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Shallow Aquifer in Mortandad Canyon at  
the Los Alamos Scientific Laboratory

by

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DISPERSION AND MOVEMENT OF TRITIUM IN A SHALLOW AQUIFER IN MORTANDAD CANYON  
AT THE LOS ALAMOS SCIENTIFIC LABORATORY

by

William D. Purtymun

ABSTRACT

Twenty (20) Ci of tritium discharged into Mortandad Canyon in November 1969 were used to determine the dispersion and movement of the tritium in a shallow aquifer in the alluvium. It took 388 days for the peak concentration to move 3 027 m from the effluent outfall to the eastern end of the aquifer. The concentration decreased from 77 700 pCi/ml to 310 pCi/ml in that distance. Ground water in transit storage contained about 0.9 Ci of tritium prior to the release of the 20 Ci. About 3.9 Ci of tritium remained in transit storage at the end of 1970. The remaining 17.0 Ci were lost with evapotranspiration, infiltration with ground water into the underlying tuff or suspended with soil moisture above the aquifer.

I. INTRODUCTION

Liquid wastes from the operation of the Los Alamos Scientific Laboratory (LASL) at Los Alamos, New Mexico are collected and processed at the Industrial Waste Treatment Plant at TA-50 (Technical Area 50). After treatment the liquids are discharged to Mortandad Canyon. The stream in the upper reach of the canyon is perennial due to the discharge of waste water from TA-50 and other nearby technical areas. Occasional storm runoff adds to the surface flow in the canyon.

The perennial surface flow and storm runoff recharge a shallow aquifer in the alluvium that is perched on the underlying tuff (Fig. 1). As the ground water in storage in the aquifer moves downgradient, steady losses to evapotranspiration and infiltration into the underlying tuff occur, so that the aquifer is of limited extent

and forms a shallow ground water body within the project area or LASL boundary. The water in the shallow aquifer is not a part of the recharge to the main aquifer which furnishes industrial and municipal water supplies. The ground water body is in movement; therefore, the water is in transit storage.

Liquid wastes treated and discharged into Mortandad Canyon generally contain only traces of tritium. About 20 Ci of tritium were discharged with 259 m<sup>3</sup> of water as the result of decontamination of equipment in November 1969. Tritium in liquids can not be removed like particulates in regular waste treatment processes.

The movement of tritium in the canyon was monitored by collecting and analyzing water samples for tritium from one surface water station and six observation holes on

