ENVIRONMENTAL TRITIUM AS HYDROLOGIC TOOL - ROSWELL ARTESIAN BASIN

D. Dan Rabinowitz and G. W. Gross*

Introduction

Tritium content of precipitation in the vicinity of Socorro, New Mexico, has been measured since 1956 by the tritium laboratory of New Mexico Institute of Mining and Technology. Well waters from the Roswell artesian basin were collected for the purpose of monitoring variations in tritium concentrations with time. This sampling program was carried out for seven wells from 1961 to 1968. Figure 1 is a map of New Mexico showing the locations of precipitation collection stations (of which tritium content was measured) and precipitation recording stations around the study area. The groundwater sampling sites are located in the vicinity of Roswell (Fig. 2). All of these wells are completed in the San Andres limestone aquifer. This report is concerned with the presentation of background material and some of the observed variations in tritium concentration of precipitation and well water. The possibilities of new contributions to the hydrologic knowledge of the Roswell artesian basin by the tritium tracing techniques are discussed. A detailed report of the study and its results will soon be completed.

Properties and Occurence of Tritium

Natural tritium was first identified by its radioactivity in rain water. Its detection in all forms of natural water became possible, and it was evident that tritiated water would be a useful tool in following the path of groundwater movement.

Tritium is usually designated by the symbol T or by the chemical symbol, ${}_1H^3$. Tritium has a half-life of 12.3 years and emits low energy beta particles with a maximum energy of 0.018 Mev, and, thus, produces a stable helium isotope of mass three. Tritium is produced naturally in the upper atmosphere by bombardment of nitrogen molecules with cosmic rays. From the atmosphere, it finds its way into the hydrologic cycle. Another source of tritium is nuclear fusion reactions. Such reactions, generated by nuclear explosions in the atmosphere, caused concentration peaks in natural waters several orders of magnitude larger than the natural concentrations. The content of tritium in water is expressed in tritium units (T.U.). T.U. has the dimensions of concentration and is defined as

$$1 \text{ T.U.} = \frac{1 \text{ Tritium atom}}{10^{18} \text{ Hydrogen atoms}}$$

* Graduate student in Geoscience and Associate Professor of Geophysics, respectively. Geoscience Department, New Mexico Institute of Mining and Technology, Socorro. The final phase of this study was funded by N. M. Water Resources Research Institute, Project No. 3109-114.

