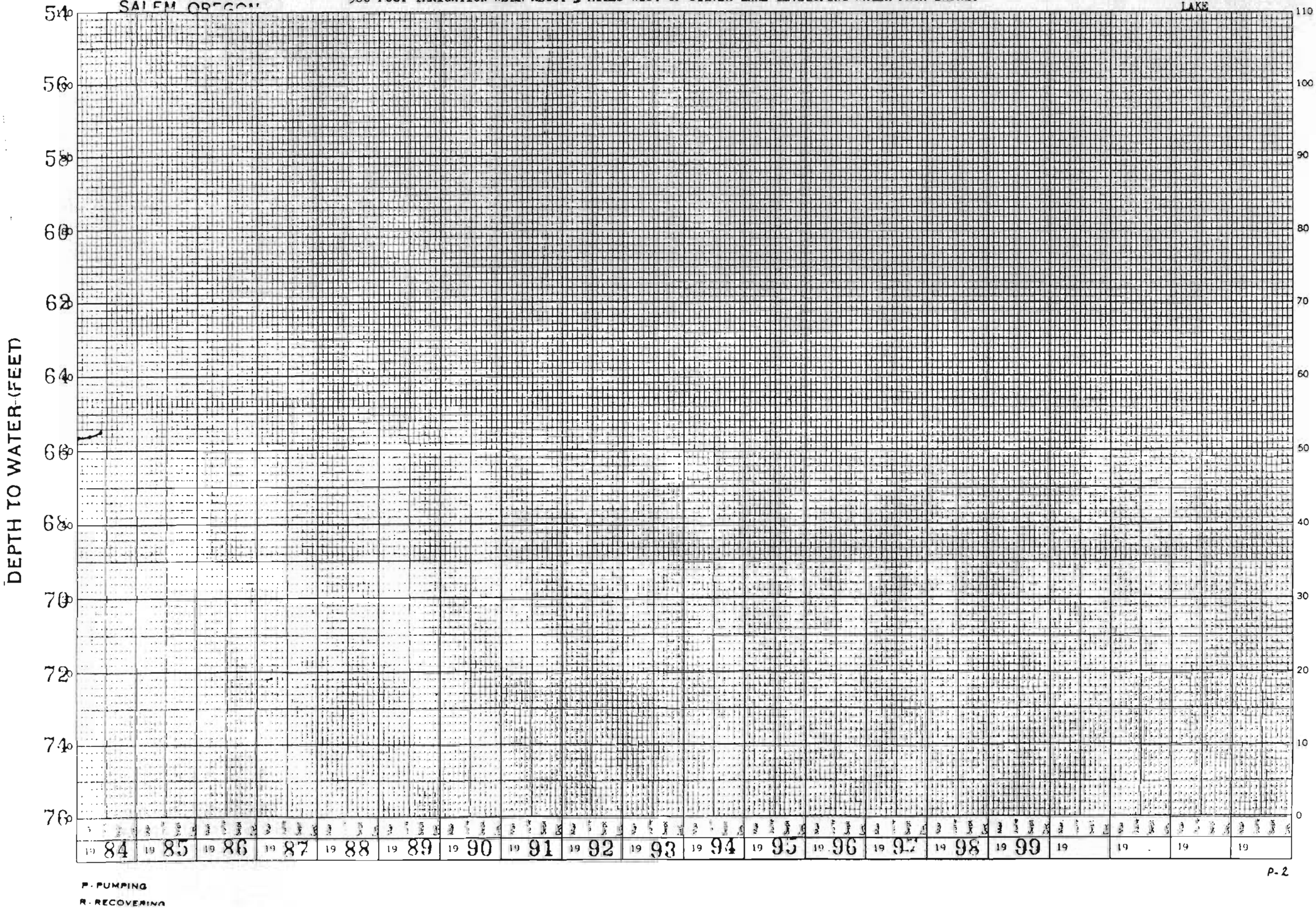
P-PUMPING
R-RECOVERING

P-1

WATER RESOURCES DEPT
SALEM OREGON

560 FOOT IRRIGATION WELL ABOUT 3 MILES WEST OF SILVER LAKE DEVELOPING WATER FROM BASALT

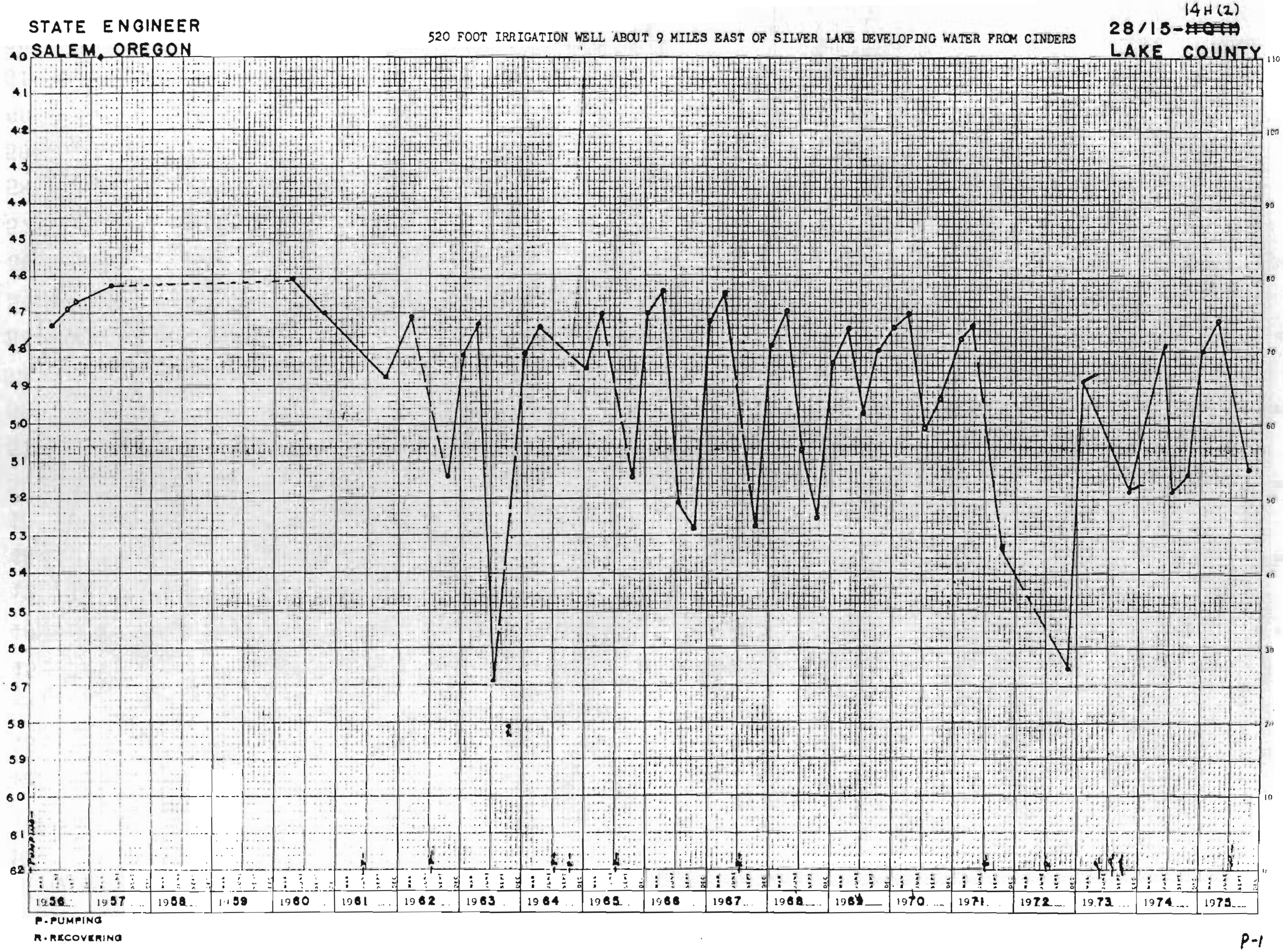
28/14-25bba
LAKE



47 3853

128

P-2


STATE ENGINEER
SALEM, OREGON
520 FOOT IRRIGATION WELL ABOUT 9 MILES EAST OF SILVER LAKE DEVELOPING WATER FROM CINDERS
14H(2)
28/15-
LAKE COUNTY
WATER LEVEL IN FEET BELOW LAND SURFACE
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1968
1969
1970
1971
1972
1973
1974
1975
P-PUMPING
R-RECOVERING
20 YEARS BY MONTHS X 110 DIVISIONS
359-21OL

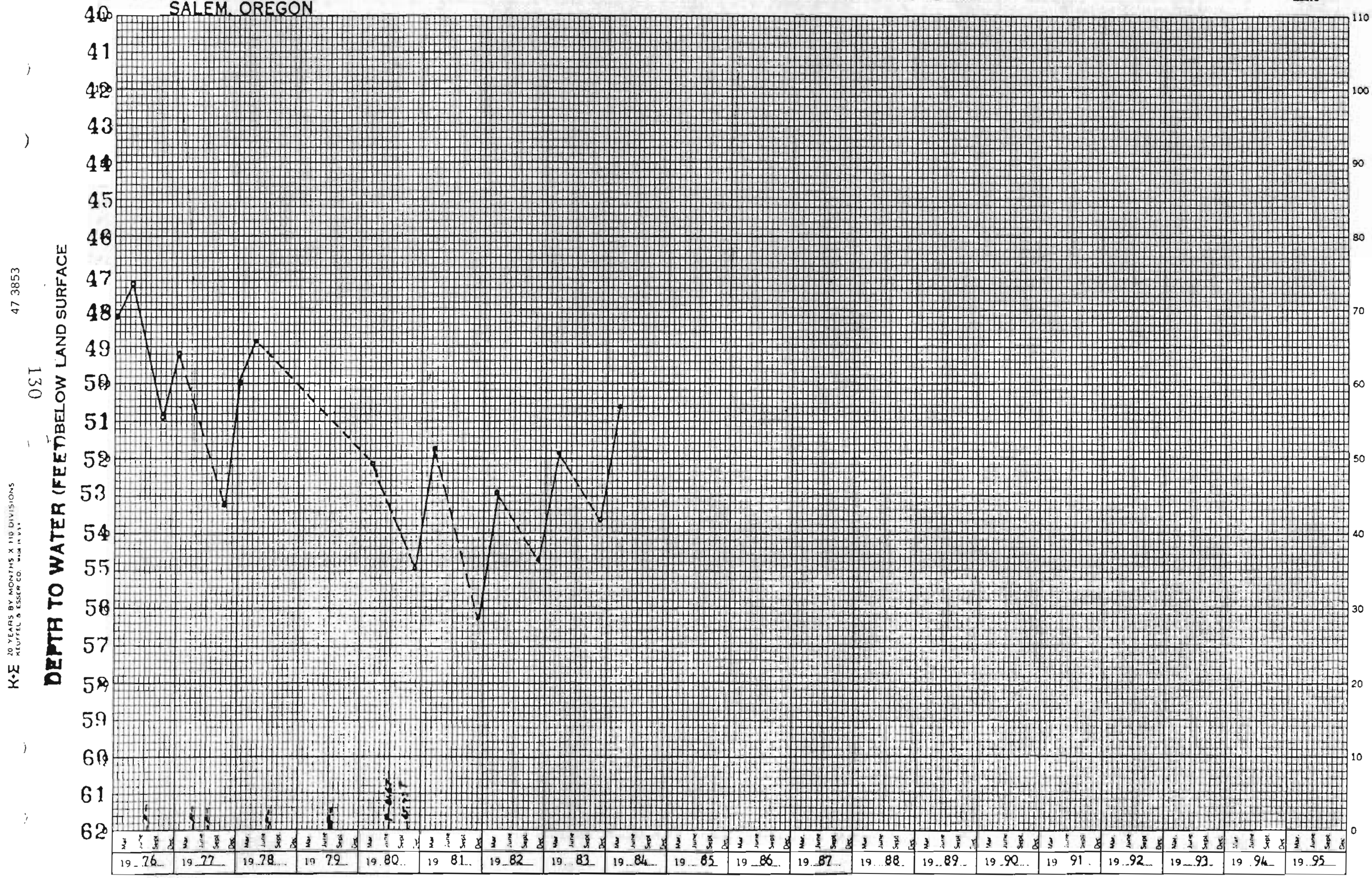
129

P-1

WATER RESOURCES DEPT
SALEM, OREGON

520 foot irrigation well about 9 miles East of Silver Lake developing water from cinders

