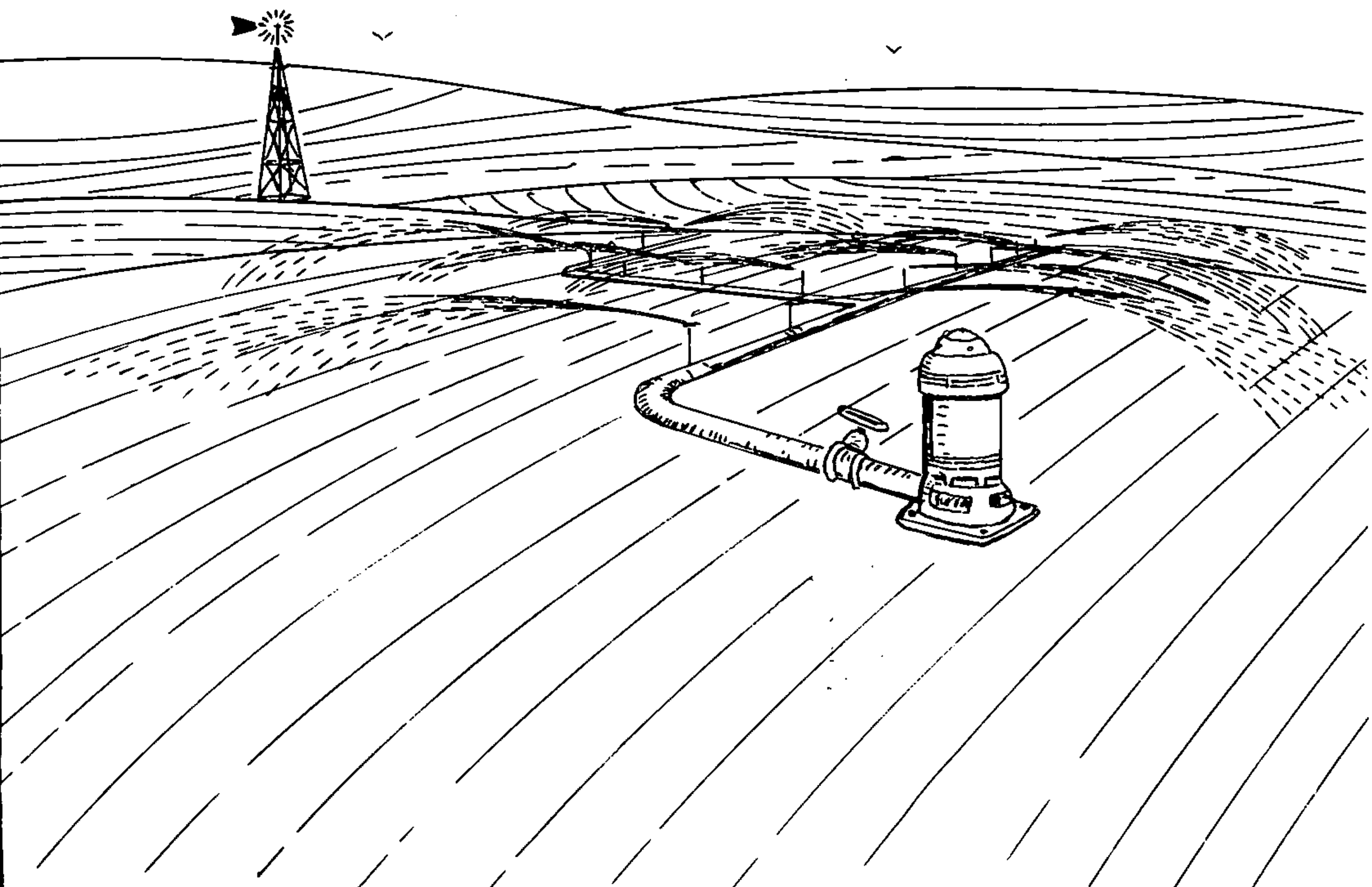
GROUND-WATER LEVELS AND PUMPAGE IN EAST-CENTRAL WASHINGTON, INCLUDING THE ODESSA-LIND AREA, 1967 TO 1981



WASHINGTON STATE DEPARTMENT OF ECOLOGY WATER-SUPPLY BULLETIN No. 55

STATE OF WASHINGTON
John D. Spellman, Governor

DEPARTMENT OF ECOLOGY
Donald W. Moos, Director

WATER-SUPPLY BULLETIN No. 55

GROUND-WATER LEVELS AND PUMPAGE IN EAST-CENTRAL WASHINGTON, INCLUDING THE ODESSA-LIND AREA, 1967 TO 1981

By

Denzel R. Cline

Prepared by the
U.S. GEOLOGICAL SURVEY
in cooperation with the
WASHINGTON STATE DEPARTMENT OF ECOLOGY

Olympia, Washington
1984

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ILLUSTRATIONS

Page

METRIC CONVERSION FACTORS

Multiply	By	To obtain
feet (ft)------------------	0.3048	meters (m)
acre-feet (acre-ft)--------	1233	cubic meters (m^3)
	0.001233	cubic hectometers (hm^3)

GROUND-WATER LEVELS AND PUMPAGE IN EAST-CENTRAL WASHINGTON, INCLUDING THE ODESSA-LIND AREA, 1967 TO 1981

By Denzel R. Cline

ABSTRACT

Ground-water pumpage, mostly for irrigation, has increased in the east-central Washington project area, from about 25,000 acre-feet of water in 1963 to about 387,000 acre-feet in 1977, causing continuing water-level declines in parts of the area. Ground-water pumpage in the Odessa-Lind subarea (studied in the 1960's) increased from about 14,000 acre-feet to 163,000 acre-feet during the same period. The area of heavy pumping has expanded beyond the border of the Odessa-Lind area, especially to the south. The number of large-capacity wells in the project area has increased from 170 in 1963 to 618 in 1977. Few wells in 1967 were deeper than 1,000 feet, but by 1977 many were deeper. Most of the water pumped in 1967 was from wells tapping the Wanapum Basalt, but by 1977 most was from wells tapping both the Wanapum Basalt and the underlying Grande Ronde Basalt aquifers. Maximum water-level declines in the Wanapum Basalt from spring 1968 to spring 1978 were over 80 feet, and from spring 1978 to spring 1981 were over 40 feet; maximum declines for the Wanapum and Grande Ronde Basalts were over 100 feet and 60 feet, respectively. Water levels were affected to a maximum distance of about 23 miles from pumping centers. Since 1967 the area affected by water-level declines has expanded and shifted and the rate of decline has increased. The maximum decline of water levels from 1968 to 1981 has occurred in southern Adams County—about 130 feet in wells that tap the Wanapum Basalt and about 150 feet in wells that tap the Wanapum and Grande Ronde Basalts.

INTRODUCTION

The Odessa subarea (fig. 1) is defined by the Washington State Department of Ecology (WDOE) as a critical water-management area. A survey of the ground water in the Odessa-Lind area was made by the U.S. Geological Survey in the 1960's, and described in Water-Supply Bulletin 36 (Luzier and others, 1968; referred to in this report as Bulletin 36). This report, done in cooperation with WDOE, describes the continued increase in pumpage and consequent lowering of ground-water levels from 1967 to 1981 in the basalt aquifers in east-central Washington. The project area extends from townships T.14 N. to T.26 N. and from ranges R.28 E. to R.37 E., and is over four times larger than the Odessa-Lind area described in Bulletin 36 (fig. 1).

Maps and graphs in this report are presented as generalized interpretations of the data; most site-specific data are not included. The two water-level-change maps for 1978-81 were compiled by Harry Tanaka, WDOE. Data used for the water-level-change maps were collected by the Geological Survey and WDOE. Pumpage data were obtained by several methods and range in accuracy from estimates to metered flows. Estimated pumpage generally was based on permitted acreage and (or) past pumpage. Most of the 1967 pumpage was computed from power-consumption records.

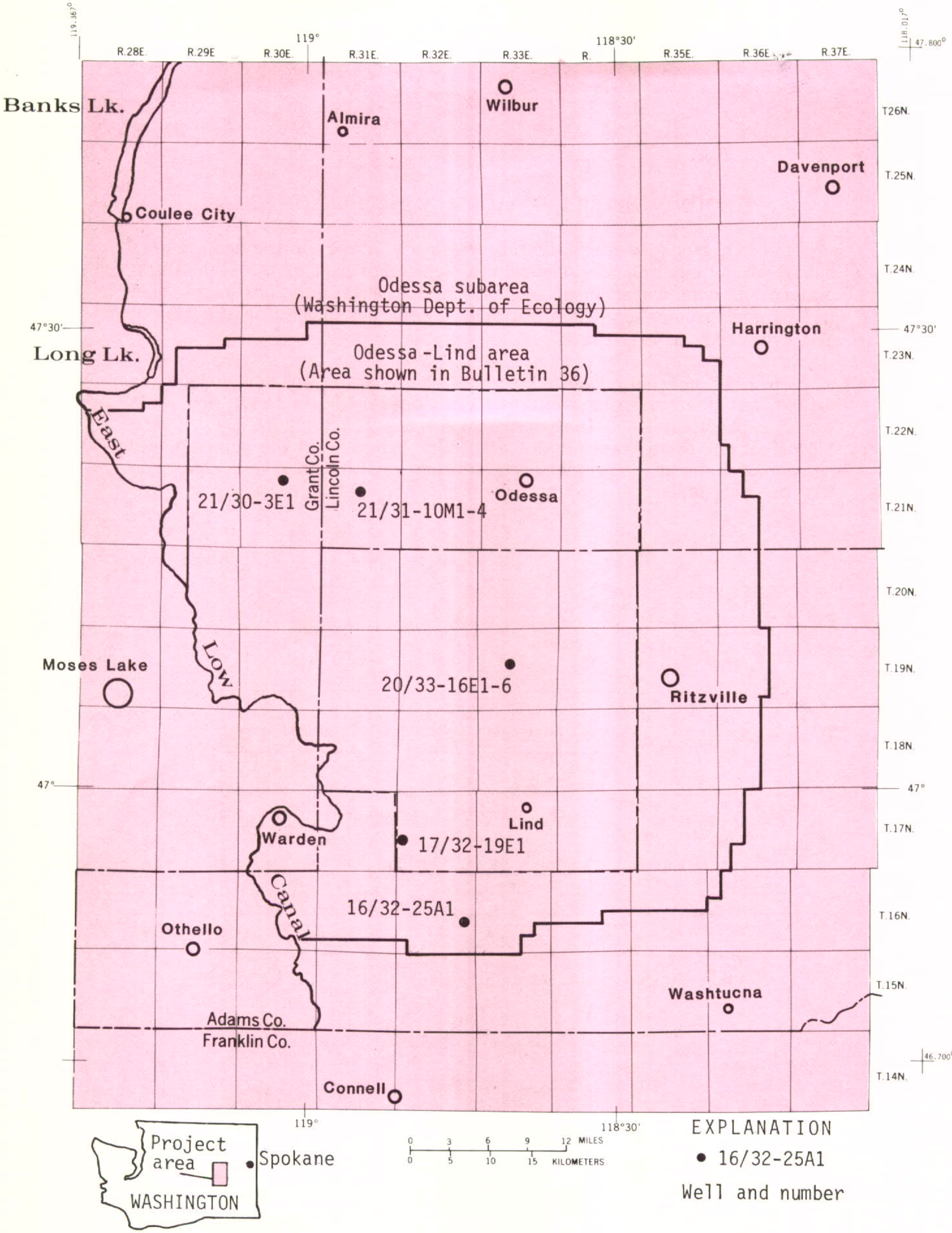


FIGURE 1.--LOCATION, IN EAST-CENTRAL WASHINGTON, OF THE PROJECT AREA, THE ODESSA SUBAREA, THE ODESSA-LIND AREA, AND SELECTED OBSERVATION WELLS.