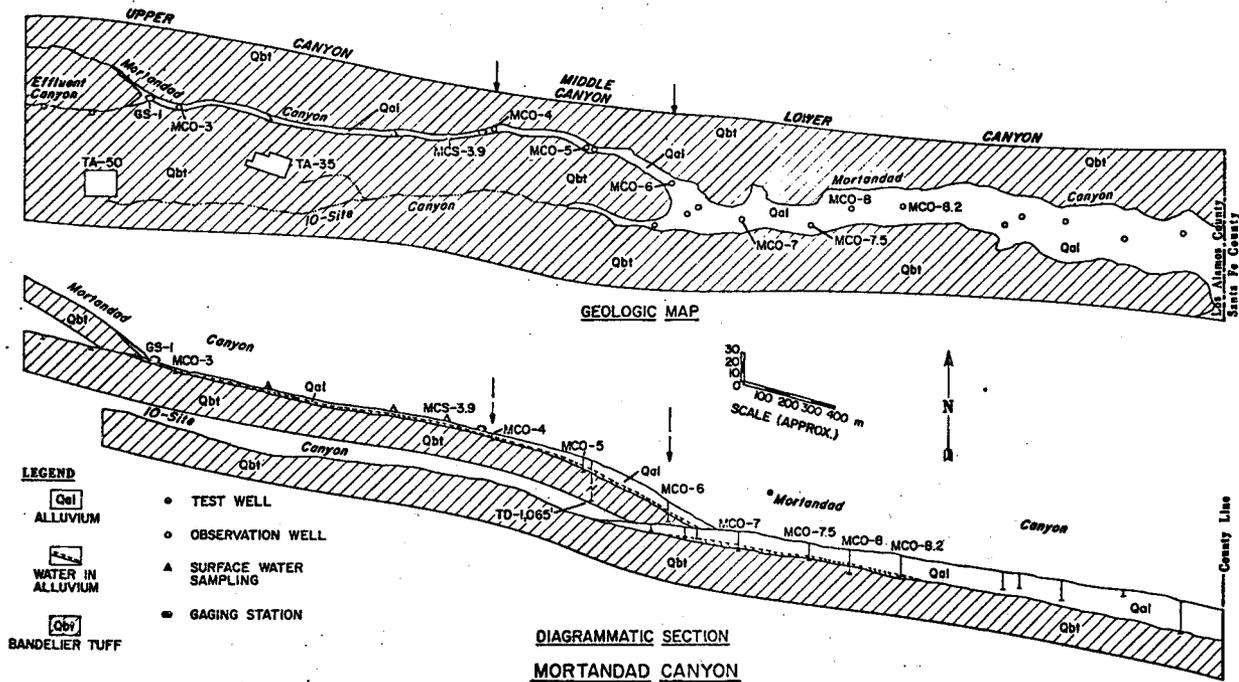


Fig. 1. Planview and geologic section showing geology and hydrology of Mortandad Canyon.

a weekly schedule from February through September 1970, and on a two or three week schedule from October through December. The purpose of the study was to determine movement and dispersion, as well as to make an inventory of tritium losses from the treatment plant outfall to the eastern extent of the aquifer. The study was conducted during the period required for the peak tritium concentrations to reach the down gradient edge of the shallow aquifer in the canyon.

The tritium in 1969 and 1970, and the chloride ion in 1972, were used as tracers to determine the hydrologic characteristics of the alluvium. These hydrologic characteristics are presented as an appendix to this report.

To facilitate the study of tritium in the aquifer the canyon has been divided

into three parts: The Upper Canyon, the Middle Canyon, and Lower Canyon (Fig. 1).

The Upper Canyon is narrow and filled with underbrush, shrubs, pine, fir, box elder, and oak trees. The alluvium thickens from less than 3 m at the effluent outfall to about 6 m at MCO-4. The stream in this section of the canyon originates at the plant outfall. There is some return to surface flow at sampling station MCS-3.9 (Fig. 1). The major recharge to the aquifer occurs in the Upper Canyon.

The Middle Canyon widens and the alluvium thickens from 6 m at MCO-4 to about 12 m at MCO-6. The stream channel is well defined but surface flow is intermittent. The underbrush thins out and the canyon floor is covered by a growth of pines.

The Lower Canyon becomes progressively wider and the alluvium continues to thicken

to about 24 m at MCO-8. The stream channel is discontinuous, braiding out on the canyon floor. The number of pines decreases eastward from the Middle Canyon.

During the period of study, January through December 1970, surface flow recharged the aquifer in the Upper Canyon and moved as ground water into the Middle and Lower Canyon. There was little, if any, surface runoff into the Lower Canyon during the study.

## II. MOVEMENT AND DISPERSION OF TRITIUM

There was no measurable tritium in transit storage in the Upper and Middle Canyon prior to November 1969. The Lower Canyon contained about 0.9 Ci in storage from materials discharged prior to 1967.<sup>1</sup> Effluents released in November 1969 contained about 20 Ci of tritium in 259 m<sup>3</sup> of waste liquids. The concentrations of the tritium in the effluent was about 77 700 pCi/ml. As the effluents moved down the Upper Canyon as surface flow, a part infiltrated into the stream channel and recharged the aquifer while a part was frozen into ice sheets along the lower section of

the canyon. Thus, as of January 1970, there were about 20.9 Ci of tritium in the canyon.