28/15-14adc
Lake



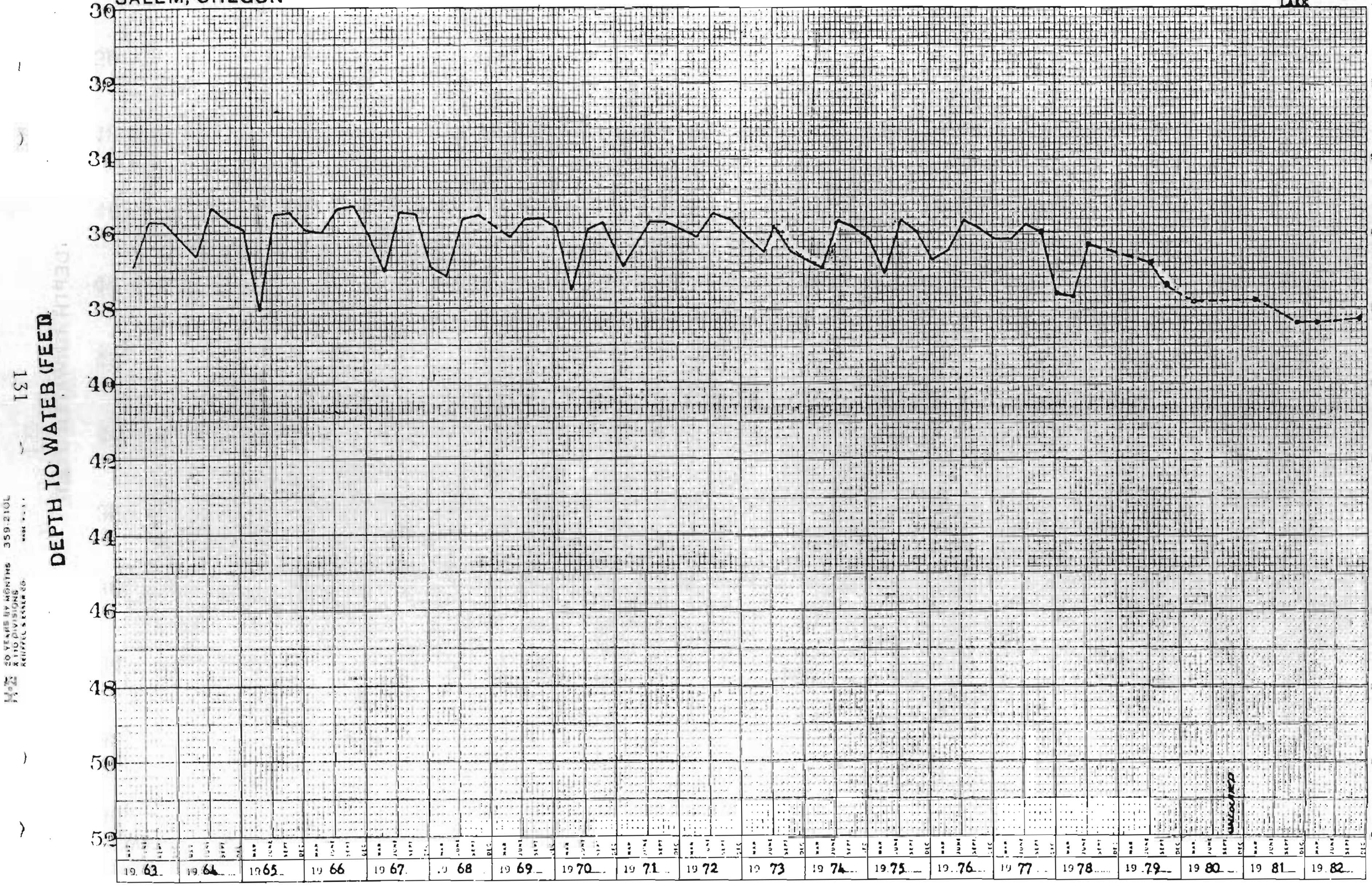
P - PUMPING
R - RECOVERING

P-7

STATE ENGINEER
SALEM, OREGON

339 FOOT UNUSED WELL ABOUT 2 MILES NE OF SUMMER LAKE DEVELOPING WATER FROM SAND

30/16-1F(1) cbb
LAKE

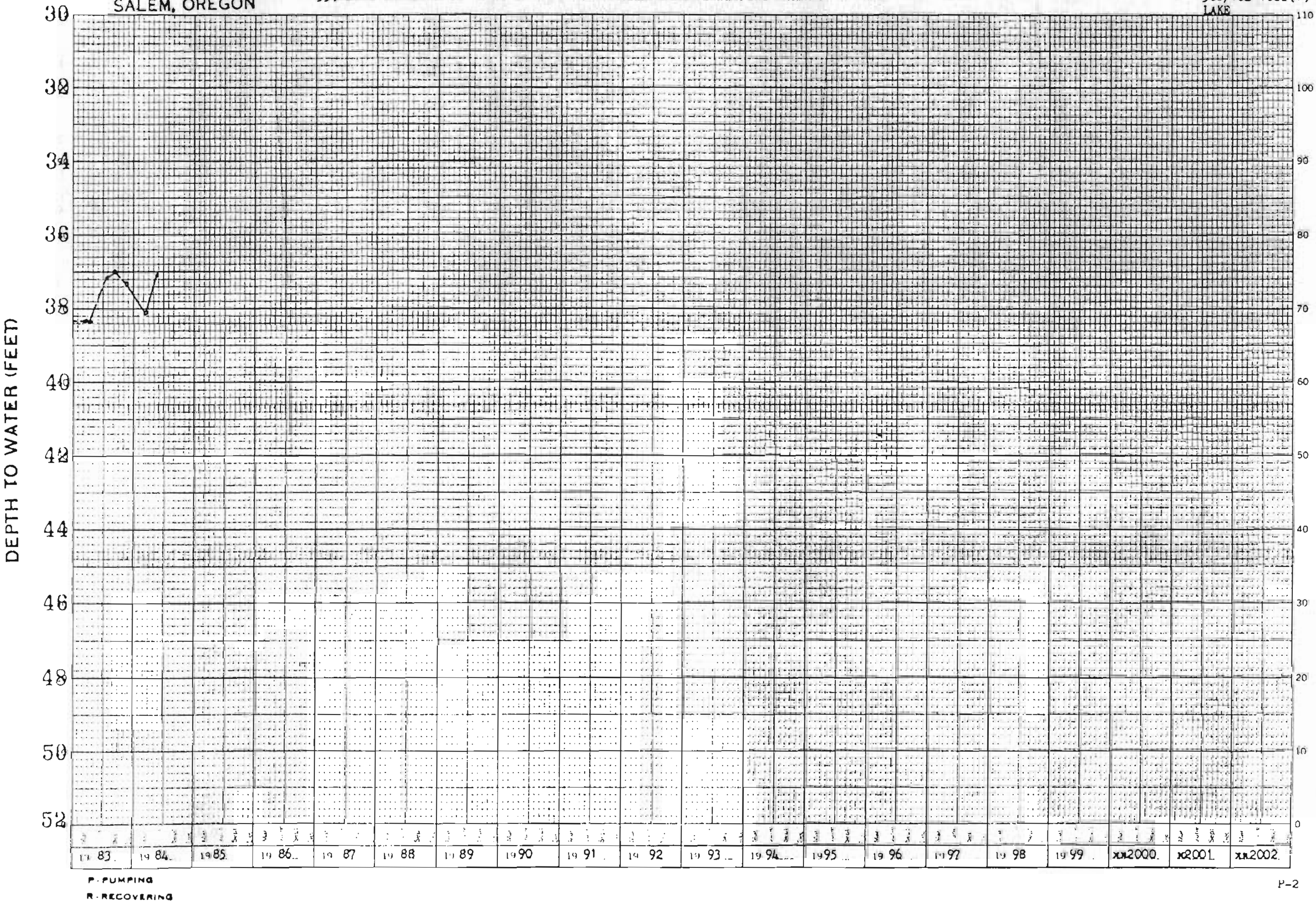


P-1

WATER RESOURCES DEPT
SALEM, OREGON

339 FOOT UNUSED WELL ABOUT 2 MILES NE OFSUMMER LAKE DEVELOPING WATER FROM SAND

30S/16E-1cbb(1)
LAKE



APPENDIX IV

PRECIPITATION AT FREMONT STATION
(43°20'N/121°10'W, prior to 3/25/58 at 43°19'N/121°09'W)

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Total Calendar Year	Total Water Year
1984	0.11	0.84	1.71	1.08	0.29									
1983	2.18	2.25	4.26	0.72	0.52	0.41	0.23	1.04M	T	0.84	2.34	4.00	18.79M	15.80M
1982	0.83	2.36M	1.70	0.85	0.35	2.86	0.99	0.15	0.45	0.47	1.47	2.25	14.73M	19.77M
1981	1.22	1.19	0.68	0.62	1.31	0.88	0.00	0.41	0.49	0.31	3.51	5.39	16.01	10.28
1980	3.20	0.90	0.59	0.59	0.60	2.33	0.42	0.00	1.07	0.53	0.48	2.47	13.18	13.53
1979	2.16	1.27	1.64	0.63	0.90	T	0.00	2.00	0.07	1.78	1.57	0.48	12.50	9.81
1978	2.28	1.34	0.97	0.90	0.57	0.86	0.10	0.70	0.50	T	0.64	0.50	9.36	14.74
1977	0.23	0.56	0.68	T	2.33	1.49	0.25	0.59	1.07	0.57	2.79	3.16	13.72	7.64
1976	1.03	2.17	0.66	0.22	0.12	0.46	0.12	2.75	0.22	0.37	T	0.07	8.19	11.64
1975	2.38	1.90	2.10	0.96	T	0.66	1.66	0.68	0.08	1.55	0.79	1.55	14.31	12.77
1974	3.02	0.79	1.94	0.37	0.70	1.25	0.84	0.65	0.00	0.36	0.65	1.34	11.91	15.94
1973	1.11	0.81	0.42	0.33	0.41	0.00	0.11	0.10	0.50	1.28	4.38	0.72	10.17	7.20
1972	1.99	1.01	2.25	0.77	0.65	0.21	0.19	0.15	0.19	1.74	0.67	1.00	10.82	11.61
1971	3.27	0.38	1.89	0.34	0.68	1.11	0.47	0.10	0.32	0.37	1.53	2.30	12.76	13.33M
1970	3.78	0.54	1.27	0.23	0.37	0.58	T	0.00	0.20	0.77	4.00	--	11.74M	10.60
1969	2.55	0.19	0.32	0.29	0.73	3.03	0.06	0.00	0.36	0.88	0.67	2.08	11.16	11.49
1968	1.21	0.93	0.32	0.10	0.94	0.54	0.00	1.7	0.10	0.69	1.93	1.34	9.17	8.19
1967	2.06	0.18	0.85	1.15	0.35	1.49	0.00	T	T	1.59	0.73	0.66	9.06	9.41
1966	2.61	0.34	0.64	0.03	T	0.68	0.53	0.46	0.26	0.30	1.81	1.22	8.88	8.75
1965	2.02	T	T	0.93	0.74	0.76	1.18	2.32	T	0.38	1.52	1.30	11.15	19.92
1964	2.00	0.04	1.08	0.13	0.10	1.35	0.86	0.25	0.09	0.13	1.70	10.14	17.87	8.53
1963	0.83	2.18	0.83	1.02	1.47	0.77	0.79	0.38	0.69	0.63	1.42	0.58	11.59	15.13
1962	0.75	1.04	0.52	0.35	1.18	T	0.43	0.29	0.65	3.59	1.41	1.17	11.38	8.20
1961	0.20	1.24	1.19	0.02	1.99	1.04	0.02	0.10	0.28	0.26	1.21	1.52	9.07	9.77
1960	0.94	1.27	1.33	0.84	0.63	0.05	0.36	0.04	0.98	0.20	3.19	0.30	10.13	7.58
1959	1.21	1.22	0.40	0.41	0.44	0.04	T	1.61	0.35	0.49	0.27	0.38	6.82	7.46
1958	2.80	1.74	0.73	0.48	1.13	1.84	0.16	0.08	0.16	0.00	1.08	0.70	10.90	9.12M
1957	1.25	1.07	2.00	0.77	1.33	--	0.12	0.12	--	--	--	--	6.66M	12.98M
1956	3.86	0.92	0.16	1.35	3.62	0.87	1.73	T	0.55	2.04	0.03	4.25	19.38	21.94
1955	0.35	0.21	0.33	0.77	0.23	0.04	0.04	0.00	0.53	0.33	2.04	6.51	11.38	3.53
1954	2.33	0.33	0.73	0.52	0.66	1.06	0.00	0.15	0.42	0.15	0.23	0.65	7.23	10.03
1953	3.16	1.36	0.92	0.40	2.01	0.92	0.00	0.80	0.17	0.35	2.25	1.23	13.57	12.87
1952	1.63	1.89	0.46	0.37	0.92	2.00	0.04	--	0.37	0.04	0.25	2.84	10.81M	15.05M
1951	--	--	--	0.21	1.21	0.05	0.47	0.20	0.08	1.34	1.23	4.80	9.59M	9.28M
1950	1.68	0.52	1.33	0.09	0.29	2.87	0.05	T	T	3.52	1.36	2.18	13.89	8.48
1949	0.23	1.41	--	0.10	--	--	0.02	0.00	0.13	0.07	0.88	0.70	3.54M	5.27M
1948	1.77	1.27	0.78	0.63	1.38	1.67	--	0.15	0.53	0.43	1.63	1.32	11.56M	9.95M