GROUND-WATER PUMPAGE AND NUMBER OF WELLS

In 1963, ground-water irrigation was in its infancy in the project area but by 1967 irrigation was becoming a significant part of the agricultural picture. Ground-water pumpage, mostly for irrigation, has more than tripled and the number of large-capacity wells has doubled in the project area from 1967 to 1977 (fig. 2).

By 1977 not only had many new, deep, large-capacity wells been drilled, but many existing wells had been deepened. In 1967, few wells were deeper than 1,000 feet, but by 1977 many wells were deeper than 1,000 feet and some deeper than 2,000 feet. Increases in the pumpage and number of wells in the project area and the Odessa-Lind area are given in the following table:

Area	Estimated acre-feet pumped			Approximate number of wells		
	1963	1967	1977	1963[a]	1967	1977
Odessa-Lind area (Bull. 36)	14,000	52,000	163,000	63	137	249
Project area outside Odessa-Lind area	11,000	59,000	224,000	107	168	369
Project area (total of above areas)	25,000	111,000	387,000	170	305	618

[a] Many wells were small producers

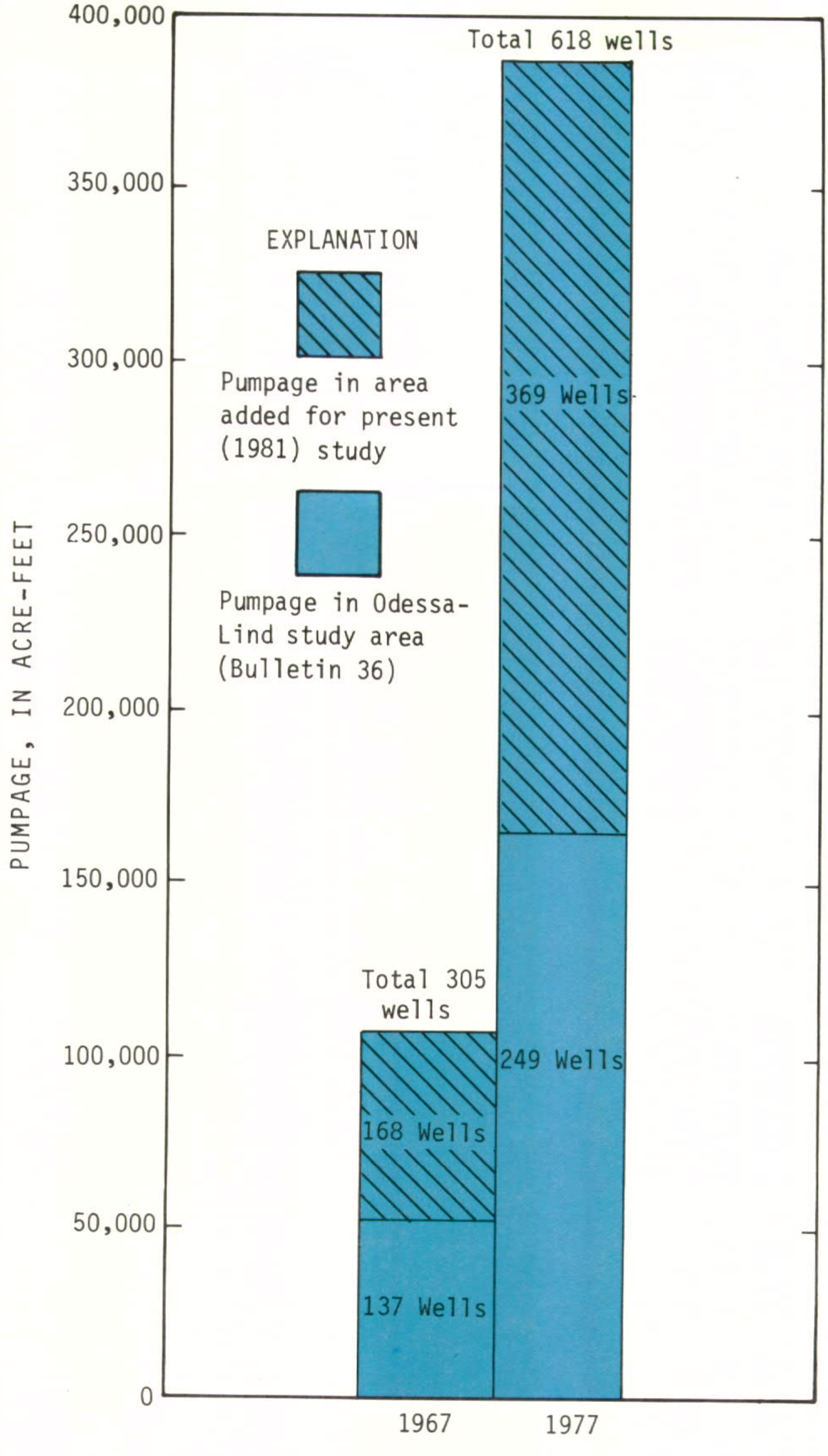
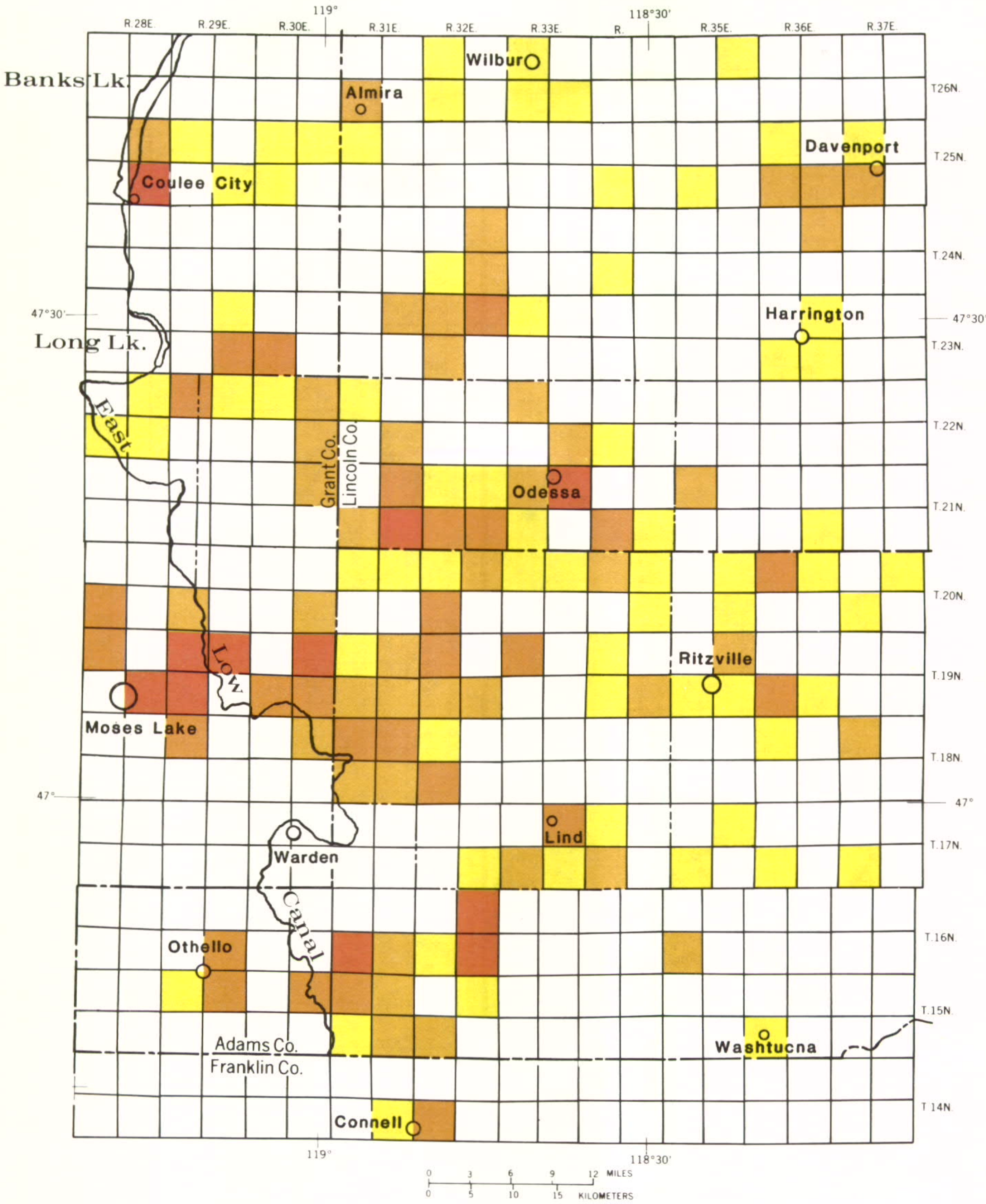


FIGURE 2.--ANNUAL ESTIMATED PUMPAGE OF GROUND WATER FROM THE BASALTS, AND THE APPROXIMATE NUMBER OF LARGE-CAPACITY IRRIGATION WELLS IN THE PRESENT (1981) STUDY AREA IN EAST-CENTRAL WASHINGTON FOR 1967 AND 1977.

The heaviest concentrations of pumpage in 1967 were between Odessa and Moses Lake and east of Othello (fig. 3). In 1977 pumpage had increased in amount and areal distribution; the heaviest concentrations were in the area approximately bounded by Wilbur, Moses Lake, Connell, and Odessa, and the area east and north of Ritzville (fig. 4). The change in pumpage (mostly an increase) between 1967 and 1977 was greatest in two areas in southern Adams County--southeast of Warden and northeast of Warden (fig. 5). In a few areas pumpage decreased.



EXPLANATION (in acre-feet)

0 - 50 | 50 - 500 | 500 - 1,000 | 1,000 - 2,000 | 2,000 - 4,000

FIGURE 3.--PUMPAGE OF GROUND WATER IN EAST-CENTRAL WASHINGTON, BY QUARTER TOWNSHIP, 1967.

