Flow and Transport at the Las Cruces Trench Site: Experiment IIb

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ABSTRACT

Three water flow and solute transport experiments were performed as part of a comprehensive field trench study near Las Cruces, New Mexico to test deterministic and stochastic models of vadose zone flow and transport. This report presents partial results from the third experiment (experiment IIb). Experiments IIa and b were conducted on the North side of the trench, on a plot 1.22 m wide by 12 m long, perpendicular to the trench. The area was drip irrigated during two time periods with water containing a variety of tracers. The advance of the water front during the two irrigation episodes was measured with tensiometers and neutron probes. Solute front positions were determined from soil solution sampling through suction samplers and from disturbed sampling.

The results from experiment IIb show predominately downward water movement through the layered unsaturated soil, as evidenced from neutron probe data and gravimetric sampling. Tritium plumes were only half as deep and half as wide as the water plumes at 310 days after the beginning of experiment IIb. Chromium, applied as Cr (VI), moved as readily as, and similar to tritium, but there was a loss of mass due to reduction of Cr (VI) to Cr (III). Chloride and nitrate, initially present at high concentrations in the soil solution, were displaced by the low concentration irrigation water, resulting in chloride and nitrate concentration distributions that looked like negative images of the tritium distributions. The extensive data presented should serve well as a data base for model testing.

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1900

January 1st - New Year's Day. A fine day with a light breeze from the north. The temperature was in the 40's. The snow was deep and the ground was frozen. The children went to school as usual. The day was spent in the usual routine of the household. The weather was pleasant for the time of year. The children were happy and the day was a good one. The snow was deep and the ground was frozen. The children went to school as usual. The day was spent in the usual routine of the household. The weather was pleasant for the time of year. The children were happy and the day was a good one.

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) has been directed by Congress in the Low Level Waste Policy Act of 1980 to develop regulatory guidance and assist the individual states and compacts in siting and assessing future low level radioactive waste (LLW) disposal facilities. Technical siting and performance requirements have been issued by NRC in 10 CFR Part 61 for use in LLW sites. These technical criteria encourage LLW disposal in the unsaturated zone (above the regional water table) and also require that the site be capable of being modeled. Conceptual models that describe two- and three-dimensional flow and solute transport in spatially variable hydrogeologic systems have been developed. However, the number of well controlled field studies to test and validate these models is limited. Therefore, NRC funded a validation study to develop an accepted laboratory and field data base suited to test deterministic and stochastic flow and transport models. The experimental plan for this study was developed by investigators at The University of Arizona, New Mexico State University, Pacific Northwest Laboratory, and Massachusetts Institute of Technology in cooperation with NRC.

The experiments were performed on a site located in southern New Mexico, 24 miles northeast of Las Cruces. Three experiments were performed on the sides of a 26.4 m long by 4.8 m wide by 6.0 m deep trench. This trench was constructed to determine the variability in subsurface hydraulic properties, and to gain access to the soil below the plots for

installation of tensiometers and solution samplers. A total of three experiments were conducted at the Las Cruces Trench Site. The results of experiment I and most of the results of experiment IIa were presented in Wierenga et al., 1990. The present report contains some results from experiment IIa and all results from experiment IIb. For experiments IIa and IIb a 1.22 m by 12 m strip, perpendicular to the trench wall, was uniformly irrigated using a carefully controlled drip irrigation system. During and after the first irrigation, the movement of water and the transport of tritium, bromide, chloride, and nitrate were measured by neutron probe, tensiometers, solution samplers, and core sampling. The results were presented in an earlier report. The analyses of the core samples taken after experiment IIa are presented in this report.

Following experiment IIa, the same strip was irrigated a second time with water containing tritium, boron, chromium, bromide, and two fluorobenzoic acids (experiment IIb). The results of this latter experiment constitute the main part of this report. They show (especially the water flow data obtained with the neutron probe, and the tritium data from core sampling) fairly regular downward and lateral flow of water and solute. Even though the soil was heterogeneous, there was no preferential flow observed at this arid soil site.

The water flow and tritium data presented here has been used to test a variety of models (Hills and Wierenga, 1993).

FOREWORD

This technical report was prepared by The University of Arizona under a contract with the Waste Management Branch of the Office of Nuclear Regulatory Research (FIN L1286). This report presents experimental methods, procedures, and data from the third Las Cruces Trench experiment.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not

necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government.

NUREG/CR is not a substitute for NRC regulations, and compliance is not required. The approaches and/or methods described in the NUREG/CR are provided for information only. Publication of this report does not necessarily constitute NRC approval or agreement with the information contained herein.

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1 Introduction

The Low Level Policy Waste Act of 1980 was enacted by the United States Congress to guide the regulation and development of low level waste disposal sites. As a result, the U.S. Nuclear Regulatory Agency has required that such sites "shall be capable of being characterized, modeled, analyzed, and monitored" (10 CFR, Part 61, Subpart D). These requirements have created a demand for flexible computer models that are useful for predicting water and solute movement through undisturbed and spatially variable soils and geologic features. Many models have emerged with claims to satisfy these needs. But due to the difficulty of conducting well-controlled field-scale experiments, few data sets exist to provide spatially descriptive soil characterization data and observations of water and solute movement in the field; thus, many of these models are inadequately validated.

The Las Cruces Trench Site experiments were begun to provide a solid set of data for model validation. A 6 m deep trench was excavated in 1986 to provide experimental access to large horizontal and vertical soil faces. As the excavation work progressed, the site was extensively sampled and characterized. A roofed structure was constructed within the trench with several levels of access to exposed soil faces. In 1987 the first water flow and transport experiment was performed in an area adjacent to the south side of the trench (Plot 1).

Afterwards, in early 1989 a single deep soil core was extracted near the center of the plot to describe the redistribution of applied water and solutes. The methodologies of the first irrigation experiment were improved upon, and in 1988 a second experiment was performed on an area adjacent to the north side of the trench (Plot 2).

In the spring of 1990 a series of 3 m deep soil cores was taken from transects in Plot 2 to describe the redistribution of water and solutes applied during the second irrigation (experiment IIa). About that time two additional deep cores were taken from Plot 1. In late summer of 1990 a third water flow and transport experiment (IIb) was started in plot 2. Finally, in 1991 a second series of soil cores, to 6.3 meter depth, was collected from Plot 2 to describe solute and water redistribution following the two irrigation experiments there. A timeline illustrates the chronological relationships between these various experiments and projects at the trench (Figure 1).

In the late 1980's the project became part of INTRAVAL, an international consortium to test and validate geosphere models. INTRAVAL participants agreed to model the third leaching experiment based on information obtained during previous experiments and trench site characterization work. Participating modelers were given initial and boundary conditions and the events of water and solute application during the third irrigation experiment. Experimental results were withheld from the modelers until model predictions were completed, thus creating a "blind validation" of a variety of stochastic and deterministic models.

The Las Cruces Trench experiments were designed by scientists at The University of Arizona and New Mexico State University in cooperation with Glendon Gee of Battelle Pacific Northwest Laboratories and Lynn Gelhar of the Massachusetts Institute of Technology. Participating modelers represent a variety of institutions, including Battelle Pacific Northwest Laboratories, New Mexico State University, Massachusetts Institute of

Technology, The University of Texas, and the Center for Nuclear Waste Regulatory Analyses.

This report describes several experiments performed at the trench site since the second irrigation experiment. The purpose of the report is to present a comprehensive summary of the data collected since the end of experiment IIa, and since the first deep core collected from Plot 1. Experiments previous to those discussed here are detailed in Wierenga et al (1988, 1989, 1990 and 1991). Comparisons of observed data with model predictions are provided in Hills and Wierenga (1993) and will be published elsewhere.

Figure 1. Timeline for Las Cruces Trench Site experiments. Shaded area denotes experiments described in this report.

2 Review of Previous Work

2.1 Site Description and Characterization

The Las Cruces Trench Site is located on the New Mexico State University College Ranch about 40 km northeast of Las Cruces, New Mexico. It is at an elevation of about 1357 m on the eastern Piedmont slope of Summerford Mountain, the northern most peak of the Dona Ana Mountains (Figure 2). The climate in the area is characterized as arid, with the boundary between the arid (less than 25 cm rain per year) and semiarid considered to be at an elevation of 1524 m. Average annual precipitation at the site is 23 cm with an average Class A pan evaporation of 239 cm per year (Wierenga et al., 1987). Soils at the site consist of well-drained coarse loamy Typic Haplargids which overlie a sequence of well-defined geomorphic surfaces exposed in the top 6 m (Gile and Grossman, 1979). Additional discussion of the geomorphology and soils at the site is presented in Appendix C-8.

In the spring and summer of 1986 a 26.4 m long, 4.8 m wide and 6.0 m deep covered trench was excavated in undisturbed soil to provide experimental access to large vertical soil flanks, to collect soil samples and undisturbed cores for laboratory characterization and to allow in-situ measurement of soil hydraulic properties. During excavation nine major soil horizons were identified in the vertical profile. Centered within each of these horizons a 25 meter horizontal transect was established along the north side of the trench with 50 sampling stations located on 50 cm intervals. Each successive transect with depth (and each sampling station) was located directly below the transect above. Beginning with the first transect at the soil surface three stations were selected which roughly divided the length of the trench

into thirds. These stations were sampled continuously in 13 cm increments from the surface to 6 m depth. With this sampling scheme a total of 594 undisturbed cores and 594 soil samples were collected to gather statistical information about soil morphology and hydraulic properties at the site. These data are discussed in detail by Wierenga et al. (1988, 1989, 1990).

Figure 2. Location of Las Cruces Trench Site within the state of New Mexico and within the county of Dona Ana.

2.2 Coordinate Systems

Three coordinate systems are used to describe the locations of the neutron probe tubes, tensiometers, solutions samplers, and irrigated areas relative to the northwest corner of the trench (Figure 3), a method first described by Wierenga et al., 1990. In each system the X axes are parallel to the north wall of the trench, which run roughly east-west; the Y axes are perpendicular to X; and the Z axis describes depth from the soil surface, always positive with depth. Each X and Y axis is located with respect to the undisturbed wall of the trench rather than any structure emplaced after excavation. The origin of the first coordinate system (X, Y, Z) is located at the northwest corner of the trench. This system is used to describe the site characterization data and to unify the other two coordinate systems

to a common point. The X axis is parallel to the north wall and positive to the east. The Y axis is horizontal and positive to the north. The Z coordinate describes depth from the soil surface. The second coordinate system (X_1, Y_1, Z_1), used to describe plot 1, originates on the south wall of the trench at the center of the plot 1 irrigated area. The X_1 axis is parallel to the south wall of the trench and is positive to the west. The Y_1 axis is perpendicular to the X_1 axis and positive to the south. The Z_1 axis is depth from an imaginary plane that is level relative to the natural slope of the terrain, a 2.5% west slope. Z_1 is at 0 meters where $X_1 = 2.0$ m. Due to the 2.5% slope, the distance to the surface from $Z_1 = 0$ is given by:

$$\text{Distance (meters)} = (0.025 \times X_1) - 0.05$$

The third coordinate system (X_2, Y_2, Z_2), used to describe plot 2, originates on the north wall of

Figure 3. Overhead view of trench, experimental irrigation plots and origination points for (X,Y), (X_1, Y_1), and (X_2, Y_2) coordinate systems.

the trench at the center of the plot 2 irrigated area. The positive direction of its axes is similar to the X, Y, Z coordinates. Note that the X_2 and X_1 axes are not parallel because the north and south walls of the trench are not exactly parallel. The coordinates for the corners of the trench and experimental plots, neutron access tubes, tensiometers and solution samplers are given in Appendix C-10.

2.3 Experiment I

In the summer of 1987 the first irrigation experiment was performed on an area adjoining the south side of the trench (Plot 1). A covered 4 m wide by 9 m long area was irrigated by a water application system composed of a closely spaced grid of drip emitters and precision controlled water application pumps. Water was applied four times a day with an average surface flux of 1.82 cm d^{-1} for 86 days; the first 10 days with tritium-containing well water and the final 76 days with non-traced water. Water flow was monitored by neutron probe and by tensiometers. Ceramic cup solution samplers were embedded 50 cm deep into the face of the trench to draw samples for tritium analysis. Further descriptions of this experiment are found in Wierenga et al. (1990).

During the first experiment the soil walls of the trench were exposed to allow visual tracking of the wetting front. Eventually a portion of the south wall was weakened by the applied water and collapsed into the trench, abruptly ending any further data gathering from tensiometers and solution samplers. The fallen debris was cleared from the floor of the trench and an engineered shoring structure was constructed to prevent further cave-ins. This structure featured heavy wooden lagging, a packed soil backfill and a plastic vapor barrier between the backfill and the undisturbed soil wall.

2.4 Experiment I Redistribution Cores

On April 6, 1989, 594 days after the last irrigation of plot 1, a 14.74 m deep borehole was advanced near the center of the 4 m by 9 m irrigated area. A 5.08 cm diameter split-spoon sampler was used to collect continuous soil cores in 61 cm intervals. Core sub-samples were analyzed for water content, tritium, chloride ion, electrical conductivity and soil morphological features.

Another pair of cores was collected from plot 1 nearly a year later, on March 16, 1990, 938 days after the last irrigation. The locations of all three boreholes are:

Borehole	X_1 (m)	Y_1 (m)	Z_{total} (m)
I	-0.46	4.67	14.72
II	2.02	4.95	15.22
III	4.00	5.00	15.19

The purpose of boreholes II and III was to supplement the data collected from the center-of-plot borehole with data from the edge of the irrigated area and 2 meters outside of the area, while remaining near the center of the plot with respect to Y_1 . A 6" hollow-stem CME rotatory drill was used to collect continuous soil cores in 152 cm long sections. The core samples were analyzed for volumetric water content, tritium, chloride ion, and nitrate ion. The methods and results of this work are described more completely in Appendix C-1.

2.5 Experiment IIa

In early 1988 a second irrigation area, 12.0 m long and 1.2 m wide, was sited on the north side of the trench (Plot 2). A covered metal structure was fabricated to support a leveled irrigation system for uniform water application to the plot

area. The irrigation system design was similar to that used in experiment I, consisting of a closely spaced grid of drip emitters (Wade Manufacturing, Fresno, CA, p/n 62-2). For this experiment individual emitter lines were 1.2 m long with 4 emitters spaced on one-foot centers. Eighty of these emitter lines were connected in parallel on alternate sequence to one of two separate header pipes along the 12 m length of the plot (Figure 4).

Water supply to the headers was obtained through solenoid control valves which merged to a single buried supply line which in turn was supplied by a precision-metered pumping system located in a separate building.

Figure 4. Plot 2 irrigation system of emitters and header lines.

Pre-irrigation levels of soil nitrate and chloride near plot 2 were analyzed from a single vertical transect of samples collected at the trench face. The purpose of this work was to identify natural distributions of these ions before experimental disturbance. These data are presented in Appendix C-2.

The first plot 2 irrigation (experiment IIa) began on August 8, 1988. Well water was applied twice a day (once a day through each header line) resulting in an average surface flux of 0.43 cm d⁻¹ over the irrigated area. Two solute tracers were added to the irrigation water during the first 11.5 days (719.5 L) of irrigation: 71.95 mCi of tritium and 575 g of bromide as potassium bromide. After a total of 75.5 days (4721 L), irrigation was discontinued, beginning a redistribution phase of the experiment. Water and solute movements were monitored during redistribution until the beginning of the next experiment, IIb.

The advance of the wetting front was tracked by neutron probe and tensiometer measurements, and the solute front by solution sampler collections of in-situ soil solution. Prior to irrigation a total of 37 aluminum, 5.08 cm-diameter neutron probe access tubes were emplaced within and adjacent to the irrigated area, each one 6 m deep. Another 6 access tubes were added on April 10, 1989 (day 246 of experiment IIa) making a total of 43 access tubes for the experiment. Readings were taken from 0.25 m to 6.0 m depth in 0.25 m increments.

A regular grid of tensiometers and solution samplers was installed along the face of the trench below the irrigated area. These devices were installed at a 10° angle through the wooden and backfill materials used to support the trench wall. The Z- coordinates and lengths of the drilled holes were adjusted so that the ceramic cups would be placed at the targeted soil depths (Z_2), in a plane at $Y_2 = 0.5$ meters from the undisturbed trench wall.

Tensiometers were constructed with ceramic cups rated for 1-bar air entry values (Soil Moisture Equip. Corp., Santa Barbara, CA, p/n 652X04-B1M3) and 1/4" nominal clear schedule 40 PVC pipe (U. S. Plastics, Lima, OH). The construction of these devices is described in Appendix C-6. A few days before arrival of the wetting front tensiometers were filled with water and then sealed with septum stoppers for easy tension measurement with a hand-held pressure transducer (Figure 5).

A solution sampler was constructed and installed in the trench wall very much like a tensiometer. A vacuum-operated apparatus was inserted within the PVC pipe of the sampler to draw soil solution into the ceramic cup and

then transfer that solution to a sample vial (Figure 6).

The irrigated plot and surrounding area were covered with a UV resistant reinforced 36 mil chlorinated polyethylene pond liner (Watersaver Co. Inc., Denver, CO., PO. Box 16465, 602-966-6892, model CPER 036) to prevent evaporation from and rain water infiltration into the soil surface. This pondliner extended approximately $X_2 = \pm 6$ meters on the plot flanks and from the face of the trench to about $Y_2 = 18$ meters.

The methods and results of experiment IIa are detailed by Wierenga et al., 1990. That report discusses results obtained through May 24, 1990 (day 655), one day before the first collection of 3 m deep soil cores from the plot.

Figure 5. Installation and use of tensiometer through trench wall

Figure 6. Installation and use of solution sampler device through trench wall.

3 Experiment IIa Redistribution Cores

3.1 Core Collection and Processing

On May 30, 1990, 586 days after the last irrigation of experiment IIa, a series of soil cores was collected from within plot 2. Cores were taken during a two-day period from two transects bisecting the irrigated plot at $Y_2 = 5.0$ and 9.0 meters from the trench face. Boreholes were made on 0.5 m centers along each transect at $X_2 = -1.5, -1.0, -0.5, 0, 0.5, 1.0,$ and 1.5 m to a depth of 1.4 to 1.8 m. Forty-two days later a second set of core samples was collected from the same boreholes to extend sampling depth to 3.0 m (Figure 7). Altogether a total of 214 soil core samples from 14 boreholes were analyzed.

One inch diameter hollow-stem soil sampling tubes (6' and 10' long) and a 13 kg drop hammer (Soil Moisture Equipment Corp., Santa Barbara, CA) were used to collect the cores. Beginning at the soil surface the sampling tube was hammered 10 cm into the soil and then removed from the hole. This first soil core was retained for analysis. A second soil core representing the next 5 cm-depth of soil was discarded. A third 10 cm-long soil core, centered at 20 cm-depth, was retained. Thereafter, the sampling tube was hammered into the soil in 10 cm increments to the bottom of the borehole. The consequent soil cores were alternately disposed or retained in sequence. Each retained core was placed in a tared aluminum soil can which was then capped, weighed and sealed with two to three layers of Parafilm® wrap (American National Can, Greenwich, CT) to prevent evaporation. The samples were protected from direct sunlight while in the field and then taken to the laboratory for refrigerated storage.

Before processing, samples were brought to room temperature, unwrapped, and reweighed to determine any evaporative loss during storage. The sample was mixed and any non-

representative coarse fragments were weighed and discarded. Samples were then divided into two sub-samples, one to determine gravimetric water content and the other to make a soil solution extract for chemical analysis. The portion used to measure water content was oven-dried at 105° C for 24 hours before re-weighing.

The sub-sample used to make a solution extract was placed in a tared plastic beaker and weighed. An amount of deionized-distilled water equal to about one-fourth of the fresh soil mass was added to the container, weighed again with the container and then mixed with a spatula for about one minute. The rim of the beaker was sealed with a close fitting acrylic plate and allowed to stand for 20 minutes before extraction. The soil paste was stirred briefly once more during the standing period.

A Buchner funnel apparatus was used to extract the paste samples. Each ceramic funnel was fit with a 5.5 cm-diameter disk of Whatman's #42 ashless filter paper and placed in a rack which was connected to a common vacuum source, about 425 mbar strong. During filtration the rim of the Buchner funnel was covered to reduce evaporation. The effluent was collected in clean 13 dram polypropylene vials which were capped and then wrapped with Parafilm® for refrigerated storage.

3.2 Sample Analysis

The extracts were analyzed for tritium, chloride ion, and bromide ion. For tritium 0.5 ml aliquots of sample were mixed with 5.0 ml of Aquasol universal liquid scintillation cocktail (Dupont New England Nuclear, Boston, MA) in 8 ml "Mini Poly-Q" scintillation vials (Beckman Instruments, Inc., Fullerton, CA) and run with a

Figure 7. Location of experiment Ila soil cores.