4684B

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Total Calendar Year	Total Water Year
1947	0.97	0.50	0.63	0.22	1.15	1.09	0.25	0.40	0.27	1.15	0.15	0.47	7.25	7.99
1946	1.72	0.17	0.91	0.08	1.68	0.50	0.42	0.46	0.73	0.74	1.58	0.19	9.18	12.26
1945	0.43	1.10	0.23	0.40	4.04	0.30	0.15	0.29	0.05	0.70	1.98	2.91	12.58	9.39M
1944	0.25	0.65	--	0.28	0.48	3.23	2.31	T	0.29	1.02	1.38	--	9.89M	10.44M
1943	2.70	0.82	0.17	1.00	0.28	0.74	0.42	0.08	T	2.07	0.70	0.18	9.16	12.35
1942	1.37	1.27	0.07	0.45	2.15	0.72	T	T	0.16	T	3.85	2.29	12.33	11.45
1941	1.57	0.94	0.20	0.44	0.48	1.22	1.10	2.03	0.48	1.50	1.82	1.94	13.72	10.84
1940	1.68	2.49	2.01	0.78	0.65	0.56	0.55	T	1.93	0.54	0.41	1.43	13.03	14.04
1939	0.64	0.85	0.50	0.12	0.48	0.05	0.40	T	0.46	0.44	T	2.95	6.89	5.41
1938	1.89	2.51	2.12	0.36	0.06	0.10	0.44	T	0.62	0.57	0.82	0.52	10.01	12.60
1937	0.41	0.56	1.07	1.34	0.09	2.31	0.74	0.00	0.42	0.85	1.46	2.19	11.44	6.94M
1936	--	--	--	--	--	--	--	--	--	--	--	--	0.00M	2.34M
1935	0.62	0.35	0.50	1.41	0.67	0.34	0.34	0.09	0.10	1.08	0.24	1.02	6.76	7.66
1934	1.09	0.44	0.58	0.83	0.41	0.98	0.00	0.50	0.14	1.11	0.86	1.27	8.21	6.71
1933	0.78	0.42	0.88	0.32	0.35	1.26	0.34	0.12	0.39	0.55	0.08	1.11	6.60	6.32
1932	0.94	0.28	0.47	1.83	1.43	0.38	0.03	T	0.00	0.07	0.99	0.40	6.82	8.03
1931	0.16	0.09	0.98	0.26	1.18	1.14	T	T	0.50	0.99	0.43	1.25	6.98	5.16
1930	2.90	0.53	0.65	0.70	0.39	0.17	T	0.58	1.46	0.47	0.27	0.05	8.17	11.05
1929	0.39	0.27	0.34	1.02	0.03	0.90	T	T	0.01	0.56	0.02	3.09	6.63	4.52
1928	1.37	0.57	1.65	0.66	0.21	1.72	0.47	0.10	0.14	0.23	0.49	0.84	8.45	9.14
1927	0.88	2.09	1.71	1.04	0.50	0.61	0.20	0.54	0.83	0.71	0.68	0.86	10.65	14.27
1926	0.53	1.10	0.05	0.78	0.27	0.07	0.38	0.08	0.04	0.77	3.59	1.51	9.17	5.13
1925	0.63	0.91	0.34	1.77	2.58	1.00	0.49	0.13	0.92	0.59	0.64	0.60	10.60	13.69
1924	--	0.45	0.27	0.09	0.08	0.27	0.16	0.38	0.64	1.70	1.70	1.52	7.26M	4.82M
1923	1.34	0.85	0.11	1.18	1.08	0.92	1.08	0.27	0.55	0.77	0.08	1.63	9.86	11.88
1922	0.51	2.41	0.63	0.42	0.95	1.29	0.07	0.78	0.02	1.23	1.56	1.71	11.58	10.67
1921	1.30	1.77	0.76	0.33	2.12	0.44	0.13	0.00	0.60	0.20	1.55	1.84	11.04	9.82
1920	0.13	0.50	1.18	0.95	T	0.56	0.75	0.41	0.33	0.52	0.96	0.89	7.18	7.80
1919	0.46	1.47	0.18	0.49	T	0.91	0.10	T	0.63	0.35	0.49	2.15	7.23	6.57
1918	0.76	--	0.47	0.09	0.16	0.02	0.31	0.72	1.92	1.28	0.77	0.28	4.45M	4.45M

T=Trace
M=Some Record Missing
--=No Record

4684B

APPENDIX V

EFFECTIVE PRECIPITATION AT FREMONT STATION (INCHES)
(43°20'N/121°10'W, prior to 3/25/58 at 43°19'N/121°09'W)

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Effective Water Year Precipitation
Potential Evapotrans-piration	0.0	0.0	0.60	1.30	2.6	3.5	4.3	4.0	2.8	1.7	0.50	0.0	
1984	0.11	0.84	1.11	0	0								(7.90)
1983	2.18	2.25	3.66	0	0	0	0	0	0	0	1.84	4.00	11.31M
1982	0.83	2.36M	1.10	0	0	0	0	0	0	0	0.97	2.25M	12.69M
1981	1.22	1.19	0.08	0	0	0	0	0	0	0	3.01	5.39	4.96
1980	3.20	0.90	0	0	0	0	0	0	0	0	0	2.47	5.73
1979	1.66	1.27	1.04	0	0	0	0	0	0	0.08	1.07	0.48	4.61
1978	2.28	1.34	0.37	0	0	0	0	0	0	0	0.14	0.50	9.44
1977	0.23	0.56	0.08	0	0	0	0	0	0	0	2.29	3.16	0.94
1976	1.03	2.17	0.06	0	0	0	0	0	0	0	0	0.07	5.10
1975	2.38	1.90	1.50	0	0	0	0	0	0	0	0.29	1.55	7.27
1974	3.02	0.79	1.34	0	0	0	0	0	0	0	0.15	1.34	9.75
1973	1.11	0.81	0	0	0	0	0	0	0	0	3.88	0.72	3.13
1972	1.99	1.01	1.65	0	0	0	0	0	0	0.04	0.17	1.00	7.98
1971	3.27	0.38	1.29	0	0	0	0	0	0	0	1.03	2.30	8.44M
1970	3.78	0.54	0.67	0	0	0	0	0	0	0	3.5	--	7.24
1969	2.55	0.19	0	0	0	0	0	0	0	0	0.17	2.08	5.51
1968	1.21	0.93	0	0	0	0	0	0	0	0	1.43	1.34	3.03
1967	2.06	0.18	0.25	0	0	0	0	0	0	0	0.23	0.66	5.02
1966	2.61	0.34	0.04	0	0	0	0	0	0	0	1.31	1.22	5.31
1965	2.02	0	0	0	0	0	0	0	0	0	1.02	1.30	13.36
1964	2.00	0.04	0.48	0	0	0	0	0	0	0	1.20	10.14	4.02
1963	0.83	2.18	0.23	0	0	0	0	0	0	0	0.92	0.58	7.21
1962	0.75	1.04	0	0	0	0	0	0	0	1.89	0.91	1.17	4.02
1961	0.20	1.24	0.59	0	0	0	0	0	0	0	0.71	1.52	5.02
1960	0.94	1.27	0.73	0	0	0	0	0	0	0	2.69	0.30	3.32
1959	1.21	1.22	0	0	0	0	0	0	0	0	0	0.38	3.71
1958	2.80	1.74	0.13	0	0	0	0	0	0	0	0.58	0.70	4.67M
1957	1.25	1.07	1.40	0	0	0	0	0	--	--	--	--	8.31M
1956	3.86	0.92	0	0.05	1.02	0	0	0	0	0.34	0	4.25	13.90
1955	0.35	0.21	0	0	0	0	0	0	0	0	1.54	6.51	1.21
1954	2.33	0.33	0.13	0	0	0	0	0	0	0	0	0.65	5.77
1953	3.16	1.36	0.32	0	0	0	0	0	0	0	1.75	1.23	7.68

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	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Effective Water Year Precipitation
1952	1.63	1.89	0	0	0	0	0	--	0	0	0	2.84	9.05M
1951	--	--	--	0	0	0	0	0	0	0	0.73	4.80	4.86M
1950	1.68	0.52	0.73	0	0	0	0	0	0	1.82	0.86	2.18	4.01
1949	0.23	1.41	--	0	--	--	0	0	0	0	0.38	0.70	4.09M
1948	1.77	1.27	0.18	0	0	0	--	0	0	0	1.13	1.32	3.69M
1947	0.97	0.50	0.03	0	0	0	0	0	0	0	0	0.47	2.77
1946	1.72	0.17	0.31	0	0	0	0	0	0	0	1.08	0.19	6.59
1945	0.43	1.10	0	1.44	0	0	0	0	0		1.48	2.91	3.95M
1944	0.25	0.65	--	0	0	0	0	0	0	0	0.88	--	1.65M
1943	2.70	0.82	0	0	0	0	0	0	0	0.37	0.20	0.18	9.16
1942	1.37	1.27	0	0	0	0	0	0	0	0	3.35	2.29	5.90
1941	1.57	0.94	0	0	0	0	0	0	0	0	1.32	1.94	3.94
1940	1.68	2.49	1.41	0	0	0	0	0	0	0	0	1.43	8.53
1939	0.64	0.85	0	0	0	0	0	0	0	0	0	2.95	2.33
1938	1.89	2.51	1.52	0	0	0	0	0	0	0	0.32	0.52	9.07
1937	0.41	0.56	0.47	0.04	0	0	0	0	0	0	0.96	2.19	1.48
1936	--	--	--	--	--	--	--	--	--	--	--	--	1.02M
1935	0.62	0.35	0	0.11	0	0	0	0	0	0	0	1.02	2.71
1934	1.09	0.44	0	0	0	0	0	0	0	0	0.36	1.27	2.64
1933	0.78	0.42	0.28	0	0	0	0	0	0	0	0	1.11	2.37
1932	0.94	0.28	0	0.53	0	0	0	0	0	0	0.49	0.40	3.00
1931	0.16	0.09	0.38	0	0	0	0	0	0	0	0	1.25	0.68
1930	2.90	0.53	0.05	0	0	0	0	0	0	0	0	0.05	6.57
1929	0.39	0.27	0	0	0	0	0	0	0	0	0	3.09	1.50
1928	1.37	0.57	1.05	0	0	0	0	0	0	0	0	0.84	4.03
1927	0.88	2.09	1.11	0	0	0	0	0	0	0	0.18	0.86	8.68
1926	0.53	1.10	0	0	0	0	0	0	0	0	3.09	1.51	2.37
1925	0.63	0.91	0	0.47	0	0	0	0	0	0	0.14	0.60	4.73
1924	--	0.45	0	0	0	0	0	0	0	0	1.20	1.52	2.08M
1923	1.34	0.85	0	0	0	0	0	0	0	0	0	1.63	4.96
1922	0.51	2.41	0.03	0	0	0	0	0	0	0	1.06	1.71	5.84
1921	1.30	1.77	0.16	0	0	0	0	0	0	0	1.05	1.84	4.58
1920	0.13	0.50	0.58	0	0	0	0	0	0	0	0.46	0.89	3.36
1919	0.46	1.47	0	0	0	0	0	0	0	0	0	2.15	2.48
1918	0.76	--	0	0	0	0	0	0	0	0	0.27	0.28	0.76M

M=Some Record Missing
--=No Record

4684B

Silver Creek Discharge (AF) and Thompson Valley Reservoir Change (AF) for Water Year
and Calender Year Water Level Changes (Ft) at selected Observation Wells

APPENDIX VI

Year	Silver Cr Discharge	Change of Reservoir Storage	T25S/R14E 15bc	T25S/R19E 31bc	T26S/R15E 6ab	T26S/R18E 26ab	T27S/R15E 4ac	T27S/R16E 13ab	T27S/R17E 22dd	T27S/R17E 27dd	T27/R18E 6bdb	T27S/R18E 21aa	T28S/R14E 25bb
1983	51,090	1940	+0.4	+0.2	+0.4	E +0.5	+0.4	-	-	+0.5	+0.3	+0.1	+0.7
1982	46,910	9900	+0.2	+0.2	+0.4	E +0.2	+0.3	-	-	+0.7	+0.5	E 0.0	E +0.4
1981	10,550	-1670	-0.9	-0.8	-0.9	E -1.0	-1.1	-	-	-1.1	-1.0	E -1.0	-1.2
1980	18,600	1790	E -0.6	E -0.4	-1.0	E -1.0	E -0.6	-	-	-0.8	E-0.8	E -0.4	E -0.4
1979	17,590	-6660	E -0.5	E -0.4	E -0.1	E 0.0	E -0.5	-	-	-0.4	E-0.7	E -0.4	E -0.8
1978	27,330	6960	E -0.5	E -0.3	E -0.4	E +0.1	E -0.5	E -0.4	-	-0.2	E-0.8	E -0.1	E -0.4
1977	12,060	-9520	-0.5	-0.2	-0.5	-0.1	-0.6	E -0.7	-	-	-0.7	-0.4	-0.6
1976	17,330	-1390	0.0	0.0	0.1	0.0	-0.5	0.0	-	-	+0.1	-0.0	-0.1
1975	31,740	-500	E 0.0	0.0	E +0.2	E -0.1	+0.1	E -0.1	-	-	E+0.2	E -0.1	-0.2
1974	52,630	6950	E +0.5	E -0.3	E +0.4	E -0.3	+0.6	E +0.1	-	-	E+0.3	E -0.0	E +0.2
1973	16,310	-4850	+0.1	E +0.2	E +0.2	E -0.2	-0.2	E 0.0	-	-	E 0.0	E -0.1	E +0.1
1972	41,400	-2410	+0.2	E 0.0	0.0	+0.2	+0.3	E +0.1	-	-	0.0	E +0.1	E +0.3
1971	44,890	3210	+0.4	E +0.1	+0.7	-0.1	+0.3	+0.4	-	E +0.1	+0.1	E 0.0	E +0.3
1970	24,000	740	-0.3	-0.1	+0.1	-0.1	-0.2	-0.2	+0.2	-0.1	0.0	-0.1	0.0
1969	22,860	3430	-0.3	-0.2	-0.1	0.0	-0.3	-0.2	-0.4	-0.2	-0.1	-0.1	-0.2
1968	14,830	-6530	-0.5	-0.2	-0.3	-0.1	-0.5	-0.4	-0.2	-0.4	-0.1	-0.2	-0.4
1967	31,230	1710	-0.2	-0.1	+0.8	-0.2	0.0	0.0	-0.3	-0.2	0.0	0.0	-0.2
1966	18,130	-4010	0.0	-0.3	+0.4	+0.1	+0.1	+0.1	0.0	0.0	+0.1	0.0	0.0
1965	41,360		+0.9	+0.9	+1.3	+0.5	+0.8	+1.1	+0.8	+0.9	+0.6	+0.5	+1.1
1964	11,340		-0.1	-0.1	-0.3	+0.1	-0.1	-0.3	-0.1	0.0	+0.1	+0.1	
1963	26,320		0.0		-0.2		0.0	-0.1	-0.1	-0.1	0.0	-0.1	
1962	13,040		-0.3				-0.2	-0.3	-0.2	-0.3	-0.1	-0.1	
1961	11,270		E -0.3				-0.3	E -0.2	-0.2	+0.1	0.0	-0.1	
1960	10,730		E 0.0				-0.2		E 0.0	+0.1	0.0	-0.2	
1959	12,670		E -0.3				-0.1		E -0.2	-0.1	+0.1	+0.2	
1958	51,810		E +0.3				+0.5		E +0.6	+0.5	+0.5	+0.6	
1957	30,290		E +0.8				+0.5		E +0.2	-	+0.6	+0.2	
1956	62,750		E +0.6				+1.1		+1.0	-		+0.7	
1955	12,510		E +0.5				+0.2		+0.3				
1954	44,160		+0.9				+0.4		+0.6				
1953	33,210		+0.6				+1.1		+0.6				
1952	39,530		+1.2				+0.6		+0.5				
1951	39,480		+0.5				+0.8		+0.7				
1950	14,090		+0.3				+0.3		+0.3				
1949	13,590		0.0				0.0		+0.1				
1948	11,260		0.0				-		-0.1				
1947	8,610		0.0				-		E 0.2				
1946	15,640		-0.1				-		-				
1945	9,020		E -0.1				E 0.0		-				
1944	8,580		E -0.2				E 0.0		-				