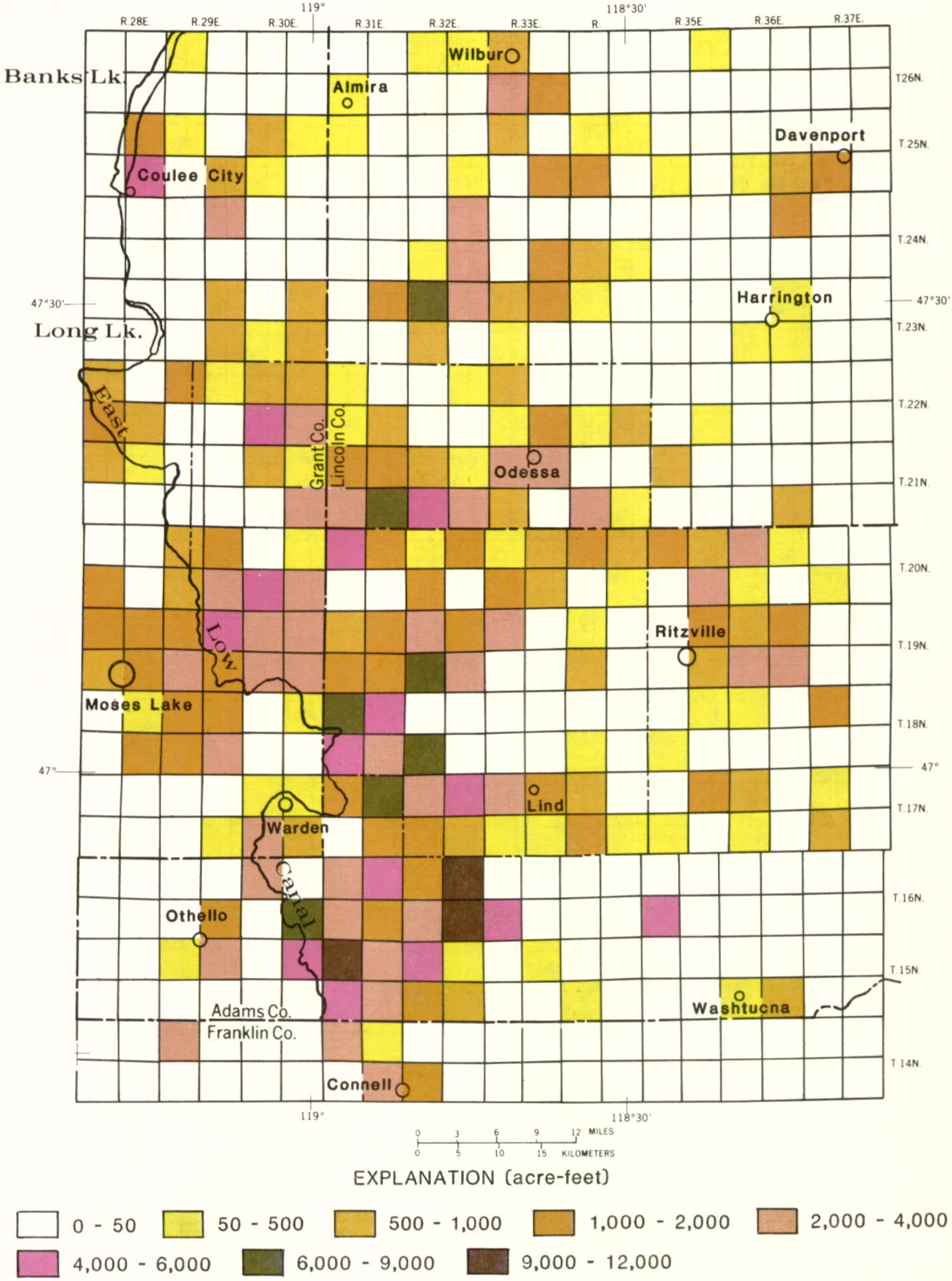


FIGURE 4. --PUMPAGE OF GROUND WATER IN EAST-CENTRAL WASHINGTON, BY QUARTER TOWNSHIP, 1977.

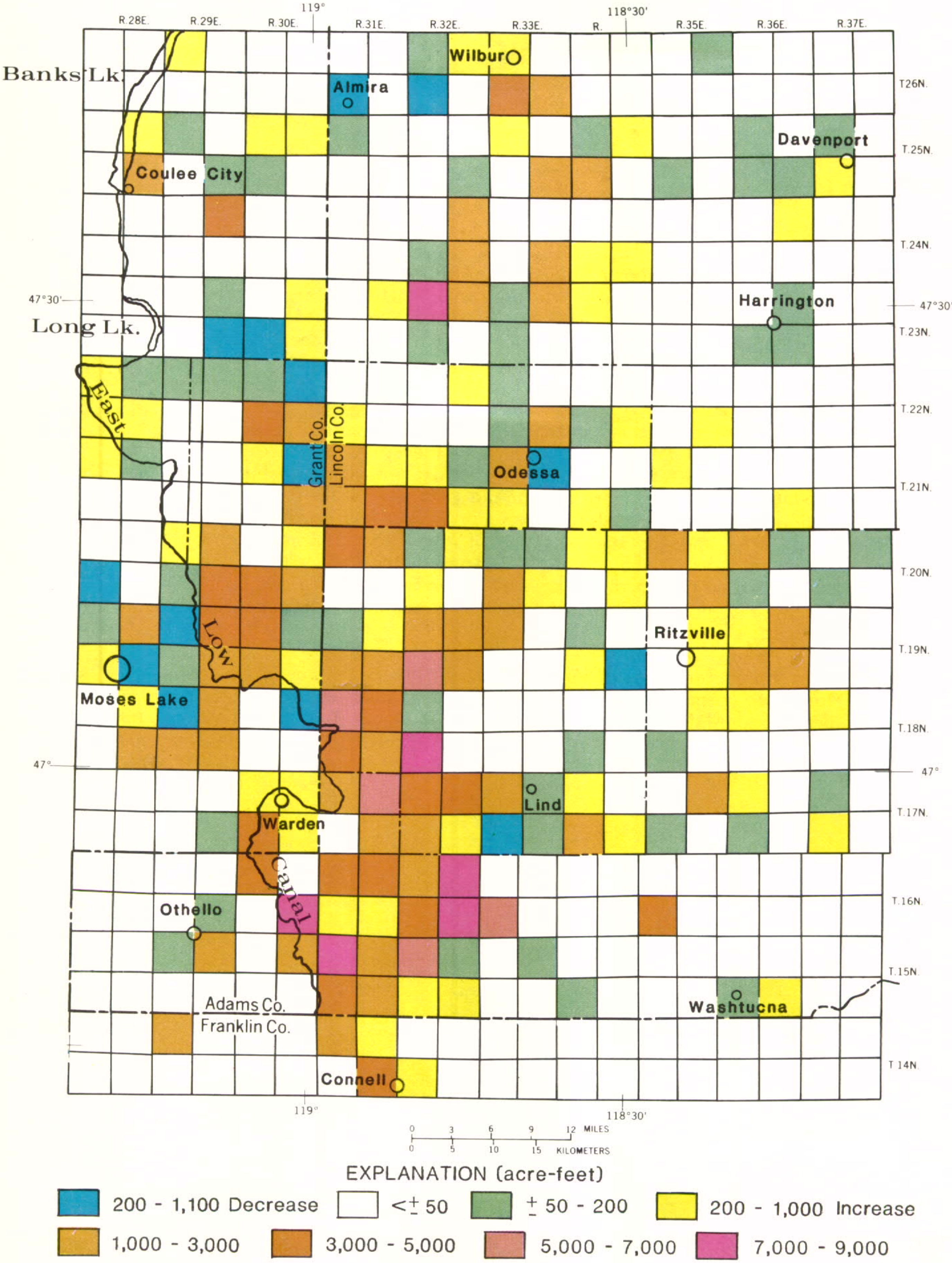


FIGURE 5.--CHANGE IN PUMPAGE OF GROUND WATER FROM 1967-77 IN EAST-CENTRAL WASHINGTON, BY QUARTER TOWNSHIP.

GROUND-WATER OCCURRENCE AND MOVEMENT

Ground water in east-central Washington moves slowly in a generally southwesterly direction and discharges into the Columbia and Snake Rivers. The source of the ground water is largely precipitation that falls on the Columbia River Plateau. Some of the ground water is intercepted by wells and pumped to the surface. Where heavy withdrawals have caused water levels to decline and form large cones of depression, ground water moves toward the cones.

Most of the ground water is contained in and between multilayered basalt rocks of Miocene age, which in the study area are named, from oldest to youngest—Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt—and are part of the Columbia River Basalt Group. The Saddle Mountains Basalt occurs only in the southwestern part of the study area and for the purposes of this report is included with the Wanapum Basalt. The top of the Grande Ronde Basalt slopes down to the southwest, so that in the southwestern part of the area this basalt unit is deeply buried; in the northern part it is shallower and even exposed in places.

The center zones of individual basalt layers are generally dense, and therefore retard vertical movement of ground water. Commonly, a porous zone that contains broken basalt or sediments or both occurs between the dense center zones of the basalt layers. These porous zones, called aquifers, provide large quantities of water to wells (fig. 6).

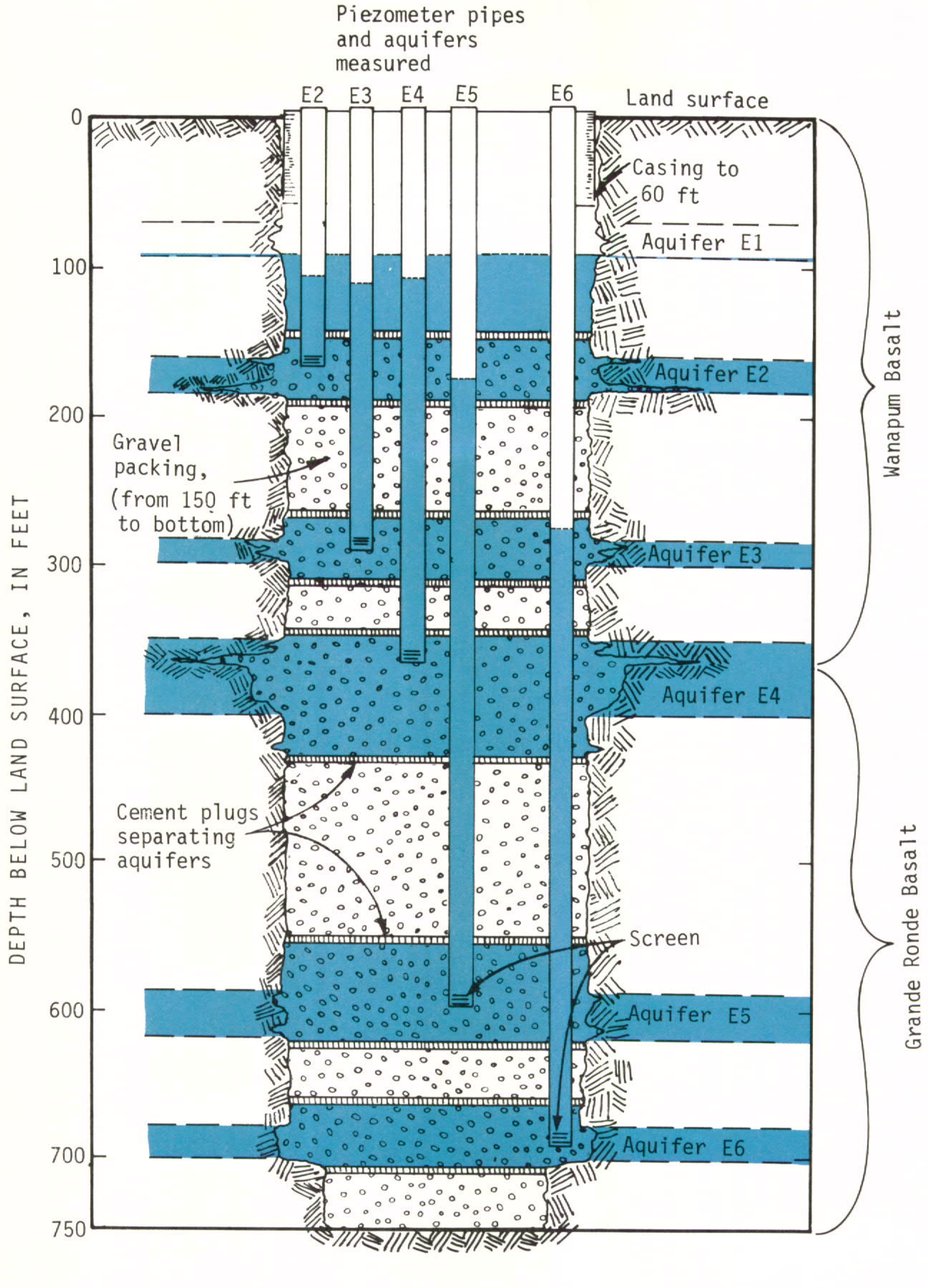


FIGURE 6.--DIAGRAMMATIC SECTION THROUGH ODESSA TEST-OBSERVATION WELL 20/33-16E1-E6, SHOWING PIEZOMETER PIPES AND THE AQUIFER ZONES THEY MEASURE. (MODIFIED FROM WALTERS, CLINE, AND LUZIER, 1972.)