Beckman model LS1800 scintillator in "auto-run" mode. Raw counts were taken for 10 minutes within a counting window of 0-400 nm. Since relative tritium content was sought rather than absolute concentrations no quenching factors or standards were used in the counting routine. Tritium background was taken from vials prepared with well water in place of extract.

Chloride was analyzed with a Buchler model 64-2500 chloridometer (Buchler Instruments, Inc., Ft. Lee, NJ). The instrument was used in high sensitivity mode. A series of five standard readings were taken with 0.1 ml aliquots of 100 me/L NaCl standard to make a one-point calibration. This calibration was updated with two new standard readings every 15 samples. Five background-correction vials were prepared with distilled-deionized water. Sample titrations were performed with 0.10 to 0.50 ml volume aliquots, depending on the concentration of the sample.

Bromide was analyzed with an Orion model 901 bromide ion electrode (Cambridge, MA). The single junction reference electrode was an Orion model 900100 filled with a saturated solution of AgCl (Orion, model 900001). Measurements were taken to the nearest millivolt using a Beckman model ϕ pH/mV meter. A calibration curve was constructed by reading 4 standard NaBr solutions containing 12.5, 125.0, 437.5, and 1250.0 mg/L. These standard readings were taken at the beginning and at the end of a run of analyses. An average of the two sets of standard readings was used to construct the curve.

Bromide analyses with an ion selective probe have tended to yield suspect data. We found that electrode performance deteriorates quickly when a new electrode is used continuously with a soil solution matrix. Though a consistent calibration curve can be made with a series of bromide salt standards, selectivity between bromide and chloride ions in a strong and complex solution matrix is compromised.

Therefore, the bromide electrode results should be viewed critically.

Gravimetric water content values from the soil core samples were converted into volumetric water units by using an estimated term for soil bulk density. The bulk density was taken from soil cores collected during the original trench characterization work, near the plane at $Y_2 = 0$ m. In that work 9 major morphological horizons were distinguished along the trench face from 0 to 6 m depth. At the center of each horizon a transect was established along the length of the trench with 50 equidistant sampling stations. Soil cores from each station were evaluated for bulk density (Wierenga et. al., 1987, 1988, and 1989). A mean value of bulk density for each depth was calculated from these 50 measurements in the transect. Experiment IIa soil core sample density was estimated directly from these means by depth-wise linear interpolation.

3.3 Results and Discussion

The moisture and solute data for the Experiment IIa redistribution soil cores are presented in tabular form in Appendix C-5a. The volumetric water contents obtained from the soil core gravimetric samples (day 661) at $Y_2 = 5$ and 9 meter planes are compared to the neutron probe water contents at $Y_2 = 6$ and 10 meters, respectively. Figure 8 shows neutron probe water at $Y_2 = 6$ m for day 78, three days after the last irrigation of experiment IIa, and for day 655, 6 days before the soil core samples were collected. The day 78 neutron probe data show that the wetting front was found between 2 and 3 m depth, with less than 3 m of lateral movement. By day 655 the wetting front had dispersed to become mostly indistinct. The day 655 distribution of water in the profile is very similar to that found in the $Y_2 = 5$ m plane of soil core samples (Figure 9). The layer of relatively high moisture content found about 0.5 m deep at $Y_2 = 5$ m is also found at $Y_2 = 6$ m by

Figure 8. Experiment IIa neutron probe volumetric moisture contours at $Y_2 = 6$ m on days 78 and 655. Boxes are added to show similar regions of the profile which were sampled by soil cores at $Y_2 = 5$ m of day 661.

Figure 9. Experiment IIa soil core volumetric moisture contours at $Y_2 = 5$ m on day 661: Gravimetric soil core moisture is converted to volumetric moisture with an estimated term for soil bulk density.

the neutron probe. Note that the horizontal and vertical scales in Figures 8 and 9 are different. Figure 8 shows the full range of neutron probe measurements at $Y_2 = 6$ m to illustrate the extent of the wetting front. In this figure the more limited area of soil core measurements (of Figure 9) is delineated by the boxed areas.

The total water content determined by neutron probe measurement was compared to that measured gravimetrically from the soil cores (with an estimated soil bulk density term). This comparison was restricted to portions of the profile in common with both methods of measurement, i.e., from $-1.5 \text{ m} \leq X_2 \leq 1.5 \text{ m}$ and to 3 m depth. Within these confines the $Y_2 = 6$ m neutron probe plane held an average 33.4 cm-long column of water versus about 32.4 cm measured in the $Y_2 = 5$ m soil core samples.

Lateral redistribution of applied water obtained from neutron probe data is more dramatic at $Y_2 = 10$ m (Figure 10). Soil core water distribution at $Y_2 = 9$ m appears less similar to neutron probe water, though areas of higher moisture content in the $+X_2$ direction, between 0.5 and 1.5 meters depth, correspond to both locations (Figure 11). Note that the soil core contours represent a two-fold increase in horizontal sampling density compared to the neutron probe measurements. The average depth of the water column is similar between the measurement planes; 31.3 cm of soil-core water at $Y_2 = 9$ m and 31.4 cm of neutron probe water at $Y_2 = 10$ m.

Tritium comparisons are made between soil core sample planes at $Y_2 = 5$ and 9 meters and the plane of solution sampler placement at the trench face, $Y_2 = 0.5$ m (Figures 12, 13, and 14). At the trench face the tritium plume is contoured from data that represents only 61-66% of the solution sampler grid, i.e., from 27 to 29 individual solution samplers. By contrast each soil core transect provides 107 samples for contour construction. For comparison with soil core transects, tritium at

the trench face is contoured from day 429 tritium data since collections of solutions after that day represented fewer samplers and would lead to poorer contour resolution. Tritium redistribution between day 429 and day 661 (soil core collection) is assumed to be negligible.

The horizontal location and shape of the largest body of the tritium plume is similar at the $Y_2 = 5$ m and 0.5 m measurement planes, centered about $X_2 = 0.5$ m from the center axis of the plot. The highest observed concentration of tritium at $Y_2 = 0.5$ m was 27% of input and at $Y_2 = 5$ m was 23%. But in other characteristics the behavior of the plume was quite different; in terms of vertical displacement the plume was found at least 0.5 m deeper at $Y_2 = 5$ m. Greater horizontal displacement is also evident at the 5 m transect, though this may be partly due to the higher resolution and more complete representation of the profile with the soil core samples.

Tritium recovery from the core samples at $Y_2 = 5$ m, was about 110% of the tritium mass originally applied to the soil surface. Planar recovery of tritium was found by multiplying individual observations of C/Co by (estimated) volumetric water content and the domain of X_2 and Z dimensions for each observation. This product was divided by the total amount of tritium applied at the surface. The calculation of this mass balance accounted for the radioactive decay of input tritium through the date when the soil core solutions were analyzed.

At $Y_2 = 9$ meters the tritium plume appears more centered under the irrigated area and with vertical displacement more like on the trench face. Horizontal redistribution is more like the plume represented at $Y_2 = 5$ m. The peak observed concentration was about 26% of input. Samples at $Y_2 = 9$ m recovered about 134% of tritium applied to the soil surface in that plane of measurement. This high recovery figure may be due to several factors. The values for bulk density, used to find volumetric water content,

Figure 10. Experiment IIa neutron probe volumetric moisture contours at $Y_2 = 10$ m on days 78 and 655. Boxes are added to show similar regions of the profile which were sampled by soil cores at $Y_2 = 9$ m on day 661.

Figure 11. Experiment IIa soil core volumetric moisture contours at $Y_2 = 9$ m on day 661. Gravimetric soil core moisture is converted to volumetric moisture with an estimated term for soil bulk density.

Figure 12. Experiment IIa relative tritium (C/Co) contours at the trench face ($Y_2 = 0.5$ m) on days 78 and 429. Liquid samples collected by solution samplers.

Figure 13. Experiment IIa relative tritium contours from soil cores at $Y_2 = 5$ m, day 661.

Figure 14. Experiment IIa relative tritium contours from soil cores at $Y_2 = 9$ m, day 661.

may be overestimated, since they assume that soil properties found at the trench face extend uniformly into the length of the plot.

Also, samples of the original applied tritium solution were not available for counting. The counts originally generated by the scintillation counter for that solution were assumed constant (less counts for decay) over time.

Bromide and chloride results from the soil core samples (day 661) are considered together. Figure 15 shows that bromide is largely absent from the profile at $Y_2 = 5$ m to about 1.5 m depth. This is due to irrigation with 27.5 cm of bromide-free water, following a 4.9 cm pulse of bromide in the first 11.5 days of experiment IIa irrigation. Like tritium, a portion of the bromide plume on the $+X_2$ side of the plane is divided from the main plume. The highest

observed bromide concentration was 0.84 of input at 1.8 m depth, $X_2 = -0.5$ m.

Chloride was not applied as a solute tracer so results can be treated as though the ion was a negative tracer, flushed from its natural placement in the profile. Chloride, again like tritium, was more effectively eluted from the $-X_2$ side of the plot. The highest concentration of chloride (36.9 me/L) was found at 2.8 m depth, $X_2 = 1.5$ m.

Compared to data for the $Y_2 = 5$ m plane, bromide and chloride ions were less effectively moved through the profile at $Y_2 = 9$ m (Figure 16). This behavior was again consistent with tritium results. The leading edge of the tritium plume dovetails with the trailing edge of the eluted chloride plume. The highest concentrations of bromide and chloride were $C/Co = 0.99$ and 38.2 me/L, respectively.

Figure 15. Experiment IIa relative bromide (C/Co) and solution chloride (me/L) contours from soil cores at $Y_2 = 5$ m, day 661.

Figure 16. Experiment IIa relative bromide (C/Co) and solution chloride (me/L) from soil cores at $Y_2 = 9$ m, day 661.

4 Experiment IIb Water and Solute Application

4.1 Preparations

A second water flow and transport experiment on plot 2 (experiment IIb) was begun on August 1, 1990, following the last water application of experiment IIa by 649 days. For both experiments the same experimental apparatus was used, with the exception of a number of improvements and additions. Figure 17 illustrates the location of data collection devices; neutron probe access tubes, tensiometers, and solution samplers relative to the trench and plot 2.

The plot pondliner and plot cover were modified for improved performance as a vapor barrier.

The area surrounding the irrigated plot which was covered by pond liner material was expanded. Pondliner pieces were added to the east and west sides of the plot which added an additional 1.8 m of lateral coverage. Existing pondliner was carefully checked for holes and defective seams, and then repaired or replaced. In experiment IIa a total of 12 tensiometers were installed through the plot cover at $Y_2 = 2.5, 5.5,$ and 6.5 meter planes. These tensiometers yielded questionable data and created problematic leaks in the cover. These tensiometers were removed prior to Experiment IIb. New devices were added to expand lateral coverage from $X_2 = -2.25$ to 2.25 meters and to the bottom of the trench, with the last row of devices installed at 6 m depth.

Figure 17. Survey of plot 2 experimental apparatus illustrating locations of neutron probe access tubes, tensiometers and solution samplers relative to irrigated area and plot vapor barrier.

Some devices were placed offset from the regular grid to avoid structural obstacles (trench walkways and vertical H-beams). In all a total of 108 tensiometers and 120 solution samplers were emplaced to monitor water and solute movement at $Y_2 = 0.5$ m. The location on the trench wall and the identification of each device by row and column is illustrated in Figure 18. In this figure the identification of each device is found by adding the row number to the column number.

During installation (or reinstallation) a native mud slurry was injected at the distal end of each drilled hole just before seating the device (Appendix C-7). This slurry was used to improve soil contact with the ceramic cup. Soil used for the slurry was collected from the trench face at several depths in the profile to approximate the target depth of the ceramic device. This material was first chipped with a mechanical soil chipper, sieved through a 2 mm mesh to remove coarse material and then sieved again through an 80 strand/inch mesh before use. To finish installation the PVC stem of each device was firmly wedged against the wooden lagging of the trench wall with a metal shim to prevent the soil/ceramic cup contact from being disturbed.

The same 6-meter-deep neutron probe access tubes used to monitor water contents in experiment IIa were used for this experiment, with some modifications. Several tubes had formed an oxidation scale at some depths which blocked free passage of the neutron probe and resulted in a loss of new data collection below the blockage.

A number of methods were used in attempts to clear these access tubes before the experiment began, with mixed results. About once a month each tube was swabbed to remove accumulated scale and moisture from within the tube. The swab was made with a 25' length of

PVC pipe with a cloth swath bound tightly to one end for a snug fit within an access tube. Problem tubes were scoured with a tight-fitting metal bristle brush to free the scale. This brush was either rotated by hand or with a power drill throughout the depth of the tube.

Some obstructions were not cleared by these treatments. The neutron probe was returned to the manufacturer for modification. The aluminum wall of the probe body was milled from an original 4.73 cm outside diameter by 0.050" to 4.48 cm diameter. This step proved helpful for some access tubes, though not all. Neutron probe counting performance was not changed by this procedure.

To reduce moisture condensation, each tube was fit with a size 10 rubber stopper and a water-absorbent tampon. The rubber stoppers fit snugly within the access tubes and were pushed to lodge against the bottom of the tubes with a length of PVC pipe. The purpose of the stoppers was to prevent condensation from entering access tubes through the open end at the bottom. For the tampons, 1"-diameter by 6"-long rigid polypropylene mesh cylinders were lined with similar lengths of nylon stocking.

Each stocking liner was filled with an indicating silicone desiccant (T.H.E. Desiccant®, EM Science, Gibbstown, NJ), and sealed at both ends. These tampons were lowered about 3 m into the access tube by a piece of string. As necessary, about once or twice a month, tampons were replaced with fresh ones. Hydrated tampons were placed in a laboratory oven at 60° C to dehydrate the desiccant for reuse.

In previous experiments, leaks in the vacuum system that supplied individual solution samplers, were often problematic. For this experiment a new vacuum system was

Figure 18. Schematic of trench face illustrating placement of tensiometers and solution samplers relative to the area of soil directly beneath irrigated area (shaded). Individual devices are identified by row + column designations, indicated by boxed areas to the right and bottom of the figure.

constructed of ½" schedule 80 PVC pipe and reinforced ports that connected to individual samplers. A vertical main header supplied vacuum to individual sub-header lines placed horizontally above each row of solution samplers. This replaced the old system which "daisy- chained" successive depths of solution samplers below a common port with lengths of Tygon® tubing. The new system was extensively leak tested before installation and proved quite reliable during pre-operational tests and normal use.

Several enhancements were made in the pumphouse plumbing system which delivered water to the irrigation plot (Figure 19). An external liquid level sight glass was added to the 300 gallon treatment tank to allow more precise measurement of applied solutes. Changes in plumbing allowed optional routing and control of water flow for improved system flushing and cleaning. New solenoid valves and electrical controls improved precision during filling and discharge of irrigation water from the 35 liter application tank. Additional in-line filtration devices were installed to prevent debris from causing leaky solenoid operation and fouling of emitters at the irrigated plot.

Before the new experiment began the volume of water pumped through the system was measured and calibrated three different ways. For testing and calibration purposes, pump flow was temporarily shunted from the irrigated plot to a tared container placed on a balance within the pumphouse. After a pump cycle the container was weighed to the nearest 10 g with a Weigh-Tronix model WI-102 electronic balance (1000 Armstrong Dr., Fairmont, MN, 56031). This provided a series of calibration marks on the treatment tank sight glass. The treatment tank was filled with successive pumping cycles of known volume. Interpolation between these marks allowed confident estimation of tank drainage volume during draining or filling to the nearest 0.5 L. This calibration was typically used to calculate the amount of concentrated

solute to add when refilling the treatment tank with tracer solution. The second method of calibration used a Stevens model 68 water stage recorder (Beaverton, OR) to measure the linear distance traveled by a float as the water level rose or fell within the cylindrical application tank. This measurement proved to be the most precise, allowing resolution to the nearest 0.1 L, but often was difficult to interpret in the event of closely spaced pump cycles or compromised system behavior. This device was useful for locating leaky solenoid valves and for monitoring pump performance. Finally, an in-line Rockwell International 5/8" inlet gallon totalizer meter (Pittsburgh, PA) was used to measure outflow from the application tank to the irrigated plot, with precision to the nearest 0.4 L. During the experiment all three methods were used to monitor water application and system behavior. For tracking the volume of irrigation water applied to the plot, the totalizer meter was used as the primary source of information.

The uniformity of dripper application within the irrigated plot was checked several times before the experiment started; on 5/30/90, 7/16/90, and 8/1/90. After irrigation was discontinued a final uniformity test was again made on 10/24/90 (Appendix B-1). For these tests 1 L plastic cups (average tare mass 25.3 g, ± 0.6 g) were placed directly beneath individual drippers. The application pump was activated to purge entrapped air from the pipes leading from the pumphouse, through all the buried water supply lines, up to a bleeder valve located just ahead of the dripper system. The solenoid valves directly ahead of the irrigation headers were adjusted to apply water from 10 to 14 psi back pressure, the normal operating range of the emitters. The pump was again turned on briefly to purge both irrigation headers through the bleeder valves located at both ends of each header and then finally reactivated for one or two pumping cycles per header to partially fill the plastic cups. Each cup was then weighed to the nearest 0.1 g to ascertain individual dripper output.

Figure 19. Schematic of pumphouse plumbing system showing delivery route of irrigation water from either 2500 gallon storage tank or 300 gallon treatment tank to plot 2 emitter headers.

Since headers were irrigated independently the test data were grouped by header. For each header mean, standard deviation and coefficient of variation values were calculated. An additional parameter, a coefficient of uniformity (CU) value, was calculated to estimate overall efficacy of plot irrigation (Christiansen, 1942):

$$CU = 100 \left(1 - \left(\sum \text{abs}(x - \bar{x}) \right) / (n\bar{x}) \right)$$

Any defective dripper lines (those with any dripper exceeding the mean by 10 percent) were identified and replaced with new lines between tests. In some cases individual emitters were spliced into existing lines.

Tracer solutions were premixed as concentrated stock solutions about two to three days before use. Sufficient chemical was prepared to provide a target solute concentration for 16 days of plot irrigation at the rate of 2 cm/d. Each component chemical of a stock solution was individually dissolved in about 200-400 ml of distilled deionized water in the laboratory, then commingled and diluted to 20 L in a polypropylene jug. Fresh analytical-grade chemicals were used. The boric acid and potassium chromate chemicals were desiccated in the presence of CaCO_3 for 72 hours prior to use. No analysis of container contents was performed; labeled purity values were assumed to be correct.

The first 20 L stock solution contained 46.54 g of pentafluorobenzoic acid, PFBA (99 percent pure), 289.93 g of boric acid (H_3BO_3 , 99+ percent pure) and 87.796 g of potassium chromate (K_2CrO_4 , 98 percent pure). The second 20 L stock solution contained 47.02 g of 2,6 difluorobenzoic acid, DFBA (98 percent pure), 205.9 g of potassium bromide and 460.8 mCi tritium (as 10 mCi/ml laboratory stock). The DFBA was difficult to dissolve in the

relatively small quantity of water used to make the stock solution. A basic environment, provided by potassium hydroxide, was needed.

By trial titrations, a ratio of 1.3 eq KOH/eq DFBA was found useful for fully dissolving this acid. This ratio of base to acid was used to successfully dissolve the acid in 3 liters of water before diluting to 20L. Afterwards, this stock was observed closely for any precipitate formation.

4.2 Irrigation and Field Data Collection

4.2.1 Plot irrigation

Plot irrigation was started on August 1, 1990. It was stopped 70 days later after a total pulse of 127.4 cm water had been applied. Well water containing tracer solutes was applied in two separate pulses.

During the first 15 days of irrigation the well water was spiked with 12.3 mg/L pentafluorobenzoic acid (PFBA), 11.6 mg/L boron and 4.8 mg/L chromium as chromate (VI) ion. During the next 14 days untreated well water was applied. The second tracer pulse was applied from days 29 to 44 and contained 0.10 mCi/L tritium, 10.3 mg/L 2,6 dichlorobenzoic acid (DFBA), and 27.75 mg/L bromine as bromide ion. The application periods are shown in Table 1.

Water was applied in about 5 minute pulses on three hour intervals (four times a day to each header line) which resulted in an average surface flux of 1.825 cm/d over the irrigated area (Appendix A-1). A number of system malfunctions occurred during the 70 day irrigation period that required attention. These difficulties are illustrated in Figure 20.

Table 1. Irrigation regime and tracers applied during experiment IIb.

Irrigation Days	0 .....10 .....20 .....30 .....40 .....50 .....60 70
Well water	***** 0 - 70
Boron, Chromium, & PFBA	***** 0 - 15
Tritium, Bromide, & DFBA	***** 29 - 44

4.2.2 Neutron probe readings

Neutron probe readings were taken at 0.25 m depth increments with a CPN model 503DR neutron probe (Martinez, CA). During plot irrigation and through day 75 probe readings were taken three times per week; the 29 access tubes nearest to the irrigated plot were read on two of those days, all 43 tubes on the third. After day 75 the frequency of neutron probe readings was gradually reduced commensurate with the rate of water redistribution. Readings were taken twice per week through day 103, once per week through day 154, once every two weeks through day 225, once a month through day 345, then not again until days 408 and 525. After day 103 all access tubes were read on a given day. On February 7 and 8, 1991 (days 190, 191) an additional 6 access tubes were installed to extend neutron probe coverage by an additional 1 m on either side of the plot, to $X_2 \pm 6$ m at the $Y_2 = 2$ m, 6 m and 10 m planes (Figure 21 and Appendix C-10).