4684B

Year	Silver Cr Discharge	Change of Reservoir Storage (AF)	T25S/R14E 15bc	T25S/R19E 31bc	T26S/R15E 6ab	T26S/R18E 26ab	T27S/R15E 4ac	T27S/R16E 13ab	T27S/R17E 22dd	T27S/R17E 27dd	T27/R18E 6bdb	T27S/R18E 21aa	T28S/R14E 25bb
1943	37,160M	-	E 0.0				E -0.1		-				
1942	10,680M	-	-0.2				0.0		E +0.1				
1941	11,120	-	-0.3				-0.3		-0.4				
1940	12,410	-	-0.2				-0.3						
1939	9,270	-	-0.3				-0.2						
1938	23,360	5580	E -0.2				-						
1937	9,400		-				-						
1936	10,320		-				E -0.2						
1935	10,170		-				-						
1934	2,647		-				-						
1933	8,960		-				-						
1932	11,300		-										
1931	1,700												
1930	5,500												
1929	-												
1928	5,070M												
1927	22,770												
1926	4,350												
1925	15,100												
1924	2,110												
1923	12,990												
1922	13,900												
1921	34,200												
1920	7,340												
1919	17,800												
1918	9,540												
1917	22,400												
1916	35,700												
1915	11,600												
1914	37,700												
1913	31,800												
1912	32,000												
1911	44,800												
1910	51,700												
1909	-												
1908	-												
1907	-												
1906	40,100												

E=Estimated
M=Some Record Missing

APPENDIX VII

MODELS FOR ADDITIONAL WELLS

In order to verify the use of results obtained by analyzing the Parks well, certain other Fort Rock Basin wells have been examined in much the same way as was the Parks well. Regressions of annual water level changes for calendar years and comparable water year streamflow on Silver Creek or effective precipitation at Fremont were developed for nine wells. These regressions are for wells which derive water from the main ground water reservoir, have good depth to water records and are located in differing areas throughout the basin (Figure 25).

Table 1 summarizes the results of the various regressions. Figures 26 and 27 display some of this data.

Items of particular note on the table are the sample length (N), slope (m) and the Y-intercept (b).

Although it should not be assumed that the natural water level changes of other wells react exactly like those of the Parks well, a plot of sample length (N) and Y-intercept (b) (Figure 26) shows the central tendency (mean) of b for the various regressions to be similar to that of the Parks well (-0.57 and -0.51 vs. -0.48 and -0.43). Variation of b apparently increases with smaller data sets. Although such data sets may have favorable correlation coefficients, their regression equations may be highly leveraged by only one or two extreme values. Similarly, a plot of sample length (N) and slope (m) (Figure 27) suggests that variation of m values increases with smaller data sets yet has a central tendency close to that of the Parks well (0.098 and 2.79×10^{-5} vs. 0.095 and 2.23×10^{-5}).

Another approach to validating the use of results obtained by analyzing the Parks well involved comparing the same data sets used at the nine other wells to the data for similar years at the Parks well. Due to some instances of poorly defined water level changes at the Parks well, similar data often fall a data point or two short of the set for the other wells. In most cases, this subset comparison shows that results at the Parks well and other wells are similar when reviewed in light of comparable data.

Examination of data subsets suggests that three categories exist: (1) The comparisons at wells 25S/14E-15, 25S/19E-31 and 27S/17E-22 (Figures 28, 29 and 34) show highly comparable results to those of the Parks well. Slope and Y-intercept values are within 15 percent of those at the Parks well, (2) The comparisons at wells 26S/15E-6, 27S/16E-13 and 28S/14E-25 (Figures 30, 33 and 37) show more parameter variation and are within 30 percent of those at the Parks well. It appears that the amplitudes of water level fluctuations may be slightly higher at these points, (3) The third category is revealed by comparisons at wells 26S/18E-26, 27S/18E-6 and 27S/18E-21 (Figures 31, 35 and 36). Parameter variations from those of the Parks well are greater than 30 percent. This category has lesser slopes and larger Y-intercepts (less negative) than those of the subsets at the Parks well. The regression equation of all data at the Parks well shows a slope and Y-intercept which rests between the shorter term regressions of each category 3 well and comparable Parks well data sets. This feature suggests that water levels at category 3 wells are generally more insensitive to change than are those of the Parks well.

Plots of data since 1975 show that annual water level changes have fallen below the several regression equations. The application of the double outflow concept for each of the nine other wells shows that recent data often approximate a double outflow condition. This similarity reveals the widespread occurrence of water level declines, or at least rises which are less than those for natural conditions, and compares the results of analyses of the Parks well data. This review of the hydrograph data suggests that pumping withdrawals closely approximate annual recharge.

In addition to generally similar water level fluctuation statistics, levels in observation wells in the main ground water reservoir display similar long term trends. Figure 5 in the body of this report shows that water levels for the various wells have declined from 0.7 to 4.6 feet for the period 1976 to 1983. In general, declines have been from two to three feet during the interval. Hydrograph analysis reveals that the 4.6 feet decline well probably contain a foot or two or residual drawdown. Also, the hydrograph showing 0.7 feet of decline may be the result of higher residual drawdown early in the interval. This could serve to dampen the actual decline for the period. In any case, declines seem to be less in the eastern portion of the basin.

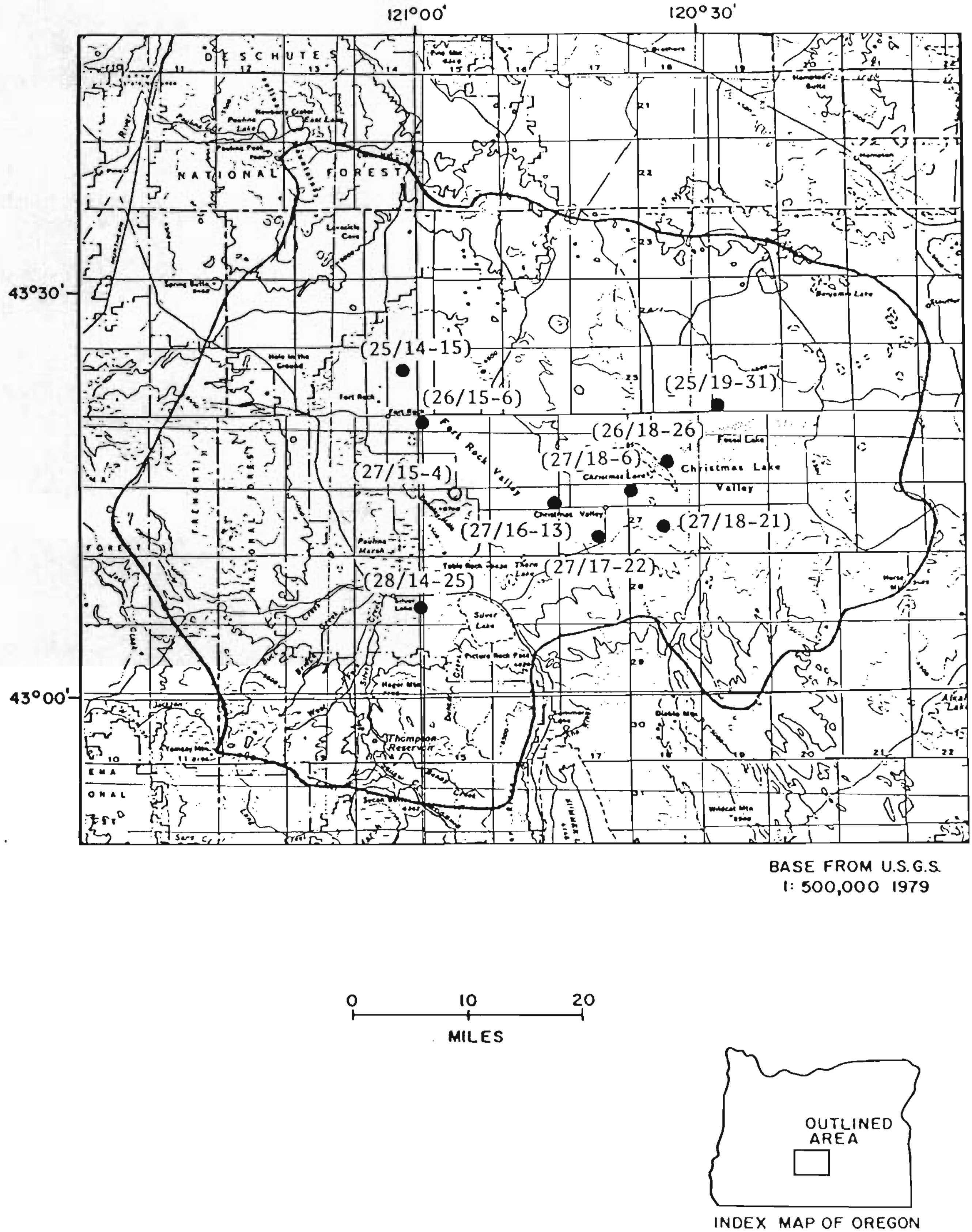
In summation, several lines of evidence appear to reinforce the suitability of the Parks well as an indicator to describe conditions in the main ground water reservoir. In addition to long term trends, statistical analyses of water level data from nine additional wells display similarities to the Parks well. In all cases the sensitivity of water level changes to recharge indicators (precipitation and streamflow) is small in terms of absolute changes of water level.

TABLE 1

Water Level Change Regression Statistics.