Water levels of individual aquifers commonly differ, and levels of shallow aquifers are more likely to be higher than levels of deeper aquifers (fig. 6). Water moves from aquifers with higher water levels to aquifers with lower water levels. In many wells in the study area water cascades down the well, thus continuously draining the shallower aquifers into deeper aquifers. Wells open to more than one aquifer have a composite water level that can vary both with time and from well to well, due to a number of factors. This is illustrated in figure 7, which shows a large drop in the water level in well 21/30-3E1 in 1965 when the well was deepened and penetrated a deeper aquifer with a lower water level. (See figure 1 for wells for which hydrographs are shown in this report.)

In east-central Washington, water levels in individual aquifers in the Grande Ronde Basalt are generally significantly lower than water levels in the overlying formations, and thus water levels can be separated into two main groups—those in the Wanapum Basalt and those in the Grande Ronde Basalt. Many wells that tap aquifers in both the Grande Ronde and Wanapum Basalts have water levels that correspond to the pattern of those in the Grande Ronde Basalt alone. Water-level-decline maps in this report use the same divisions: wells that tap the Wanapum Basalt and wells that tap both the Wanapum Basalt and the underlying Grande Ronde Basalt. Most of the water pumped in the project area in 1967 came from wells tapping the Wanapum Basalt; by 1977 most came from wells that tap both the Wanapum and Grande Ronde Basalts. To date (1981), few wells are cased through the Wanapum Basalt to tap only the Grande Ronde Basalt. The "upper and lower water-bearing zones" in Bulletin 36 cannot be correlated with the Wanapum Basalt and the Grande Ronde Basalt.

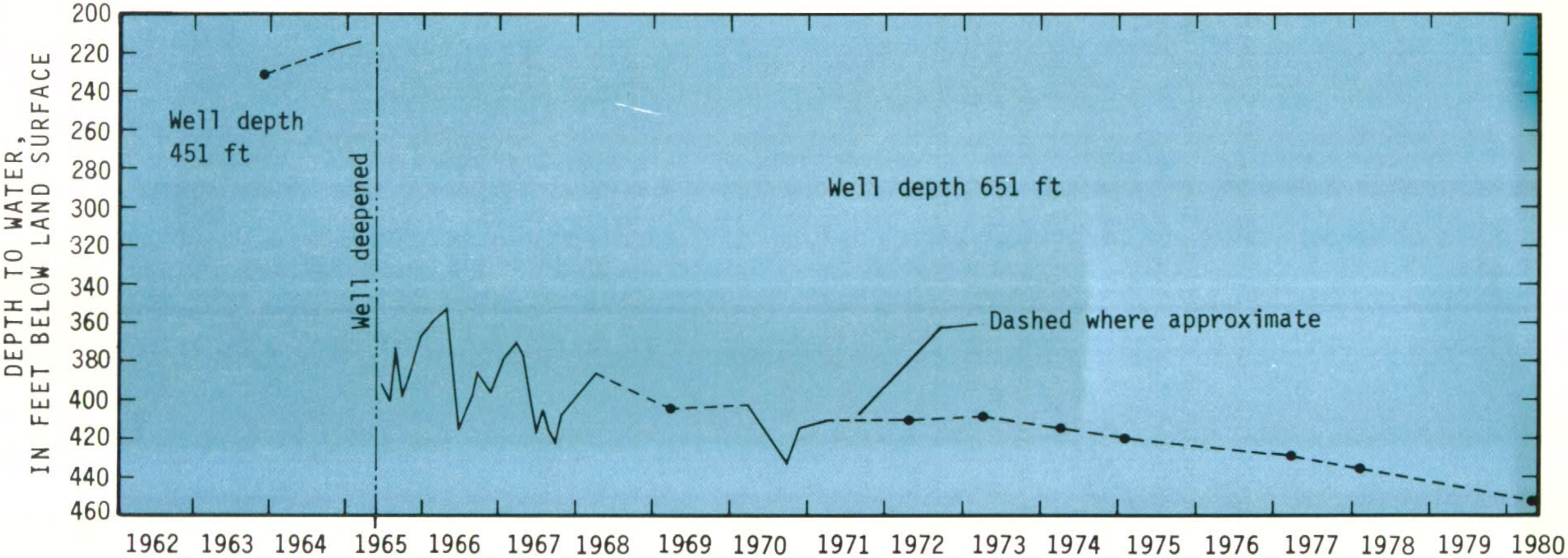
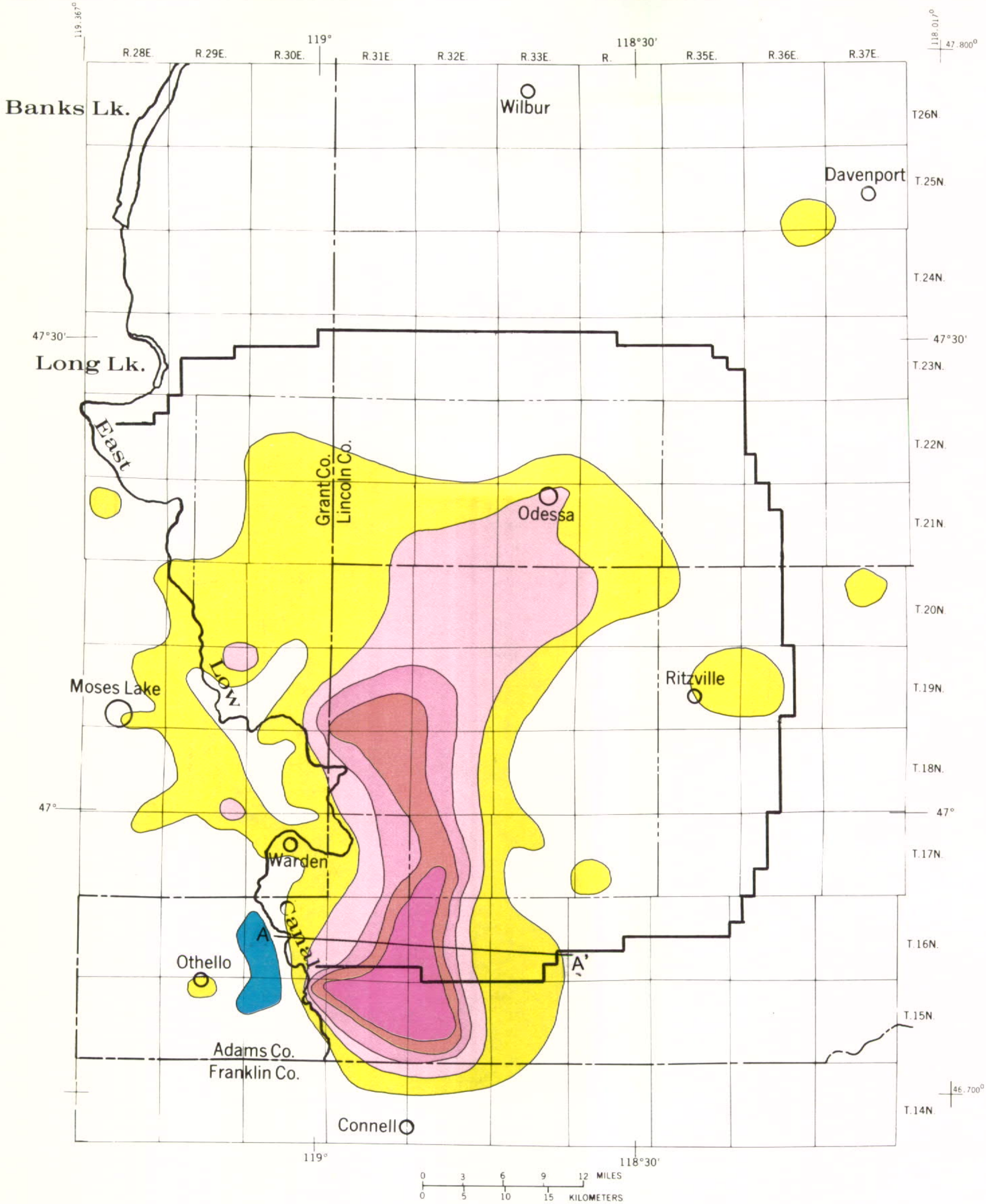


FIGURE 7.--WATER-LEVEL FLUCTUATIONS IN WELL 21/30-3E1, WHICH WAS DEEPENED.

RESPONSE OF THE GROUND-WATER SYSTEM TO DEVELOPMENT

Water levels have continued to decline since 1967 in the areas of heaviest pumping, especially in wells tapping both the Wanapum and Grande Ronde Basalts. The 10-year change in water levels, from spring 1968 to spring 1978, for the Wanapum Basalt and the Wanapum and Grande Ronde Basalts (figs. 8 and 9) demonstrates the cumulative effect of the pumpage during this period. (Note in figures 3 and 4 that the pumpage changed in both distribution and quantity.) Water-level declines of more than 80 feet have occurred in both the Wanapum Basalt and the Wanapum and Grande Ronde Basalts east of Othello; declines of more than 100 feet have occurred in the Wanapum and Grande Ronde Basalts southwest and northwest of Odessa.



EXPLANATION

Rise		Decline	
20		0 - 20	20 - 40	40 - 60
Little or no change		60 - 80	> 80	

FIGURE 8.--WATER-LEVEL DECLINE (IN FEET), EXCEPT FOR RISE NEAR OTHELLO, IN WELLS TAPPING THE WANAPUM BASALT, SPRING 1968 TO SPRING 1978 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1 - MARCH 31 PERIODS).

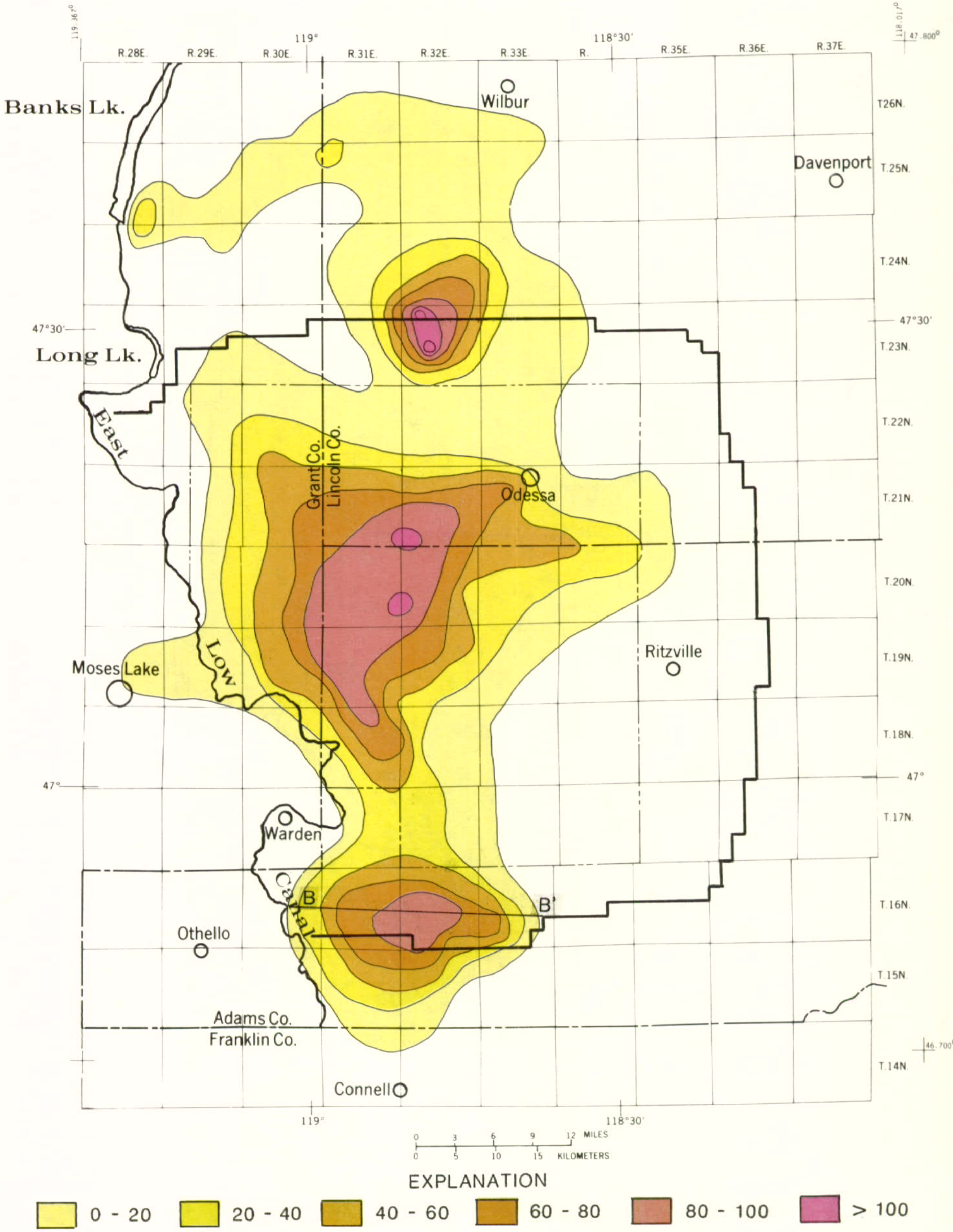


FIGURE 9.--WATER-LEVEL DECLINE (IN FEET) IN WELLS TAPPING THE WANAPUM BASALT AND THE GRANDE RONDE BASALT, SPRING 1968 TO SPRING 1978 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