Peak concentration of tritium had passed surface water station MCS-3.9 and Observation Hole MCO-4 52 days after release. The tritium concentrations were declining as the maximum concentrations moved down the canyon except for the analyses from MCO-6 (Table I). The apparent increase at MCO-6 is due to stratification of water in the aquifer. The casing in MCO-5 is only slotted in the bottom section of the hole. In the remaining observation holes, the casing is slotted through the entire thickness of the aquifer. Water samples collected from MCO-5 were from the lower part of the aquifer. In the remaining observation holes the samples were a composite of water in the vertical section of the aquifer. From MCO-6 to MCO-7.5 the concentrations decreased from 1 520 pCi/ml to 870 pCi/ml. Travel time took 143 days. Travel time was about 109 days for the 183 m distance between MCO-7.5 and MCO-8. The peak concentrations declined from 870 pCi/ml to 310 pCi/ml.

TABLE I

### EFFLUENT OUTFALL TO OBSERVATION HOLE MCO-8

<u>Station</u>	<u>Peak Concentrations (pCi/ml)</u>	<u>Transit Time (days)</u>	<u>Distance from Outfall (meters)</u>
MCS-3.9	2 290 <sup>a</sup>	52 <sup>a</sup>	1231
MCO-4	2 180 <sup>a</sup>	52 <sup>a</sup>	1460
MCO-5	1 410	116	1841
MCO-6	1 520	136	2234
MCO-7	915	213	2554
MCO-7.5	870	279	2844
MCO-8	310	388	3027

<sup>a</sup> Peak passed, concentrations on the decline.

Tritium concentrations in the Upper and Middle Canyon (effluent outfall to MCO-6) decreased at a rate of about 560 pCi/ml per day or 34 pCi/ml per m. The decrease in concentration was largely due to dilution by normal operational subsequent release of treated liquid effluents and storm runoff. The decrease in concentration was also due to the high evapotranspiration rate as the aquifer is near land surface and the abundant growth of underbrush and trees in the canyon. Dispersion and dilution in the aquifer was minor due to the small volume of water in transit storage and the rapid transit rate in the aquifer.

Tritium concentrations showed a rate of dilution in the Lower Canyon (MCO-6 to MCO-8) of about 4.8 pCi/ml per day, or 1.5 pCi/ml per m. Dilution and dispersion of the tritium in the aquifer caused the major decrease in concentration because of the slower transit rate in the aquifer and the larger volume of transit storage. Evapotranspiration played a secondary role since the depth to water is greater and growth of underbrush and trees is considerably less than in the Upper and Middle Canyon. Some tritium was lost in all three sections of the canyon with water that infiltrated the tuff.

The distribution of the tritium in the aquifer was estimated by calculating the amount of tritium and ground water inflow at the cross section of the aquifer at MCO-6 (between the Middle and Lower Canyons, Fig. 1). The aquifer in the Lower Canyon during 1970 was recharged by ground water inflow. The average monthly inflow of ground water into the Lower Canyon at the cross section of the aquifer was calculated by using the formula:

$$Q = A V p$$

where

Q = Inflow of ground water in  $m^3/day$ .

A = The saturated cross-section area of the aquifer.

V = Transit rate of water at 20 m/day.

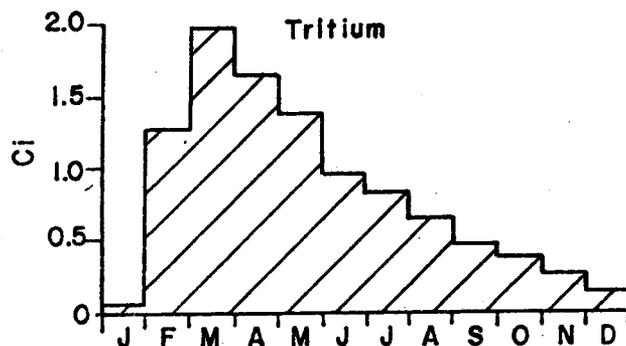
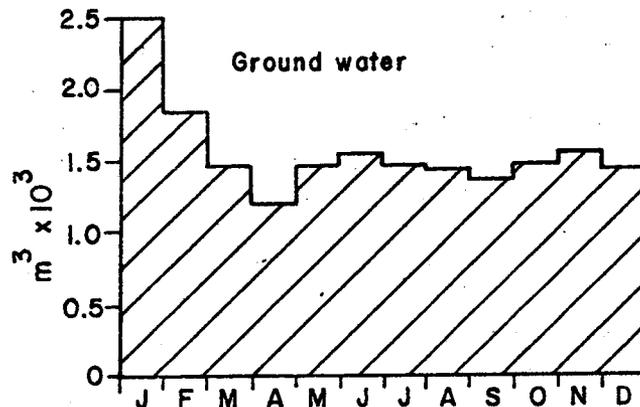


Fig. 2. Ground water inflow and amount of tritium entering the Lower Canyon at MCO-6.

p = Porosity of the aquifer at 25 per cent.