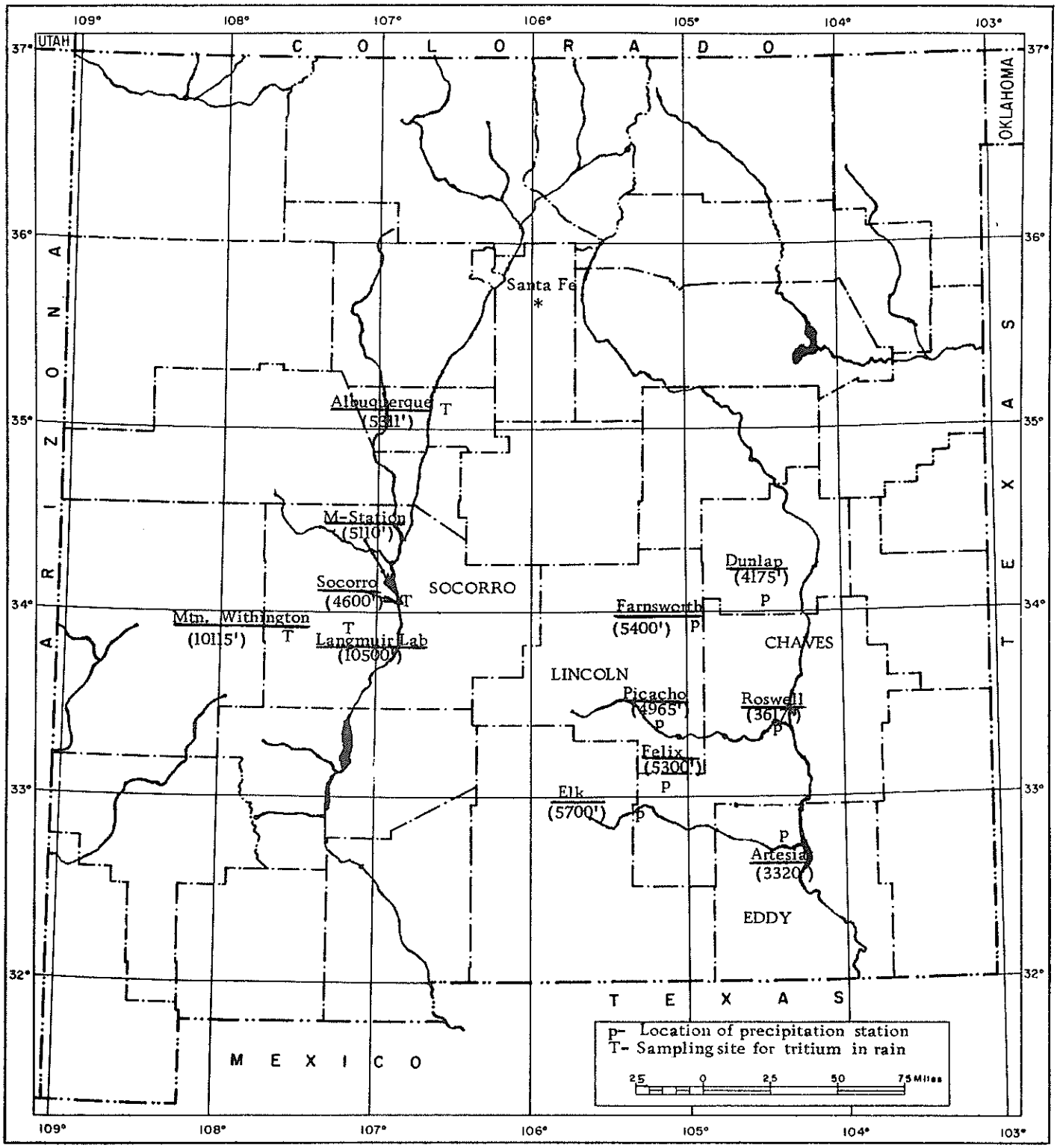

Figure 1. Map of New Mexico with precipitation measuring stations and tritium monitoring stations.

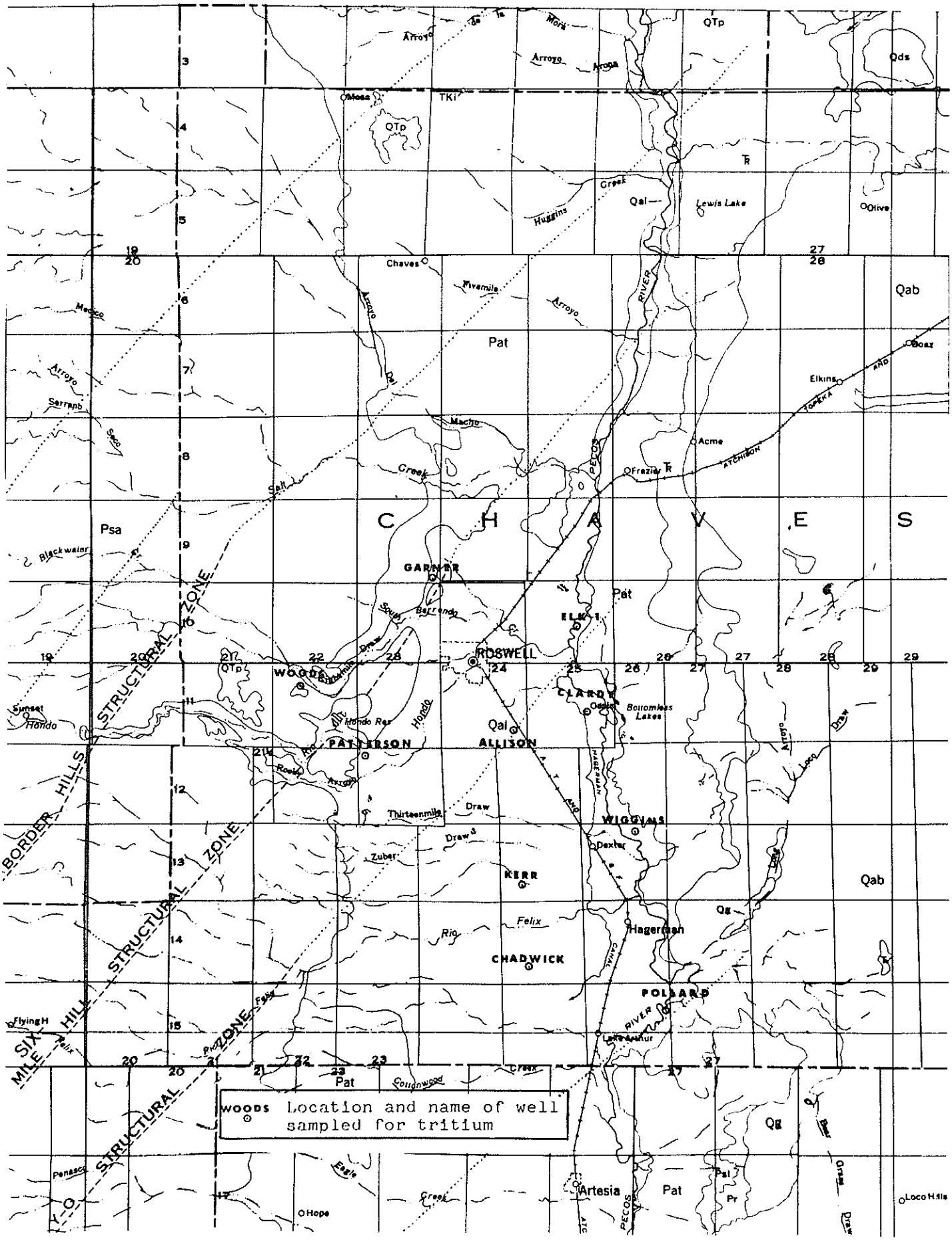

Figure 2. Locations of wells sampled for tritium in the Roswell artesian basin.