4.2.3 Soil tension readings

Soil tensions were measured and solution samples were collected 3 times per week during irrigation. This frequency was reduced after irrigation was discontinued, generally to match the days when neutron probe readings were taken.

Soil tensions were measured to the nearest millibar with a hand-held pressure transducer (Soil Measurement Systems, Tucson, AZ). A backup transducer was used occasionally. The operation and calibration of these units was checked periodically against a regulated laboratory manometer (Appendix B-3). Tension was measured through a rubber septum which sealed the exposed end of the tensiometer. The air column within the stem of the device was measured to the nearest 1 cm to correct the raw tension reading for water head from the visible water level to the center of the ceramic cup. If the water level within the stem dropped below the septum by more than 3 cm the tensiometer was refilled with distilled-deionized water. This operation was performed at least 1 day before taking measurements to allow the device to come to equilibrium with soil moisture. This equilibration period was extended to several days during the redistribution phase of the experiment. In very dry soils (> 800 mb) tensiometers were left unfilled to prevent cavitation and unnecessary water additions to the profile. The progress of the wetting front was estimated and tensiometers filled for use just before its anticipated arrival.

4.2.4 Soil solution samples

Soil solution samples were taken on the same days as tension readings. Solution samplers

Figure 20. Experiment IIB totalizer record. Plotted application rates are calculated as mean application from one observation to the next. Aberrations from normal irrigation rates are noted.

Figure 21. Schematic of neutron probe access tubes in relation to plot 2, pondliner cover and the covered trench.

were connected to a vacuum system that was plumbed to a source regulated to supply about 200 mb of vacuum. During later redistribution stages of the experiment the vacuum was increased to about 450 mb. During plot irrigation the vacuum was turned on for periods ranging from 30 minutes to more than an hour to collect sufficient sample volume for analysis. As the profile became drier during redistribution, the evacuation period was extended to as long as 24 hours to collect sufficient sample volume. Samples were collected in 13 dram polypropylene vials with snap-on caps.

Periodically during the vacuum period the air-inlet tubing of individual samplers was briefly opened to clear any accumulated liquid from the ceramic cup to the vial. This "sample pumping" tended to improve collection rates. If an individual vial was filled to more than about 75 percent capacity it was closed to vacuum. Vials containing only traces of liquid (≤ 0.1 ml, approx.) were discarded.

Filled vials were capped and labeled with the date and solution sampler identification. At least two layers of Parafilm® wrap were applied around the rim of the cap to reduce evaporative loss. The vials were then taken to the laboratory for processing. The liquid volume of individual samples collected through February 1, 1991 (day 184) was estimated. For this estimate a random group of 10 empty vials was weighed on a balance. A vial was selected from the group with a mass near the mean. This vial was used during the course of the experiment to tare the balance before weighing vials (Parafilm® removed) containing liquid sample. This sample volume data was used to identify individual solution samplers which might need replacement or repairs. The vial caps were then rewrapped with Parafilm® and placed in refrigerated storage.

4.3 Sample Analysis

4.3.1 Sample handling

Liquid samples collected from the trench were analyzed for tracer solutes as well as the naturally occurring solutes, nitrate and chloride. Analyses of tritium, boron and chromium were performed in laboratories at New Mexico State University. Analysis of PFBA, DFBA, boron, chloride and nitrate, were performed on a limited number of samples at The University of Arizona.

For low-volume samples where the number of analyses would be limited, a priority for solute analysis was assigned. The order of this priority, from the most important solute to the least was as follows:

tritium > PFBA > chromium > DFBA >
bromide > boron > all others

Analyses were not necessarily performed in this order chronologically, but enough sample was reserved to perform higher priority analyses if runs for a lower priority analyzes were in progress. Some solutes were run simultaneously from the same aliquot.

Tritium, chromium and boron were analyzed first. After these analyses the samples were transferred from the original polypropylene vials to 20 ml borosilicate glass scintillation vials, with foil-lined caps (VWR Scientific, Denver, CO, p/n 66022-004) to reduce evaporation and conserve space. The vials were then packed in ice and shipped to laboratories at The University of Arizona to analyze remaining solutes.

During the redistribution phase of the experiment the volume of liquid sample

collected by solution samplers began to decline. These samples were diluted with water to increase volume and extend the number of analyses which could be performed with a limited original volume. Beginning with the samples collected on February 15, 1991 (day 198) individual polypropylene vials were weighed (less cap) to the nearest mg before use. The vial's mass was written on the side of the vial with a permanent marker. With mass known the mass of the liquid sample within a vial could be determined with 0.001 g precision. This data was used to calculate appropriate sample dilution prior to chemical analyses. The sample dilution was limited to no more than 5x the original volume, to ensure that the detection limit of the least sensitive analyses would not be exceeded for the highest (C/Co) concentration of solute.

Long holding times between sample collection and chemical analyses were common. It was necessary to protect samples from chemical degradation and evaporative loss as best as possible. Before any analysis proceeded samples were removed from the refrigerator and brought to room temperature to prevent condensation on the vials and temperature effects on the analyses. After any dilution, chemical analysis or liquid transfers between containers, the vials used for storing samples were wrapped with Parafilm® and returned to refrigerated storage. In a simple laboratory trial it was found that

Parafilm® wrap greatly reduces evaporative losses when liquid samples are stored for long periods (Appendix C-3).

4.3.2 Tritium

Tritium was analyzed with a Beckman LS-1800 liquid scintillation counter (Beckman Instruments Inc., Fullerton, CA). Single replications of solution samples were prepared for scintillation by pipetting 0.1-0.5 ml aliquots of sample to 5 ml of scintillation cocktail into

Beckman 8 ml Mini Poly-Q vials. Each vial was capped, marked to identify its contents, and then placed in a rack with other vials. When the entire rack was filled it was vigorously shaken to mix the sample with cocktail to form the desired gel. Vials were then transferred to a counting rack compatible with the counter. The counter was programmed to run with a single-channel counting window of 0-400 nm and no internal standard. Counting time per vial was set to a maximum of 10 minutes. Vials with early counts of less than 16 counts per minute, an approximate background count, were terminated within 1 minute of the routine.

At the beginning of an analytical run a series of five background vials and five tritium input sample vials was counted. Background vials were prepared with 0.5 ml aliquots (500 ul Eppendorf pipettor, Brinkman Instruments, Inc., Westbury, NY, $\pm 0.6\%$ error) of well water in place of solution sample in the scintillation vials. The input vials were prepared with 0.5 ml aliquots of traced well water, collected from the 300 gallon solute tank on 9/4/90. This collection was refrigerated in a capped 3 L glass bottle, sealed with Parafilm®. The input vials were used to track the consistency of tritium scintillation for the same solution over time.

The aliquot volumes used to prepare scintillation vials was a factor in counting results. The preferred aliquot size was 0.5 ml (500 ul Eppendorf pipettor), whenever sufficient sample volume was available. Since many samples were well below this preferred volume, 0.1, 0.2, 0.3, or 0.4 ml aliquots ($\pm 1.0\%$ error) of sample were used instead (adjustable Eppendorf pipettor, 1-100 ul). As aliquot size is reduced counts become less quenched.

Therefore, a sample counted with 0.1 ml added to a scintillation vial will produce more than $0.1/0.5 = 20\%$ of the counts as when 0.5 ml of sample is used. However, this quenching characteristic is linear with aliquot volume and was characterized for this experiment

(Appendix B-2). A correction factor was used to correct raw counts for various aliquot volumes.

Two different scintillation cocktails were used for samples collected at different times in the experiment. All samples collected through day 184 were prepared with Aquasol universal LSC, a xylene based product manufactured by Dupont New England Nuclear (p/n NEF-934, Boston, MA). After day 184 samples were prepared with Ready-Safe (Beckman Instruments, Inc.), a newer cocktail formulation with significantly higher counting efficiency than xylene based cocktails (Klein and Gershey, 1990). Ready-Safe was less expensive, more safely handled, and proved to mix more readily with sample to form a gel than did Aquasol. Since Ready-Safe yields higher counts than Aquasol, and has a different volume/quenching characteristic, an experiment was performed in the laboratory to correct for substitution effects (Appendix B-2). Tritium data (Appendix A-4) is expressed as relative tritium concentration:

$$\text{Relative Concentration} = \frac{C}{C_0}$$

$$= \text{Diln} \frac{[(C' - \text{Bkg})K_{yc}]}{C_0' - \text{Bkg}} \times 0.622$$

where C is the adjusted input concentration; C' is the observed raw counts per minute for a sample; Bkg is the background counts per minute on a given day of analysis and K_{yc} is the correction factor for aliquot volume, specific to a cocktail. Diln is the dilution factor for a sample.

C_0 is the concentration of tritium applied as tracer to the plot, expressed as raw counts per minute (17,142). To find this value 9 samples of solution were drawn from the 300 gallon solute tank on different days during the 15 day period of tritium application. Six replicate scintillation vials were prepared from each of

these collections, counted normally and then averaged. The constant 0.622 is used to normalize data to the concentration of tritium applied during experiment IIa, 27,574 counts per minute (Hills and Wierenga, 1991).

Much of the tritium analysis for samples collected through day 184 was repeated to correct procedural errors made during the original analyses. Many of these samples had been incorrectly mixed before counting.

Scintillation counts are very sensitive to gel homogeneity. When an aliquot of sample is added to cocktail and capped the vial must be vigorously shaken with an up and down motion, especially when using a more viscous cocktail such as Aquasol. This mixing motion was inconsistent between technicians and was often performed with a less effective side to side motion. This resulted in an insufficiently homogenized gel and counts which were more variable between vials, i.e., lower than normal.

When the correct nature of the problem was identified a decision was made to reanalyze tritium for all the samples collected through day 184 using the more effective mixing procedure. For many samples this reanalysis involved a dilution step to obtain sufficient volume. Original data was retained for samples with good original data or where liquid sample was no longer available for re-analyses.

4.3.3 Chromium and boron

Chromium and boron were analyzed simultaneously with a Perkin-Elmer model 6000 inductively coupled plasma instrument (ICP) and a model 7500 integrated computer (Norwalk, CT). The linear working range given by Perkin-Elmer for this instrument is from 0.02-300 mg/L for chromium and from 0.05-300 mg/L for boron, with a detection limit of 0.004 and 0.002 mg/L, respectively. In practice, the detection limits were found to be much higher

for this machine; 0.029 mg/L for chromium and 0.130 mg/L for boron.

The ICP was programmed to measure spectral emission of chromium at 267.7 nm, then to switch the monochromator wavelength to 249.77 nm for boron. The instrument was calibrated with a series of three solutions; a standard containing 10 mg/L chromium and 10 mg/L boron, a water blank, and a second standard to check for reproducibility. This calibration procedure was repeated after every 15 samples.

Samples were transferred to 15 ml polystyrene conical tubes (Becton Dickinson, Lincoln Park, NJ) and run in groups of 50 samples (including calibration tubes). The run would begin after allowing the machine at least 20 minutes to warm up and produce a stable plasma field, confirmed by successful calibration.

Both elements are expressed in the data as relative concentrations, C/C_0 , where C is the observed concentration of the element in the sample (mg/L) and C_0 is the input concentration (mg/L).

4.3.4 Fluorobenzoates

High Performance Liquid Chromatography instruments (HPLC) at laboratories of the Agricultural Research Service, U.S.

Department of Agriculture in Tempe, Arizona, and at the Department of Soil and Water Science at The University of Arizona were used to analyze the fluorobenzoic acid tracers.

Sample analyses were performed during two periods: samples analyzed between January 7-9, 1991 were collected on days 0, 14, 30, 47, and 70; those analyzed between September 23-25, 1991 were collected on days 127 and 310.

Fluorobenzoic acid tracers are best analyzed using High Performance Liquid Chromatography (HPLC). The reason for this is interference from nitrate and bromide ions under UV light at the optimum wavelength for benzoic acid tracers (i.e. 205 nm). Bowman (1984a) showed that nitrate and bromide became excited under UV energy at 205 nm wavelength, and that HPLC methods allow the separation of different fluorobenzoates from other anions. Analytical equipment used during the two analyses periods differed slightly (Table 2). The column used for these analyses was a Regis Rexchrome S5-100-SAX 5 mm Reverse Phase HPLC column. The column length was 250 mm with an internal diameter of 4.6 mm.

This is the same type of column used by Bowman (1984a), except that the packing material, which has been improved over the years, differs slightly.

Table 2. Analytical equipment and software used for analysis of the fluorobenzoates.

Date	Jan. 7-9, 1991	Sept. 23-25, 1991
Pump	Waters 510	Waters 510
Detector	Waters 490 Multi-wavelength	Waters 480 Multi-wavelength
Sampler	Waters 710 Wisp	Perkin-Elmer ISS 100
Software	Waters Maximum 820	Waters Maxima 820

The assays used for both analyses were modified from Bowman (1984a, b). The gradient system (Table 3), used a potassium phosphate (K_2PO_4) mobile phase adjusted to a

pH of approximately 2.8, and acetonitrile. The detector wavelength was kept constant at 205 nm. After the sample was injected into the fluid stream, the percentage of acetonitrile was increased (ramped) to enhance the separation of the constituents in the sample. Once the benzoates and bromide were released from the column material, the acetonitrile was decreased

to the original concentrations, thus allowing the column to return to equilibrium for the next sample. The increases and decreases of acetonitrile in the mobile phase were optimized to improve separation.

Because of significant interference of nitrate and bromide with the benzoic acid tracers, and because each column has slightly different adsorption characteristics, the molarity and pH of the mobile phase had to be adjusted to improve the separation of the constituents, while maintaining an acceptable analytical time.

Table 3. Mobile phase characteristics and gradients for analytical events of January 7-9, 1991.

Mobile Phase Character						
pH K_2PO_4 molarity Flow rate	2.8 0.01 M 2.0 ml/min					
Run Time	0	3.5	4.5	6.0	7.0	10.0
% K_2PO_4	15	15	70	70	15	15
% acetonitrile	85	85	30	30	85	85
pH K_2PO_4 molarity Flow rate	2.8 0.01 M 2.0 ml/min					
Run Time	0	6.0	7.0	11.5	12.5	15.0
% K_2PO_4	15	15	85	85	15	15
% acetonitrile	85	85	15	15	85	85

Retention times were (Table 4) also found to vary significantly between analytical events. A possible reason for this could be the change in columns. Although each column is manufactured with the same packing material, slight variations between columns can cause retention times to vary. It is noted that retention times did drift during the analyses. This was caused by changes in the column's ability to

retain the anions. As the column ages, the retention characteristics decrease, leading to shorter retention times. The computer program which operated the HPLC (Water Dynamic Solutions, Ventura, CA) was programmed to allow for 10% drift. Larger drifts indicated a problem with the column, in which case the column was cleaned.

Table 4. Retention times for benzoates, bromide, and nitrate.

Event	1	2
DFBA	3.65	6.30
PFBA	3.34	8.55
Bromide	4.39	9.20
Nitrate	4.09	9.60

The large number of samples run during each event required a new batch of mobile phase. For each new mobile phase, standard samples were run so that a new calibration curve would be generated. The standards for the calibration curve were made from four individual solution mixtures of 1, 2, 5, or 10 ppm of both PFBA and DFBA and a fifth water blank. Retention times and possible interferences were checked for each new mobile phase mixture. Checking for interferences ensured that shifts in the retention times would be accounted for and noted during the analyses. Furthermore, to ensure that the calibration curves remained valid for each method, one standard was run for each 10 samples. Slight deviations in the results from the existing calibration curve were incorporated by the software, and new calibration equations were generated. Large deviations indicated problems with the column, instrumentation or mobile phase.

In one case during the second analytical event, for samples collected on day 310, the column began to fail. This was seen as a widening of the solute peak and an inability of the software to discern a retention time. Column failure was the only logical explanation for this problem and, consequently data for samples collected on day 310 were considered invalid.

4.3.5 Bromide, chloride, and nitrate

Bromide, chloride, and nitrate ions were analyzed with ion chromatography (IC)

apparatus at the Soil and Water testing Laboratory of The University of Arizona. All three anions were analyzed simultaneously with Dionex equipment; a 2320i ion chromatography module, a 2021i conductivity detector and an HPIC-AS4A analytical column (Dionex Corporation, Sunnyvale, CA). The eluant used was 7.5×10^{-4} M NaHCO_3 / 2.2×10^{-3} M Na_2CO_3 at a flow rate of 2.0 mL/minute. The Dionex chromatography module utilizes a suppressor component to remove unwanted cations from the sample stream ahead of the detector. For these samples a 0.025 N H_2SO_4 regenerant was supplied to the suppressor.

A series of four standard solution mixtures (Table 5) was used to construct an initial calibration curve at the beginning of the analysis.

A sequence of runs was used to update the calibration curve for every 10 samples; a single run of one selected standard mixture, followed by a blank (water) solution, and a duplicate of one of the previous samples. When necessary to bring an analyzes into the IC linear working range, sample dilutions were performed with Rainin EDP electronic pipettors (Rainin Instruments Co., Inc., Woburn, MA) to dilute solution with water in a test tube.

4.4 Data Manipulation

Neutron probe water content data were transferred via RS-232 cable from the

Table 5. Standard solutions for bromide, chloride and nitrate analyses.

Mixture #	1	2	3	4
Br (ppm):	0.25	2.5	6.25	12.5
Cl (ppm):	0.50	5.0	12.50	25.0
NO ₃ (ppm):	0.75	7.5	18.75	37.5

probe memory to an ASCII text file on an IBM XT personal computer. The data was transferred from disk to an Apple Macintosh computer for further manipulation. Macro routines in a WingZ spreadsheet (Informix Software, Lenexa, KS) were used to strip the file of unwanted output lines, produce preliminary graphics, and store the data in a usable format. Tensiometer data and data from all the chemical analyses were entered by hand into WingZ spreadsheets. For final data storage Double Helix software (Odesta Corp., Northbrook, IL) was used to combine, sort and store the data in database format.

Contour figures for this report were produced with DeltaGraph Professional software (DeltaPoint Inc., Monterey, CA, version 2.0.1) which creates triangular patches between true data points. It does not convert data into grids with algorithms based on kriging or inverse distance to power n.

Other software applications used to produce X-Y plots and other figures and tables from data were Microsoft Excel (Microsoft Corp., Redmond, WA, version 3.0), KaleidaGraph (Synergy Software, Reading, PA, version 2.0.2), and Canvas (Deneba Systems Inc., Miami, FL, version 3.0.2).

4.5 Discussion of Results for Experiment IIb

4.5.1 Soil moisture-neutron probe data

The distribution of volumetric water contents is presented in a series of contour plots from data that is presented in Appendix A-2. Plots for day 0 show absolute water contents at the beginning of the experiment. Plots for subsequent days show water contents as differences in water content from day 0. A final series of contour plots show absolute water contents for day 525.

Water content contours are plotted for planes of measurement at $X_2 = 0$ meters, which lies lengthwise along the center of the irrigated plot, and $Y_2 = 2, 6,$ and 10 meters from the trench face, where each of these latter planes of measurement lie perpendicular to the length of the plot. The figures for $X_2 = 0$ represent a 15 m-long transect, monitored by 11 access tubes. Each of the planes in Y_2 represent 10 m-long transects, monitored by 11 access tubes (12 m long, 13 tubes after day 191). Therefore the plot-bisecting planes have a somewhat higher sampling density and greater density of data for plotting.

Figures 22 and 23 show the water contents on the first day of the experiment, day 0. These represent initial conditions for this experiment, following the redistribution of experiment IIa-applied water. The mean value for these 1025 individual measurements is $0.093 \text{ cm}^3/\text{cm}^3$.

Figure 22. Experiment IIb neutron probe volumetric water content on day 0 for a plane through $X_2 = 0$ m along the length of plot 2, and for a plane through $Y_2 = 2$ m parallel to the trench face.

Figure 23. Experiment IIb neutron probe volumetric water content on day 0 for planes through $Y_2 = 6$ m and $Y_2 = 10$ m parallel to the trench face.

Values range from a maximum of $0.229 \text{ cm}^3 / \text{cm}^3$ to a minimum of $0.027 \text{ cm}^3 / \text{cm}^3$, where both of these latter values were obtained from the same access tube at $Y_2 = 14 \text{ m}$. The apparent spatial variability illustrated by these plots is a strong indication that water content is layered within the profile. Relatively consistent layers of higher moisture content are found about 3.25 and 4.5 meters deep. Additional layers, more spatially variable, are suggested above those depths. Soil texture data collected from a profile at the face of the trench ($X_2 = -0.6 \text{ m}$) shows an abrupt increase in clay content at the 3.31 meter mark and a similar increase in calcium carbonate at 4.61 meters (Nash, 1990; Wierenga et al, 1989) which corresponds to these high-moisture-content lenses.