The ground water inflow decreased January through April (Fig. 2). The inflow increased in May when storage in the Upper and Middle Canyon received recharge from melting of ice sheet and snow. The inflow May through December varied slightly, dependent on the amount of water in transit storage in the Middle Canyon. The inflow was less than the amount lost from storage in the Lower Canyon.

The amount of tritium moving through the cross section of the aquifer at MCO-6 was estimated by integrating the average monthly tritium concentration with the monthly volume of ground water inflow (Fig. 2). About 0.08 Ci moved through the aquifer during the last 11 days of January. The

amount of tritium increased in February and reached a maximum in March when about 1.98 Ci of tritium moved through the aquifer in about 1 480 m<sup>3</sup> of ground water. The amount of tritium declined from March through December. It is estimated that from January through December about 10 of the 20 Ci of tritium released had moved into the Lower Canyon with 10 Ci remaining in the Upper and Middle Canyon.

### III. TRITIUM INVENTORY

The tritium inventory was based on 20.9 Ci of tritium in the canyon (10 Ci in the Upper and Middle Canyon; 10.9 Ci in the Lower Canyon) and the amount of tritium remaining in transit storage in the aquifer as of December 31, 1970. In order to calculate the inventory it was necessary to combine the storage in the Upper and Middle Canyon as the amount of surface water entering the canyon was unknown. Transit storage in the aquifer was calculated at the end of each month (Fig. 3).

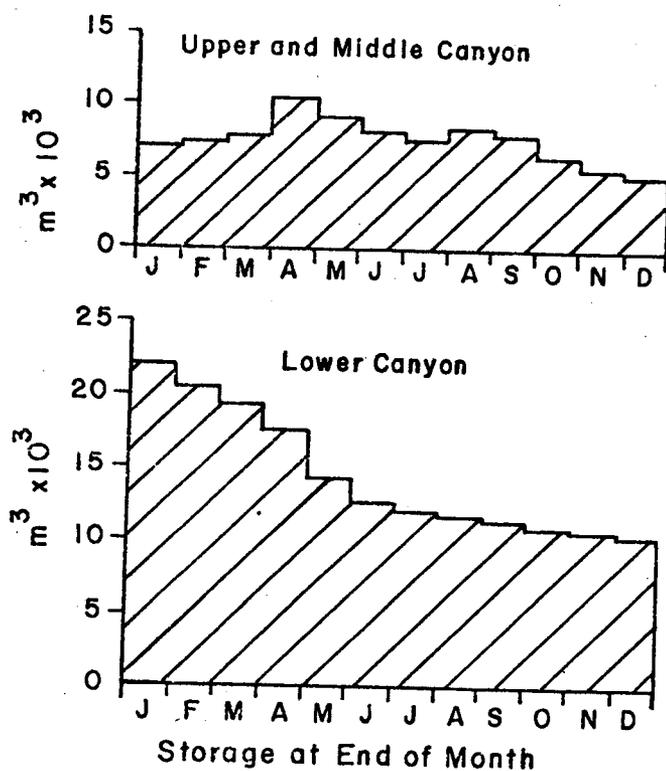


Fig. 3. Ground water in transit storage (storage at end of month).

### A. Upper and Middle Canyon

Transit storage in the aquifer of the Upper and Middle Canyon increased slightly from January through March as most of the recharge from surface runoff was frozen into ice sheets in the channel and snows had not begun to melt (Fig. 3). Storage reached a maximum in April as the ice sheet and snows melted. Storage declined through July and increased in August due to summer rains. Storage then declined until the end of the year.