Water-level changes from spring 1978 to spring 1981 in the Wanapum Basalt and in the Wanapum and Grande Ronde Basalts (figs. 10 and 11) indicate that water levels have continued to decline, dropping more than 40 feet east of Othello for the 3-year period in the Wanapum Basalt and more than 60 feet in the same area in the Wanapum and Grande Ronde Basalts. The water-level decline in the Wanapum Basalt occurs in the same general part of the study area as did the preceding 10-year decline, but there are some notable differences between the two periods in the Wanapum and Grande Ronde Basalts. At Connell, little change in water levels occurred from 1968 to 1978, but a large decline occurred from 1978 to 1981. Areas to the southwest and to the northwest of Odessa had large declines from 1968 to 1978; however, the declines were generally moderate from 1978 to 1981.

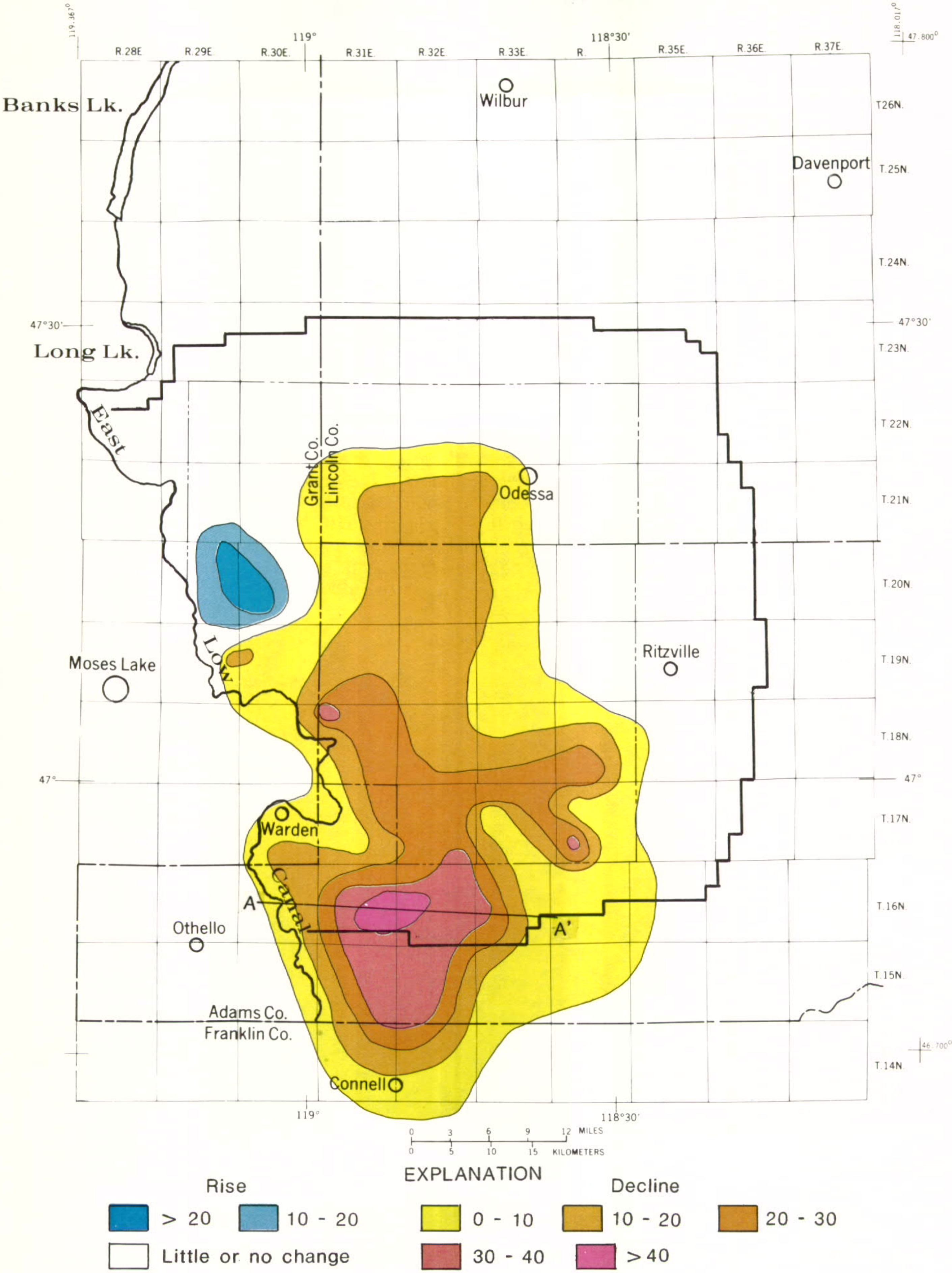


FIGURE 10.--WATER-LEVEL DECLINE (IN FEET), EXCEPT FOR RISE NORTHEAST OF MOSES LAKE, IN WELLS TAPPING THE WANAPUM BASALT, SPRING 1978 TO SPRING 1981 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

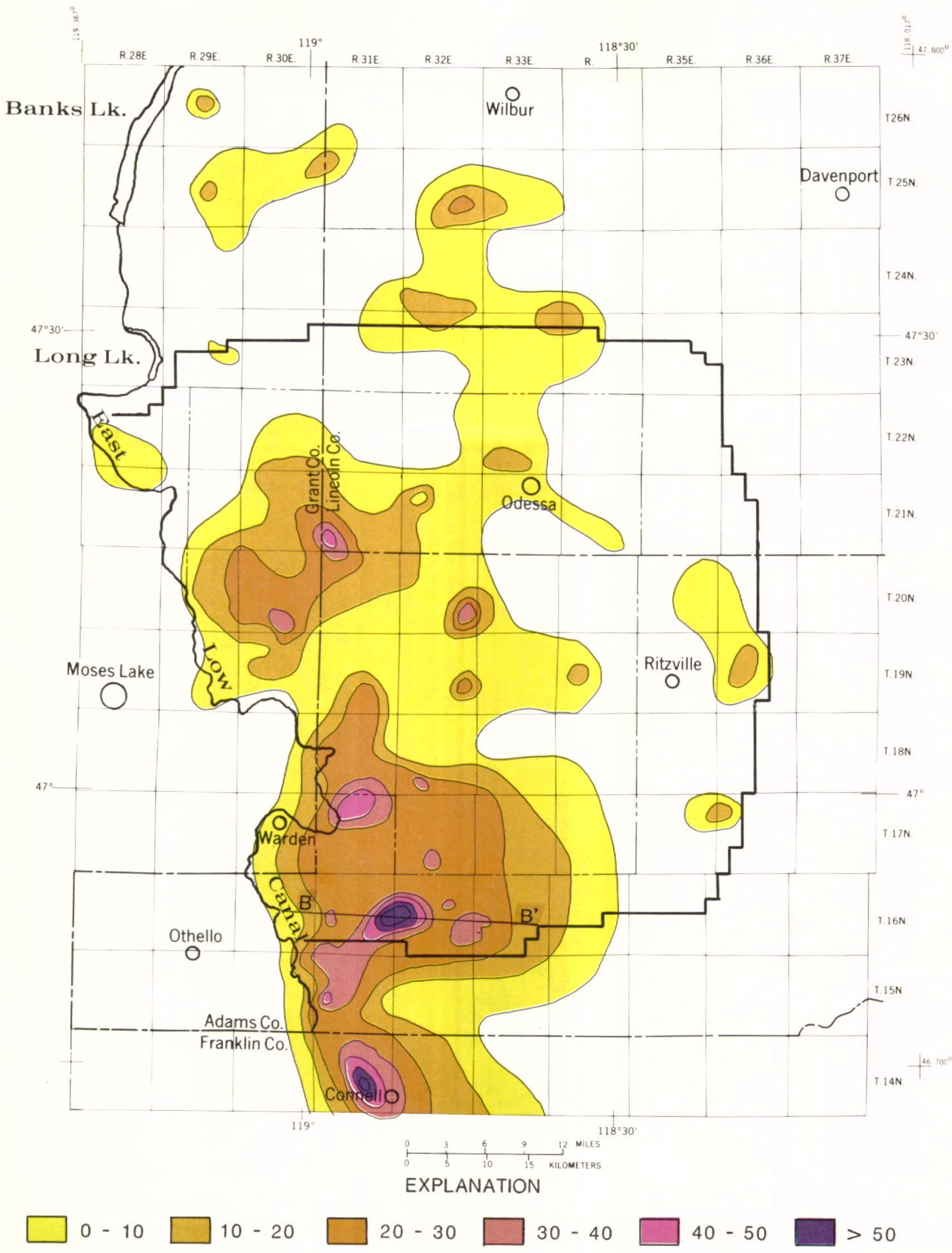


FIGURE 11.--WATER-LEVEL DECLINE (IN FEET) IN WELLS TAPPING THE WANAPUM BASALT AND THE GRANDE RONDE BASALT, SPRING 1978 TO SPRING 1981 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

Cross-sectional views of the cones of depression east of Othello for the Wanapum Basalt and the Wanapum and Grande Ronde Basalts (figs. 12 and 13) show the 10-year change in water levels from spring 1968 to spring 1978, and also the succeeding 3-year decline from spring 1978 to spring 1981, which was at an accelerated rate. According to the WDOE Odessa subarea management regulations, the planned maximum allowable drawdown of the water level in this area is 300 feet, and ground-water withdrawal is such that water-level declines of 30 feet for any 3-year period are not exceeded.