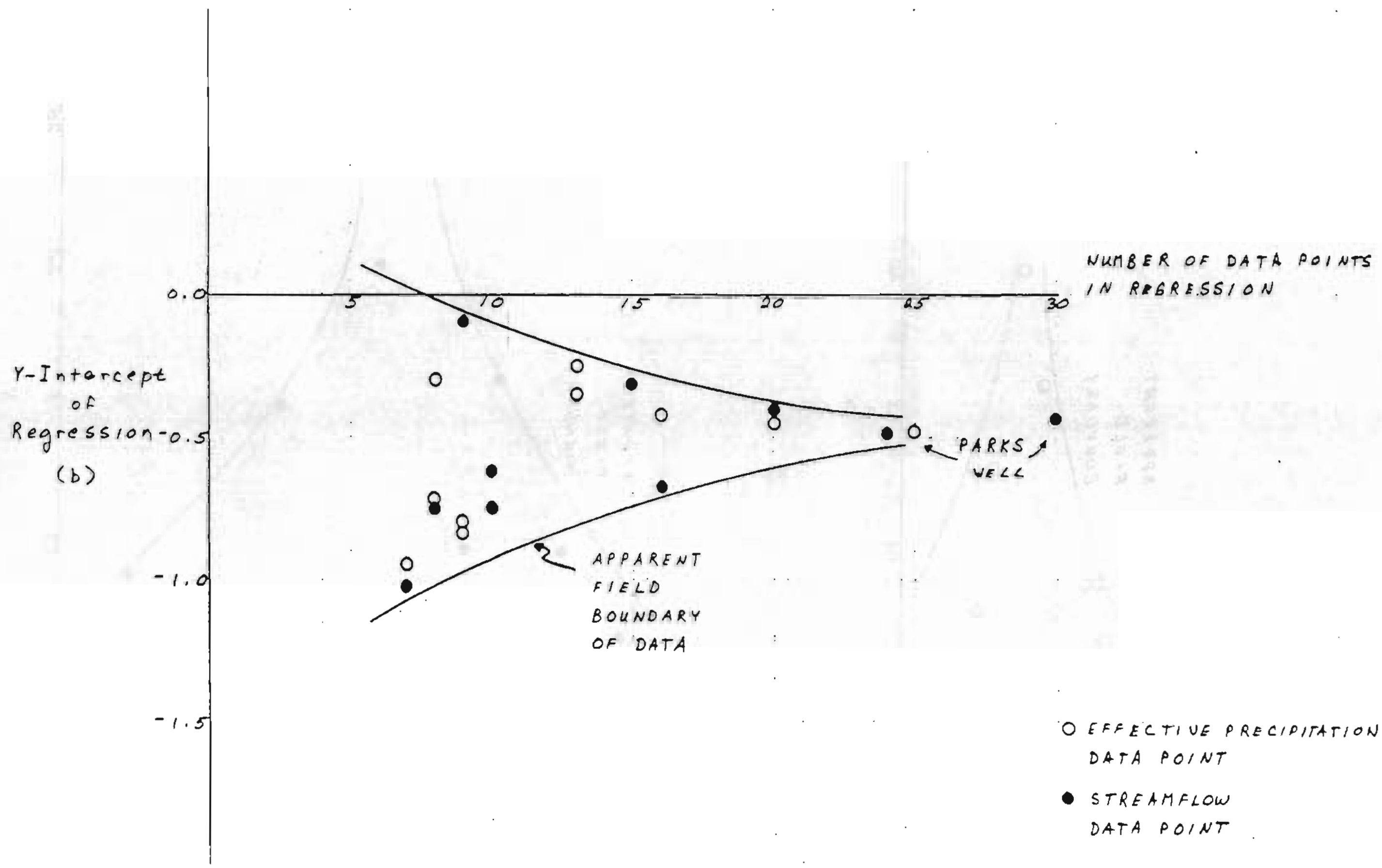
Well Location	Independent Variable (X)	N	m	R	b	$\bar{X}$ (in/yr or AF/yr)	$\bar{Y}$ (ft)
25/14-15bc	Effective precipitation	20	0.086	0.54	-0.45	5.67	0.01
	Streamflow	24	2.43×10^{-5}	0.74	-0.49	23,253	0.10
25/19-31bc	Effective precipitation	8	0.11	0.91	-0.71	6.35	-0.01
	Streamflow	8	2.89×10^{-5}	0.76	-0.72	24,436	-0.01
26/15-6ab	Effective precipitation	9	0.14	0.85	-0.84	6.77	0.12
	Streamflow	10	2.88×10^{-5}	0.67	-0.62	27,687	0.18
26/18-26ab	Effective precipitation	8	0.055	0.80	-0.29	6.43	0.06
	Streamflow	9	4.96×10^{-5}	0.29	-0.09	27,782	0.04
27/15-4ac (Parks well)	Effective precipitation	25	0.095	0.68	-0.48	5.93	0.08
	Streamflow	30	2.23×10^{-5}	0.79	-0.43	26,632	0.16
27/16-13ab	Effective precipitation	9	0.13	0.91	-0.85	6.08	0.00
	Streamflow	10	3.16×10^{-5}	0.81	-0.77	24,800	0.01
27/17-22dd	Effective precipitation	16	0.10	0.69	-0.42	6.02	0.12
	Streamflow	20	2.25×10^{-5}	0.78	-0.40	24,804	0.16
27/18-6bd	Effective precipitation	13	0.05	0.77	-0.24	5.75	0.05
	Streamflow	16	9.8×10^{-6}	0.56	-0.14	25,386	0.11
27/18-21aa	Effective precipitation	13	0.064	0.83	-0.35	6.21	0.05
	Streamflow	15	1.56×10^{-5}	0.85	-0.31	25,509	0.09
28/14-25bb	Effective precipitation	7	0.143	0.94	-0.94	6.68	0.01
	Streamflow	7	3.99×10^{-5}	0.73	-1.03	26,307	0.01

X = Independent variable
N = Data length (sets)
m = Regression slope
R = Correction coefficient
b = Y-intercept of regression
Y = Dependent variable (water level change)
$\bar{X}$, $\bar{Y}$ = Average value of data



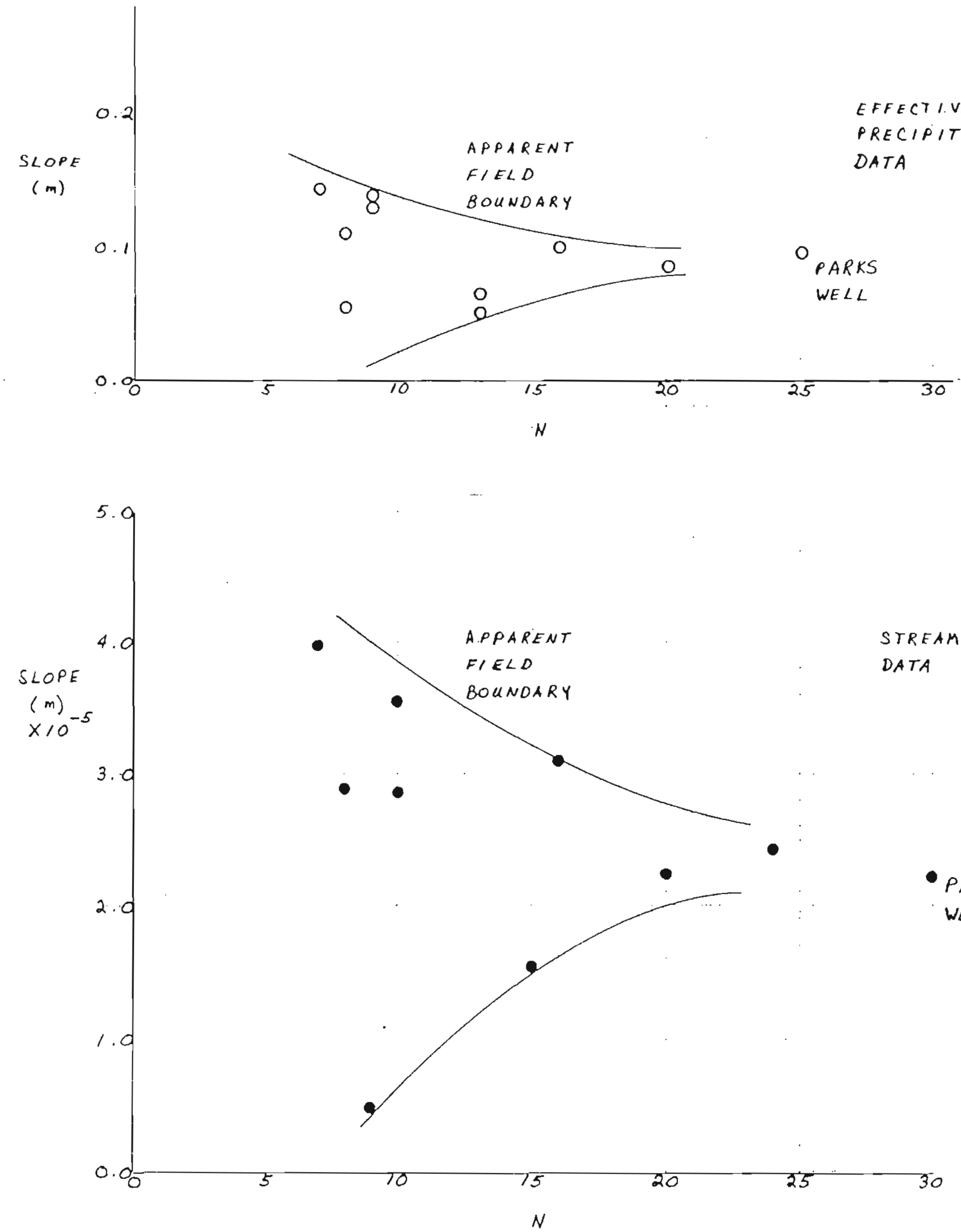
LOCATION OF WELLS USED FOR REGRESSION ANALYSES

Fig. 25



Y-INTERCEPT VS. DATA LENGTH AT VARIOUS WELLS

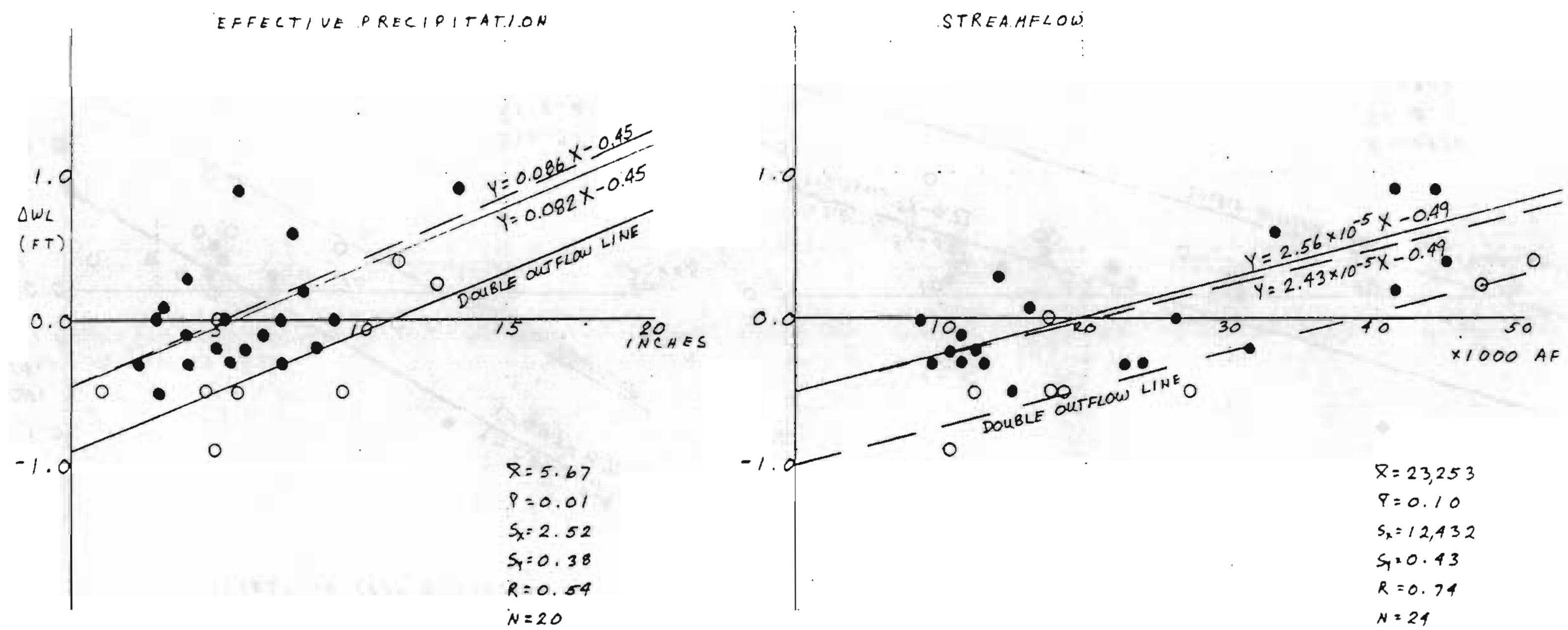
Fig. 26



SLOPE VS. DATA LENGTH AT VARIOUS WELLS

Fig. 27

T25S/R14-15 bc



● DATA FOR REGRESSION

○ DATA AFTER 1975 (SOME ESTIMATED)

— — EQN USING COMPARABLE

DATA AT PARKS WELL

——— EQN OF DATA

Fig. 28

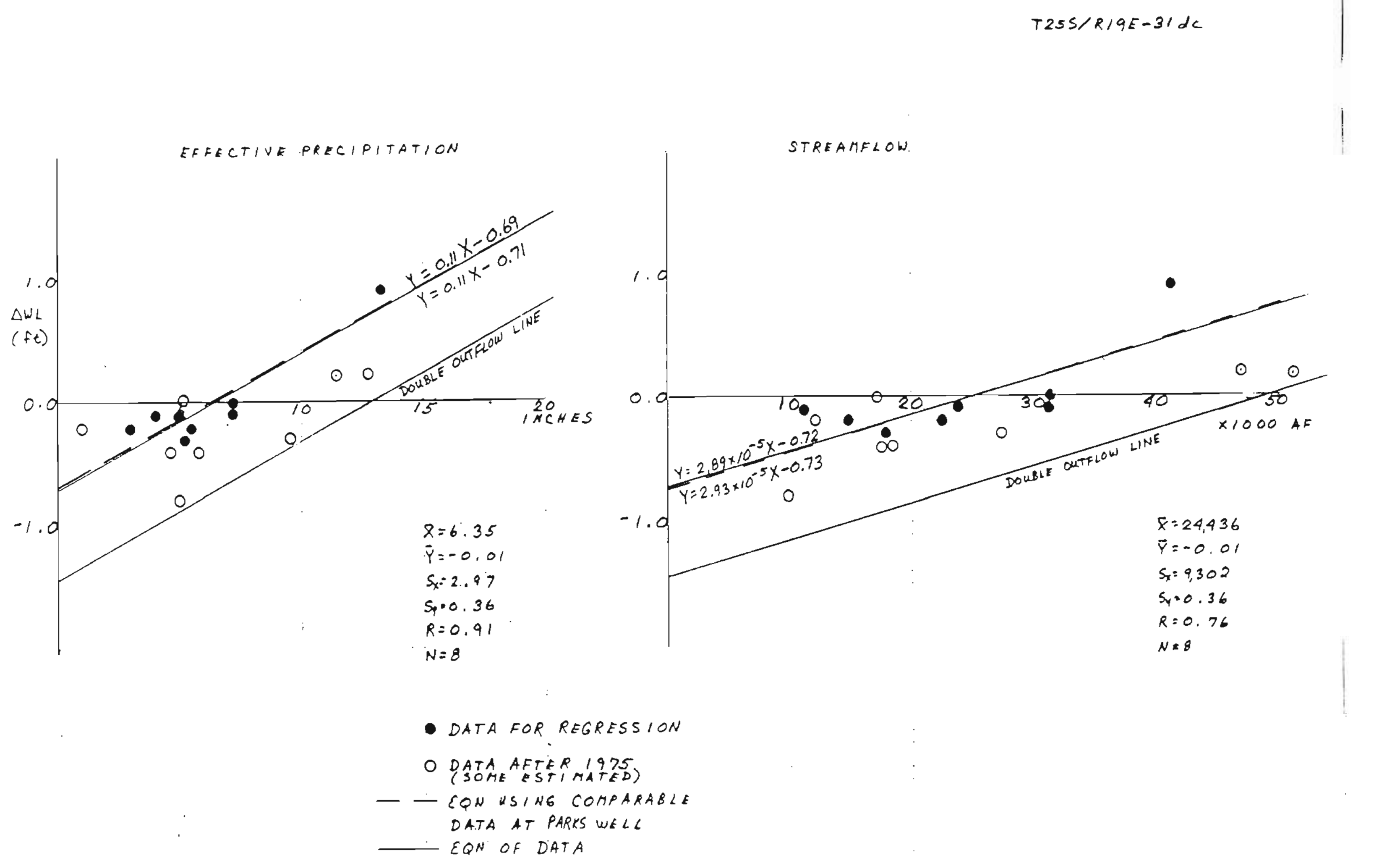

T25S/R19E-31dc
EFFECTIVE PRECIPITATION
ΔWL (ft)
1.0
0.0
-1.0
10
15
20
INCHES
Y = 0.11X - 0.69
Y = 0.11X - 0.71
DOUBLE OUTFLOW LINE
X̄=6.35
Ȳ=-0.01
Sx=2.97
Sy=0.36
R=0.91
N=8
STREAMFLOW
1.0
0.0
-1.0
10
20
30
40
50
X1000 AF
Y=2.89x10^-5X-0.72
Y=2.93x10^-5X-0.73
DOUBLE OUTFLOW LINE
X̄=24,436
Ȳ=-0.01
Sx=9,302
Sy=0.36
R=0.76
N=8
DATA FOR REGRESSION
DATA AFTER 1975 (SOME ESTIMATED)
EQN USING COMPARABLE DATA AT PARKS WELL
EQN OF DATA