The amount of tritium in the aquifer in January was estimated to be about 9.5 Ci (Fig. 4). At this time very little of the tritium had moved into the Lower Canyon. The remaining tritium (10.5 Ci) was tied up in the ice sheet in the Upper Canyon, was lost with evaporation, was held with soil moisture above the aquifer, or had moved with ground water into the underlying tuff. There appeared to be a continued movement of tritium from the ice sheet and periodic

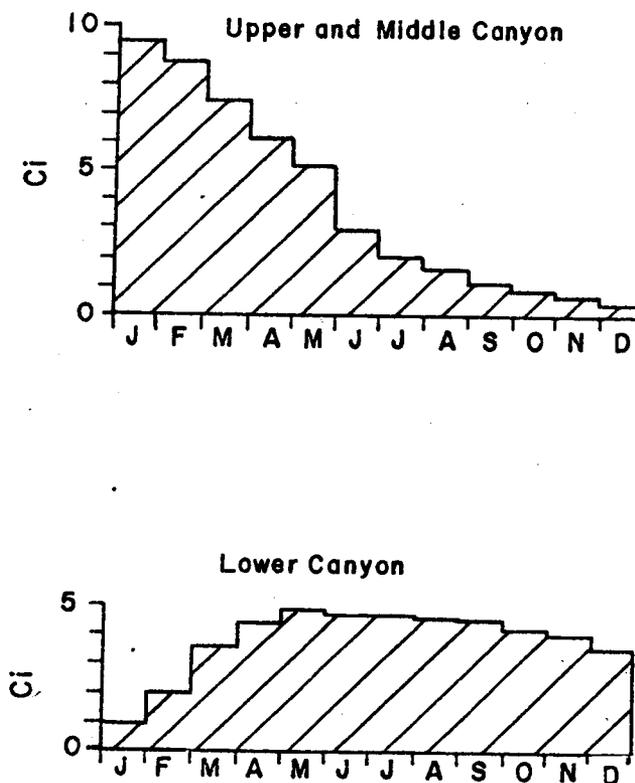


Fig. 4. Amount of tritium in transit storage (calculated at end of month).

flushing of the tritium from the soil moisture into the aquifer during the year as 10 Ci moved into the Lower Canyon by December 31, 1970.

The amount of tritium in storage in the canyon declined from 9.5 Ci in January to 0.4 Ci in late December. The remaining 9.6 Ci of the 10 Ci in the canyon may have been released in part to the atmosphere with evapotranspiration during the year.

The evapotranspiration in the Upper Canyon has been estimated to range from 7560 to 18 900 m<sup>3</sup> annually.<sup>2</sup> The transpiration of water from fir and box elder trees has been measured to contain, in general, the same concentration of tritium that was found in near-surface ground water in the Upper Canyon. Using an average concentration of the near-surface ground water for the year of 400 pCi/ml (average of 42 analyses from return flow MCS-3.9) and the average annual evapotranspiration of 13 200 m<sup>3</sup> the amount of tritium released to the atmosphere is estimated to be about 5.3 Ci.

The remaining 4.3 Ci of tritium is either suspended with soil moisture in the capillary zone above the aquifer or has moved with ground water into the tuff. Tritium in the capillary zone will be transpired through the vegetation, lost with evaporation, or flushed back into transit storage during periods of excessive runoff. Tritium infiltrating with ground water into the tuff will move through the capillary size pores from areas of high moisture content to areas of lower moisture. Movement into the tuff is as unsaturated flow.

#### B. Lower Canyon

Transit storage in the aquifer of the Lower Canyon was above normal during the latter part of 1969 due to a large release of waste water into the canyon during the summer (Fig. 3). The storage declined from January through December. During this period the loss from storage was greater than the inflow of ground water through the cross section of the aquifer at MCO-6.

The Lower Canyon had about 0.9 Ci of tritium in storage as of January 1970 (Fig. 4). During 1970 about 10 Ci of tritium entered the aquifer through the section at MCO-6. The amount of tritium increased from the original 0.9 Ci in January to about 4.8 Ci in May and then declined to about 3.5 Ci in December (Fig. 4).