In more conventional radiation units the T.U. is defined as follows:

$$1 \text{ T.U.} = 3.24 \times 10^{-15} \text{ Ci/ml}$$

Before 1952, the date of the first atmospheric nuclear bomb explosion, the steady state level of tritium in rain water was about 10 T.U. The maximum concentration of tritium observed in New Mexico rains was about 12,000 T.U. in June 1963. It is these peaks of artificially produced tritium that prove useful in hydrologic studies. As such a peak slowly travels through the aquifer and decays, it can provide valuable clues about residence time, flow patterns, and recharge in an aquifer.

The present study is concerned with the interpretation of such data.

Presentation and Discussion of Data

The variations of tritium concentrations in precipitation as measured in the vicinity of Socorro are presented in Figure 3. For orientation, the history of thermonuclear atmospheric testing is outlined on Figure 3. Following the second period of atmospheric testing (September 1961-December 1962) tritium wash-out was slower than the one following the 1958 moratorium. This is indicative of the amount of tritium injected into the stratosphere during these periods. Figure 3 is a comparison between tritium observations in Socorro and Ottawa, Canada (Environmental Isotope Data: World Survey of Isotope Concentration in Precipitation, International Atomic Energy Agency, Vienna, 1969-1971). Each point represents a monthly average of up to 10 samples (during the summer months). It is clear that some correlation of high and low tritium values exists between the two locations. In a study of this nature it is important to know the variations of tritium concentrations of precipitation a few years before the beginning of groundwater sampling. Since the measurements at Socorro did not start until late 1956, the Ottawa record is used for the period 1953 - 1956.

Figure 3 also shows tri-monthly (seasonal) mean rainfall values at Roswell. The two periods that should be noticed are 1958 - 1960 and 1963 - 1966 which are wet and dry, respectively. Although there are seven precipitation recording stations around the basin, the trend in rainfall at Roswell is representative only of the northern stations. From 1953 to 1968, the annual rainfall at Elk, Felix, and Picacho (Fig. 2) was quite regular with small deviations from one year to the next.

The observed variations of tritium concentrations in groundwater are presented in Figure 4 - 8 as moving averages of 3 months. This smoothing procedure was used in order to eliminate some background variations in the individual data points. Some variations are due to an excessive summer pumpage which may draw water from greater depths of the aquifer. A few vertical profiles, constructed from water samples taken at different depths, indicated tritium stratification,