Fig. 29

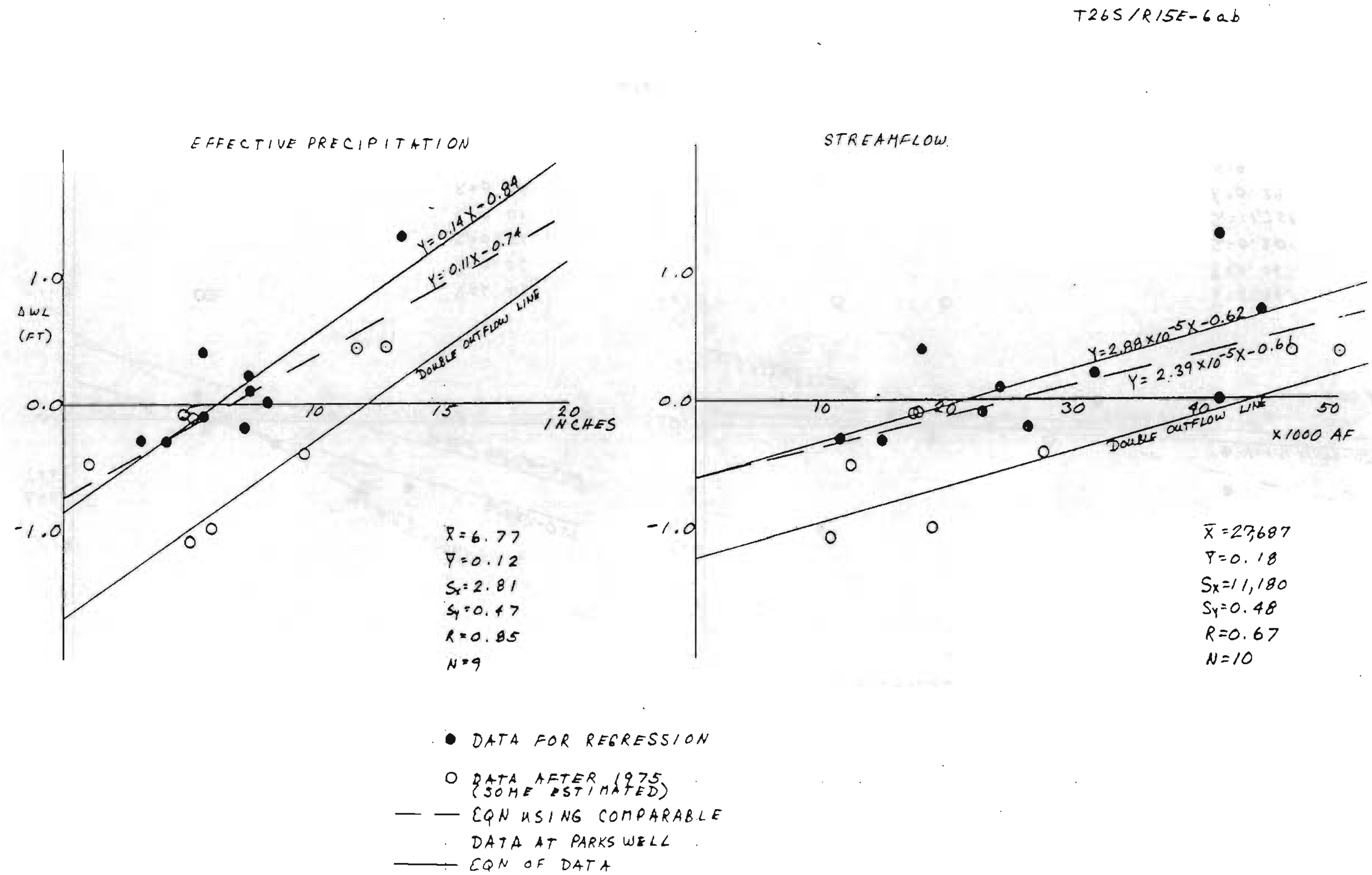

T26S/R15E-6ab
EFFECTIVE PRECIPITATION
ΔWL (FT)
1.0
0.0
-1.0
10
15
20
INCHES
Y=0.14X-0.84
Y=0.11X-0.74
DOUBLE OUTFLOW LINE
X̄=6.77
Ȳ=0.12
Sx=2.81
Sy=0.47
R=0.85
N=9
STREAMFLOW
1.0
0.0
-1.0
10
20
30
40
50
X1000 AF
Y=2.88×10^-5X-0.62
Y=2.39×10^-5X-0.66
DOUBLE OUTFLOW LINE
X̄=27,687
Ȳ=0.18
Sx=11,180
Sy=0.48
R=0.67
N=10
DATA FOR REGRESSION
DATA AFTER 1975 (SOME ESTIMATED)
EQN USING COMPARABLE
DATA AT PARKS WELL
EQN OF DATA

Fig. 30

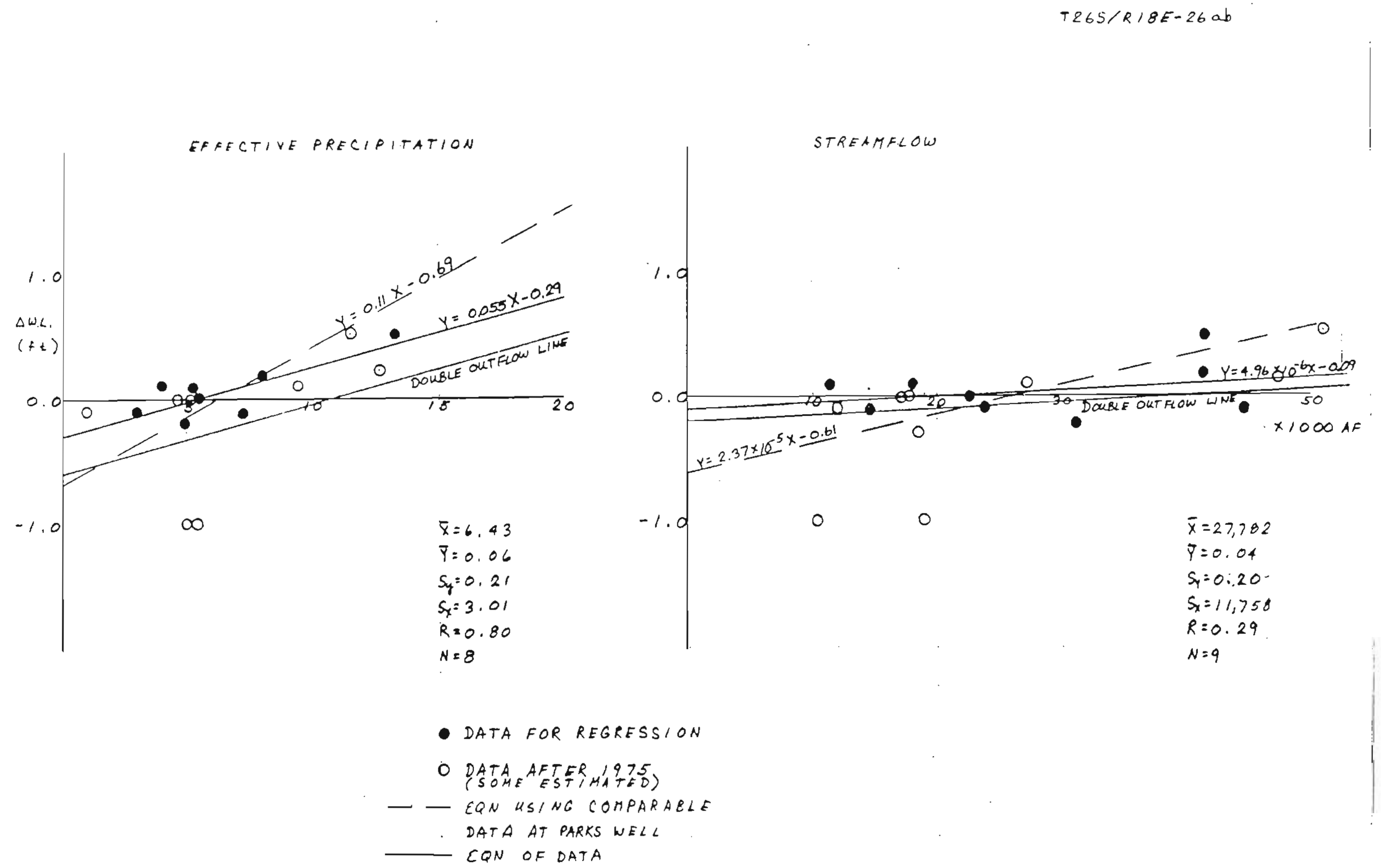

T26S/R18E-26ab
EFFECTIVE PRECIPITATION
STREAMFLOW
1.0
ΔWL. (ft)
0.0
-1.0
5
10
15
20
Y=0.11X-0.69
Y=0.055X-0.29
DOUBLE OUTFLOW LINE
X̄=6.43
Ȳ=0.06
Sy=0.21
Sx=3.01
R=0.80
N=8
10
20
30
50
X1000 AF
Y=4.96x10⁻⁶x-0.09
Y=2.37x10⁻⁵x-0.61
X̄=27,782
Ȳ=0.04
Sy=0.20
Sx=11,758
R=0.29
N=9
DATA FOR REGRESSION
DATA AFTER 1975 (SOME ESTIMATED)
EQN USING COMPARABLE
DATA AT PARKS WELL
EQN OF DATA

Fig. 31

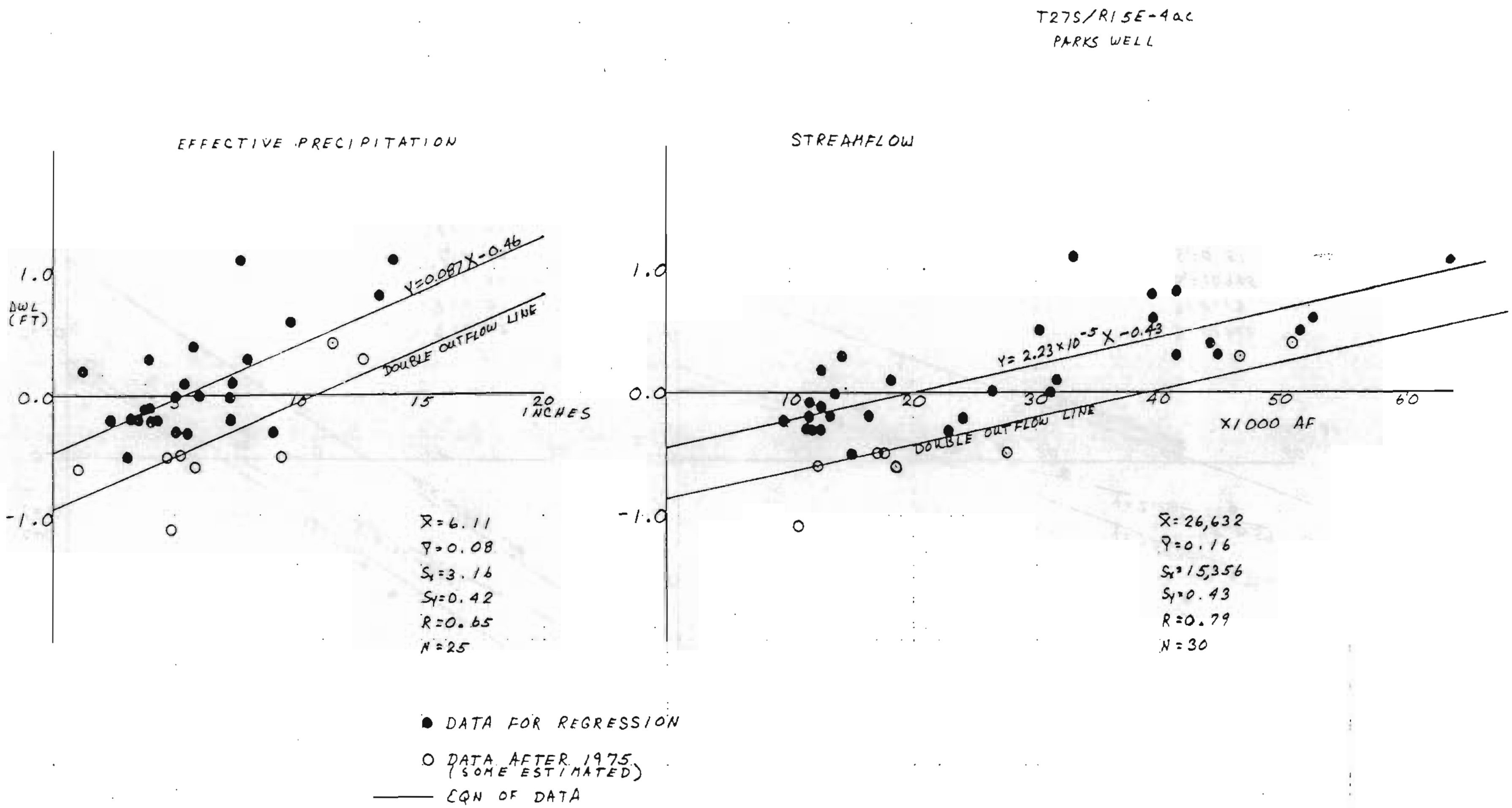

T27S/R15E-4ac
PARKS WELL
EFFECTIVE PRECIPITATION
ΔWL (FT)
1.0
0.0
-1.0
5
10
15
20
INCHES
Y=0.087X-0.46
DOUBLE OUTFLOW LINE
X̄=6.11
Ȳ=0.08
Sx=3.16
Sy=0.42
R=0.65
N=25
STREAMFLOW
1.0
0.0
-1.0
10
20
30
40
50
60
X/1000 AF
Y= 2.23×10^-5 X -0.43
DOUBLE OUTFLOW LINE
X̄=26,632
Ȳ=0.16
Sx=15,356
Sy=0.43
R=0.79
N=30
DATA FOR REGRESSION
DATA AFTER 1975 (SOME ESTIMATED)
EQN OF DATA