In the upper half of Figure 22 a zone of relatively high moisture content is found from about 2.75 m to 3.5 m depth, beyond the north end of the irrigated plot at $Y > 12 \text{ meters}$. The source of this moisture is uncertain. The bulk of this moisture appears in the profile after experiment Ila irrigation, following rain events. Undetected leaks in pondliner seams at the north end of the plot are likely sources for much of this moisture. A large section of this pondliner was defective, and contained a large number of poorly sealed seams. It was replaced before experiment Iib began. Also, near the end of Iib irrigation (day 66), a leaking union was discovered in the buried 1" PVC irrigation supply line, located about $X_2 = 13.5 \text{ m}$ and $Y_2 = 0.6 \text{ m}$. These combined sources contributed about 1 percent of the total water applied during experiment Iib, as measured with the neutron probe.

The next series of plots show water content differences for day 31, about halfway through the irrigation pulse (Figures 24 and 25). Again, note that these plots show moisture as differences in water content from day 0. By this time the leading edge of the wetting front had moved through the profile to about 3.5 to 4 meters depth, depending upon the location in Y_2 .

Lateral movement in the bisecting planes was about 2 to 2.5 meters and applied water was fairly evenly distributed across the $X = 0$ axis.

By day 73, three days after irrigation was discontinued, the wetting front was near the 6 meter depth mark (Figures 26 and 27). In the plot at X_2 meters wetting appeared somewhat more effective at $Y_2 = 6-8 \text{ meters}$. In the bisecting measurement planes the wetting front had moved laterally to about $X_2 \pm 3$ to 4 meters. The bulk of the applied and translocated water in the profile was found below 3 meters depth. In areas of soil above this depth layering of retained water is evident.

The next series of plots show water contents for day 126, 56 days after irrigation (Figures 28 and 29). The wetting front had continued to progress, though at a much slower rate. In all locations the front had passed below 6 meters, below the range of neutron probe measurement. There is further evidence of moisture layering and drying above 3 meters depth. Bisecting views of the plot show that water continued to move laterally, with more pronounced movement in portions of the profile above 3 meters depth.

The most recent data, from day 525, show that the observed pattern of redistribution was continued (Figures 30 and 31). Downward movement of water since day 126 was almost imperceptible. However, above 3 meters a drying front is evident. This new front appeared to lag the wetting front as applied water moved laterally from the plot. At $Y_2 = 6 \text{ meters}$ the wetting front had moved over 5 meters from the center of the irrigated area. At the $Y_2 = 6$ and 10 meter planes of measurement soil moisture values above 3 meters depth and between $X_2 \pm 2 \text{ meters}$ had almost returned to the initial conditions of day 0. What appears to be moisture migration from areas outside of the pondliner-covered area began to be measured downhill from the irrigated area, at $X_2 = 4$ to 6 meters. This moisture is likely the result of

Figure 24. Experiment IIb neutron probe volumetric water content differences on day 31 for a plane through $X_2 = 0$ m along the length of plot 2, and for a plane through $Y_2 = 2$ m parallel to the trench face. Values expressed as differences from day 0 water content.

Figure 25. Experiment IIb neutron probe volumetric water content differences on day 31 for planes through $Y_2 = 6$ m and $Y_2 = 10$ m parallel to the trench face. Values expressed as differences from day 0 water content. Small circles in plots indicate missing data.

Figure 26. Experiment IIb neutron probe volumetric water content differences on day 73 for a plane through $X_2 = 0$ m along the length of plot 2, and for a plane through $Y_2 = 2$ m parallel to the trench face. Values expressed as differences from day 0 water content.

Figure 27. Experiment IIb neutron probe volumetric water content differences on day 73 for planes through $Y_2 = 6$ m and $Y_2 = 10$ m parallel to the trench face. Values expressed as differences from day 0 water content. Small circles in plots indicate missing data.

Figure 28. Experiment IIb neutron probe volumetric water content differences on day 126 for a plane through $X_2 = 0$ m along the length of plot 2, and for a plane through $Y_2 = 2$ m parallel to the trench face. Values expressed as differences from day 0 water content.

Figure 29. Experiment IIb neutron probe volumetric water content differences on day 126 for planes through $Y_2 = 6$ m and $Y_2 = 10$ m parallel to the trench face. Values expressed as differences from day 0 water content. Small circles in plots indicate missing data.

Figure 30. Experiment IIb neutron probe volumetric water content differences on day 525 for a plane through $X_2 = 0$ m along the length of plot 2, and for a plane through $Y_2 = 2$ m parallel to the trench face. Values expressed as differences from day 0 water content. Small circles in plots indicate missing data.

Figure 31. Experiment IIb neutron probe volumetric water content differences on day 525 for planes through $Y_2 = 6$ m and $Y_2 = 10$ m parallel to the trench face. Values expressed as differences from day 0 water content. Small circles in plots indicate missing data.

runoff, where downhill sections of pondliner cover acted as a watershed, promoting rainwater entry to soil along the $X_2 = 8$ m limit of the cover (see Figure 21).

A final series of plots show day 525 water contents as observed values, not as differences from day 0 water contents (Figures 32 and 33). When compared to "day 0 differences" plots for day 525 (see Figures 30 and 31) the location of the observed wetting plume is about the same. However, soil moisture layering and spatial variability is much more prominently displayed in the "observed" contours. In Figure 33 the lateral extent of the wetting front, about 4.5 m in depth, may be underestimated because of missing neutron probe readings near the bottom of the $Y_2 = 10$ m transect. When compared to observed values at day 0 of the experiment (Figures 22 and 23) one finds that the strata of moisture-retaining areas of the profile are consistent. Above 3 m depth the profile appears much as it did on the first day of the experiment.

Below 3 m the moisture-retaining layers have higher water contents than on day 0, especially between $X_2 \pm 3$ to 4 meters. Perhaps the most notable feature of Figure 32 is the zone of high moisture content located at $Y_2 > 12$ m, about 2.75 to 4.25 m deep, that was discussed earlier. Compared to Figure 22, the location and extent of this high-moisture zone appears to have shifted only a little deeper and diminished little in the 525 elapsed days (Figure 33). During this time the size of this area increased slightly. A small area adjoining the bottom of the zone became wetter, perhaps supplying moisture to a moisture-retaining layer of soil about 4.5 m deep.

A summary of the observed moisture content means, standard deviations, maxima and minima for each neutron probe measurement plane of Figures 22 through 33 is given in Table 6. Note that these data are given as observed moisture contents (upper horizontal blocks in Table 6) as well as moisture content

differences from day 0 (lower blocks).

Additional data for a subset of the $X_2 = 0$ m measurement plane is shown for only those access tubes which were located within the irrigated area, to $Y_2 = 10$ m. As expected, these moisture values are higher than for other planes since tubes located in dryer portions of soil are not included. From this table it is evident that mean planar moisture contents increase from days 0 through 73 and then gradually decrease through day 525. Further, the soil planes at $Y_2 = 2$ m and 6 m hold similar amounts of moisture compared to the dryer $Y_2 = 10$ m plane of soil.

The progress of the wetting front is summarized for $Y_2 = 2$ meters in Figure 34. The arrival of the wetting front at a particular location was arbitrarily taken as the time for water content to increase by a value halfway between the maximum and initial (day 0) observed values and restricted to water content increases of at least 1 percent (Wierenga, et al., 1991). These criteria seem reasonable given the steep wetting curve for vertical water movement and random error in measurement. The figure shows that water moved, or influenced in-situ water translocation, quickly through portions of the profile which were previously wet during the irrigation of experiment IIa. At the center of the plot the downward progress of the wetting front averaged 11.3 cm d^{-1} during the first 31 days. From then until the end of the irrigation period the front slowed dramatically, moving an average of 4.2 cm d^{-1} between days 31 and 73. In the early stages of redistribution the front again slowed to an average of 1.9 cm d^{-1} between days 73 and 112.

A mass balance for neutron probe water was calculated as the ratio of combined water observed in access tube planes at $Y_2 = 2, 6,$ and 10 m to the total of water applied to the soil surface (Figure 35). Observed water contents were taken as differences from day 0, summed across all individual observations and their representative soil volumes in Y_2 . This ratio increases from day 0 to a maximum value of

Figure 32. Experiment IIb neutron probe volumetric water content on day 525 for a plane through $X_2 = 0$ m along the length of plot 2, and for a plane through $Y_2 = 2$ m parallel to the trench face. Small circles in plots indicate missing data.

Figure 33. Experiment IIb neutron probe volumetric water content on day 525 for plane through $Y_2 = 6$ m and $Y_2 = 10$ m parallel to the trench face. Small circles in plots indicate missing data.

Table 6. Mean water contents (cm^3/cm^3) and mean water content differences (cm^3/cm^3) for each of 4 observational planes at days 31, 72, 126, and 525.

Measurement	Day	Plane	Meters	N-obs	Mean	Stdev	Max	Min	Median
θ	0	X	0	262	0.107	0.0381	0.229	0.028	0.102
θ	0	Y	2	263	0.092	0.0278	0.176	0.035	0.087
θ	0	Y	6	262	0.091	0.0286	0.187	0.031	0.085
θ	0	Y	10	262	0.082	0.0283	0.170	0.035	0.076
θ	525	X	0	255	0.132	0.0403	0.229	0.029	0.132
θ	525	Y	2	298	0.113	0.0372	0.207	0.041	0.112
θ	525	Y	6	306	0.113	0.0349	0.209	0.033	0.115
θ	525	Y	10	282	0.096	0.0369	0.203	0.037	0.088
$\theta - \theta_0$	31	X	0	261	0.023	0.0275	0.087	-0.014	0.008
$\theta - \theta_0$	31	Y	2	262	0.008	0.0180	0.072	-0.011	0.001
$\theta - \theta_0$	31	Y	6	254	0.009	0.0173	0.076	-0.008	0.001
$\theta - \theta_0$	31	Y	10	255	0.009	0.0205	0.087	-0.007	0.001
$\theta - \theta_0$	73	X	0	261	0.045	0.0371	0.148	-0.006	0.042
$\theta - \theta_0$	73	Y	2	263	0.022	0.0313	0.132	-0.011	0.004
$\theta - \theta_0$	73	Y	6	259	0.024	0.0311	0.116	-0.011	0.007
$\theta - \theta_0$	73	Y	10	247	0.025	0.0353	0.130	-0.015	0.004
$\theta - \theta_0$	126	X	0	260	0.037	0.0379	0.157	-0.009	0.022
$\theta - \theta_0$	126	Y	2	262	0.024	0.0329	0.128	-0.013	0.010
$\theta - \theta_0$	126	Y	6	261	0.022	0.0299	0.114	-0.007	0.009
$\theta - \theta_0$	126	Y	10	241	0.024	0.0331	0.113	-0.021	0.008
$\theta - \theta_0$	525	X	0	254	0.025	0.0364	0.131	-0.030	0.009
$\theta - \theta_0$	525	Y	2	296	0.020	0.0285	0.115	-0.012	0.007
$\theta - \theta_0$	525	Y	6	305	0.022	0.0250	0.090	-0.009	0.012
$\theta - \theta_0$	525	Y	10	281	0.016	0.0268	0.099	-0.026	0.004

θ is water content (cm^3/cm^3)

$\theta - \theta_0$ is water content difference from day 0 (cm^3/cm^3)

Figure 34. Experiment IIb neutron probe wetting front in a plane through $Y_2 = 2$ m parallel to the trench face.

Figure 35. Experiment IIb neutron probe mass balance over time.

1.0008 at day 96. From day 86 through 103 the water balance was ≥ 0.99 of applied. As water began to leave the profile, as measured to 6 m depth, the ratio began to decline.

4.5.2 Soil moisture-tensions

The wetting (and drying) changes in the profile were also monitored at the trench face, $Y_2 = 0.5$ meters, with tensiometers located from $-2.11 \leq X_2 \leq 2.25$ meters. These data are found in Appendix A-3. A series of contour plots illustrates tension changes from days 0 through of the experiment (Figures 36 through 38), though data taken during the later periods of redistribution were sometimes compromised by faulty tensiometers. Day 525 measurements were compromised by insufficient equilibration time allowed between tensiometer fill-up and tension measurement. On day 0 tensions were recorded before irrigation began. A zone of relatively low tensions (higher water content), to about 3 m deep, was skewed to the east ($+X_2$). The median tension was 347 mb with tensions below 200 mb found only at 0.25 meters depth.

After irrigation began a low-tension plume quickly developed, moving downward and shifting to become more centered beneath the irrigated area. During irrigation a prominent pattern of quasi-stable tension ranges was observed for tensiometers that were placed near the center of the plot. After the wetting front reached a particular horizon, tension remained near a "set point" until irrigation was discontinued. This "set point" tension tended to increase with depth. By day 7 tensions from $-0.5 \leq X_2 \leq 0.5$ meters, to 0.75 m depth, dropped below 50 mb and remained there through day 70, with slightly lower tensions at 0.25 meters. Below 0.75 meters tension never dropped below 50 mb. Tensions below 100 mb were found as deep as 2 meters by day 14, and to 3 meters by day 33, though tensions below 4.5 meters never dipped below 100 mb.

The progress of the wetting front is summarized by tension isobars in Figure 39 and Figure 40. The first figure shows the arrival time of the wetting front measured as tension ≤ 100 mb (Wierenga et al, 1991). A regular pattern of wetting is apparent near the center of the plot down to 4 meters depth. Laterally, this wetting front reaches the east limit of measurement only from 2 to 3 meters depth and on the west side, only at a single point, 2 meters deep. Below 4 meters this pattern of wetting is disrupted. Recall that the final penetration of the experiment IIa wetting front was about 3 meters.

Figure 40 shows the arrival times of the wetting front as tensions dropped below 300 mb. Using the less restrictive limit of 300 mb tension, the wetting front extends to the lateral limits of tensiometer coverage more often and earlier than measurements restricted to more moist soil at 100 mb. Of further note, the 300 mb plot closely resembles the progress of the wetting front measured with the neutron probe at $Y_2 = 2$ meters (Figure 34).

When irrigation was discontinued after day 70 a new pattern of drying was observed in the profile. As expected, tensions near the soil surface began to change more rapidly than measurements taken at a greater depth. Within 2 days of the last irrigation tension began to increase quickly at depths of 0.25 and 0.75 meters. For the three tensiometers located from $-0.5 \leq X_2 \leq 0.5$, mean tension changed from 24 mb to 57 mb during the 2 day period at 0.25 meters depth (Table 7). This drying pattern continued in deeper soil for measurements collected from the (3) tensiometers centered below the irrigation area at each depth. Thus moisture flow was much faster near the surface than with soil depth in this early period of redistribution.

By day 112 most of the tensions at the "previously wetted" tensiometers (tensions ≤ 300 mb) throughout the profile had dried to a dryer, but more narrow range of variability.

Table 7. Mean tensions on days 70 and 72 for the three center tensiometer locations at each of six depths.

y (mb)			
Depth (m)	day 70	day 72	Δ (%)
0.5	24	57	137
0.75	45	70	56
2	56	61	9
3	56	62	10
4	76	81	7
5	122	121	-1

The median tension for all tension measurements at all depths changed from a median of 85 mb on day 70 ($n = 96$) to 217 mb on day 112 ($n = 100$). During those 42 days of redistribution, tensiometers "wetted" by day 70 showed a decrease in variability from $CV = 38\%$ to $CV = 12\%$. Redistribution of water caused tensions within the "wetted" portion of the profile to exhibit greater uniformity.

4.5.3 Tritium

Tritium was applied in two separate pulses to plot 2. In experiment IIa tritium input averaged 27,574 counts per minute and was applied during the first 11.5 days of 75.5 total days of irrigation. For experiment IIb applied tritium concentration was about 0.622 of that first pulse, at 17,142 counts per minute during days 29-44 of 70 days of irrigation. For this discussion tritium is normalized for input of the second pulse, so $C/C_0 = 1$ when observed counts = 17,142. Note, however, that the experiment IIb tritium data is presented in the appendix as values normalized for the experiment IIa pulse (Appendix A-4).

Solutions were collected from solution samplers on day 0, just before initiating irrigation. These

first samples were drawn in order to quantify residual plume tritium of experiment IIa. In the most shallow samplers (0.5 meters depth) concentrations as high as 5 percent of IIa input were found. The extent of this plume is poorly defined; because of the relatively dry soil only a limited number of solution samples could be drawn from the profile, so the contour plot (Figure 41) is represented by few observations. Within this plume the highest concentration (0.203 of IIa input) was found at 1 meter depth. The center of the plume was located about 0.75 meters to the east of the center of the plot and about 1 meter deep, similar to the location of the day 0 plume of low-tension values (Figure 36).

By day 33 the new experiment IIb pulse of tritium was 4 days in progress and not yet detected at the $Z_2 = 0.5$ meter row of solution samplers. The center of the older, experiment IIa plume, had moved to about 2 meters depth, though the neutron probe wetting front at $Y_2 = 2$ meters (Figure 34) and the 300 mb tensiometer tension front (Figure 40) had moved below 3 meters. The older tritium plume shifted medially similar to the zone of lower tensions.

The bottom of the new tritium plume was well developed by day 47, 3 days after the last application of new tritium. The leading edge of

Figure 36. Experiment IIb soil tension contours at $Y_2 = 0.5$ m from trench face for days 0, 7, 14, and 33 of the experiment. Median tension values are shown within individual plots.

Figure 37. Experiment IIb soil tension contours at $Y_2 = 0.5$ m from trench face for days 47, 61, 72, and 79 of the experiment. Median tension values are shown within individual plots.

Figure 38. Experiment IIb soil tension contours at $Y_2 = 0.5$ m from trench face for days 112, 147, 281, and 525 of the experiment. Median tension values are shown within individual plots.

Figure 39. Experiment IIb soil tension front at $Y_2 = 0.5$ m from trench face.
Front delimited by tensions less than or equal to 100 mb.

Figure 40. Experiment IIb soil tension front at $Y_2 = 0.5$ m from trench face.
Front delimited by tensions less than or equal to 300 mb.

the new pulse was found at samplers 1.5 meters deep. For the portion of the plume which could be observed at and below 0.5 meters, the center of mass was located east of $X_2 = 0$ m. The center of mass appeared to remain east of the center of the plot throughout the experiment. By day 70, the new plume was readily distinguished from the old. The new plume appeared to have divided into two main bodies separated across the $X_2 = 0$ meter axis. These bodies can be distinguished in contour plots throughout the remainder of the experiment.

During redistribution the new tritium plume moved very slowly (Figure 42). The top of the plume appeared to remain fixed about 1 meter deep with some lateral migration, while the bottom of the plume moved slowly downward. Generally, lateral movement appeared more pronounced towards the top of the plume. From days 79 to 525 the leading edge of the new plume moved from about 2.5 m depth to almost 4 m while the center of the plume (mass) moved from about 2 m to about 2.5 m. These observations are generally supported by breakthrough curves for individual solution samplers.

A series of plots illustrate tritium breakthrough curves across a range of soil depths for fixed locations in X_2 (Figures 43-45). Again tritium data for these plots are normalized for experiment IIb input. In general, close examination of these data shows that the first pulse of tritium (experiment IIa) is distinguishable from the second pulse tritium and is the dominant source of observed tritium in deeper portions of the profile.

Figure 43 shows breakthrough curves for solution samplers at $X_2 = 0.25$ meters, those nearest to the center of the plot. Remnants of the experiment IIa pulse are evident in all the curves. Only at 0.5 and 1 m depths are the two tritium pulses fully separated. Comparing peak-to-peak concentrations during irrigation, the pulses are separated by 37 days at 0.5 m depth

and by 42 days at 1 m. Below this depth the separation of the two pulses is less clear. At 3 m the first pulse appears between days 33 and 35 (measured as an increase of 1% of input). This pulse appears on day 65 at 4 meters depth, and gradually decreases in concentration after day 200 to a low of 0.10 by day 525. Tritium appears at 5 m on day 126 and gradually increases to a maximum of 0.06 by day 525. The downward redistribution of second-pulse tritium is best illustrated at 3 m depth; from a local low concentration on day 93 of 0.06, which is a likely crossover day between the first and second pulses, tritium slowly increases to 0.35 by day 525.

Complete breakthrough curves for second-pulse tritium are generally found only for samplers located at 0.5 and 1 m depth. At $X_2 = 0.25$ m (Figure 43) the highest concentrations are not centered above the tritium mass. At 0.5 m depth the highest concentration occurs on day 42 (0.963 of input), though the center of the peak is better located on day 44 (0.920). Similarly, at 1 m depth, the highest concentration occurs on day 47 (0.841), though the center of the breakthrough is better estimated by day 51. From the estimated center-to-center of breakthrough concentrations the peaks were separated by 6 days. At $X_2 = 0.75$ m (Figure 44) the highest concentrations were better placed above the center of the breakthrough. In this case, peak concentration at 0.5 m depth occurred on day 51 (0.895) and the concentration at 1 m depth occurred on day 56 (.952), with the peaks separated by only 5 days. Comparative breakthrough curves for 0.5 and 1 m depths appear similar in magnitude and relative timing across X_2 , though the delay between laterally distant curves at $X_2 = 0.25$ and 0.75 meters is about 5 days.