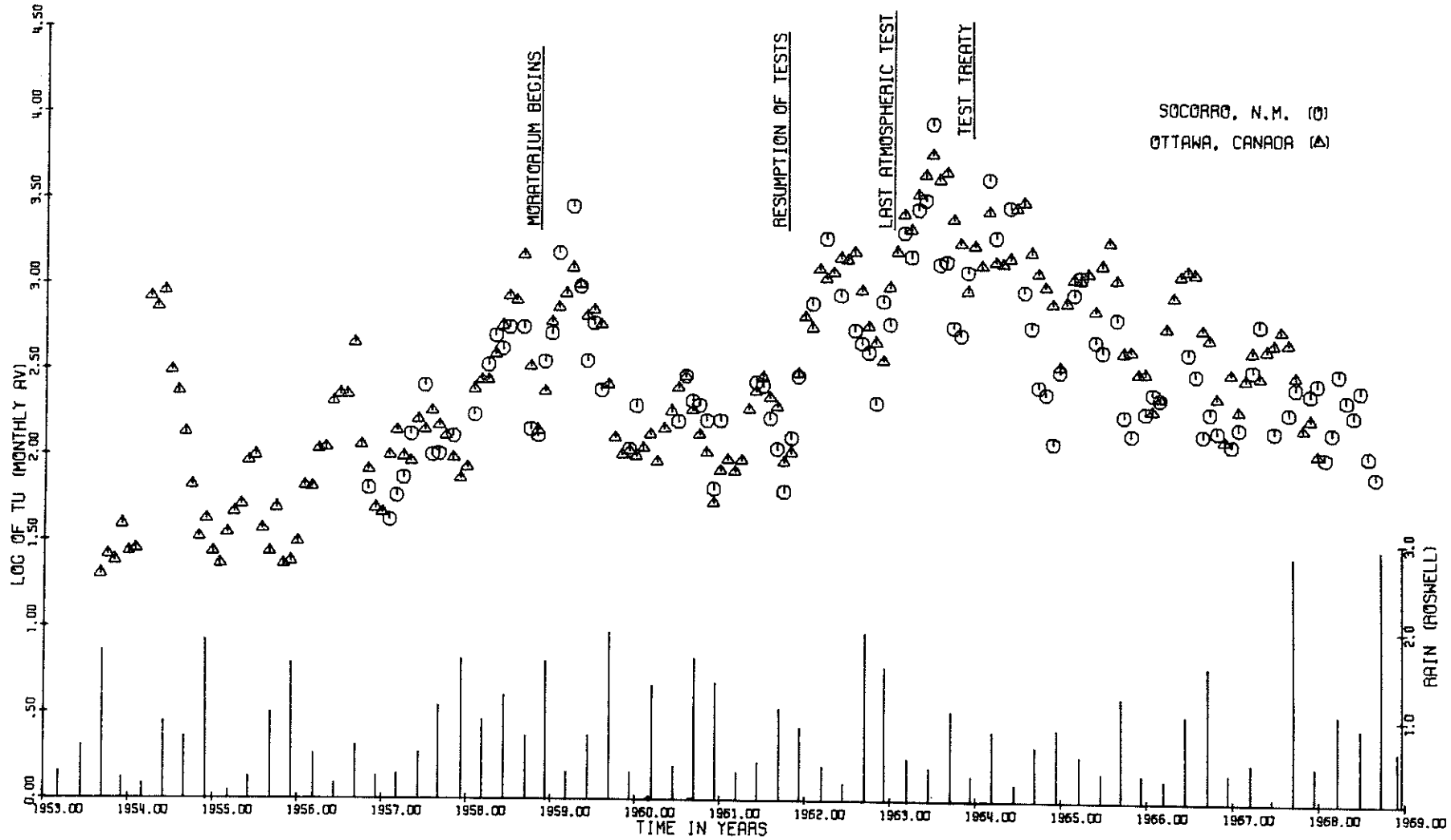

Figure 3. Variations of tritium concentrations in precipitation (Socorro, New Mexico, and Ottawa, Canada). Superposed is the mean tri-monthly rainfall in Roswell.