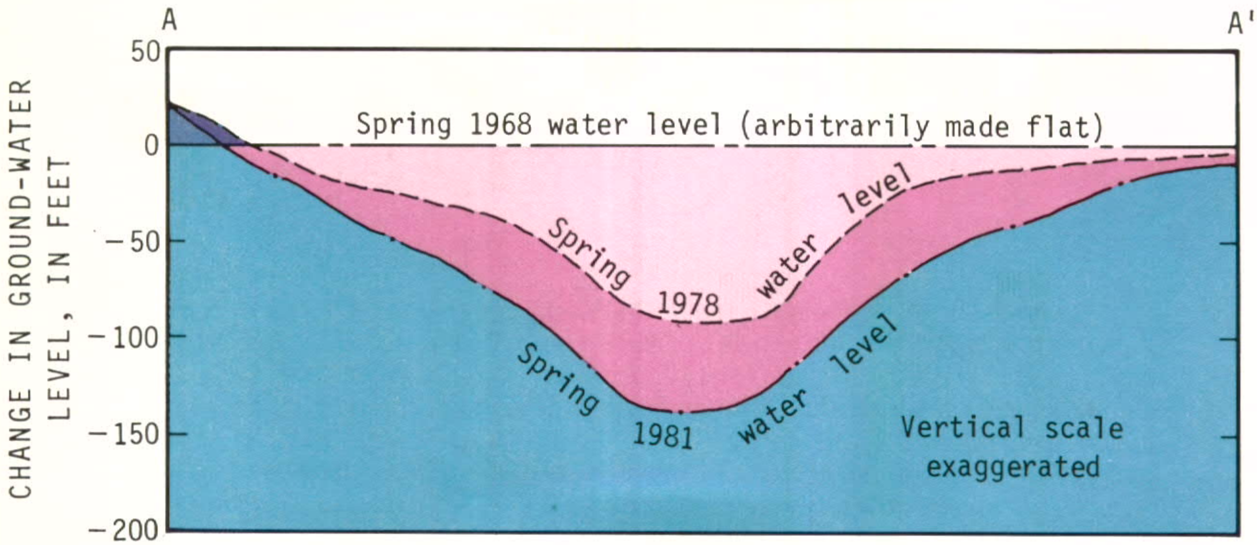


FIGURE 12.--WATER-LEVEL CHANGE IN WELLS TAPPING THE WANAPUM BASALT, SPRING 1968 TO SPRING 1981. CROSS-SECTION LOCATION SHOWN ON FIGURES 8 AND 10.

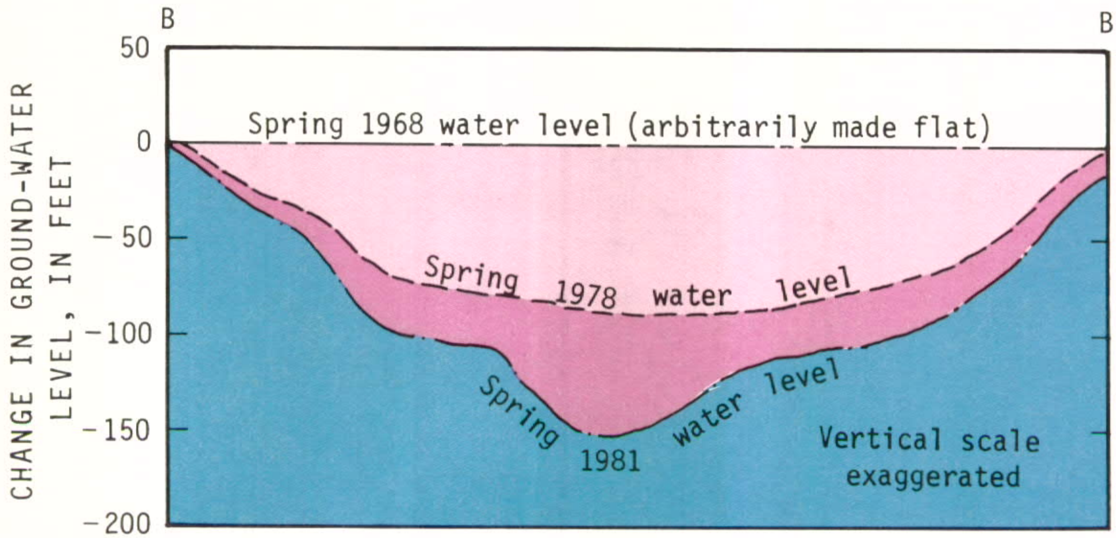


FIGURE 13.--WATER-LEVEL CHANGE IN WELLS TAPPING THE WANAPUM BASALT AND THE GRANDE RONDE BASALT, SPRING 1968 TO SPRING 1981. CROSS-SECTION LOCATION SHOWN ON FIGURES 9 AND 11.

NOTE: MAXIMUM ALLOWABLE DRAWDOWN OF WATER LEVEL UNDER CURRENT WASHINGTON STATE DEPARTMENT OF ECOLOGY REGULATIONS IS 300 FEET

Ground-water levels have declined in parts of east-central Washington since the mid-to-late 1960's (figs. 7, 14, and 15). Before this time, water levels stayed fairly constant, except near the East Low Canal where water levels rose because of leakage from the canal and local irrigation. Except for well 21/31-10M1 (fig. 17), the well hydrographs that appear in Bulletin 36 were not updated and used in this report because water-level measurements were discontinued in four wells, and one well is located in an area of little decline. The fluctuation of the water level in an unused well tapping the Wanapum Basalt (fig. 14) shows a general, although not continuous, decline since 1964 at this site. The fluctuation of the water level in an irrigation well tapping both the Wanapum Basalt and the Grande Ronde Basalt (fig. 15) shows a similar decline since 1969.

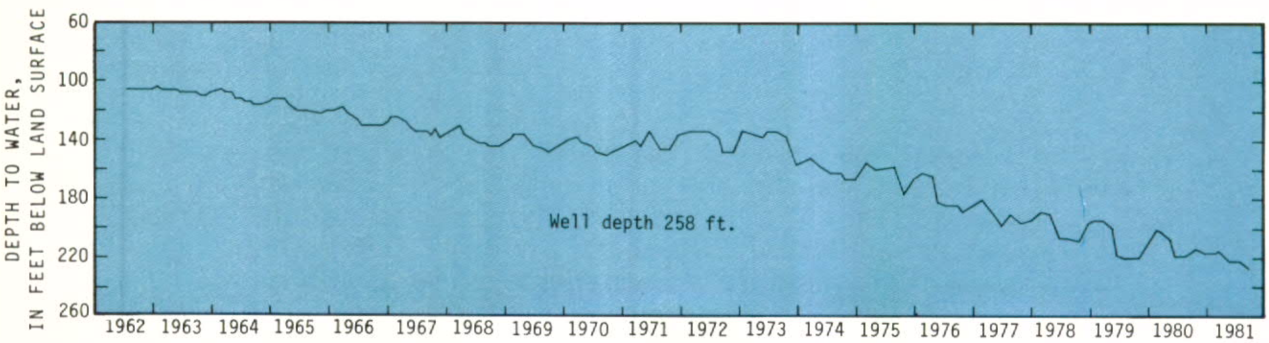


FIGURE 14.--WATER-LEVEL FLUCTUATIONS IN WELL 17/32-19E1
TAPPING WANAPUM BASALT.

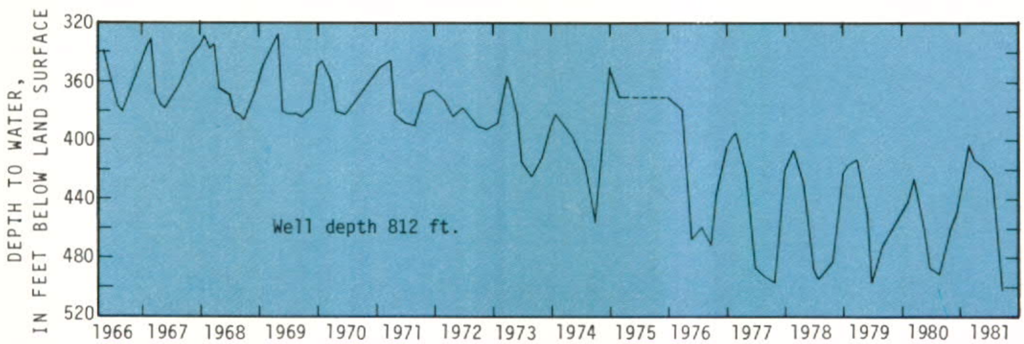


FIGURE 15.--WATER-LEVEL FLUCTUATIONS IN WELL 16/32-25A1
TAPPING THE WANAPUM BASALT AND THE GRANDE RONDE BASALT.

The different aquifers tapped by a well may show variations in their water-level fluctuations and also in their depths to water (figs. 16 and 17). Figure 16 shows the multiple hydrographs of the Odessa test-observation well (Walters, Cline, and Luzier, 1972) depicted in figure 6 (E2 is not shown because it is nearly identical to E3). Note that the composite water level in the well prior to the installation of the piezometers does not match levels of any of the individual aquifers after installation.

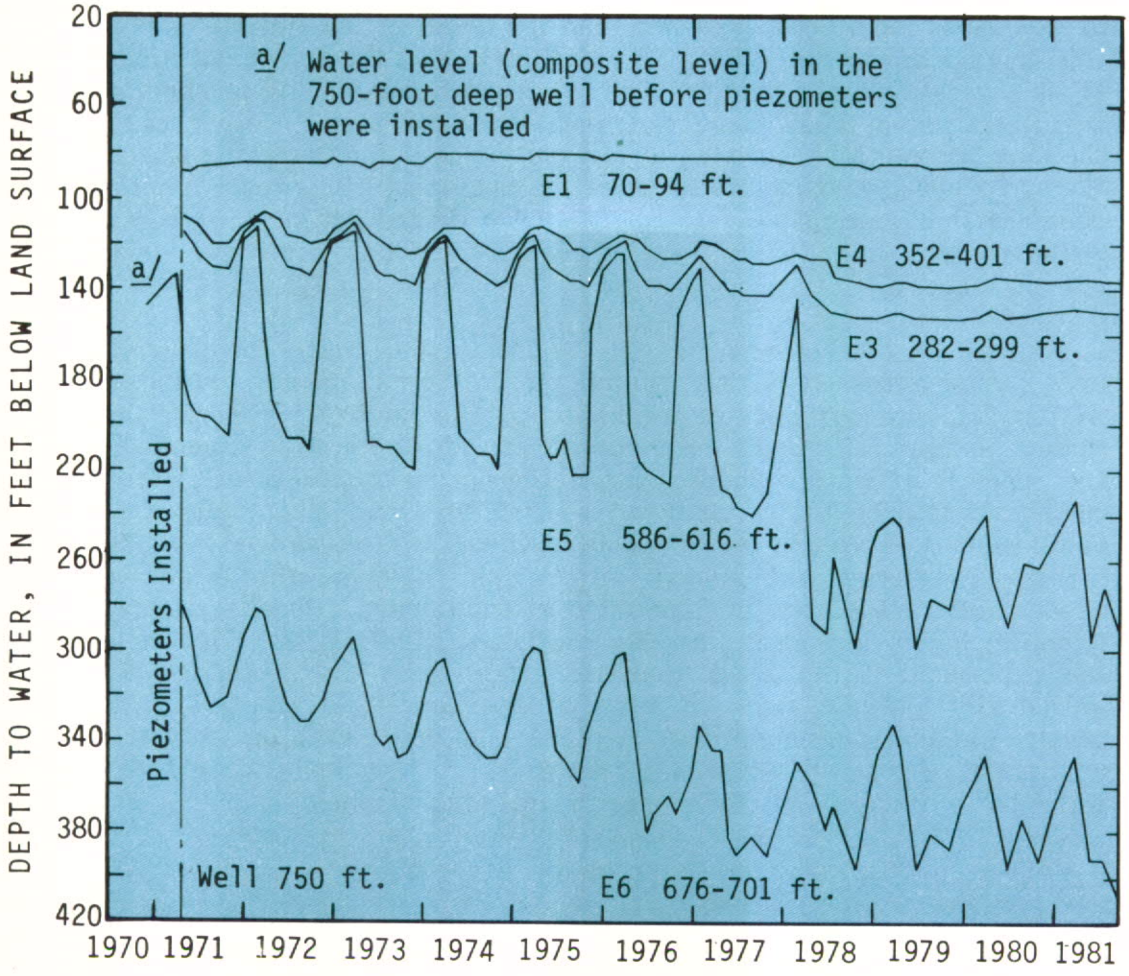


FIGURE 16.--WATER-LEVEL FLUCTUATIONS IN THE ODESSA TEST-OBSERVATION WELL AND PIEZOMETERS 20/33-16E1-E6 (NUMBERS INDICATE AQUIFER ZONE INTERVAL TAPPED BY THE PIEZOMETER).