The monthly loss of water from transit storage in the Lower Canyon was calculated from the monthly inflow of ground water through the aquifer at MCO-6 and the change in storage during the month (Fig. 5). In general the loss from storage decreased from January through December with the exception of the months April through June. The increased losses which occurred in April through June reflect increased uptake of water from the aquifer by the pine trees on the canyon floor when they come out of winter dormancy.

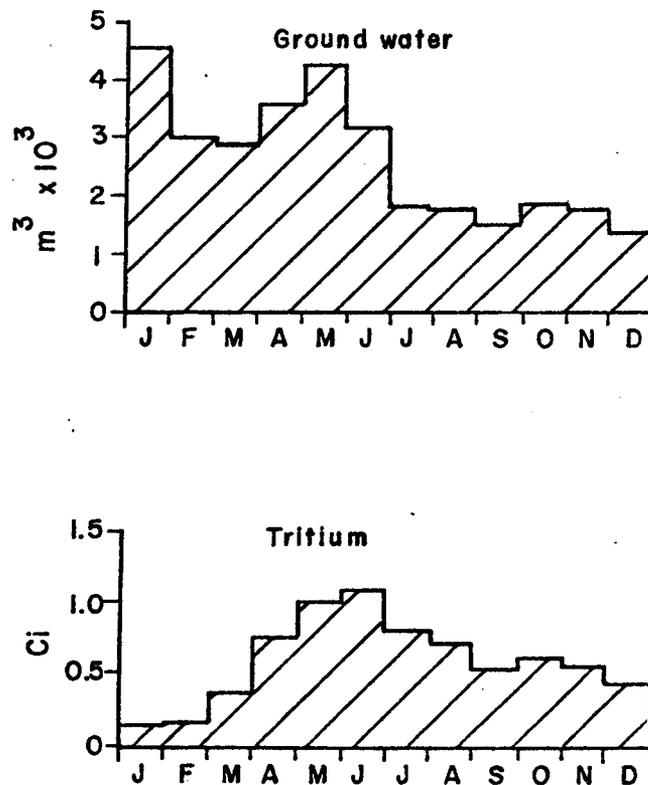


Fig. 5. Monthly loss of ground water and tritium from transit storage in the Lower Canyon, 1970.

The monthly tritium losses from storage in the Lower Canyon were estimated from the monthly loss from storage and the weighted average of tritium concentrations in the aquifer. The tritium loss from storage in January and February was due to the tritium released into the canyon prior to 1967 (Fig. 5). The tritium losses from the release of November 1969 began in March, reached a maximum in June, and declined through December.

The total tritium loss from transit storage from January through December was about 7.4 Ci of the 0.9 Ci in the canyon as of January 1, 1970 and the 10 Ci which entered the canyon during the year. Thus, it is estimated that about 3.5 Ci remained in storage as of December 31, 1970.

The tritium losses of 7.4 Ci can be attributed to evaporation, transpiration through the deeper rooted shrubs and trees, suspension in the capillary zone above the aquifer and by movement with ground water into the tuff underlying the aquifer. Loss to evaporation was probably very small because the depth to water ranges from 10.6 m at MCO-6 to 24 m at MCO-8. Loss to transpiration probably was somewhat greater as indicated by loss from storage due to uptake of water by the pines when they came out of winter dormancy. A larger part of the tritium probably was suspended with the soil moisture above the aquifer in the capillary zone, since during 1970 the water table was declining in the Lower Canyon. A portion of the tritium moved with ground water into the tuff.

#### IV. SUMMARY

About 20 Ci of tritium were discharged into Mortandad Canyon which borders the Los

Alamos Scientific Laboratory. The peak concentration took 388 days to move 3 027 m downgradient from the outfall. The tritium concentration decreased from 77 700 pCi/ml to 310 pCi/ml in that distance. During the period of study, January through December 1970, about 10 Ci of the 20 Ci moved from the Upper and Middle Canyons into the Lower Canyon.