Fig. 32

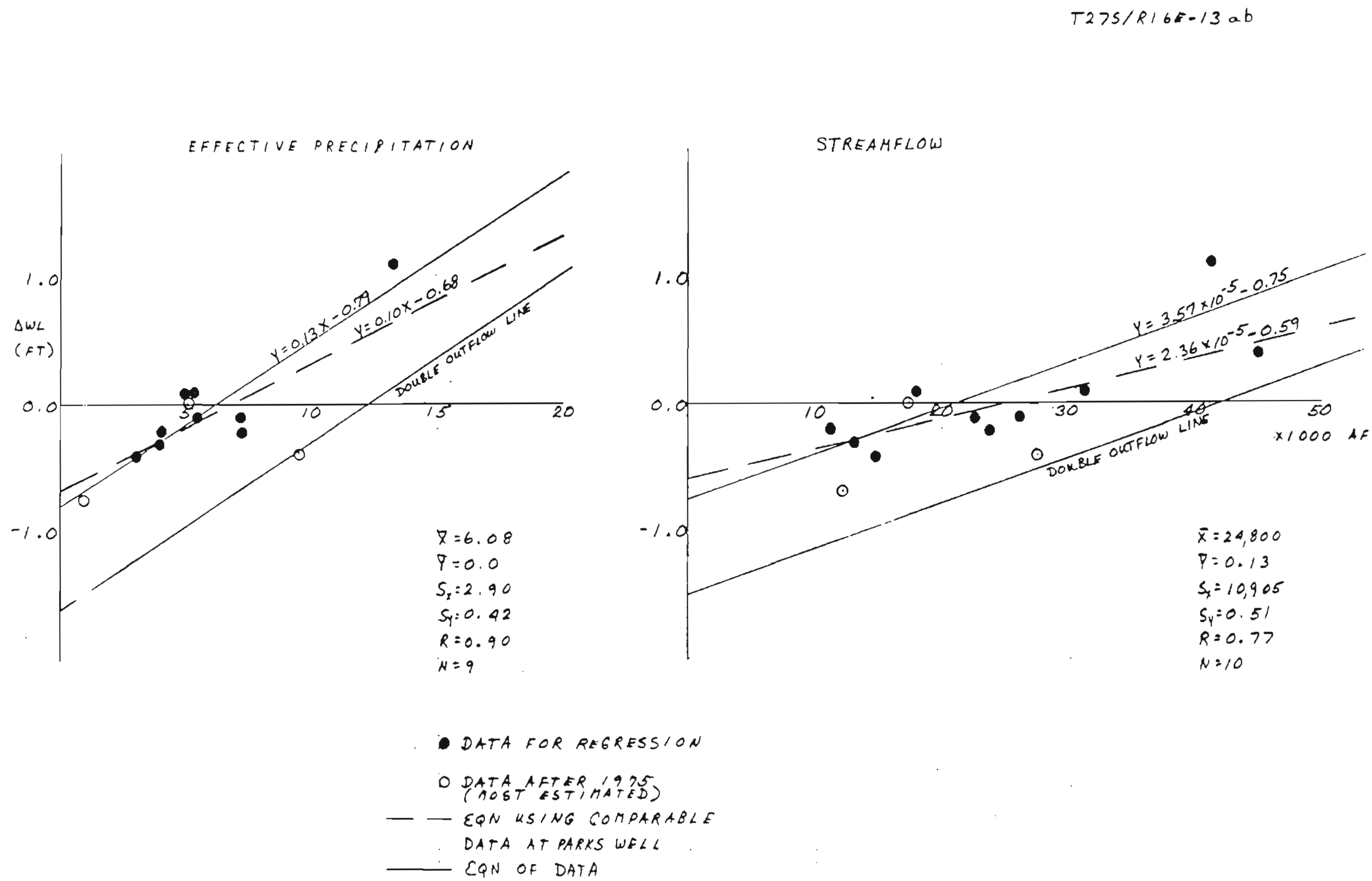
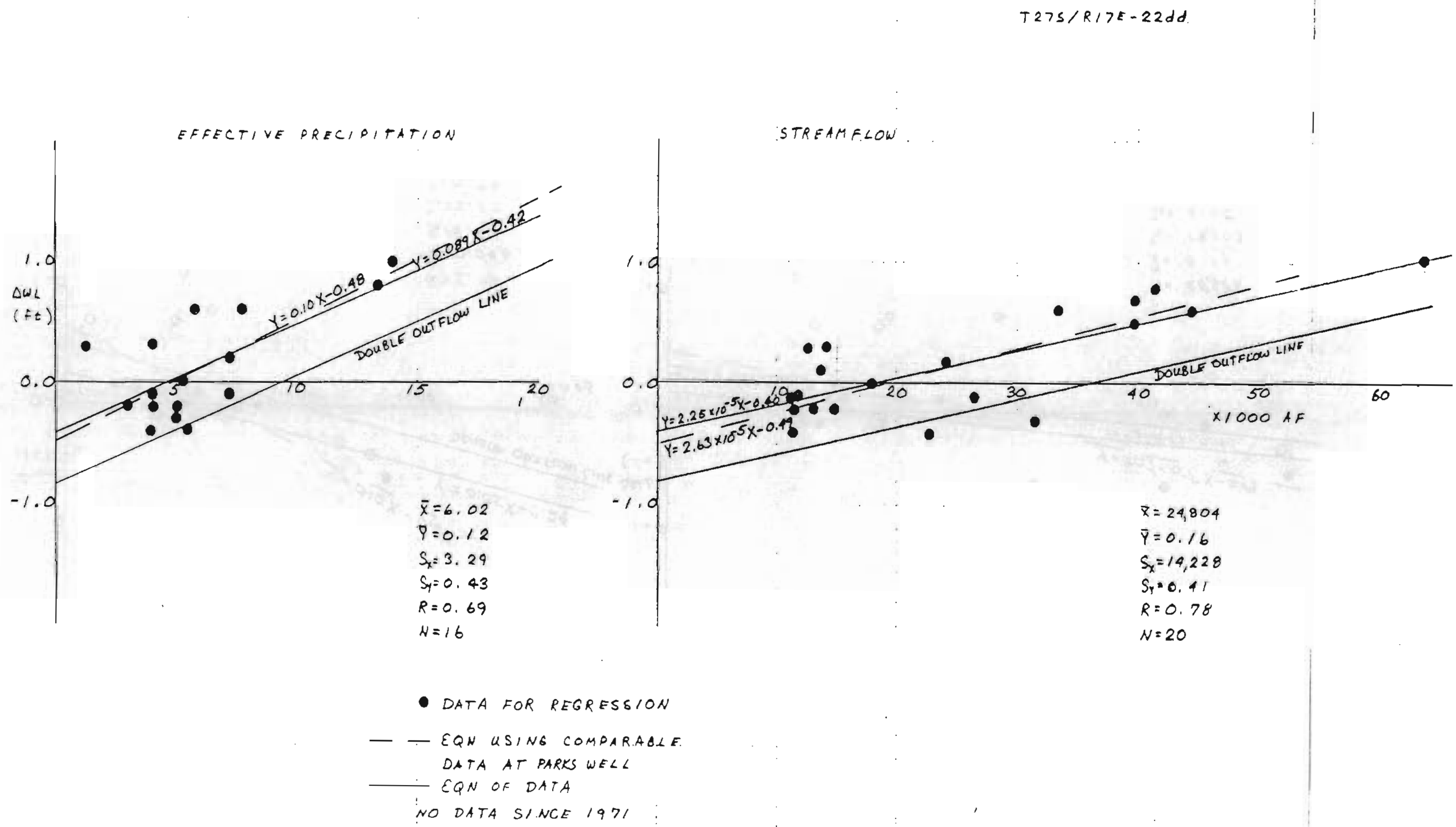

T27S/R16E-13 ab
EFFECTIVE PRECIPITATION
STREAMFLOW
ΔWL (FT)
1.0
0.0
-1.0
5
10
15
20
30
40
50
x1000 AF
Y=0.13X-0.79
Y=0.10X-0.68
Y=3.57x10-5-0.75
Y=2.36x10-5-0.59
DOUBLE OUTFLOW LINE
X̄=6.08
Ȳ=0.0
Sx=2.90
Sy=0.42
R=0.90
N=9
X̄=24,800
Ȳ=0.13
Sx=10,905
Sy=0.51
R=0.77
N=10
DATA FOR REGRESSION
DATA AFTER 1975 (MOST ESTIMATED)
EQN USING COMPARABLE
DATA AT PARKS WELL
EQN OF DATA

Fig. 33



T27S/R17E-22dd
EFFECTIVE PRECIPITATION
STREAMFLOW
1.0
0.0
-1.0
ΔWL (Ft)
5
10
15
20
30
40
50
60
X1000 AF
Y=0.10X-0.48
Y=0.089X-0.42
DOUBLE OUTFLOW LINE
DOUBLE OUTFLOW LINE
X̄=6.02
Ȳ=0.12
Sx=3.29
Sy=0.43
R=0.69
N=16
X̄=24,804
Ȳ=0.16
Sx=14,228
Sy=0.41
R=0.78
N=20
DATA FOR REGRESSION
EQN USING COMPARABLE DATA AT PARKS WELL
EQN OF DATA
NO DATA SINCE 1971