In the Basalt Explorer oil test well the water level of M4, the deepest zone monitored, is higher than the levels of M2 and M3 (fig. 17); this may occur naturally, but it is more likely that the zone monitored by M4 is generally deeper than the zones that are being heavily pumped, and therefore water levels have not been lowered much. Note that the shallowest zone (M2) shows an annual water-level fluctuation (caused by the surrounding pumping wells) since the beginning of its record, but M3 does not show noticeable fluctuations until 1977, when new wells were drilled nearby and others were deepened into this zone and started pumping from it.

In areas of heaviest pumping, the lowering of water levels during each pumping season is only partially offset by their rise during the winter "off season" because recharge to the aquifers from the land surface and lateral ground-water movement into the area is exceeded by the quantity of water pumped out. If the annual pumpage rate were to remain constant, the ground-water system would eventually reach equilibrium and water levels would recover to the same level each spring. The larger the annual withdrawal, however, the larger and deeper will be the cone of depression at equilibrium. Because pumpage is continuing to increase, both the downward trend of water levels and the expansion of the areas that are affected by the declining water levels will continue also. In some of the uppermost aquifers in the basalt, water has drained away in places and wells that tap only these aquifers have gone dry. Most of these wells produced small quantities of water and were used only for domestic and stock supplies.

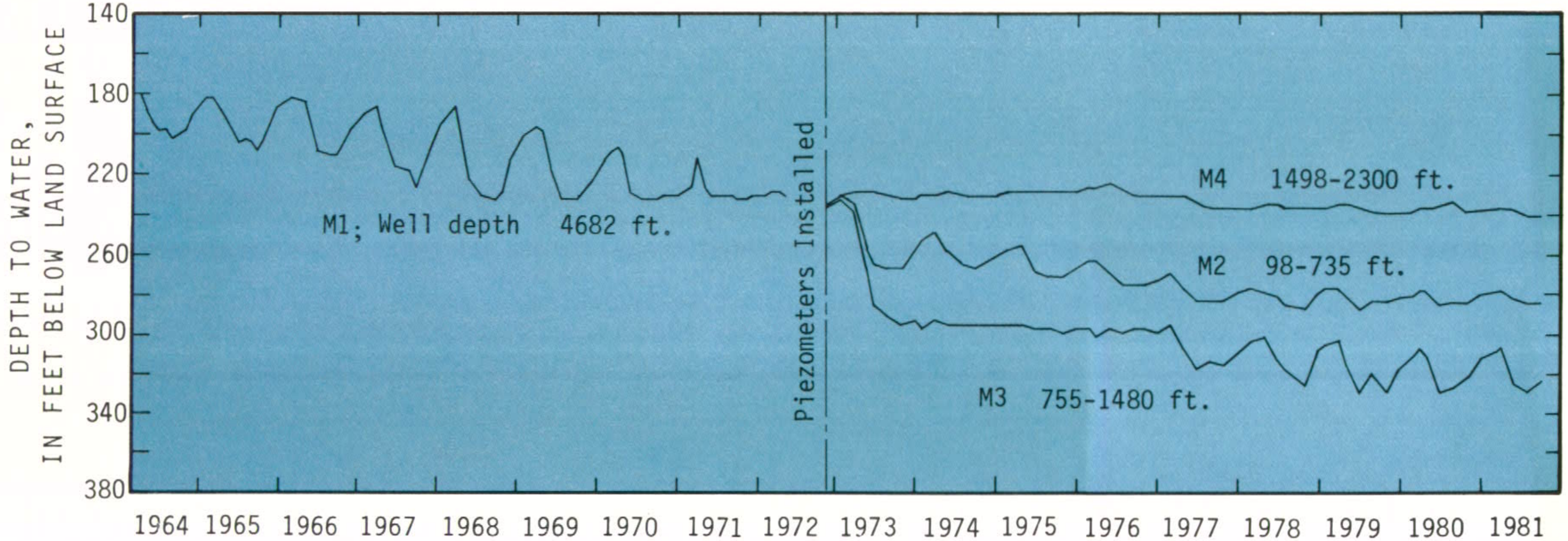


FIGURE 17.--WATER-LEVEL FLUCTUATIONS IN THE BASALT EXPLORER OIL TEST WELL (21/31-10M1) AND PIEZOMETERS 21/31-10M2-M4 (NUMBERS INDICATE WELL ZONE INTERVAL TAPPED BY THE PIEZOMETER).

A comparison of the water-level-change maps for spring 1967-spring 1968 (figs. 18 and 19) and spring 1977-spring 1978 (figs. 20 and 21) shows an increase in the extent and amount of yearly water-level declines in the project area over 10 years, especially for wells that tap both the Wanapum and Grande Ronde Basalts (figs. 19 and 21). Note that in 1977-78 water-level declines occurred in all wells in the basalts in the southern part of Adams County (figs. 20 and 21). The 1-year water-level-change maps for 1967 and 1977 reflect the influence of the pumpage (figs. 3 and 4) during each of those years, and the difference in the annual water-level change between 1967 and 1977 reflects the difference (change) in pumpage between those years. Water levels in wells beyond the influence of heavy pumping changed little during this time, even though 1976 and 1977 were severe drought years.

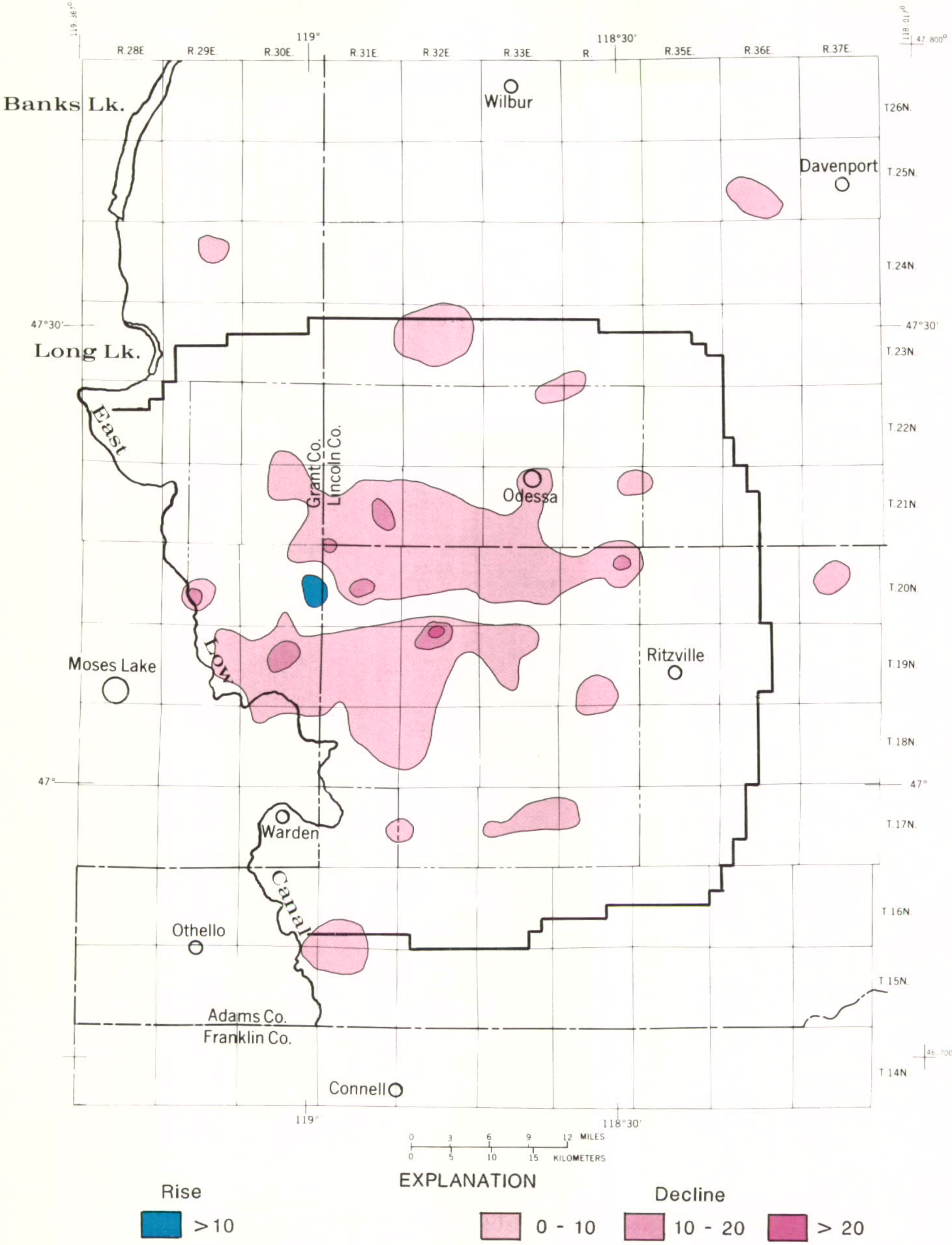


FIGURE 18.--WATER-LEVEL DECLINE (IN FEET), EXCEPT FOR RISE HALFWAY BETWEEN MOSES LAKE AND ODESSA, IN WELLS TAPPING THE WANAPUM BASALT, SPRING 1967 TO SPRING 1968 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