The beginning and endpoints of curves at $X_2 = 0.25$ m, defined here as $C/C_0 \leq 1$ percent of input, were from days 35 to 58 (23 days wide) for the 0.5 m depth curve and from days 40 to 70 (30 days wide) for the 1 m depth curve.

Figure 41. Experiment IIb tritium contours at $Y_2 = 0.5$ m from trench face for days 0, 33, 47, and 70 of the experiment. Concentrations as C/C_0 normalized for experiment IIb input.

Figure 42. Experiment IIb tritium contours at $Y_2 = 0.5$ m from trench face for days 79, 112, 281, and 525 of the experiment. Concentrations as C/C_0 normalized for experiment IIb input.

Respective base widths for those curves at $X_2 = 0.75$ m were 28 and 38 days wide. This indicates greater plume dispersion at positions where $X_2 = 0.75$ m than counterpart curves at $X_2 = 0.25$ m.

At $X_2 = 1.25$ meters (Figure 45) the second-pulse breakthroughs occurred after the end of irrigation. The timing of tritium arrival and the magnitude of concentration increases, is reversed of what might be expected for depths from 0.5 to 1.5 meters. Second-pulse tritium arrived about day 79 at 0.5 m depth, about day 63 at 1 m and about day 65 at 1.5 m depth.

These breakthrough curves indicate that there was some overlap between the first and second pulses of applied tritium, especially at $X_2 = 0.25$ m locations. Concentrations of first pulse tritium at 1.5, 2 and 3 m depths do not reach $C_o = 0$ before beginning to increase with the appearance of the second pulse. However, this pulse overlap is not as apparent at more lateral samplers at $X_2 = 0.75$ and 1.25 m. Perhaps this effect is the result of time lags created in the vertical displacement of tritium by horizontal shifting of portions of the plume to and from the area of soil directly below irrigation drippers.

4.5.4 Chromium, boron and PFBA

Chromium, boron and PFBA solutes, all anions, were applied together in the first solute pulse, from days 0 to 15. Inter-ion comparisons are difficult because the quality and quantity of data sets are quite variable. Of the three, chromium is the most complete data set (1313 observations) and is of good quality. Although boron was analyzed in the same ICP run with chromium, the boron results are unsatisfactory. Boron analysis was troubled by a drifting baseline and probable detection of interfering solutes. The causes of this poor ICP performance for this species are uncertain. During the initial ICP set-up, several different monochromat or wavelengths were used in

attempts to correct these problems, but with little effect. Boron data was unacceptable and is not presented. The PFBA data set is limited by quantity, comprised of 178 total observations from solution samples collected on 5 different days. Thus, PFBA contour plots are based on relatively few observations.

The chromium data is presented in Appendix A-5. Chromium, applied as chromate ion during the first 15 days of irrigation, was first observed ($C/C_o \geq 1\%$) at 0.25 m depth on day 7. By day 30 the leading edge of the chromate plume was down to 1.5 meters with the highest observed concentration (0.55 of input) at $X_2 = 0.75$ meters (Figure 46). The largest portion of the plume was skewed to the east side of the plot, though this observation is based upon contour plots drawn with few horizontal data points per measurement depth.

At the end of irrigation, day 70, the leading edge and the highest concentration of the plume coincided at approximately 4 m depth. By day 525, chromate was observed as deep as 5 meters with a peak concentration at 4.5 m. Note that chromate contour plots are based upon relatively few data points per plot and with many data values missing from the grid of solution samplers.

Chromate breakthrough curves are more instructive. Individual samplers tended to yield enough solution to complete several solute analyses on any given day of sampling. This resulted in more complete day-to-day data sets for selected samplers. Data from the more productive samplers are presented for various depths at $X_2 = 0.25$, 0.75 and 1.25 meters (Figures 47, 48, and 49). Note that different time scales are used for top and bottom plots on a page. The areas beneath the chromate curves above 1.5 meters depth do not account for the total mass of chromium applied. Peak concentrations never reach 80 percent of input. This loss is probably the result of reduction of chromium (VI) to insoluble chromium (III) in

Figure 43. Experiment IIb tritium breakthrough curves at $X_2 = 0.25$ m and samplers at various depths. Concentrations as C/C_0 normalized for experiment IIb input. Isolated symbols boxed to the right of the plots indicate day 525 concentrations. Vertical dashed lines indicate the end of plot irrigation.

Figure 44. Experiment IIb tritium breakthrough curves at $X_2 = 0.75$ m and samplers at various depths. Concentrations as C/C_0 normalized for experiment IIb input. Isolated symbols boxed to the right of the plots indicate day 525 concentrations. Vertical dashed lines indicate the end of plot irrigation.

Figure 45. Experiment IIb tritium breakthrough curves at $X_2 = 1.25$ m and samplers at various depths. Concentrations as C/C_0 normalized for experiment IIb input. Isolated symbols boxed to the right of the plots indicate day 525 concentrations. Vertical dashed lines indicate the end of plot irrigation.

the presence of organic matter in the top 0.5 m of the profile.

Chromate analyses for samplers directly below the irrigation system, at $X_2 = 0.25$ m are shown in Figure 47. By the end of irrigation breakthrough curves for samplers from 0.5 through 3 meters depth were fairly complete. By the end of the irrigation period element concentrations were increasing at 3.5 m depth. Breakthrough curves at $X_2 = 0.75$ m (Figure 48) were similar in appearance, but more advanced in time than at $X_2 = 0.25$ m. For example, at those samplers located 1.5 m deep, chromium first appeared at $X_2 = 0.75$ m on day 23 and at $X_2 = 0.25$ m on day 28. Elution of chromate through samplers at 3 m depth was likewise more complete by the end of irrigation at $X_2 = 0.75$ m than at 0.25 m. Interestingly, these data and supporting contour plots indicate that chromium moved more freely in areas of soil outside of the zone directly below the irrigation drippers.

At $X_2 = 1.25$ m the first appearance of chromium at 1.5 m depth was on day 35, well behind samplers located more medially (Figure 49). However, at 3.5 m and 4 m depths the timing of chromium appearance and behavior are very similar to the more medial samplers. Comparisons of shallow and deep sampler data indicate that, as the chromium plume progressed deeper, lateral dispersion was significant enough to cause the chromium to migrate downward in broader plumes. This led to closer arrival times at adjacent samplers at the same depth.

During irrigation chromium appeared to progress through the profile at about the same rate as tritium, at least near the soil surface (Figure 50). The similarity of elution patterns for the two solutes is striking. At $X_2 = 0.25$ m the chromium breakthrough at 0.5 m depth is centered about day 15, estimated between measurement days 14 and 16, rather than on day 19 where the highest concentration occurred.

For tritium this concentration peak occurred about 15 days after the first tritium was applied to the surface. For samplers located below 2 meters deep inter-solute comparisons are difficult to make since second-pulse tritium appears at those deeper solution samplers after plot irrigation ceased. At 1.5 meters depth about the same time elapsed between the first application of solute the soil surface and the arrival times ($C/C_0 > 0.01$) of chromium and second-pulse tritium; at about 28 and 29 days respectively. Chromium peaked on day 44.

Second-pulse tritium concentration was yet increasing when irrigation was discontinued. Note that the time axis of Figure 50 is scaled for days after the beginning of the respective solute applications, where in fact, the solute pulse containing tritium was started 29 days after the pulse containing chromium. On this scale irrigation ended on day 70 for chromium and on day 41 for tritium.

One of the most striking features of the chromium breakthrough plots, when compared to those for tritium, is the post-irrigation elution of the chromate plume through the profile. During redistribution the chromate plume continued to elute effectively to depths of 4.5 to 5 m below the irrigated area (Figure 47) and at locations lateral to center (Figures 48 and 49).

By contrast, the tritium plumes developed very slowly after irrigation was discontinued (Figures 43-45). Tritium tended to remain near fixed concentrations beyond day 100 while the chromate plume continued to move. For example, at 5.0 m depth chromate first appeared on day 170 and then reached a high concentration of $C/C_0 = 0.25$ of input by day 525 ($X_2 = -0.25$ m). At the same depth tritium first appeared on day 112 and then gradually reached a high concentration of $C/C_0 = 0.06$ at the same sampler, almost certainly an observation of experiment IIa solute. It is evident that during redistribution the vertical progress of chromium was faster than for tritium.

Figure 46. Experiment IIb chromium contours at $Y_2 = 0.5$ m from trench face for days 30, 70, 112, and 525 of the experiment. Concentrations as C/C_0 .

Figure 47. Experiment IIb chromium breakthrough curves at $X_2 = 0.25$ m and samplers at various depths. Concentrations as C/C_0 . Vertical dashed lines indicate the end of plot irrigation.

Figure 48. Experiment IIB chromium breakthrough curves at $X_2 = 0.75$ m and samplers at various depths. Concentrations as C/C_0 . Vertical dashed lines indicate the end of plot irrigation.

Figure 49. Experiment IIb chromium breakthrough curves at $X_2 = 1.25$ m and samplers at various depths. Concentrations as C/C_0 . Vertical dashed lines indicate the end of plot irrigation.

Figure 50. Experiment IIb chromium and tritium breakthrough curves at $X_2 = 0.25$ m and samplers at 0.5 and 1.5 m depths. Tritium curves shifted to the left by 29 days to normalize pulse applications at the soil surface. Concentrations expressed as C/C_0 .

This is most likely related to the fact that chromium was applied before tritium, and therefore, was already deeper in the profile at the time redistribution started.

PFBA was analyzed for days 0, 14, 30, 47, and 70. The progress of PFBA is given by contour plots in Figure 51. The first PFBA was found on day 14 at only three locations at 0.5 m depth, with a high concentration of 0.76 of input, at $X_2 = 0.25$ m. By day 30 PFBA was found at locations from 1 to 2.5 meters depth with the largest portion of the plume found west of the plot centerline. On day 47 the bulk of observed PFBA was found east of the plot centerline, to 3 m depth, and with a peak concentration of 0.85 of input at $X_2 = .75$, at the 3 m depth. By day 70 the plume seemed to divide into several bodies with appreciable concentrations of solute stratified from 0.5 m through 4.5 m depths and evidence of lateral movement to $-1.75 \geq X_2 \geq 1.75$. On that day the highest concentration of PFBA (0.77) was found at $X_2 = 1.25$ at the 3 m depth.

4.5.5 DFBA and bromide

DFBA data are available for days 47 and 70 only (Figure 52, Appendix A-6). On day 47 DFBA was found between 0.5 and 1.5 m depth and between -0.75 and 0.75 m in X_2 . Input concentration ($C/C_0 = 1$) was attained at 0.5 m and 1.0 m depths at $X_2 = 0.25$ m. The center of mass was shifted to the positive X_2 direction.

By day 70 DFBA spread laterally from $X_2 = -1.25$ m to 0.75 m and to 3.5 m depth. The highest concentration was found at 2.5 m depth. The plume appeared to have divided into several bodies, with a center of mass shifted to the $-X_2$ direction. However, these observations on day 70 are somewhat speculative because of the limited number of data points to represent the grid.

The evaluation of bromide is complicated by bromide presence in the profile at the beginning of the experiment and by missing values in the grid of solution samplers. In the IIa experiment bromide was applied at a relatively high concentration of 939 mg/L. In experiment IIb bromide ion was applied from days 29 through 44, at a much lower concentration, 28 mg/L, or about 3% of experiment IIa input. Samples from days 0, 14, 30, 47, and 70 were analyzed. Figure 53 shows bromide results normalized for experiment IIa input (Appendix A-6).

Concentrations above twice those of experiment IIb input are shown as solid black.

On day 0 bromide ion is present in all five analyzed samples, to 3 m depth, at concentrations 0.26 to 5.23 times experiment IIb input. Likewise, bromide observed on days 14 and 30 is remnant solute applied during experiment IIa, with a high concentration on day 30 of 417 mg/L at 2 m depth ($X_2 = 0.75$ m). Considering only the four solution samplers at $X_2 = 0.25$ and 0.75 m, and from 0.5 to 1 m depth, bromide concentration decreased from a mean value of 0.68 on day 14, to 0.04 on day 30, and then increased to 1.09 by day 47. Finally, relative concentration for these samplers decreased to 0.32 by day 70. The separation of experiment IIa and experiment IIb plumes may be discerned near the center of the plot, possibly to a depth of about 3.5 m by day 70.

An unexpectedly high concentration of bromide appears at a single sampler, 1.5 m deep at $X_2 = 0.75$ m on day 47 ($C/C_0 = 2.51$). Also, peak concentrations of experiment IIb bromide are often above 1 which indicates incomplete elution of experiment IIa bromide before the arrival of the second plume or, more likely, some concentration of solutes within sample vials by evaporation during storage (Appendix C-3). As with other solutes, overall elution appears more effective to the positive X_2

Figure 51. Experiment IIb PFBA contours at $Y_2 = 0.5$ m from trench face for days 30, 47, and 70 of the experiment. Concentrations as C/C_0 .

Figure 52. Experiment IIb DFBA contours at $Y_2 = 0.5$ m from trench face for days 47 and 70 of the experiment. Concentrations as C/C_0 .

Figure 53. Experiment IIb bromide contours at $Y_2 = 0.5$ m from trench face for days 14, 30, 47, and 70 of the experiment. Concentrations as C/C_0 are normalized for experiment IIb application of the solute.

direction. Other anomalous plume behavior seen in the contour plots is at least partly attributable to missing values from the sampler grid on certain measurement dates.

4.5.6 Nitrate and chloride

The progressive leaching of chloride and nitrate ions from the profile is illustrated by a series of contour plots in Figures 54 and 55 (data in

Appendix A-6). These plots show that the movement of these ions inversely track the progress of the applied wetting front and other applied solutes. With time the in-situ concentration of both ions in front of wetting increased to values well above what was originally present in the soil before the irrigation experiments began (Appendix C-2). The ratio of median chloride to nitrate ions concentrations (me/L) is 2.95.

Figure 54. Experiment IIb nitrate ion contours at $Y_2 = 0.5$ m from trench face for days 14, 30, 47, and 70 of the experiment. Concentrations as mg/l of soil solution.

Figure 55. Experiment IIb chloride ion contours at $Y_2 = 0.5$ m from trench face for days 14, 30, 47, and 70 of the experiment. Concentrations as mg/l of soil solution.

 

5 Experiment IIb Redistribution Cores

5.1 Core Collection and Processing

The second set of soil cores was collected from 24 boreholes within Plot 2 beginning on May 20, 1991, 222 days after the last irrigation of experiment IIb. This second set of cores was more extensive in number and depth than cores taken after experiment IIa. Like those first cores these were also taken at $Y_2 = 5.0$ and $Y_2 = 9.0$ meters from the trench face except that the new boreholes were offset in the X_2 direction by 0.25 m from the first set. Relative to the center of the irrigated plot, the cores were taken at $X_2 = -2.75, -2.25, -1.75, -1.25, -0.75, -0.25, 0.25, 0.75, 1.25, 1.75, 2.25$, and 2.75 meters to a depth of about 6.4 meters (Figure 56).

The JMC Environmentalist probe (Clements Assoc., Newton, IA) used to collect these cores utilizes a lined sample tube (Kodar PETG co-polyester 6763) which takes 2.29 cm - diameter soil cores in 3' intervals of soil depth. For each core the soil probe was hammered into the soil for 3' then removed from the borehole to collect the liner and sample. Seven cores were taken from each borehole to a total depth of 21'.

At depths below the first three foot intervals a layer of contaminant soil was often found with the desired soil core, presumably to have fallen into the open borehole when the probe was removed. This material was easily distinguished from the core of interest and was removed from the liner before further handling. Soil recovery within each 3' liner section was usually better than 80% after removing contaminant material.

The final sample handling in the field included trimming the liner material to flush with the soil core, sealing both ends with vinyl caps and then removing core sections in a protected location out of direct sunlight. At the end of the day cores were taken to the laboratory for further processing.

Each 3' core section was divided into four equal-length core segments. The center of each segment was assigned a depth (Z meters) by proportioning the length of the recovered soil core to the column of soil being sampled (3'). The accuracy of this scheme assumed that the core contained a uniform representation of the 3' in-situ profile, and that compaction of the core or losses of soil to the perimeter of the sample tube occurred uniformly with depth. Each segment was capped with a vinyl cap and then weighed to the nearest 0.001 g on a Sartorius E2000D (Brinkman Instrument, Inc., Westbury, NY) balance, which was used for all subsequent mass measurements. Segments were then placed in refrigerated storage.

Core segments were divided into two sub-samples. One sub-sample was oven-dried to determine moisture content. The other sub-sample was diluted with water and then extracted with a Buchner funnel apparatus to yield liquid solution samples. These solutions were analyzed for tritium, chromium, chloride, and nitrate solutes.

Any segments to be used in a particular day were taken from storage, organized on a workbench and then brought to room temperature. Each segment was reweighed to determine evaporative loss during storage. From this point forward care was taken to minimize the exposure time of the soil sample to evaporation. Soil within the liner segment was placed into a plastic beaker and then lightly crushed and mixed with a metal spatula. Since the sample size was relatively small any non-representative coarse fractions were removed, weighed separately and then discarded. Those were usually less than 1% of the total mass. At this point the sample was divided into two sub-samples, one for a determination of gravimetric water content and the other for liquid extraction.

Figure 56. Location of experiment IIb soil cores relative to irrigated plot, earlier experiment IIa soil cores, and nearby neutron probe access tubes.

An average of 36% of each fresh sample was used for moisture determination. Soil was spooned from the beaker into a tared aluminum soil can, reweighed and then placed in a 105° C oven for 24 hours to determine gravimetric moisture content. Samples were removed from the oven, reweighed, and then sieved through a 2 mm metal sieve. The fraction of material which was larger than 2 mm was weighed to determine the percentage of coarse materials, resulting in an average mass of 25% of the sub-sample (range from 2-59%). This coarse fraction generally was quite small near the soil surface but increased with depth. All oven-dried fractions were discarded after weighing.

Gravimetric water content values were converted into volumetric water units by using an estimated term for soil bulk density. This parameter was estimated from soil cores collected during the original trench characterization work, near the plane at $Y_2 = 0$ m.

The second sub-sample was moistened with distilled-deionized water to make a solution extract. The goal of dilution was to add the least amount of water necessary to extract sufficient solution to complete the chemical analyses yet provide meaningful analytical results. A-priori estimates of 6% fresh soil moisture content (by weight) and a 5 times maximum dilution of that moisture were used to calculate a ratio of 0.24 g added water/1.0 g fresh soil as a target dilution rate. The sub-sample was weighed in its original plastic beaker. After re-taring the balance, distilled-deionized water was slowly added to the sub-sample to an amount equal to 26% of the fresh soil weight, on average. The dilution was varied according the sub-sample texture and moisture content as judged by the technician. The diluted samples were then stirred with a metal spatula for about one minute, covered with an acrylic plate which closely fit the rim and then allowed to stand for 20 minutes. The soil paste was briefly stirred once more during the standing period.

A ceramic Buchner funnel apparatus was used to extract the paste samples. A bank of 15 Buchner funnels was plumbed to a common vacuum source, about 425 mb strong. Each funnel was fitted with a 5.5 cm-diameter disk of Whatman's #42 ashless filter paper. During filtration the Buchner funnel was covered to reduce evaporation. Filtrate was collected in a 13 dram polypropylene vials and then transferred to 20 ml glass scintillation vials. These vials were wrapped with Parafilm® before being placed in refrigerated storage.

5.2 Methods: Sample Analyses

For the preparation of samples for tritium analysis 0.5 ml aliquots of sample were mixed with 5.0 ml of Ready-Safe liquid scintillation cocktail (Beckman Instruments, Inc., Fullerton, CA) in "Mini-Poly Q" 8 ml scintillation vials (Beckman Instruments, Inc.) and run as single replications with a Beckman model LS1800 scintillator in "auto-run" mode. Raw counts were taken for 10 minutes per sample within a single-channel counting window of 0-400 nm. Vials with less than 16 counts per minute, an approximate background count, were terminated within 1 minute of the routine.

A sequence of tritium analyses began by counting a series of five background vials and five tritium input sample vials. Background vials were prepared with 0.5 ml aliquots of un-traced well water in place of solution sample in the scintillation vials. The input vials were prepared with 0.5 ml aliquots of traced well water, that had been collected from the 300 gallon solute tank on 9/4/90. This stock of input traced water was refrigerated in a 3 L capped glass bottle.