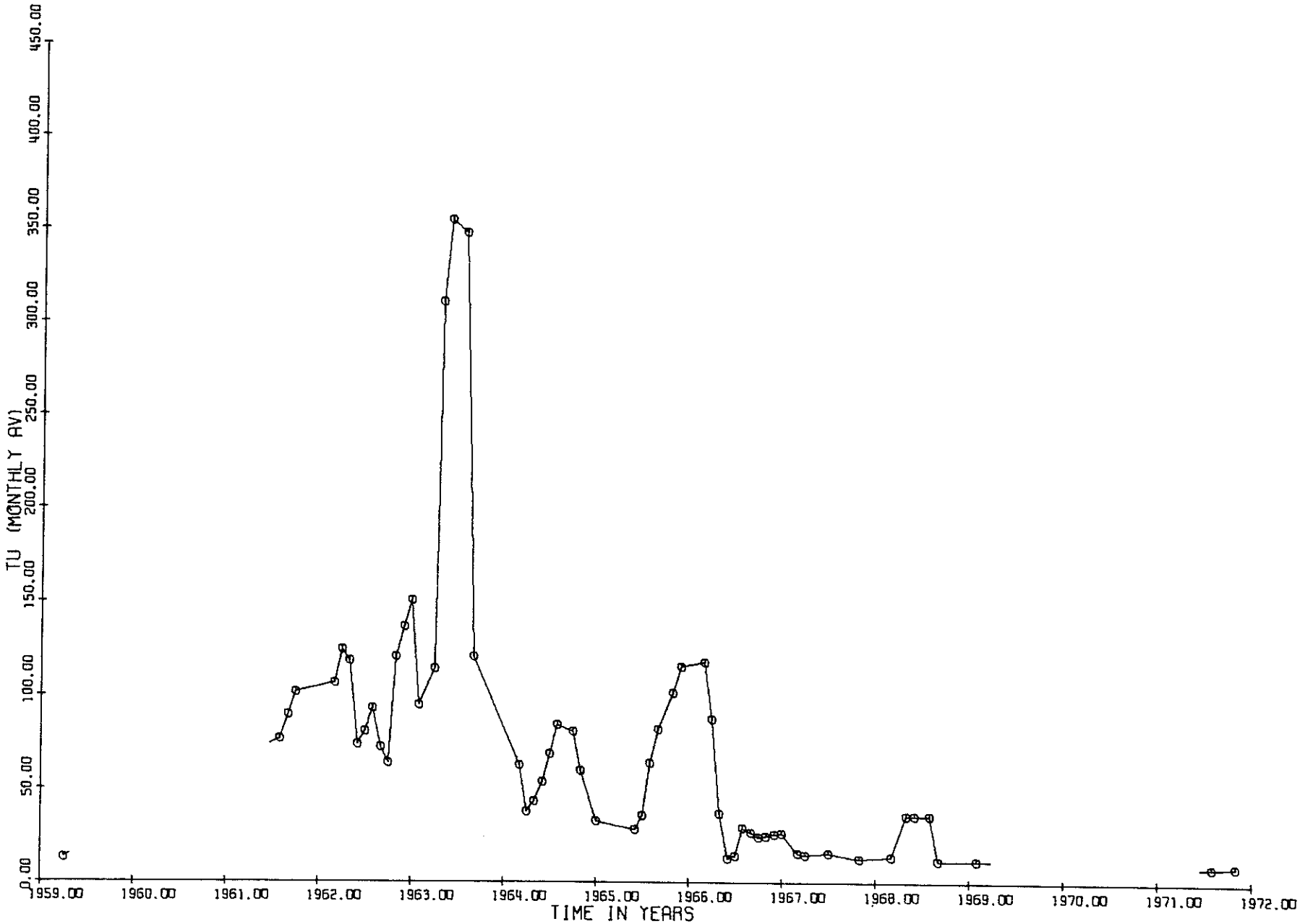

Figure 4. Tritium concentrations in Woods well (11.22. 9. 321).

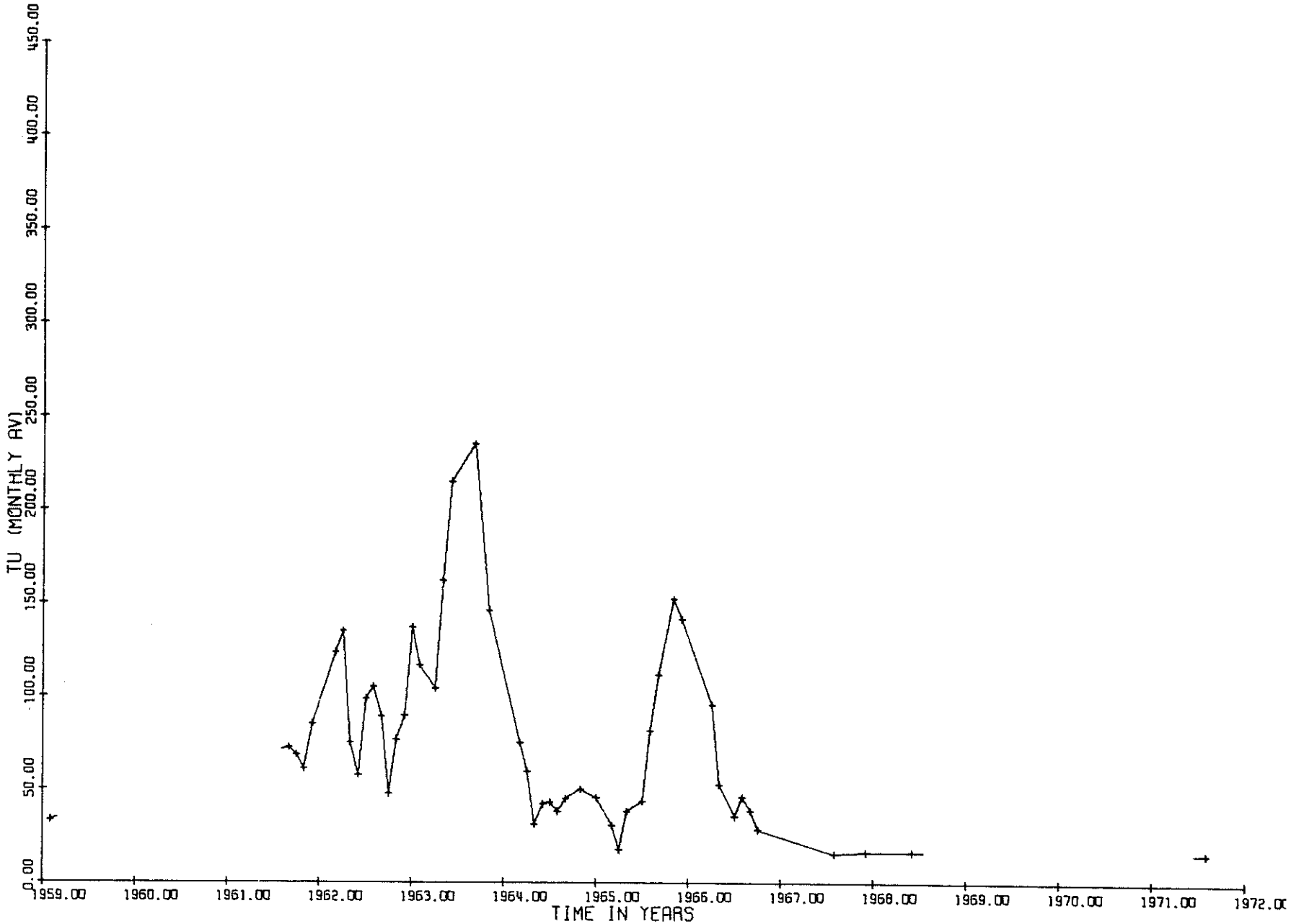

Figure 5. Tritium concentrations in Allison well (11.24.25.341).