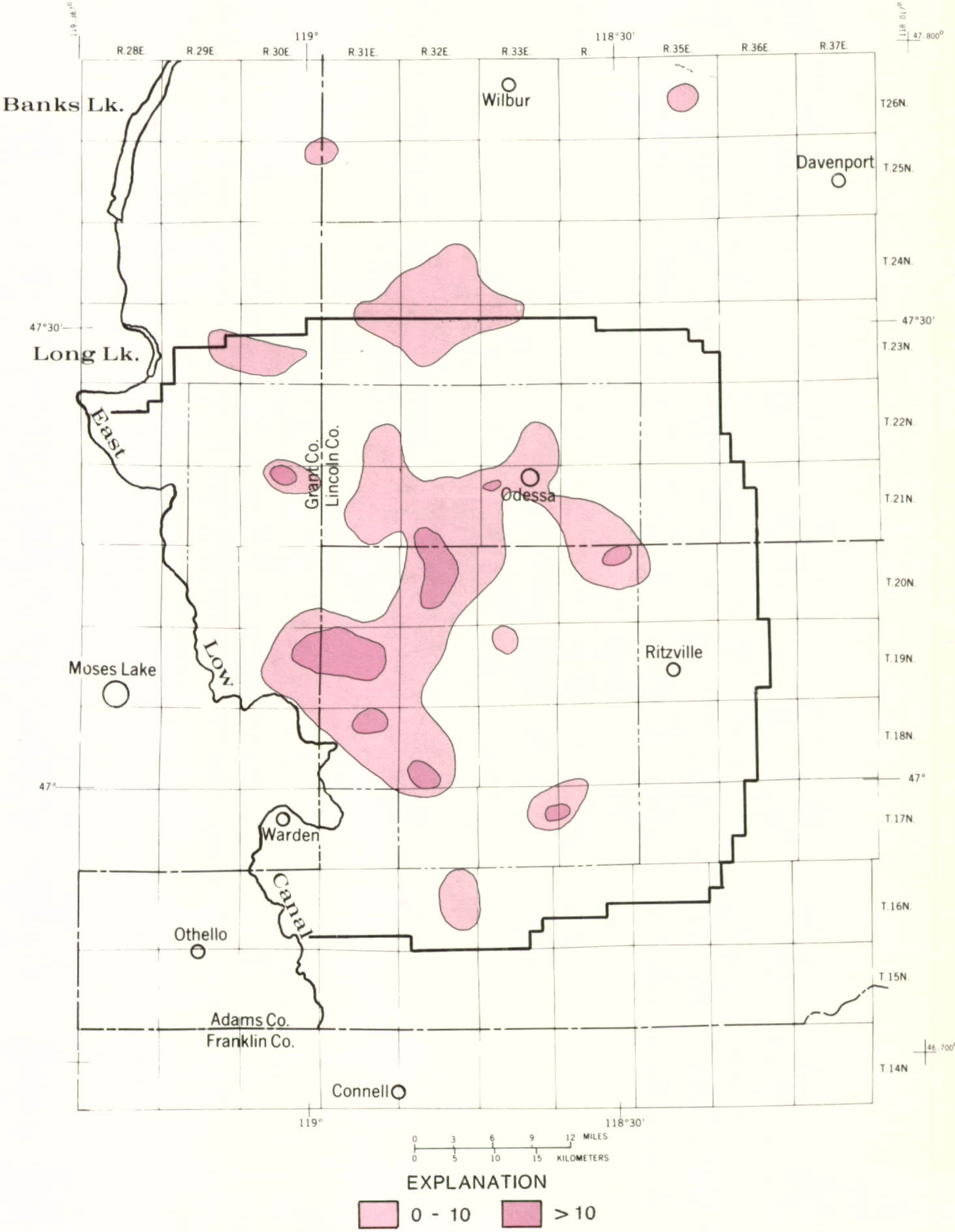


FIGURE 19.--WATER-LEVEL DECLINE (IN FEET) IN WELLS TAPPING THE WANAPUM BASALT AND THE GRANDE RONDE BASALT, SPRING 1967 TO SPRING 1968 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

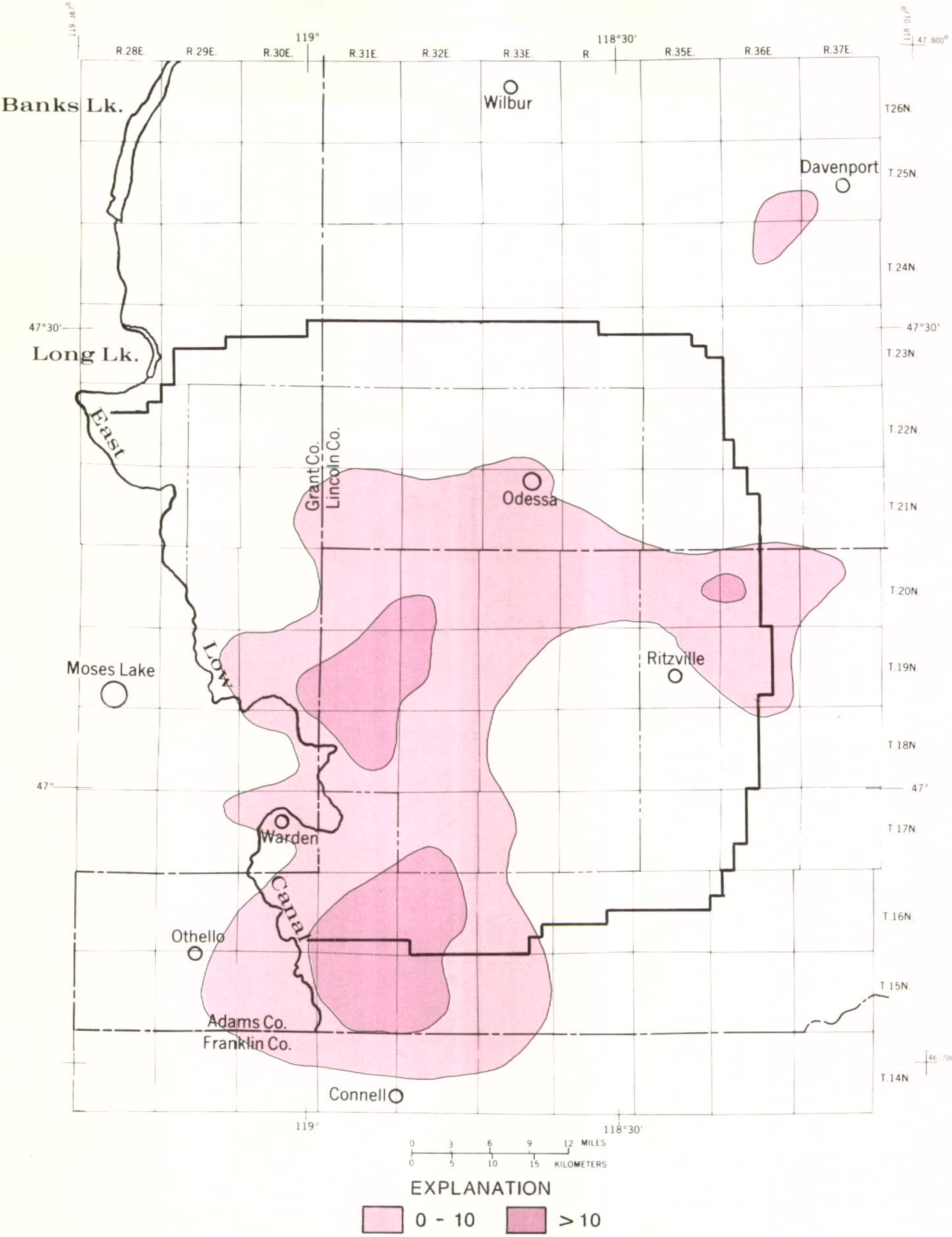


FIGURE 20.--WATER-LEVEL DECLINE (IN FEET) IN WELLS TAPPING THE WANAPUM BASALT, SPRING 1977 TO SPRING 1978 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

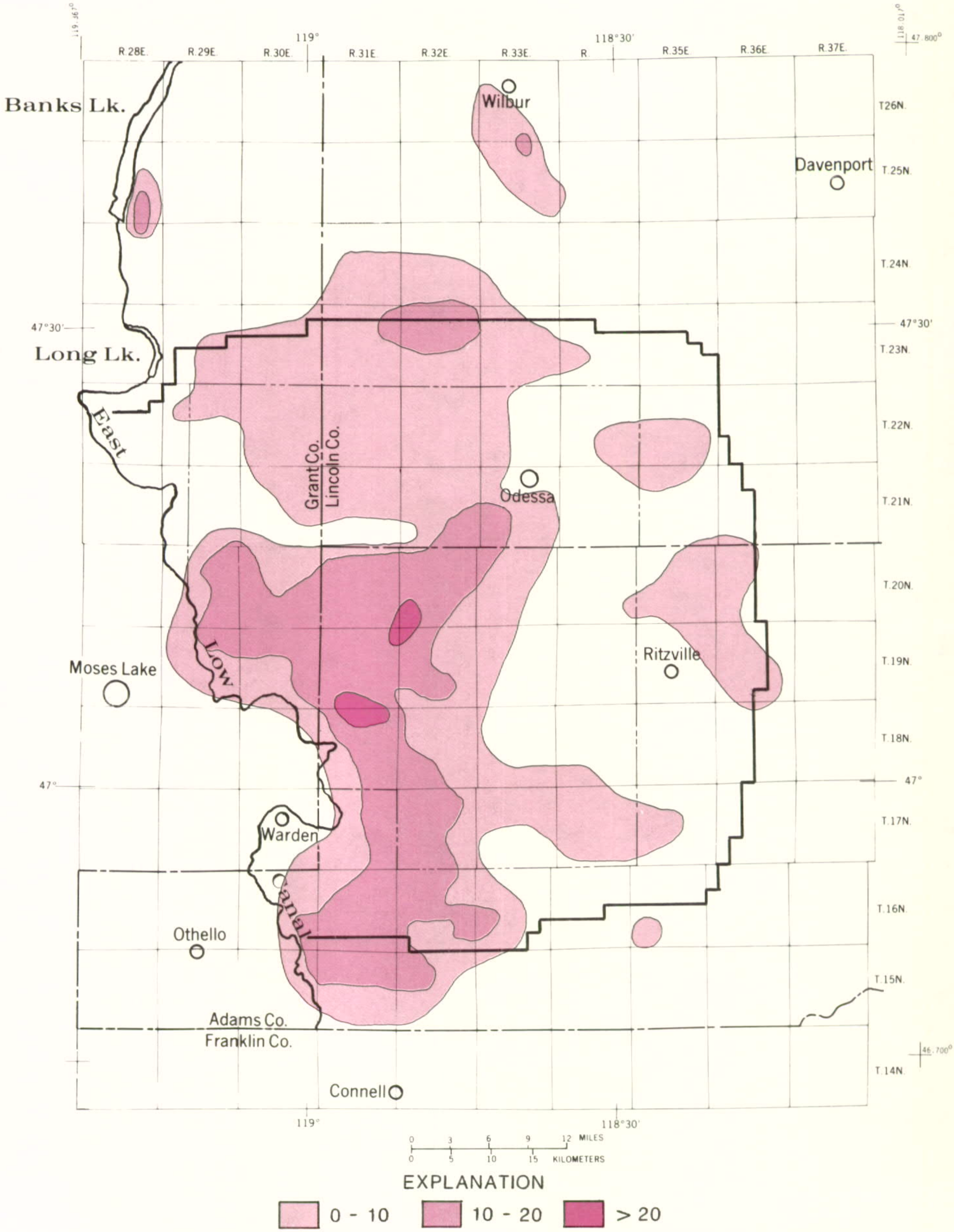


FIGURE 21.--WATER-LEVEL DECLINE (IN FEET) IN WELLS TAPPING THE WANAPUM BASALT AND THE GRANDE RONDE BASALT, SPRING 1977 TO SPRING 1978 (HIGHEST WATER LEVEL MEASURED FOR DECEMBER 1- MARCH 31 PERIODS).

SUMMARY AND CONCLUSIONS

Ground-water pumpage from the basalts in the Odessa-Lind area, the study area for Water-Supply Bulletin 36, increased from 14,000 acre-feet in 1963 to 52,000 acre-feet in 1967 (Luzier and others, 1968); by 1977, pumpage was about 163,000 acre-feet. Similarly, the number of large-capacity wells increased from 63 in 1963 to 137 in 1967 (Luzier and others, 1968) and to 249 in 1977. Pumpage in the present (1981), larger study area in east-central Washington was estimated to be 25,000 acre-feet in 1963. By 1967, pumpage was about 111,000 acre-feet, and by 1977, about 387,000 acre-feet. The approximate number of large-capacity wells increased from 170 in 1963 (many were small producers) to 305 in 1967 and 618 in 1977. By 1980, both pumpage and number of wells were even greater, according to the Washington State Department of Ecology (Ted Olsen, oral commun., 1981). Pumpage has caused a continuous lowering of water levels in the areas of heaviest pumping that lie east of the East Low Canal.

Water levels fell a maximum of about 130 feet in wells tapping the Wanapum Basalt aquifer and about 150 feet in wells tapping both the Wanapum Basalt and Grande Ronde Basalt aquifer from the spring of 1968 to the spring of 1981. Water levels were affected to a maximum distance of about 23 miles from pumping centers. However, large areas of the study area show little or no water-level declines. Declines in water levels can be expected to continue; if pumpage does not increase, however, water levels will eventually stabilize as the system reaches equilibrium. Also, increased pumpage in areas that are presently unaffected and are adjacent to areas presently experiencing a water-level decline will increase the overall decline in all these areas.

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* GPO 796-134 1984