Tritium data is expressed as a relative concentration, the ratio of adjusted tritium concentration of individual samples (C) to the adjusted tritium concentration applied to the plot during the irrigation of experiment IIb (C_0):

$$\text{Relative Concentration} = \frac{C}{C_0}$$

$$= \frac{\text{Diln}(C' - \text{Bkg})}{C_0' - \text{Bkg}}$$

where Diln is the dilution factor of in-situ (fresh) soil moisture with added water, and Bkg is the mean background counts per minute for the five vials of a run. For calculation of relative concentration mean counts for the five vials of input solution were used, a value which varied slightly between analytical runs.

Tritium is also calculated on the basis of experiment IIa input concentration:

$$\text{Relative Concentration} = \frac{C}{C_0}$$

$$= \frac{\text{Diln}(C' - \text{Bkg})}{C_0' - \text{Bkg}} \times 0.9379$$

In this case C_0 is a constant value, the counts per minute of tritium applied during experiment IIa (27,574). The constant 0.9379 is used to normalize counts for the equivalent use of Aquasol (Dupont New England Nuclear, Boston, MA), the scintillation cocktail used for experiment IIa. The cocktail used for the experiment IIb analyses was Ready-Safe, which has a higher counting efficiency than Aquasol (Appendix B-2).

Chloride was analyzed with a Buchler model 4-2500 chloridometer (Buchler Instruments, Inc., Ft. Lee, NJ) which utilizes timed Ag/AgCl titration to determine chloride ion. Before using the instrument the silver electrodes were thoroughly cleaned with a commercial silver cleaner or replaced with new electrode wire, depending on the condition of the wire. The instrument was switched to high sensitivity mode, which provides a detection limit of about

0.3 me/l. Ten replicated readings of 10 me/L chloride standard were used to make a one-point calibration curve. Ten replications of background correction vials were prepared with distilled-deionized water and read. The high number of replications was used to ensure stable instrument performance before analyzing sample extracts. Sample titrations were performed with 0.10 to 1.00 ml volume aliquots, depending on the concentration of Cl^- within the sample. Samples were read as single replications.

Nitrate analysis was performed with a Technicon AutoAnalyser II (Technicon Industrial Systems, Terrytown, NY) in the New Mexico State University Soil & Water Testing Laboratory. This instrument determines nitrate by a colorimetric procedure; a copperized cadmium column is used to reduce sample nitrate to nitrite in the presence of NH_4Cl . The resulting nitrite is treated with a colorizing agent to form a pink color. A colorimeter is then used to measure absorbance of the colorized solution at 540 nm.

The sample extracts were first screened for approximate nitrate content by using nitrate test strips (EM Science Inc., Gibbstown, NJ). From these approximations the final sample dilutions to bring the samples into the working linear range (0-10 mg/l) of the AutoAnalyser were determined. Samples were diluted from 1x (full strength) to 100x with distilled-deionized water in dilution steps of no more than 10x per dilution. The instrument was calibrated with a 1 mg/L N-NO_3 standard to produce a single-point calibration curve. The instrument was recalibrated with two replications of nitrate standard for every 10 sample extracts in a sequence of runs.

Chromium was analyzed with a Perkin-Elmer model 6000 inductively coupled plasma instrument (ICP) and a model 7500 integrated computer (Norwalk, CT). The linear working range given by Perkin-Elmer for this instrument

is from 0.02-300 mg/L for chromium, with a detection limit of 0.004 mg/L. In practice, the detection limits were found to be much higher for this machine, 0.029 mg/L.

The ICP was programmed to measure spectral emission of chromium at 267.716 nm, then switch the monochromator wavelength to 249.77 nm for boron. The instrument was calibrated with a series of three solutions; a standard containing 10 ppm chromium and 10 ppm boron, a blank of distilled-deionized water and a second standard to check reproducibility. This calibration procedure was repeated after every 15 samples.

Samples were transferred to 15 ml polystyrene conical tubes (Becton Dickinson, Lincoln Park, NJ) and then placed in the ICP auto-sampler rack in groups of 50 samples (including calibration tubes). The run would begin after allowing the machine at least 20 minutes to warm up and produce a stable plasma field, which was confirmed by successful calibration.

5.3 Results and Discussion

Neutron probe volumetric water content (day 310) is compared to soil core volumetric water content ($\approx$ day 293) in Y_2 planes separated by 1 meter. Neutron probe data from day 310 are found in Appendix A-2. Data for soil core moisture and solutes are found in Appendices A-7 and A-8.

Neutron probe moisture at $Y_2 = 6$ m is compared to soil core moisture at $Y_2 = 5$ m (Figure 57). Similar comparisons are made between $Y_2 = 10$ m (probe) and 9 m (core) planes (Figure 58). Note that soil core sampling density was about 2 times greater than neutron probe sampling density. Within each plane neutron probe measurements were made on 1 m intervals in X_2 and 0.25 m intervals in depth, or

about 168 measurements per Y_2 soil core measurement plane is defined by 0.5 m intervals in X_2 and 0.225 m intervals in depth, or about 320 measurements per Y_2 -plane, to 6 m depth. Altogether, the two soil core planes are represented by 666 measurements to a depth of 6.3 m.

By day 310 the lateral redistribution of experiment IIb applied water (measured by neutron probe) had largely exceeded the $X_2 \pm 2.75$ m bounds of the soil cores (Figure 59). Therefore the soil cores did not fully sample the extent of lateral spread of applied water. Lateral heterogeneities between neutron probe and soil core water distributions are expected to be minimal.

In terms of vertical distribution the bulk of applied water had moved below the 3 m depth mark by day 310. In absolute water content, higher overall moisture contents are found in those measurements taken below 3 m depth, a feature common with neutron probe and soil core measurement planes.

Though the comparative water distributions are similar the mean planar moisture contents differ. The mean neutron probe water contents were 0.113 and 0.109 at $Y_2 = 6$ and 10 m, respectively. Mean soil core water contents were 0.121 and 0.123 at $Y_2 = 5$ and 9 m, respectively, for an overall difference of about 1% in measured water content by volume. These differences may be due to the use of estimated terms for bulk density for the soil cores, an inaccurate calibration curve for the neutron probe or, less likely, consistent real differences between water contents at the measured planes.

The most striking feature of all the comparative moisture plots is the layering of high-moisture-content zones in the profile. These zones are located at nearly identical depths in all Y -planes but are more clearly defined by the soil cores.

Figure 57. Experiment IIb redistribution cores volumetric water at $Y_2 = 5$ m compared with neutron probe volumetric water at $Y_2 = 6$ m.

Figure 58. Experiment IIb redistribution cores volumetric water at $Y_2 = 9$ m compared with neutron probe volumetric water at $Y_2 = 10$ m.

Figure 59. Experiment IIb neutron probe volumetric water content differences on day 310 for planes of access tubes at $Y_2 = 6$ m and $Y_2 = 10$ m from the trench face. Values expressed as differences from day 0 water content.

This added definition is probably due to two factors: the higher sampling density in the soil cores and the non-point, "sphere of influence" measurement of moisture by the neutron probe. In addition to lenses of high-moisture-content soil at 3.25 and 4.5 m depth, the soil core contour plots disclose less distinct lenses about 0.5 and 1.5 m deep that are not evident in the neutron probe data.

As with the high-moisture lenses of soil at 3.25 and 4.5 m depth, which were discussed earlier in this report, the 0.5 and 1.5 m lenses may be associated with soil morphological properties. Soil morphology data collected from the trench face at $X_2 = -0.6$ m indicates a lithologic discontinuity at 1.7 m depth, the boundary between the Isaacks' Ranch and Jornada II soil units. About 1.5 m deep in the trench face the content of clay and silt abruptly decreases relative to sand. Likewise, the lens at 0.5 m depth may be associated with an abrupt increase of calcium carbonate content that was identified between 0.42 and 0.56 m deep along the trench face (Nash, 1990). The validity associations of these assume isotropic continuity of soil properties from the trench face to the planes of measurement.

Soil tritium observations are contoured in Figures 60 and 61 as the concentration of tritium relative to experiment IIb input solution. Tritium elution appeared to be more effective at $Y_2 = 9$ m than at 5 m. While lateral redistribution appears similar between the two measurement planes the leading edge of the combined tritium plumes (experiments IIa and IIb) occurs about 4.75 m deep at 5 m and about 5.5 m deep at 9 m. For $Y_2 = 5$ m the maximum observed concentration was found at 1.9 m depth, $X_2 = -0.70$ m (58 percent of input concentration). At $Y_2 = 9$ m the maximum concentration was found at 2.9 m depth, $X_2 = -0.25$ m (55 percent).

Note that the relative distribution of tritium within the two planes is in marked contrast to

the distribution of first-plume tritium of soil cores collected after experiment IIa. Recovery of applied tritium mass within the two measurement planes was 81.9% at $Y_2 = 5$ m and 101.5% at $Y_2 = 9$ m. Unlike the data used for contour plots these calculations of mass balance were adjusted for radioactive decay of tritium input through the day of sample analyses. For these calculations, the input mass and decay of experiment IIa and experiment IIb pulses were treated separately.

Separation between the first and second pulses of tritium is recognizable in the plots though there appears to be significant overlap. Without the breakthrough curve analysis presented earlier in this report the interpretation of these contour plots might have led to the conclusion that the two pulses had nearly coalesced. Note that the first-pulse of tritium, at the bottom of the plume, has relatively low activity compared to the second pulse, even though the initial concentration of tritium in the first pulse was 1.61 times more concentrated. This reduced first-pulse activity was also found in the soil core samples taken after the experiment IIa irrigation.

The results for chromium are contoured from 627 individual sample points in Figure 62 as relative concentration. The shape and extent of the chromium plumes are almost identical to the plumes of the combined tritium pulses. Chromium was most likely extracted from the soil core samples as soluble and mobile chromate ion (CrO_4), which was not appreciably retarded in this experiment.

However, the mass recovery of the chromium was much lower than for tritium. The highest relative values of Cr for the $Y_2 = 5$ m transect was located at $X_2 = 0.25$ m and 4 m depth (0.215 of input concentration), and for the $Y_2 = 9$ m transect, at $X_2 = -0.75$ m and 4.46 m depth (0.222). When the overall mass balance for chromium is calculated from only those observations where $C/C_0 \geq 0$, the mass recovery

Figure 60. Experiment IIb redistribution cores tritium contours at $Y_2 = 5$ m from the trench face. Concentration expressed as C/C_0 .

Figure 61. Experiment IIb redistribution cores tritium contours at $Y_2 = 9$ m from the trench face.
Concentration expressed as C/C_0 .

Figure 62. Experiment IIb redistribution cores chromium contours at $Y_2 = 5$ and 9 m from the trench face. Concentration expressed as C/C_0 .

amounts to 13.9% at $Y_2 = 5 \text{ m}$ and 15.4% at $Y_2 = 9 \text{ m}$. These low recovery values may be attributable to a valence change of elemental chromium from Cr^{+6} to immobile Cr^{+3} precipitate in the presence of organic matter.

Although many contoured values for chromium are somewhat negative this does not indicate poor analytical results. All chromium values were found by multiplying raw ICP readings by the soil sample dilution factor. For example, a slightly negative raw value (i.e. no chromium present) was reduced to more negative values when multiplied by the dilution factor. The median raw negative reading was -0.01 mg/L , a value within the observed detection limit for the ICP instrument used for these analyses. Nitrate and chloride ions are contoured per

transect in Figures 63 and 64. The appearance of these plumes strongly resembles the inverse image of tritium plumes for both ions in both transect planes. Higher concentrations of nitrate near the soil surface may be at least partly due to on-going mineralization of organic matter. A paired comparison of observed nitrate and chloride ions shows a strong relationship (Figure 65). The ratio of median chloride ion concentration to median nitrate concentration is 1.6, about 54% of the same ratio for samples analyzed at the $Y_2 = 0.5 \text{ m}$ trench face. Many of the high nitrate values which deviate from the main grouping of data points are located near the soil surface. Further insights which lend to the interpretation of this data may be found in an Appendix C-2, which examines pre-irrigation levels of nitrate and chloride in the profile.

Figure 63. Experiment IIb redistribution cores chloride and nitrate contours at $Y_2 = 5$ m from the trench face. Concentration expressed as me/L of soil solution.

Figure 64. Experiment IIb redistribution cores chloride and nitrate contours at $Y_2 = 9$ m from the trench face. Concentration expressed as me/L of soil solution.

Figure 65. Experiment IIb redistribution cores chloride ion vs nitrate ion scatter plot for combined $Y_2 = 5$ m and 9 m observations. Concentration expressed as me/L of soil solution.

6 Conclusions

This report describes the third and final experiment conducted at the Las Cruces Trench site under this contract. The goal of this and the previous two experiments was to provide a data set that could be used by modelers and others, for checking existing and future simulation codes for soil water and solute transport. Moreover, the site characterization activities carried out for these experiments have taught us about some of the limitations in our ability to characterize deep soil profiles, and to understand how water and solute move under unsaturated conditions.

As described in Wierenga et al. (1988, 1989, 1990, and 1991), site characterization activities at the trench consisted of extensive field sampling, with subsequent in-situ field determination of saturated hydraulic conductivity. Laboratory experiments for determining the conductivity and tension relationships were performed on undisturbed samples collected from the field. Solute transport experiments were conducted for understanding dispersion properties of the soil from the site.

Any study undertaken for characterizing a site for LLW disposal, or possibly for hazardous waste disposal, must balance the need for collecting data in-situ, with associated higher costs and less controlled field conditions, against inherent problems associated with taking soil samples into the laboratory for analysis. Though the laboratory experiments may provide a cleaner data set, applying the results to the field always leads to difficulties in describing spatial variability of a soil profile with point samples. The experiments conducted at the Las Cruces Trench site, both the characterization studies and the transient field

infiltration experiments, address many of the common uncertainties associated with site characterization activities. Field saturated hydraulic conductivity results were compared to laboratory conductivities. Retention curves derived from the laboratory experiments were used in simulation models, prior to initiating Experiments IIa and IIb, to predict wetting front movement for possible flux rates. Collection of tension data from the tensiometers installed in the wall of the trench can be used in tandem with the water contents from the neutron probe readings taken less than 1.5 meters away, along the same horizontal plane. Thus, we can confirm the laboratory retention curves to actual paired values of water content and water tension collected in the field. Other relationships between field and laboratory activities can be described as well.

The Las Cruces Trench studies have provided modelers with infiltration data for simulating soil water and solute transport in the soil. The site characterization activities, conducted before the experiments began, have provided researchers with data for studying the spatial variability of soil hydraulic properties in an undisturbed soil profile. Site characterization studies conducted in preparation for license applications for LLW disposal should use the lessons learned from the trench studies. Those are 1) the need to collect data on soil hydraulic properties using more than one approach, and 2) the need to design a monitoring program that enhances the data set developed during site characterization. These lessons learned may reduce the uncertainties that arise during license review or actual site monitoring. They will also lead to a more coherent picture of potential physical processes that can be expected at the site during and after disposal of waste material.

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Appendix A. Experiment IIb Data Base Tables

Appendix A-1. Experiment IIb Water and Solute Application Record.

Timevalue (days)	Cumulative Totalizer (L)	Increment Rate (cm/d)	Mean Rate (cm/d)	PFBA (g)	B (g)	Cr (g)	Trit (uCl)	DFBA (g)	Br (g)
0.13	32.9	1.82	1.83	0.40	0.38	0.16	0	0	0
0.25	64.7	1.77	1.80	0.80	0.75	0.31	0	0	0
0.38	96.5	1.77	1.79	1.19	1.12	0.47	0	0	0
0.63	160.1	1.77	1.78	1.97	1.86	0.77	0	0	0
0.75	191.9	1.77	1.78	2.36	2.23	0.93	0	0	0
0.88	223.3	1.75	1.77	2.75	2.59	1.08	0	0	0
1.00	254.7	1.75	1.77	3.13	2.96	1.23	0	0	0
1.13	321.3	3.70	1.98	3.95	3.73	1.56	0	0	0
1.88	513.6	1.78	1.90	6.32	5.96	2.49	0	0	0
2.00	546.6	1.83	1.90	6.72	6.35	2.65	0	0	0
2.13	578.7	1.79	1.89	7.12	6.72	2.80	0	0	0
2.88	771.4	1.78	1.86	9.49	8.96	3.73	0	0	0
4.00	1060.6	1.79	1.84	13.05	12.31	5.13	0	0	0
4.75	1253.2	1.78	1.83	15.41	14.55	6.07	0	0	0
4.88	1285.8	1.81	1.83	15.82	14.93	6.22	0	0	0
5.00	1318.7	1.83	1.83	16.22	15.31	6.38	0	0	0
5.13	1351.6	1.83	1.83	16.62	15.69	6.54	0	0	0
6.00	1579.1	1.81	1.83	19.42	18.33	7.64	0	0	0
6.13	1610.9	1.77	1.83	19.81	18.70	7.80	0	0	0
6.88	1809.2	1.84	1.83	22.25	21.00	8.76	0	0	0
7.00	1842.2	1.83	1.83	22.66	21.39	8.92	0	0	0
7.13	1875.1	1.83	1.83	23.06	21.77	9.08	0	0	0
7.25	1907.6	1.81	1.83	23.46	22.15	9.23	0	0	0
7.88	2031.0	1.37	1.79	24.98	23.58	9.83	0	0	0
8.00	2064.0	1.83	1.79	25.39	23.96	9.99	0	0	0
8.13	2096.9	1.83	1.79	25.79	24.35	10.15	0	0	0
9.00	2327.4	1.83	1.80	28.63	27.02	11.26	0	0	0
9.13	2360.3	1.83	1.80	29.03	27.40	11.42	0	0	0
10.00	2590.1	1.82	1.80	31.86	30.07	12.54	0	0	0
11.88	3053.4	1.72	1.79	37.56	35.45	14.78	0	0	0
12.00	3085.5	1.79	1.79	37.95	35.82	14.93	0	0	0
12.13	3118.5	1.83	1.79	38.36	36.21	15.09	0	0	0
13.75	3546.5	1.83	1.79	43.62	41.17	17.17	0	0	0
13.88	3579.5	1.83	1.79	44.03	41.56	17.32	0	0	0
14.00	3612.8	1.85	1.79	44.44	41.94	17.49	0	0	0
15.00	3847.1	1.63	1.78	47.32	44.66	18.62	0	0	0
15.13	3879.6	1.81	1.78	47.32	44.66	18.62	0	0	0
15.88	4077.6	1.83	1.78	47.32	44.66	18.62	0	0	0
16.00	4110.5	1.83	1.78	47.32	44.66	18.62	0	0	0
16.88	4341.4	1.83	1.79	47.32	44.66	18.62	0	0	0
17.00	4374.3	1.83	1.79	47.32	44.66	18.62	0	0	0
17.13	4407.6	1.85	1.79	47.32	44.66	18.62	0	0	0
19.00	4902.3	1.83	1.79	47.32	44.66	18.62	0	0	0
19.75	5100.3	1.83	1.79	47.32	44.66	18.62	0	0	0
20.00	5172.2	2.00	1.80	47.32	44.66	18.62	0	0	0
20.88	5470.8	2.37	1.82	47.32	44.66	18.62	0	0	0
21.00	5512.5	2.31	1.82	47.32	44.66	18.62	0	0	0
21.13	5545.4	1.83	1.82	47.32	44.66	18.62	0	0	0
21.38	5611.3	1.83	1.82	47.32	44.66	18.62	0	0	0
23.00	6038.6	1.83	1.82	47.32	44.66	18.62	0	0	0
23.13	6071.1	1.81	1.82	47.32	44.66	18.62	0	0	0

Appendix A-1. Experiment IIb Water and Solute Application Record. (Continued)

Timevalue (days)	Cumulative Totalizer (L)	Increment Rate (cm/d)	Mean Rate (cm/d)	PFBA (g)	B (g)	Cr (g)	Trlt (uCl)	DFBA (g)	Br (g)
23.75	6234.7	1.82	1.82	47.32	44.66	18.62	0	0	0
23.88	6267.2	1.81	1.82	47.32	44.66	18.62	0	0	0
26.00	6819.8	1.81	1.82	47.32	44.66	18.62	0	0	0
26.13	6852.7	1.83	1.82	47.32	44.66	18.62	0	0	0
26.88	7048.0	1.81	1.82	47.32	44.66	18.62	0	0	0
28.00	7341.4	1.81	1.82	47.32	44.66	18.62	0	0	0
28.13	7374.3	1.83	1.82	47.32	44.66	18.62	0	0	0
28.88	7569.6	1.81	1.82	47.32	44.66	18.62	0	0	0
29.00	7602.9	1.85	1.82	47.32	44.66	18.62	0	0	0
29.13	7635.5	1.81	1.82	47.32	44.66	18.62	3260	0.33	0.98
30.00	7865.2	1.82	1.82	47.32	44.66	18.62	26230	2.62	7.87
30.13	7898.2	1.83	1.82	47.32	44.66	18.62	29530	2.95	8.86
32.88	8620.7	1.82	1.82	47.32	44.66	18.62	101780	10.18	30.53
33.00	8653.6	1.83	1.82	47.32	44.66	18.62	105070	10.51	31.52
33.13	8686.6	1.83	1.82	47.32	44.66	18.62	108370	10.84	32.51
34.13	8950.0	1.83	1.82	47.32	44.66	18.62	134710	13.47	40.41
35.00	9180.9	1.83	1.82	47.32	44.66	18.62	157800	15.78	47.34
35.13	9214.2	1.85	1.82	47.32	44.66	18.62	161130	16.11	48.34
37.00	9708.1	1.83	1.82	47.32	44.66	18.62	210520	21.05	63.16
37.13	9741.1	1.83	1.82	47.32	44.66	18.62	213820	21.38	64.16
37.88	9938.7	1.83	1.82	47.32	44.66	18.62	233580	23.36	70.07
38.00	9971.6	1.83	1.82	47.32	44.66	18.62	236870	23.69	71.06
40.00	10498.1	1.83	1.82	47.32	44.66	18.62	289520	28.95	86.86
40.13	10531.0	1.83	1.82	47.32	44.66	18.62	292810	29.28	87.84
42.00	11024.6	1.83	1.82	47.32	44.66	18.62	342170	34.22	102.65
42.13	11057.5	1.83	1.82	47.32	44.66	18.62	345460	34.55	103.64
44.00	11550.3	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42
44.88	11781.2	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42
47.00	12341.0	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42
47.13	12373.9	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42
49.13	12901.6	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42
49.88	13099.9	1.84	1.82	47.32	44.66	18.62	394740	39.47	118.42
50.88	13363.7	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42
54.00	14188.5	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
54.13	14221.0	1.81	1.83	47.32	44.66	18.62	394740	39.47	118.42
56.00	14716.8	1.84	1.83	47.32	44.66	18.62	394740	39.47	118.42
56.13	14749.4	1.81	1.83	47.32	44.66	18.62	394740	39.47	118.42
57.88	15211.5	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
58.88	15475.7	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
61.00	16036.7	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
61.13	16069.6	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
63.00	16565.1	1.84	1.83	47.32	44.66	18.62	394740	39.47	118.42
65.00	17095.3	1.84	1.83	47.32	44.66	18.62	394740	39.47	118.42
65.13	17128.3	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
65.88	17327.4	1.84	1.83	47.32	44.66	18.62	394740	39.47	118.42
66.00	17360.3	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
66.13	17393.2	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
66.25	17426.1	1.83	1.83	47.32	44.66	18.62	394740	39.47	118.42
68.13	17883.7	1.69	1.82	47.32	44.66	18.62	394740	39.47	118.42
70.00	18378.8	1.83	1.82	47.32	44.66	18.62	394740	39.47	118.42

Appendix A-2. Example of Neutron Probe Soil Moisture Data.