Fig. 34

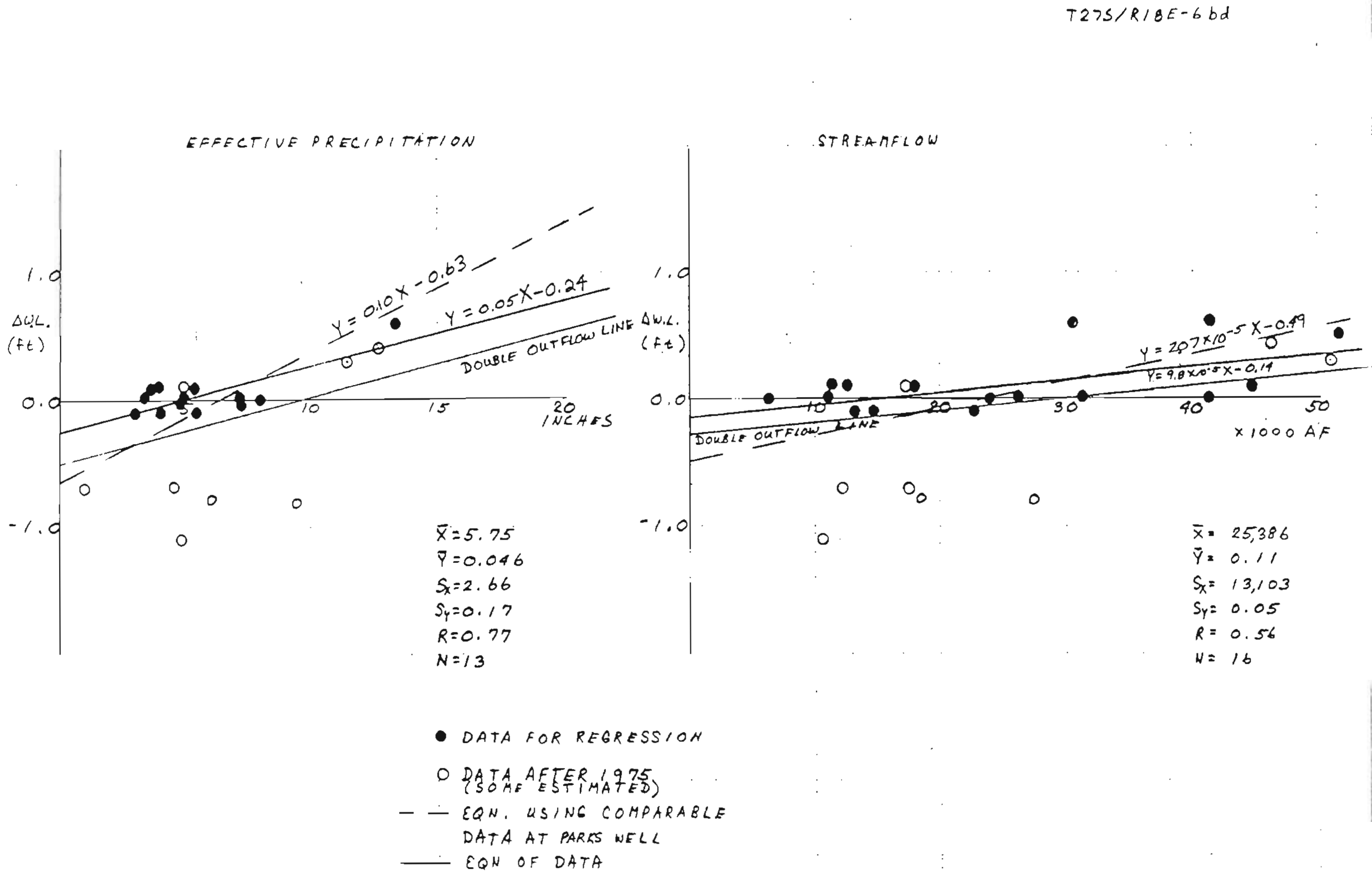

T27S/R18E-6bd
EFFECTIVE PRECIPITATION
STREAMFLOW
ΔWL. (ft)
1.0
0.0
-1.0
Y = 0.10X - 0.63
Y = 0.05X - 0.24
DOUBLE OUTFLOW LINE
5
10
15
20
INCHES
X̄ = 5.75
Ȳ = 0.046
Sx = 2.66
Sy = 0.17
R = 0.77
N = 13
Y = 2.07×10-5 X - 0.49
Y = 9.8×10-5 X - 0.14
DOUBLE OUTFLOW LINE
10
20
30
40
50
x1000 AF
X̄ = 25,386
Ȳ = 0.11
Sx = 13,103
Sy = 0.05
R = 0.56
N = 16
DATA FOR REGRESSION
DATA AFTER 1975 (SOME ESTIMATED)
EQN. USING COMPARABLE DATA AT PARKS WELL
EQN OF DATA

Fig. 35

T27S/R18E-21aa

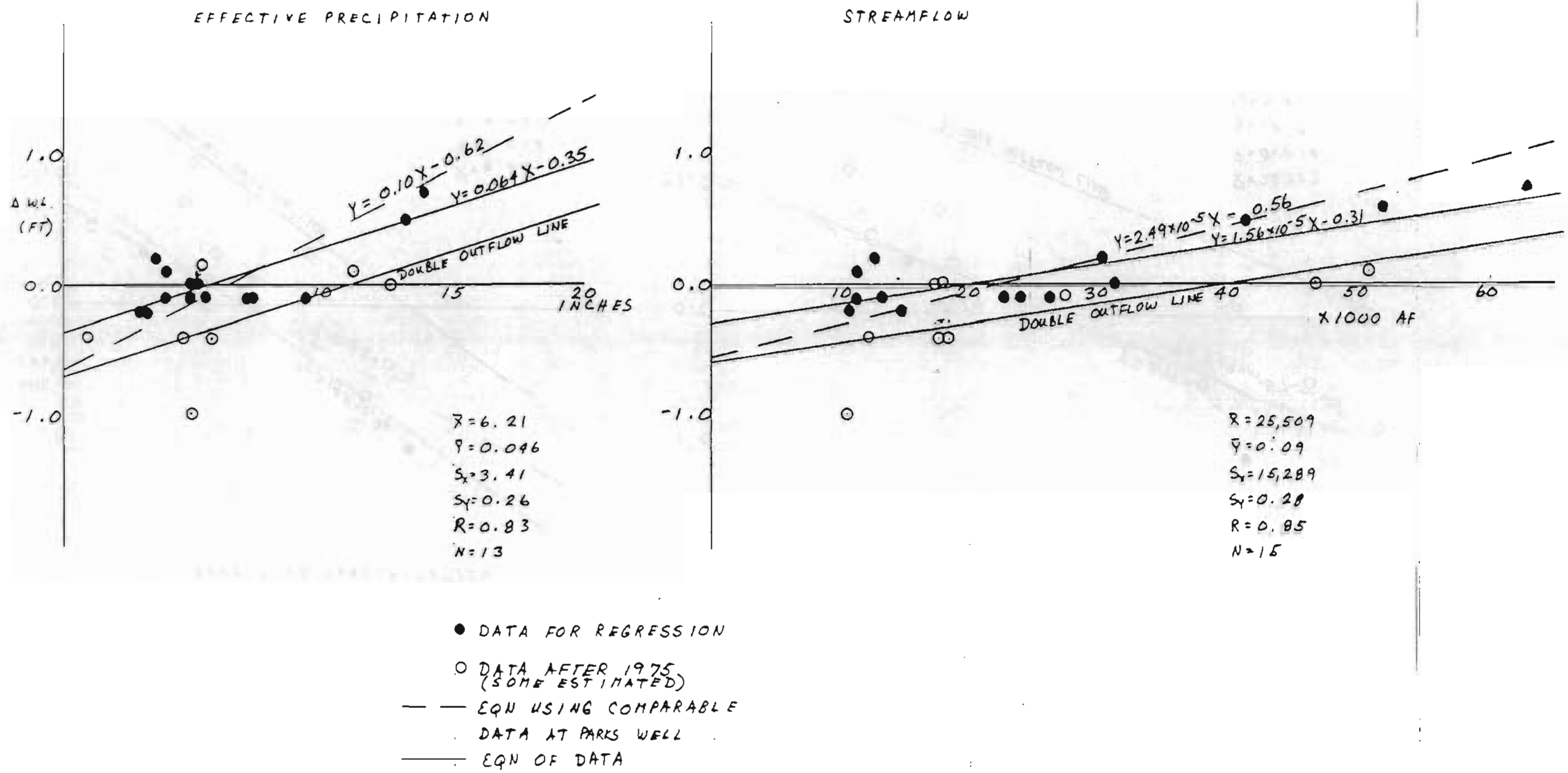


Fig. 36

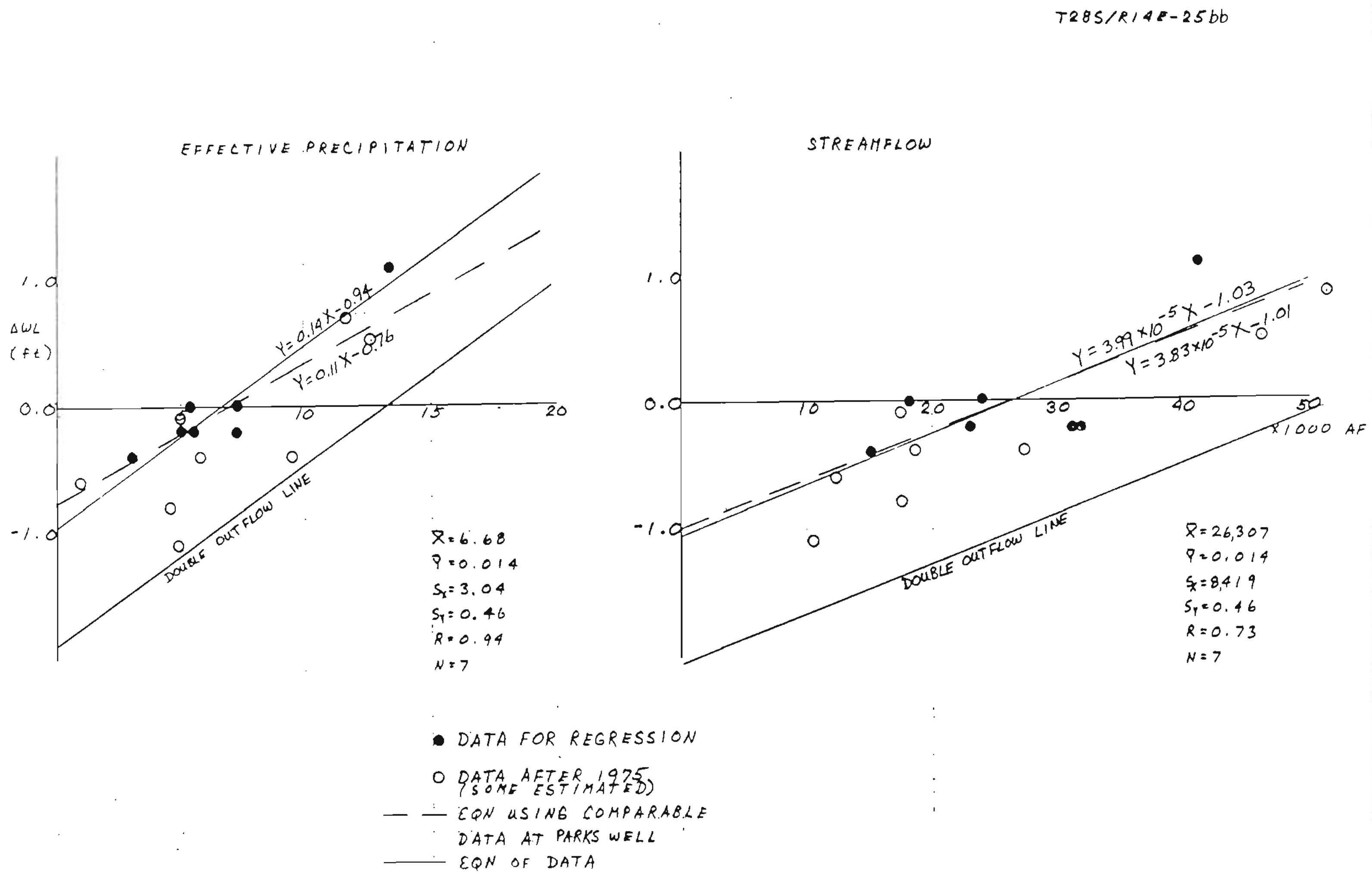

T28S/R14E-25bb
EFFECTIVE PRECIPITATION
ΔWL (ft)
1.0
0.0
-1.0
10
15
20
Y=0.14X-0.94
Y=0.11X-0.76
DOUBLE OUTFLOW LINE
X̄=6.68
Ȳ=0.014
Sx=3.04
Sy=0.46
R=0.94
N=7
STREAMFLOW
1.0
0.0
-1.0
10
20
30
40
50
X1000 AF
Y=3.99×10^-5 X-1.03
Y=3.83×10^-5 X-1.01
DOUBLE OUTFLOW LINE
X̄=26,307
Ȳ=0.014
Sx=8,419
Sy=0.46
R=0.73
N=7
DATA FOR REGRESSION
DATA AFTER 1975 (SOME ESTIMATED)
EQN USING COMPARABLE DATA AT PARKS WELL
EQN OF DATA

Fig. 37

BEFORE THE WATER RESOURCES DIRECTOR OF OREGON

LAKE, KLAMATH AND DESCHUTES COUNTIES

IN THE MATTER OF INITIATION OF A CRITICAL GROUND WATER AREA DETERMINATION IN THE FORT ROCK BASIN	))))	PROCLAMATION

The intiation of a critical ground water area proceeding is hereby proclaimed pursuant to OAR 690-10-050 in the Fort Rock Basin. The proposed exterior boundaries of this area, which include parts of Lake, Klamath and Deschutes Counties, are described as follows:

> Beginning at the southwest corner of Section 35, Township 22 South, Range 13 East, WM; thence northeasterly to the southeast corner of Section 25, Township 22 South, Range 15 East, WM; thence southeasterly to the southwest corner of Section 35, Township 23 South, Range 19 East, WM; thence southeasterly to the southeast corner of Section 9, Township 28 South, Range 21 East, WM; thence southwesterly to the southwest corner of Section 6, Township 29 South, Range 20 East, WM; thence northwesterly to the southwest corner of Section 16, Township 28 South, Range 18 East, WM; thence southwesterly to the southwest corner of Section 14, Township 29 South, Range 16 East, WM; thence scuthwesterly to the southeast corner of Section 21, Township 31 South, Range 15 East, WM; thence northwesterly to the southeast corner of Section 36, Township 30 South, Range 12 East, WM; thence northwesterly to the southwest corner of Section 34, Township 26 South, Range 10 East, WM; thence northeasterly to the point of beginning.

This initiation of proceedings for the determination of a critical ground water area is brought under ORS 537.730(a) and ORS 537.730(d). ORS 537.730(a) allows for such action when

> "Ground water levels in the area in question are declining or have declined excessively".

ORS 537.730(d) allows for such action when

> "The available ground water supply in the area in question is being or is about to be overdrawn".

Preliminary investigation has disclosed that water level declines are occurring at rates which reflect a close match between recharge and pumping demand. Such conditions would provide water level equilibrium in the future at somewhat lower water levels. Further appropriation threatens to overdraw the reservoir and may result in water level declines which will not equilibrate in the future.

The ground water reservoir covered by this proclamation is herein termed the "Main Ground Water Reservoir". This reservoir includes all water contained in the basalt, as well as the interbedded and overlying pyroclastic and sedimentary aquifers. Further, the potentiometric level of water in these aquifers is approximately 4300 feet above mean sea level or lower.

Prior to completion of the proceeding for determination of a critical ground water area, no application for a permit to appropriate water from the Main Ground Water Reservoir will be approved or denied.

Dated at Salem, Oregon this 26th day of March, 1984. This proclamation is effective immediately.

William H. Young

WILLIAM H. YOUNG
Director

1431C