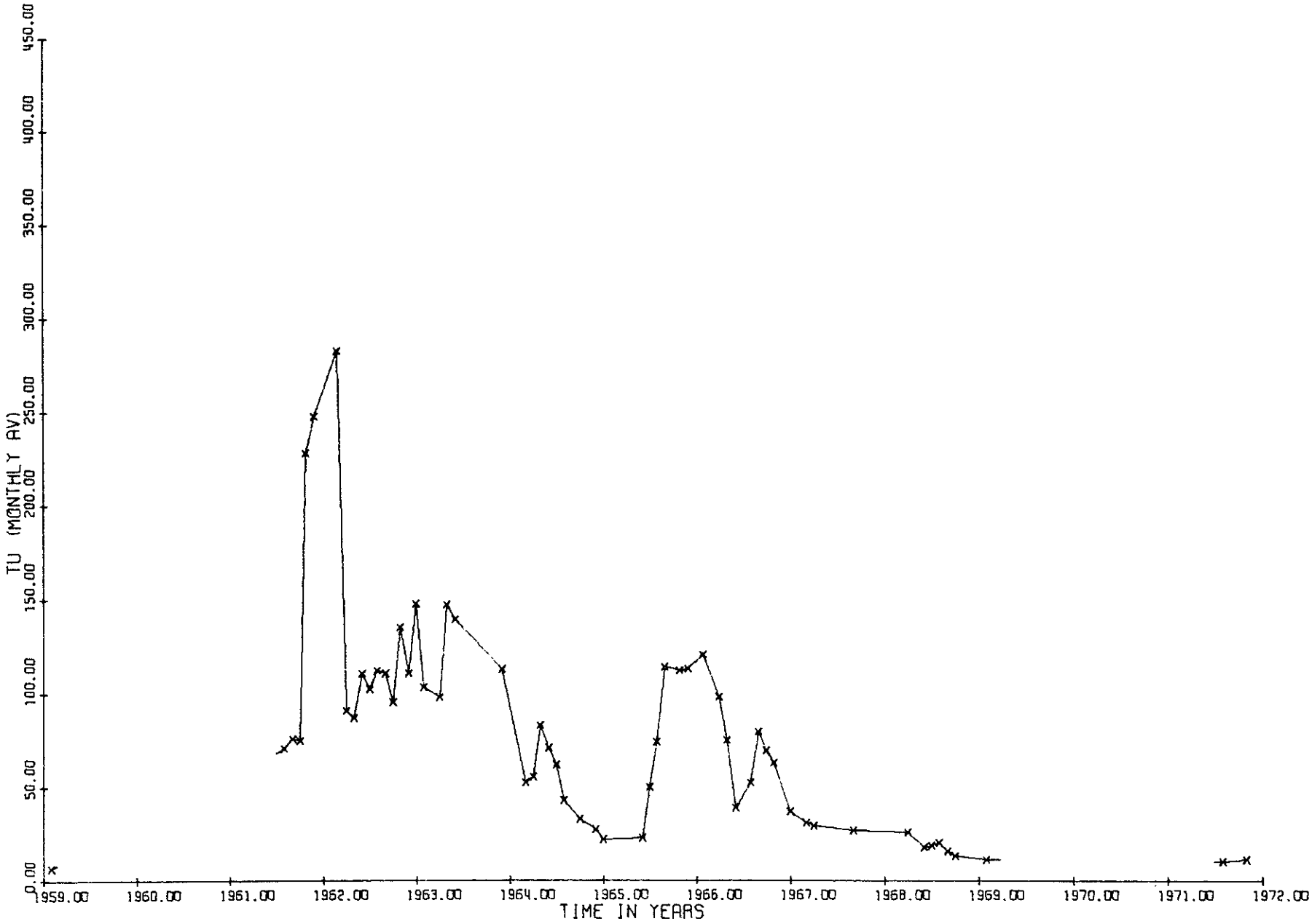

Figure 6. Tritium concentrations in Clardy well (11.25.15.343.).