Day	Tube	Z ₂	Theta	Day	Tube	Z ₂	Theta	Day	Tube	Z ₂	Theta
525	60	3.00	0.2018	525	71	3.25	0.1923	525	90	2.50	0.1084
525	60	3.25	0.2099	525	71	3.50	0.1455	525	90	2.75	0.1172
525	60	3.50	0.1260	525	71	3.75	0.0875	525	90	3.00	0.2287
525	60	3.75	0.1259	525	71	4.00	0.0553	525	90	3.25	0.2276
525	60	4.00	0.1513	525	71	4.25	0.0509	525	90	3.50	0.2032
525	60	4.25	0.1421	525	71	4.50	0.0916	525	90	3.75	0.1565
525	60	4.50	0.1824	525	71	4.75	0.1500	525	90	4.00	0.1756
525	60	4.75	0.1744	525	71	5.00	0.0998	525	90	4.25	0.1456
525	60	5.00	0.1620	525	71	5.25	0.0768	525	90	4.50	0.1729
525	60	5.25	0.1417	525	71	5.50	0.0827	525	90	4.75	0.1425
525	70	0.25	0.1088	525	71	5.75	0.0628	525	90	5.00	0.1023
525	70	0.50	0.1412	525	71	6.00	0.0716	525	90	5.25	0.0506
525	70	0.75	0.1686	525	80	0.25	0.1060	525	90	5.50	0.0313
525	70	1.00	0.1393	525	80	0.50	0.1485	525	90	5.75	0.0278
525	70	1.25	0.1212	525	80	0.75	0.1808	525	90	6.00	0.0570
525	70	1.50	0.0865	525	80	1.00	0.1524	525	100	0.25	0.1017
525	70	1.75	0.1210	525	80	1.25	0.1216	525	100	0.50	0.1331
525	70	2.00	0.1286	525	80	1.50	0.0973	525	100	0.75	0.1526
525	70	2.25	0.0913	525	80	1.75	0.1209	525	100	1.00	0.1427
525	70	2.50	0.1113	525	80	2.00	0.1246	525	100	1.25	0.1384
525	70	2.75	0.1089	525	80	2.25	0.0832	525	100	1.50	0.1272
525	70	3.00	0.2041	525	80	2.50	0.1066	525	100	1.75	0.1299
525	70	3.25	0.2278	525	80	2.75	0.1081	525	100	2.00	0.1186
525	70	3.50	0.1889	525	80	3.00	0.2176	525	100	2.25	0.1085
525	70	3.75	0.1151	525	80	3.25	0.2275	525	100	2.50	0.0834
525	70	4.00	0.1005	525	80	3.50	0.1989	525	100	2.75	0.0953
525	70	4.25	0.0951	525	80	3.75	0.2056	525	100	3.00	0.2016
525	70	4.50	0.1751	525	80	4.00	0.1492	525	100	3.25	0.2222
525	70	4.75	0.1532	525	80	4.25	0.1170	525	100	3.50	0.1465
525	70	5.00	0.1158	525	80	4.50	0.1846	525	100	3.75	0.1126
525	70	5.25	0.1199	525	80	4.75	0.1382	525	100	4.00	0.1505
525	70	5.50	0.1144	525	80	5.00	0.1318	525	100	4.25	0.1333
525	70	5.75	0.0759	525	80	5.25	0.1155	525	100	4.50	0.1468
525	71	0.25	0.1010	525	80	5.50	0.0829	525	100	4.75	0.1308
525	71	0.50	0.1523	525	80	5.75	0.0610	525	100	5.00	0.1052
525	71	0.75	0.1397	525	80	6.00	0.0642	525	110	0.25	0.1122
525	71	1.00	0.1193	525	90	0.25	0.1063	525	110	0.50	0.1217
525	71	1.25	0.1076	525	90	0.50	0.1298	525	110	0.75	0.1315
525	71	1.50	0.1068	525	90	0.75	0.1464	525	110	1.00	0.1110
525	71	1.75	0.1177	525	90	1.00	0.1527	525	110	1.25	0.0896
525	71	2.00	0.0902	525	90	1.25	0.1277	525	110	1.50	0.0666
525	71	2.25	0.0827	525	90	1.50	0.1042	525	110	1.75	0.0625
525	71	2.50	0.0977	525	90	1.75	0.0889	525	110	2.00	0.0335
525	71	2.75	0.1024	525	90	2.00	0.1004	525	110	2.25	0.0443
525	71	3.00	0.2133	525	90	2.25	0.1047	525	110	2.50	0.1107

Appendix A-3. Experiment IIb Tensiometer Soil Moisture Data.

Day	Tens ID	cm-H ₂ O	Day	Tens ID	cm-H ₂ O	Day	Tens ID	cm-H ₂ O	Day	Tens ID	cm-H ₂ O
0	142	442	2	142	345	2	1248	220	5	356	259
0	144	253	2	144	114	2	1250	263	5	358	315
0	146	513	2	146	420	2	1252	299	5	642	483
0	148	405	2	148	19	2	1254	254	5	644	400
0	150	432	2	150	26	2	1256	332	5	646	376
0	152	190	2	152	37	2	1258	209	5	648	355
0	154	117	2	154	73	2	1442	434	5	650	317
0	156	249	2	156	106	2	1444	471	5	652	245
0	158	518	2	158	396	2	1446	331	5	654	283
0	344	493	2	342	393	2	1448	346	5	656	276
0	346	392	2	344	410	2	1450	365	5	658	273
0	348	346	2	346	274	2	1452	443	5	844	379
0	350	307	2	348	194	2	1454	495	5	846	341
0	352	278	2	350	241	2	1456	546	5	848	312
0	354	268	2	352	249	2	1458	612	5	850	303
0	356	288	2	354	250	2	1642	527	5	852	279
0	358	338	2	356	269	2	1644	509	5	854	293
0	642	485	2	642	435	2	1646	406	5	856	301
0	644	415	2	644	388	2	1648	369	5	858	360
0	646	376	2	646	313	2	1650	402	5	1044	376
0	648	329	2	648	301	2	1652	462	5	1046	345
0	650	270	2	650	230	2	1654	548	5	1048	320
0	652	284	2	652	134	2	1656	599	5	1050	319
0	654	284	2	654	260	2	1658	587	5	1052	306
0	656	271	2	656	241	2	1842	572	5	1054	301
0	658	269	2	658	236	2	1848	602	5	1056	343
0	844	376	2	842	75	2	1850	569	5	1058	149
0	846	347	2	844	347	2	1852	611	5	1242	435
0	848	322	2	846	321	2	1854	513	5	1244	397
0	850	307	2	848	289	2	1856	551	5	1246	368
0	852	275	2	850	287	2	1858	635	5	1248	323
0	854	301	2	852	271	5	142	401	5	1250	314
0	856	297	2	854	284	5	144	232	5	1252	306
0	858	357	2	856	143	5	146	136	5	1254	324
0	1044	377	2	858	295	5	148	53	5	1256	353
0	1046	355	2	1042	67	5	150	17	5	1442	606
0	1048	323	2	1044	361	5	152	19	5	1444	571
0	1050	317	2	1046	325	5	154	32	5	1446	471
0	1052	315	2	1048	305	5	156	231	5	1448	415
0	1054	301	2	1050	222	5	158	371	5	1450	478
0	1058	455	2	1052	296	5	342	536	5	1452	547
0	1248	321	2	1054	287	5	344	493	5	1454	626
0	1250	311	2	1056	254	5	346	353	5	1456	716
0	1252	301	2	1058	382	5	348	33	5	1642	646
0	1444	590	2	1242	337	5	350	50	5	1644	634
0	1446	485	2	1244	362	5	352	56	5	1646	537
0	1448	456	2	1246	307	5	354	180	5	1648	485

Appendix A-4. Experiment IIb Tritium Data.

Day	Sampl. ID	Rel. Conc.	Day	Sampl. ID	Rel. Conc.	Day	Sampl. ID	Rel. Conc.	Day	Sampl. ID	Rel. Conc.
0	251	0.0308	7	851	0.0362	14	453	0.0455	19	455	0.1047
0	255	0.0482	7	853	0.0330	14	455	0.0990	19	457	0.0083
0	453	0.2026	7	1249	0.0011	14	645	0.0069	19	645	0.0266
0	455	0.0819	7	1251	0.0006	14	647	0.0878	19	647	0.1228
0	645	0.0202	9	245	0.0555	14	649	0.1181	19	649	0.1225
0	651	0.1462	9	249	0.0170	14	651	0.1201	19	651	0.1316
0	655	0.0546	9	251	0.0048	14	653	0.1414	19	653	0.1542
0	657	0.0021	9	253	0.0507	14	655	0.0474	19	655	0.0665
0	851	0.0352	9	255	0.0446	14	847	0.0215	19	657	0.0022
0	853	0.0359	9	447	0.1670	14	849	0.0360	19	847	0.0320
0	855	0.0100	9	449	0.1697	14	851	0.0209	19	849	0.0579
0	857	0.0005	9	451	0.1117	14	853	0.0188	19	851	0.0602
0	1043	0.0004	9	453	0.1367	14	1251	0.0004	19	853	0.0433
0	1245	0.0000	9	455	0.0814	16	245	0.0630	19	855	0.0128
0	1249	0.0011	9	649	0.1286	16	249	0.0008	19	1049	0.0068
0	1251	0.0005	9	651	0.1434	16	251	0.0004	19	1249	0.0001
0	1255	0.0001	9	653	0.1454	16	253	0.0069	21	243	0.0046
2	251	0.0787	12	245	0.0647	16	255	0.0407	21	245	0.0514
2	651	0.1476	12	249	0.0036	16	447	0.0983	21	249	0.0004
2	655	0.0557	12	251	0.0005	16	449	0.1036	21	251	0.0004
2	657	0.0022	12	253	0.0349	16	451	0.0085	21	253	0.0008
2	853	0.0348	12	255	0.0478	16	453	0.0338	21	255	0.0294
2	1251	0.0009	12	447	0.0905	16	455	0.0986	21	445	0.0454
5	249	0.0791	12	449	0.1568	16	645	0.0222	21	447	0.0742
5	251	0.0302	12	451	0.0536	16	647	0.1009	21	449	0.0387
5	253	0.0724	12	453	0.0673	16	649	0.1217	21	451	0.0010
5	255	0.0420	12	455	0.0997	16	651	0.1215	21	453	0.0040
5	447	0.1436	12	645	0.0188	16	653	0.1432	21	455	0.0676
5	449	0.1824	12	647	0.1173	16	655	0.0515	21	457	0.0046
5	451	0.1808	12	649	0.1087	16	847	0.0222	21	645	0.0238
5	453	0.1993	12	651	0.1140	16	849	0.0420	21	647	0.1121
5	455	0.0748	12	653	0.1207	16	851	0.0392	21	649	0.1143
5	651	0.1450	12	655	0.0450	16	853	0.0346	21	651	0.1404
5	655	0.0493	12	657	0.0017	16	1051	0.0044	21	653	0.1300
5	657	0.0022	12	847	0.0194	16	1251	0.0003	21	655	0.0711
5	847	0.0171	12	849	0.0312	19	243	0.0040	21	657	0.0021
5	851	0.0335	12	851	0.0366	19	245	0.0720	21	843	0.0003
5	853	0.0345	12	853	0.0307	19	249	0.0004	21	845	0.0060
5	855	0.0079	12	855	0.0073	19	251	0.0004	21	847	0.0339
5	1249	0.0007	14	245	0.0070	19	253	0.0034	21	849	0.0376
5	1251	0.0009	14	249	0.0015	19	255	0.0404	21	851	0.0542
7	251	0.0117	14	251	0.0008	19	257	0.0074	21	853	0.0544
7	447	0.1002	14	253	0.0082	19	445	0.0454	21	855	0.0128
7	453	0.1455	14	255	0.0214	19	447	0.0888	21	857	0.0003
7	653	0.1358	14	447	0.1213	19	449	0.0697	21	1047	0.0022
7	655	0.0441	14	449	0.0603	19	451	0.0024	21	1049	0.0063
7	657	0.0027	14	451	0.0056	19	453	0.0108	21	1051	0.0136

Appendix A-5. Experiment IIb Chromium Data.

Day	Sampl. ID	Rel. Conc.	Day	Sampl. ID	Rel. Conc.	Day	Sampl. ID	Rel. Conc.	Day	Sampl. ID	Rel. Conc.
5	251	0.0006	23	649	0.0745	37	655	0.0457	44	1051	0.2168
7	251	0.1818	23	651	0.0006	37	1051	0.0028	44	1247	0.0000
7	447	-0.0018	23	653	0.0135	37	1253	-0.0018	44	1253	0.0057
7	453	0.0000	23	655	0.0022	40	251	0.0000	44	1445	0.0022
9	251	0.4459	23	1051	0.0006	40	453	0.0267	44	1451	0.0000
12	251	0.7079	28	251	0.0261	40	455	-0.0020	44	1453	0.0022
12	253	0.0000	28	453	0.7838	40	647	0.5311	44	1455	-0.0002
12	447	-0.0032	28	649	0.2917	40	649	0.2412	44	1653	0.0026
12	453	-0.0026	28	651	0.0141	40	651	0.3432	44	1655	0.0030
12	649	-0.0004	28	653	0.3745	40	653	0.4533	47	251	0.0032
12	651	0.0010	28	655	0.0063	40	655	0.1083	47	443	-0.0018
12	653	0.0000	28	853	0.0059	40	857	0.0085	47	453	0.0087
12	655	0.0000	28	1051	0.0063	40	1051	0.0368	47	647	0.3305
14	251	0.6889	28	1247	0.0115	40	1247	-0.0004	47	649	0.1422
14	449	-0.0014	28	1251	0.0002	40	1253	-0.0004	47	651	0.3816
14	453	0.0012	28	1253	-0.0020	42	251	0.0008	47	653	0.0844
14	649	-0.0022	30	251	0.0135	42	443	-0.0018	47	655	0.2962
14	651	-0.0042	30	453	0.6733	42	447	0.1970	47	1051	0.3543
14	653	0.0000	30	649	0.2929	42	453	0.0117	47	1247	-0.0016
14	655	-0.0020	30	651	0.0384	42	649	0.1909	47	1253	0.0485
16	251	0.7010	30	653	0.4384	42	651	0.4081	47	1451	-0.0020
16	449	0.0010	30	655	0.0026	42	653	0.3000	47	1453	-0.0008
16	453	0.0057	30	1051	0.0010	42	655	0.1651	47	1455	0.0012
16	647	-0.0002	30	1253	0.0028	42	853	0.2204	47	1457	0.0028
16	649	0.0000	33	251	0.0073	42	1051	0.1257	47	1655	0.0004
16	651	-0.0006	33	453	0.3851	42	1245	-0.0061	47	1849	0.0022
16	653	-0.0020	33	649	0.3285	42	1247	-0.0053	49	251	0.0018
16	655	-0.0020	33	651	0.1240	42	1251	-0.0073	49	453	0.0071
16	851	-0.0028	33	653	0.5549	42	1253	-0.0046	49	647	0.1885
16	853	0.0016	33	655	0.0026	42	1255	-0.0059	49	649	0.1305
19	251	0.7527	33	853	0.0046	42	1445	0.0014	49	651	0.3040
19	253	0.5901	33	1051	-0.0048	42	1447	-0.0022	49	653	0.0345
19	447	-0.0051	33	1247	-0.0020	42	1449	-0.0028	49	655	0.3410
19	453	0.2933	33	1253	-0.0020	42	1451	-0.0004	49	1253	0.1588
19	647	-0.0065	35	243	0.0000	42	1453	-0.0018	49	1457	0.0032
19	649	-0.0048	35	251	0.0079	42	1455	-0.0016	49	1655	0.0000
19	651	-0.0053	35	253	0.1780	42	1653	-0.0002	51	251	0.0053
19	653	-0.0044	35	649	0.3297	44	251	0.0002	51	453	0.0036
19	655	-0.0026	35	651	0.2036	44	253	0.0036	51	649	0.1234
19	853	-0.0065	35	653	0.5895	44	443	-0.0042	51	651	0.2588
21	251	0.5216	35	655	0.0162	44	447	0.1218	51	653	0.0289
21	453	0.4689	35	1051	-0.0018	44	453	0.0089	51	655	0.3416
21	649	0.0063	35	1253	-0.0053	44	647	0.4590	51	853	0.4758
21	651	-0.0040	37	251	0.0048	44	649	0.1667	51	1051	0.4962
21	653	-0.0059	37	453	0.0788	44	651	0.4206	51	1245	-0.0040
21	655	-0.0059	37	649	0.3299	44	653	0.1875	51	1247	-0.0010
21	1051	-0.0040	37	651	0.2840	44	655	0.2164	51	1251	0.0139
23	453	0.6024	37	653	0.5943	44	853	0.3287	51	1253	0.2115

Appendix A-6. Solute Concentrations: PFBA, DFBA, Br, NO3, and Cl.

Exp IIb Day	Sampler ID	----- Relative Conc. -----			-- Solution ppm --	
		PFBA	DFBA	Bromide	Nitrate	Chloride
0	251	0.000		0.014	718.2	58.3
0	453	0.000		0.154	190.9	39.1
0	655	0.000		0.136	167.7	109.0
0	853	0.000		0.154	143.2	71.1
0	1251	0.000		0.008	414.9	266.0
14	245	0.000		0.058	98.0	82.8
14	249	0.247		0.005	101.8	43.6
14	251	0.756		0.006	23.0	19.8
14	253	0.476		0.007		48.7
14	255	0.000		0.071	646.0	43.0
14	447	0.000		0.064	194.8	41.0
14	449	0.000		0.057	390.5	46.5
14	451	0.000		0.011	146.7	79.4
14	645	0.000		0.078	140.6	80.4
14	647	0.000		0.273	188.9	26.0
14	649	0.000		0.196	183.0	34.8
14	651	0.000		0.301	186.1	44.4
14	653	0.000		0.301	170.5	25.9
14	655	0.000		0.284	307.7	29.5
14	847	0.000		0.207	151.2	170.0
14	851	0.000		0.260	362.0	106.0
14	853	0.000		0.447	351.1	50.6
30	243	0.000		0.008		32.2
30	245	0.000		0.210	495.0	25.2
30	249	0.000		0.002	45.1	50.1
30	251	0.000		0.000	19.3	19.3
30	253	0.000		0.001	26.5	21.1
30	255	0.000		0.031	607.9	178.0
30	443	0.000		0.005	287.5	37.0
30	445	0.000		0.110	376.9	62.7
30	447	0.648		0.340	33.3	23.9
30	449	0.041		0.006	41.2	22.4
30	451	0.025		0.003	25.7	26.8
30	453	0.000		0.000	17.9	19.2
30	455	0.000		0.035		14.6
30	645	0.000		0.266	208.7	33.2
30	647	0.644		0.007	85.6	24.8
30	649	0.076		0.048	112.1	22.7
30	651	0.245		0.062	202.3	29.0
30	653	0.397		0.003	48.0	19.7

Appendix A-7. Experiment IIb Redistribution Cores (Baseline Data).