Of the 10 Ci remaining in the Upper and Middle Canyon, an estimated 5.3 Ci were lost to evapotranspiration with an additional 4.3 Ci lost with infiltration of ground water into the tuff or suspended with soil moisture zone above the aquifer. As of December 31, 1970, only about 0.4 Ci remained in transit storage in the Upper and Middle Canyon.

The Lower Canyon contained 0.9 Ci of tritium when the study began. An additional 10 Ci of tritium moved into the canyon with ground water during 1970. As of December 31, 1970, only 3.5 Ci of tritium remained in transit storage in the aquifer. The tritium loss with evapotranspiration, with infiltration of ground water into the tuff, and suspended above the aquifer with the soil moisture was about 7.4 Ci.

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## APPENDIX

### HYDROLOGIC CHARACTERISTICS OF THE ALLUVIUM IN MORTANDAD CANYON

#### I. INTRODUCTION

Tritium (1969) and the chloride ion (1971) were used as tracers to evaluate the hydrologic characteristics of the alluvium. The tracers were used to determine the velocity of the ground water movement in the alluvium. The average velocity of the tracers was used to determine the field coefficient of permeability of the alluvium.

The alluvium in Mortandad Canyon consists of two distinguishable units.<sup>1</sup> The upper unit is a coarse, slightly silty sand. It is about 6 m thick at MCO-4 and about 9 m thick at MCO-8. The coarse sand unit is underlain by a sand-silty clay that thickens about 15 m from MCO-5 to MCO-8. The upper sand unit is a product of mechanical erosion and deposition, while the lower silty clay unit is a product of weathering in place of the tuff. Water in the aquifer is in the sand unit west of MCO-5 and is transitional into the lower silty clay unit at MCO-6. East of MCO-6 the aquifer is within the lower silty clay unit.

The reach of the canyon from the effluent outfall to observation hole MCO-5 is the major surface water recharge area to the aquifer. All of the effluents from the waste treatment plant and waste water from the cooling process infiltrate the alluvium in this reach of the canyon. Determination of hydrologic characteristics of the alluvium was made in the reach of the canyon east of MCO-5 due to the difficulty in interpreting ground water movement in the recharge area.

#### II. TRITIUM AND CHLORIDE TRACER STUDIES

The use of tritium as a tracer in water is ideal since it is incorporated as part of the hydrogen molecule in water. It does not modify the flow properties of the

water. It moves through the aquifer relatively unaffected by base exchange or adsorption with the alluvial materials of the aquifer. The chloride ion, widely used as a tracer in ground water, has also been found very satisfactory in low concentration.<sup>2</sup> The movement of the tracers in the aquifer was determined in four reaches of the canyon, MCO-5 to MCO-6, MCO-6 to MCO-7, MCO-7 to MCO-7.5, and MCO-7.5 to MCO-8 (Fig. 1).

##### A. Velocity of Tritium

About 259 m<sup>3</sup> of effluent with an average tritium concentration of 77 700 pCi/ml were discharged into the canyon on November 21, 1969. The travel time of the peak concentration of the tritium from the effluent outfall to MCO-5 as surface water and ground water was about 116 days.

The transit time for the peak concentration of tritium to travel as ground water in the sandy unit from MCO-5 to MCO-6 was about 20 days with a velocity of about 20 m/day (Table A-I). The velocity in the silty clay unit was 4.2 m/day between MCO-6 and MCO-7, 4.4 m/day between MCO-7 and MCO-7.5 and 1.7 m/day between MCO-7.5 and MCO-8.

##### B. Velocity of Chloride Ion

About 2 440 m<sup>3</sup> of effluents with an average chloride ion concentration of 640 mg/liter were released into the canyon during the period of June 7 to June 23. Subsequent releases varied in chloride concentrations with ranges from 35 mg/liter to 535 mg/liter. The travel time for the peak concentration of chloride ion from the effluent outfall to MCO-5 as surface water and as ground water was about 215 days.