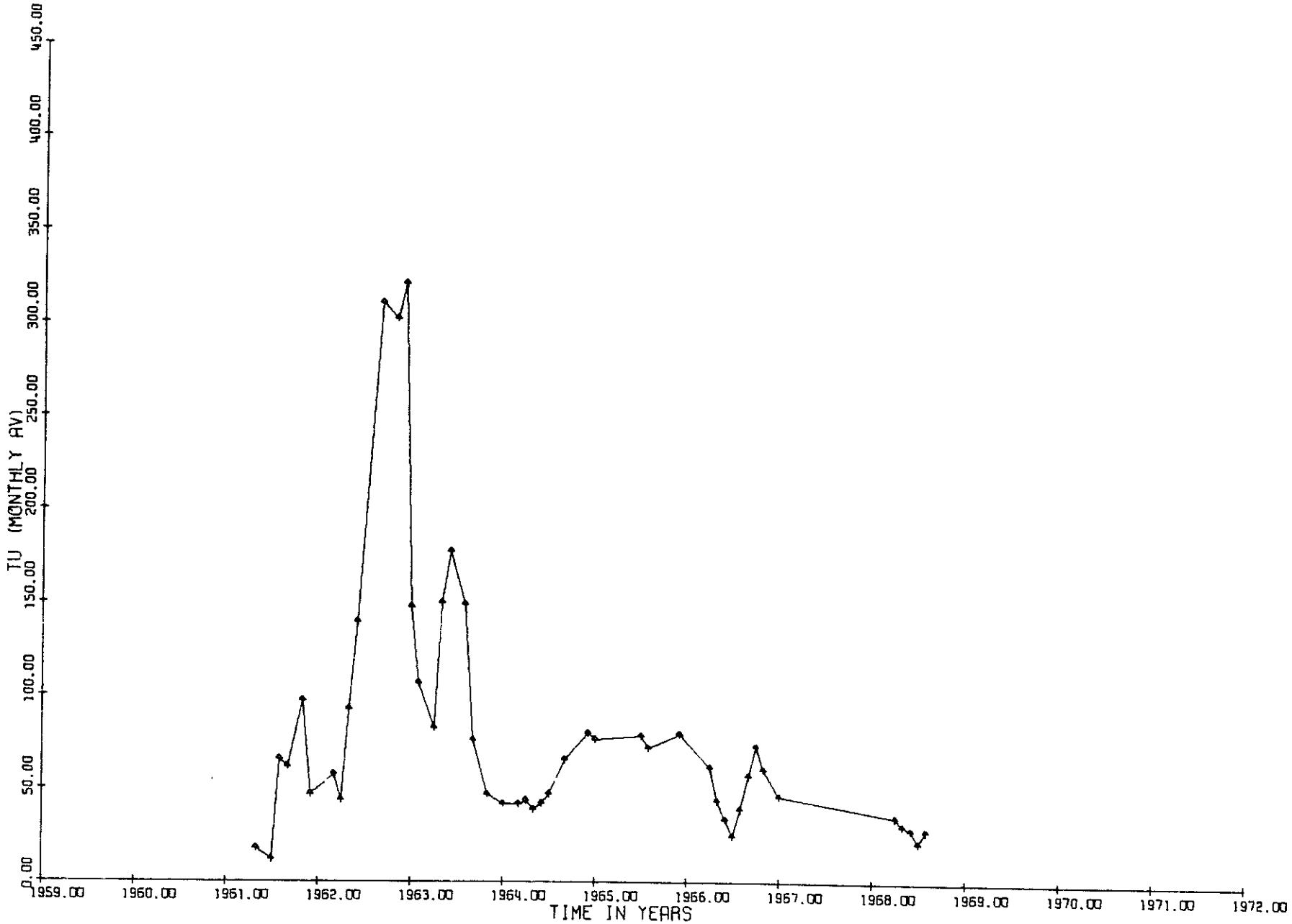

Figure 7. Tritium concentrations in Wiggins well (13.25. 3.114).

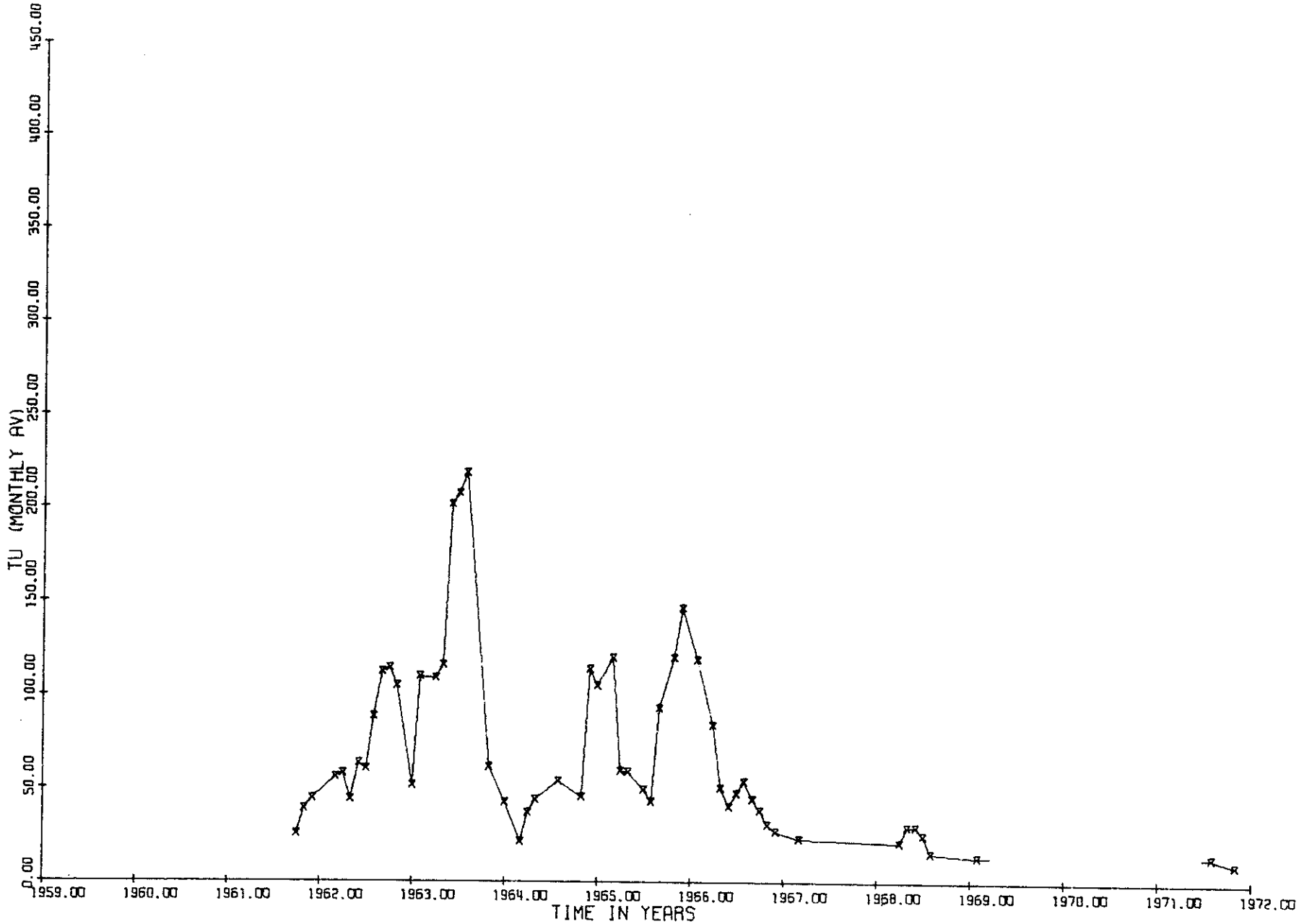

Figure 8. Tritium concentrations in Pollard well (15.26.13.121).

with the older water below. The similarity in the variations of tritium concentrations with time is striking. The main feature of the concentration variations is the rapid increase from the middle of 1961 to about 1964, followed by a sharp decrease, with two or three moderate peaks in 1965 and 1966. During 1961 - 1964, concentrations varied from about 50 to 350 T.U. The peaks in 1965 and 1966 were of the order of 100 T.U. Three of the wells (Woods, Clardy, and Allison) were sampled at the beginning of 1959. Tritium concentrations at that time were already above the natural levels. Sampling during 1971 revealed relatively low levels of tritium, though higher than the natural levels.

Interpretation

The starting point for a meaningful interpretation of this type of data must be an examination of precipitation trends. Without taking into account the variations of recharge per unit precipitation near the study area, any attempt of direct correlation between the variations of tritium concentration in precipitation and groundwater must fail. The size of a tritium peak in groundwater depends not only on the concentration of tritium in precipitation but also on the amount and intensity of the precipitation itself. This is especially true in the semi-arid region of southeastern New Mexico, where large variations of precipitation are the rule rather than the exception.

The correlation was done through a tritium input profile, defined as the product of the monthly average tritium concentration in precipitation and the amount of precipitation during that month. This product is the tritium fallout (in Ci/square mile) at the surface, of which only a certain amount will actually reach the groundwater system. This fraction varies with precipitation. It was found that the best correlation between precipitation tritium and the observed groundwater tritium was through precipitation that was measured at Dunlap and Farnsworth Ranch. The observed rise in tritium concentrations in the wells between 1961 and 1964 is the result of rainfalls during 1958, 1959, and 1960, the tritium levels in precipitation were lower than 1958 or 1963. However, consistently wet months increased the amount of recharge as indicated by the observed tritium content of groundwater. Little mixing between the recharging water and the native water of the aquifer is characteristically shown by the sharp tritium peaks. From the delay time between precipitation (1958) and first arrival at the wells (1962), a residence time of about four years is deduced. From the distance between the wells along the Pecos River and the exposure of the San Andres limestone west of Roswell, a groundwater velocity of about 65 feet per day is calculated.