The transit time for the peak concentration of the chloride ion to travel as ground water in the sand unit from MCO-5 to

TABLE A-I

## TRANSIT TIME AND VELOCITIES OF TRACERS

Section	Distance (meters)	Tritium		Chloride	
		Transit Time (days)	Velocity (meters per day)	Transit Time (days)	Velocity (meters per day)
MCO-5 to MCO-6	393	20	20	25	16
MCO-6 to MCO-7	320	77	4.2	63	5.1
MCO-7 to MCO-7.5	290	66	4.4	52	5.6
MCO-7.5 to MCO-8	183	109	1.7	79	2.3

MCO-6 was about 25 days with a velocity of about 16 m/day (Table A-I). The velocity in the silty clay unit was 5.1 m/day between MCO-6 and MCO-7, 5.6 m/day between MCO-7 and MCO-7.5, and 2.3 m/day between MCO-7.5 and MCO-8.

### III. FIELD COEFFICIENT OF PERMEABILITY

A comparison of the velocity of the tracers in each section of the canyon showed variations due to the changing hydrologic conditions in the aquifer (Table A-I). East of MCO-6, the velocity of the chloride ion was greater than the velocity of the tritium as the amount of recharge in the Lower Canyon was greater when the chloride ion was released than when tritium was released.

The average velocity of the tracers in the coarse sand unit between MCO-5 and MCO-6 was about 18 m/day. The average velocities of the tracers decreased to about 5 m/day between MCO-6 and MCO-7.5 when the tracers moved into the less permeable section of the silty clay unit. A decrease in the permeability of silty clay unit between MCO-7.5 and MCO-8 caused the average velocity to decrease to about 2 m/day between these two stations.

The average velocities of the tracers in the sand unit and in the two sections of the silty clay unit were used to determine

the field coefficient of permeability. The field coefficient of permeability is defined as the rate of flow of water, in  $m^3$ , per day, through a cross-sectional area of one  $m^2$  under a unit hydrologic gradient at prevailing water temperature in the aquifer. The field coefficient of permeability determined by the velocity of the tracers is determined by the following equation modified from Wenzel.<sup>3</sup>

$$P = \frac{p V}{I} \quad (1)$$

where:

P = Field coefficient of permeability in m/day.

p = Porosity of the aquifer in percent.

V = Average velocity of the tracers in m/day.

I = Hydrologic gradient of the aquifer in m/m.

The average velocity of the tracers was used to determine the field coefficient of permeability of the sand unit between MCO-5 and MCO-6 by using the equation (1). Porosity at MCO-5 and MCO-6 in the sand unit was estimated at 25 per cent ( $p = 0.25$ ) with an average ground water movement (tritium and chloride) of 18 m/day ( $V = 18$ ). The hydrologic gradient of the aquifer between MCO-5 and MCO-6 was 32 m/km

(I = 0.032).

Thus

$$P = \frac{(0.25)(18)}{.032}$$

or P, the field coefficient of permeability is 141 m/day in the sand unit between MCO-5 and MCO-6.

Two areas of different permeability in the silty clay unit were indicated by change in velocity of the tracers. The average velocity between MCO-6 and MCO-7.5 was about 5 m/day. This decreased to about 2 m/day between MCO-7.5 and MCO-8.

The estimated porosity of the aquifer in the silty clay unit between MCO-6 and MCO-8 was about 25 percent. Though there is an increase in the smaller particle size of the aquifer material which would increase the porosity, the effective porosity (porosity available to transmit water) would remain about the same or decrease slightly. The effect of the finer material in the lower unit would decrease the permeability as the coarser grained materials have a larger permeability.

The field coefficient of permeability of the silty clay unit between MCO-6 and MCO-7.5 was determined using a porosity of

25 percent (p = 0.25); an average velocity of the tracers of 5 m/day (V = 5); and a gradient of 25 m/km (I = 0.025). Thus using equation (1) the field coefficient of permeability of the silty clay unit between MCO-6 and MCO-7.5 is 50 m/day.

The coefficient of permeability of the silty clay unit between MCO-7.5 and MCO-8 was determined using a porosity of 25 percent (p = 0.25); an average velocity of the tracers of 2 m/day (V = 2); and a gradient of the aquifer of 66 m/km (I = 0.066). Thus, the field coefficient of permeability of the silty clay unit between MCO-7.5 and MCO-8 is 7.6 m/day.

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