ID	Seg #	Y (m)	X (m)	Z (m)	Extr. Date	Orig. Mass (g)	Post-Stg Mass (g)	Evap. Loss (g)	Soil Mass (g)	Discard (g)	Repres. Mass (g)	Gravimetric Tare (g)	Water Meas. +FreshS (g)	+ODryS (g)
1	1	5	-2.75	0.11	2-Jul-91	134.864	134.352	0.512	119.268	0	119.268	62.676	101.890	99.402
1	2	5	-2.75	0.34	2-Jul-91	130.083	129.914	0.169	114.067	0	114.067	60.449	94.107	91.449
1	3	5	-2.75	0.57	2-Jul-91	131.479	131.308	0.171	115.457	0	115.457	62.975	104.202	100.432
1	4	5	-2.75	0.80	2-Jul-91	133.560	133.394	0.166	118.351	0	118.351	62.757	102.931	100.627
2	1	5	-2.75	1.03	2-Jul-91	126.654	126.480	0.174	111.408	2.336	109.072	63.532	103.241	100.840
2	2	5	-2.75	1.26	2-Jul-91	129.818	129.647	0.171	115.956	0	115.956	59.691	98.871	96.549
2	3	5	-2.75	1.49	2-Jul-91	132.426	132.242	0.184	118.540	0	118.540	60.153	100.056	97.169
2	4	5	-2.75	1.71	2-Jul-91	138.540	138.363	0.177	124.574	0	124.574	66.212	115.883	113.090
3	1	5	-2.75	1.94	2-Jul-91	131.423	131.256	0.167	117.595	0	117.595	63.373	102.232	99.874
3	2	5	-2.75	2.17	2-Jul-91	145.077	144.894	0.183	113.844	0	113.844	59.576	102.405	100.105
3	3	5	-2.75	2.40	2-Jul-91	143.781	143.608	0.173	129.649	0	129.649	63.565	101.732	99.665
3	4	5	-2.75	2.63	2-Jul-91	138.692	138.515	0.177	124.815	0	124.815	60.254	104.301	101.435
4	1	5	-2.75	2.86	2-Jul-91	140.774	140.603	0.171	126.525	1.497	125.028	62.159	96.420	94.731
4	2	5	-2.75	3.09	2-Jul-91	140.993	140.800	0.193	126.662	0	126.662	62.528	98.880	96.193
4	3	5	-2.75	3.31	2-Jul-91	136.784	136.525	0.259	122.403	0	122.403	63.646	107.497	103.779
4	4	5	-2.75	3.54	2-Jul-91	141.085	140.899	0.186	126.985	1.615	125.370	62.053	99.995	98.040
5	1	5	-2.75	3.77	3-Jul-91	131.475	131.289	0.186	116.273	0	116.273	63.192	109.211	107.584
5	2	5	-2.75	4.00	3-Jul-91	121.486	121.300	0.186	107.913	0	107.913	60.417	97.863	95.624
5	3	5	-2.75	4.23	3-Jul-91	131.223	130.920	0.303	117.562	0	117.562	60.239	101.955	99.914
5	4	5	-2.75	4.46	3-Jul-91	126.078	125.900	0.178	112.838	0	112.838	62.601	102.968	100.913
6	1	5	-2.75	4.69	3-Jul-91	117.344	117.277	0.067	102.987	2.080	100.907	62.133	100.369	98.438
6	2	5	-2.75	4.91	3-Jul-91	138.403	138.215	0.188	124.788	2.289	122.499	62.859	101.679	99.703
6	3	5	-2.75	5.14	3-Jul-91	151.374	151.177	0.197	137.654	1.567	136.087	58.480	95.971	94.090
6	4	5	-2.75	5.37	3-Jul-91	133.723	133.531	0.192	120.306	0	120.306	65.880	113.851	112.212
7	1	5	-2.75	5.64	3-Jul-91	129.953	129.724	0.229	113.913	2.095	111.818	63.500	107.831	106.283
7	2	5	-2.75	5.94	3-Jul-91	138.395	138.146	0.249	125.194	0.892	124.302	63.538	116.959	115.196
7	3	5	-2.75	6.25	3-Jul-91	120.555	120.353	0.202	108.077	0	108.077	62.943	111.207	109.728
8	1	5	-2.25	0.11	3-Jul-91	117.799	117.620	0.179	103.821	0	103.821	63.121	91.113	89.277
8	2	5	-2.25	0.34	3-Jul-91	124.862	124.666	0.196	110.734	0.852	109.882	62.557	98.325	95.628
8	3	5	-2.25	0.57	3-Jul-91	124.148	123.964	0.184	109.781	0	109.781	62.250	100.894	97.421
8	4	5	-2.25	0.80	3-Jul-91	127.203	127.198	0.005	113.565	0	113.565	65.171	104.245	101.341
9	1	5	-2.25	1.03	3-Jul-91	133.505	133.310	0.195	118.818	0.839	117.979	62.496	98.682	96.317
9	2	5	-2.25	1.26	3-Jul-91	131.378	131.178	0.200	116.756	1.720	115.036	59.795	95.231	92.639

Appendix A-8. Experiment IIb Redistribution Cores (Solute Data).

ID	Seg #	Y2 (m)	X2 (m)	Z2 (m)	Rel. Tritium	Cr-solid (ppm)	Cr-solution (ppm)	NO3-solid (ppm)	NO3-sln (me/l)	Cl-solid (ppm)	Cl-sln (me/l)
1	1	5	-2.75	0.11	0.000	-0.005	-0.068	48.3	9.54	19.5	7.04
1	2	5	-2.75	0.34	0.001	-0.004	-0.052	70.2	11.67	3.9	1.14
1	3	5	-2.75	0.57	0.000	-0.003	-0.048	62.0	8.68	7.5	1.85
1	4	5	-2.75	0.80	-0.001	-0.004	-0.045	23.0	5.49	3.6	1.52
2	1	5	-2.75	1.03	0.000	-0.008	-0.128	17.0	3.81	5.6	2.25
2	2	5	-2.75	1.26	0.000	-0.009	-0.127	11.6	2.66	5.5	2.26
2	3	5	-2.75	1.49	0.006	-0.011	-0.167	7.7	1.41	4.4	1.44
2	4	5	-2.75	1.71	0.018	-0.008	-0.132	3.1	0.75	4.3	1.85
3	1	5	-2.75	1.94	0.017	-0.009	-0.121	12.3	2.76	8.0	3.20
3	2	5	-2.75	2.17	0.023	-0.008	-0.138	5.2	1.33	5.4	2.44
3	3	5	-2.75	2.40	0.019	-0.004	-0.048	22.9	5.81	16.4	7.42
3	4	5	-2.75	2.63	0.010	-0.011	-0.105	66.5	13.80	216.4	79.73
4	1	5	-2.75	2.86	0.006	-0.017	-0.283	85.7	24.03	332.6	166.65
4	2	5	-2.75	3.09	0.000	-0.001	-0.036	152.3	27.31	142.4	45.30
4	3	5	-2.75	3.31	0.001	-0.001	-0.018	165.2	24.99	199.9	53.75
4	4	5	-2.75	3.54	0.002	-0.004	-0.069	77.2	20.57	N/A	N/A
5	1	5	-2.75	3.77	0.002	-0.005	-0.087	38.5	15.03	86.6	61.36
5	2	5	-2.75	4.00	-0.001	-0.004	-0.066	62.2	14.05	144.6	58.26
5	3	5	-2.75	4.23	-0.001	-0.002	-0.040	49.8	13.50	131.7	64.90
5	4	5	-2.75	4.46	0.002	-0.003	-0.051	43.3	11.65	126.9	61.15
6	1	5	-2.75	4.69	0.002	-0.003	-0.070	45.9	12.88	108.1	53.56
6	2	5	-2.75	4.91	0.000	0.003	0.063	46.4	12.53	126.8	61.16
6	3	5	-2.75	5.14	-0.001	-0.001	-0.029	34.7	9.54	106.1	52.07
6	4	5	-2.75	5.37	-0.001	-0.003	-0.082	24.3	9.82	84.3	61.87
7	1	5	-2.75	5.64	0.000	-0.008	-0.102	25.8	10.00	84.7	59.96
7	2	5	-2.75	5.94	0.002	-0.001	-0.016	25.3	10.37	90.5	67.94
7	3	5	-2.75	6.25	0.001	-0.003	-0.025	22.6	10.01	83.8	68.14
8	1	5	-2.25	0.11	-0.001	-0.007	-0.082	84.2	17.17	2.8	1.01
8	2	5	-2.25	0.34	0.001	-0.005	-0.057	48.8	8.51	2.5	0.78
8	3	5	-2.25	0.57	0.001	-0.002	-0.024	17.4	2.48	7.0	1.75
8	4	5	-2.25	0.80	0.000	-0.001	-0.008	16.8	3.11	4.0	1.30
9	1	5	-2.25	1.03	0.002	-0.005	-0.053	9.2	1.90	2.0	0.74
9	2	5	-2.25	1.26	0.005	-0.003	-0.048	8.9	1.60	2.4	0.76

Appendix B. Experiment IIb Extension.

Appendix B-1. Experiment IIb Dropper Uniformity Test.

Test Date, 30 May, 1990
East Header

West Header

Mass of dropper output, less tare mass					Mass of dropper output, less tare mass				
line	row 1	row 2	row 3	row 4	line	row 1	row 2	row 3	row 4
1	238.6	239.9	274.4	238.9	1	347.1	349.9	355.3	351.2
2	240.2	237.9	239.0	235.0	2	350.2	343.5	350.9	353.2
3	234.8	254.3	287.2	237.4	3	348.1	350.8	353.0	352.4
4	241.8	238.8	243.5	236.8	4	350.1	352.1	352.0	344.7
5	234.0	244.7	231.8	234.1	5	350.4	348.8	350.2	348.7
6	271.0	243.8	235.1	247.0	6	355.0	353.1	348.3	351.8
7	237.6	245.5	233.1	260.3	7	345.3	359.0	348.3	348.1
8	238.1	236.2	233.9	243.1	8	349.2	347.8	349.7	378.4
9	254.6	280.6	235.0	235.6	9	347.4	345.6	363.5	345.6
10	255.9	236.4	239.7	236.8	10	352.9	378.8	346.3	348.5
11	232.6	237.6	239.3	238.5	11	358.7	351.7	352.7	352.0
12	242.3	241.5	236.5	231.0	12	387.4	1024.1	354.7	355.2
13	241.6	238.1	239.3	241.5	13	355.7	350.1	350.0	350.8
14	239.0	263.9	236.7	233.0	14	354.2	345.0	351.9	349.2
15	236.4	258.1	257.8	231.4	15	352.1	350.4	363.7	350.4
16	236.9	237.0	229.8	252.7	16	350.2	353.3	343.3	350.5
17	236.9	245.0	236.6	238.3	17	348.1	346.2	347.2	350.3
18	235.9	273.4	232.5	257.5	18	346.4	344.1	344.5	342.8
19	233.0	272.5	230.4	231.5	19	367.7	344.2	341.7	337.0
20	237.4	230.6	228.8	228.9	20	341.0	344.6	345.6	340.4
21	234.1	241.9	244.1	228.8	21	350.0	343.8	358.8	353.6
22	236.0	239.4	259.2	232.5	22	341.9	343.7	340.9	346.2
23	238.8	236.7	235.2	236.8	23	348.2	354.3	370.7	350.0
24	246.4	236.8	235.0	231.3	24	384.4	360.0	348.5	352.3
25	264.9	241.3	236.7	235.1	25	348.8	346.4	351.6	353.1
26	254.1	253.2	245.2	248.6	26	351.0	358.6	362.2	366.3
27	249.4	247.1	241.1	236.7	27	352.2	392.5	365.2	394.6
28	237.7	250.8	251.1	248.2	28	350.2	359.3	367.3	384.4
29	237.3	236.0	237.0	236.9	29	348.9	383.1	358.0	365.9
30	240.6	269.9	239.2	239.2	30	344.6	374.2	353.0	708.6
31	245.5	239.0	252.7	235.1	31	347.9	348.6	390.0	364.5
32	229.1	248.4	235.1	229.1	32	346.2	350.0	353.5	356.8
33	248.4	235.1	240.2	240.0	33	348.7	350.8	357.6	352.3
34	235.5	239.7	287.2	249.2	34	349.8	350.6	363.4	353.9
35	261.9	277.7	236.3	235.3	35	347.1	420.6	352.0	351.1
36	238.2	276.8	243.9	241.2	36	346.1	348.6	355.2	355.8
37	238.0	241.2	281.3	236.8	37	348.6	350.4	360.7	355.9
38	237.0	232.3	231.7	232.0	38	348.7	378.5	367.9	714.2
39	250.4	247.7	255.8	261.2	39	346.3	377.3	352.8	353.0
40	239.4	235.8	235.1	239.8	40	350.1	349.1	393.9	357.1
mean				242.9	mean				363.2
stdev				12.2	stdev				67.0
max				287.2	max				1024.1
CV%				5.0	CV%				18.5
coeff.unif.				96.3	coeff.unif.				94.1

Appendix B-1. Experiment IIb Dripper Uniformity Test. (Continued)

Test Date, 16 July, 1990

East Header

West Header

Mass of dripper output, less tare mass					Mass of dripper output, less tare mass						
Line	Row 1	Row 2	Row 3	Row 4	Line	Row 1	Row 2	Row 3	Row 4		
1	367.3	370.0	371.6	369.9	1	335.9	337.9	377.2	336.0		
2	368.7	368.1	367.3	368.3	2	337.8	336.7	333.8	335.6		
3	368.0	368.1	368.7	368.3	3	342.7	347.8	516.9	496.6		
4	369.0	369.4	368.3	367.8	4	339.3	335.8	336.7	335.0		
5	367.9	370.9	369.1	366.9	5	335.4	348.9	332.9	334.7		
6	369.3	370.4	366.8	369.3	6	366.2	334.9	334.5	336.4		
7	373.5	385.1	364.6	365.9	7	337.5	334.5	361.3	334.6		
8	369.7	368.7	367.6	419.4	8	333.3	336.5	331.9	341.7		
9	366.0	365.6	379.0	367.8	9	354.9	379.3	335.1	334.5		
10	392.8	400.5	365.6	364.8	10	344.8	337.8	333.0	335.5		
11	365.0	365.5	368.7	368.9	11	332.3	332.7	336.9	331.1		
12	446.5	551.6	466.7	393.0	12	337.3	339.3	336.7	335.9		
13	370.0	367.2	368.2	368.2	13	334.1	336.8	337.8	335.5		
14	367.7	362.3	370.1	366.4	14	334.5	336.4	336.7	332.3		
15	367.3	365.2	379.2	367.0	15	335.9	350.7	354.7	330.2		
16	366.3	440.6	362.4	368.6	16	333.6	334.0	329.8	356.3		
17	364.9	363.8	368.9	366.9	17	334.7	333.0	331.2	328.8		
18	363.8	363.1	366.2	372.3	18	332.6	379.0	330.2	338.7		
19	384.7	363.5	361.7	360.8	19	334.3	349.2	336.6	330.9		
20	361.6	363.1	364.1	365.4	20	336.2	331.0	329.1	331.6		
21	361.6	363.8	373.7	368.9	21	332.8	331.0	341.1	329.7		
22	363.5	361.6	361.3	366.4	22	334.1	331.4	343.6	335.0		
23	370.8	366.2	382.7	369.6	23	334.7	360.7	335.7	335.9		
24	420.8	368.1	365.1	371.4	24	340.3	333.7	333.8	334.7		
25	366.3	365.0	365.9	361.2	25	335.9	334.7	352.8	336.1		
26	367.4	367.6	366.8	367.1	26	332.5	338.7	337.4	352.0		
27	523.5	373.7	442.6	401.3	27	333.0	333.7	332.9	342.6		
28	368.1	368.4	366.6	373.8	28	335.8	345.8	348.6	350.0		
29	368.4	398.4	369.5	368.3	29	336.0	334.9	335.5	335.0		
30	369.4	368.1	368.8	373.0	30	332.6	357.3	337.3	339.4		
31	429.2	414.5	390.0	385.1	31	340.3	335.7	359.5	336.7		
32	400.1	371.3	377.4	372.3	32	331.0	348.2	338.3	339.3		
33	370.5	370.3	377.6	373.8	33	335.5	337.7	340.8	339.1		
34	367.3	368.1	383.3	372.0	34	365.7	395.9	356.5	339.9		
35	373.2	467.2	411.6	467.0	35	412.7	339.4	341.8	387.9		
36	365.4	370.6	374.2	370.7	36	332.9	366.1	344.2	341.6		
37	368.0	370.5	386.1	372.3	37	334.7	337.9	392.7	338.5		
38	368.2	368.9	395.3	390.1	38	337.3	334.5	336.5	332.1		
39	363.6	392.6	369.6	368.2	39	338.7	335.2	343.1	367.7		
40	365.2	367.5	415.8	372.3	40	340.8	335.7	335.3	339.2		
				mean	377.7					mean	343.0
				stdev	27.1					stdev	22.7
				max	551.6					max	516.9
				cv%	7.2					cv%	6.6
				coeff. unif	95.9					coeff. unif	96.6

Appendix B-1. Experiment IIb Dripper Uniformity Test. (Continued)

Dripper Uniformity Test, 16 July 1990

Appendix B-1. Experiment IIb Drinker Uniformity Test. (Continued)

Test Date, 1 August, 1990

East Header

West Header

Mass of dripper output, less tare mass					Mass of dripper output, less tare mass						
Line	Row 1	Row 2	Row 3	Row 4	Line	Row 1	Row 2	Row 3	Row 4		
1	386.0	385.6	387.4	386.5	1	366.7	368.9	368.1	408.8		
2	398.9	388.8	387.6	410.4	2	368.5	366.0	366.4	365.7		
3	387.1	387.9	391.7	396.2	3	363.7	457.4	378.3	384.1		
4	386.1	384.5	392.9	381.9	4	370.9	365.0	365.7	370.0		
5	387.5	393.7	384.5	382.4	5	363.9	393.2	362.7	364.7		
6	384.9	383.9	382.4	385.1	6	411.0	369.6	362.3	358.6		
7	380.7	391.8	381.1	387.0	7	367.3	362.8	361.4	396.5		
8	385.3	385.0	381.9	425.2	8	361.7	365.0	365.3	364.3		
9	N/A	379.8	389.8	380.8	9	420.8	394.8	364.6	367.0		
10	390.0	415.6	381.2	381.3	10	370.9	365.1	363.1	365.9		
11	384.3	381.7	383.2	380.4	11	363.0	362.6	367.9	365.4		
12	396.2	395.6	418.8	463.2	12	366.1	368.9	366.4	367.3		
13	389.2	386.1	384.2	382.4	13	360.8	366.0	362.2	362.4		
14	385.4	383.7	390.3	380.9	14	365.2	366.3	368.5	362.6		
15	388.6	390.1	399.6	385.9	15	364.6	381.3	383.8	358.7		
16	391.3	397.4	380.4	389.2	16	361.9	363.6	359.7	380.7		
17	395.4	396.5	392.0	384.4	17	361.8	362.3	363.7	360.8		
18	386.9	385.3	384.7	386.1	18	365.6	395.2	362.8	371.3		
19	395.7	383.7	380.3	377.8	19	364.4	381.0	366.6	360.6		
20	380.2	381.6	381.6	380.9	20	366.5	360.0	358.1	363.9		
21	382.3	382.0	389.4	381.9	21	363.7	359.4	368.8	357.2		
22	379.3	379.2	379.6	380.8	22	363.1	359.2	365.9	365.0		
23	387.6	383.3	398.3	384.3	23	364.6	378.1	364.5	365.4		
24	399.4	381.3	378.1	383.0	24	369.7	360.8	363.2	363.3		
25	385.4	382.5	383.7	379.9	25	363.6	364.9	386.8	364.6		
26	405.2	400.8	394.9	387.1	26	357.4	361.6	365.9	380.4		
27	404.9	397.4	401.0	400.8	27	360.1	367.2	365.9	372.2		
28	384.9	390.2	387.3	391.8	28	365.6	377.3	380.6	377.6		
29	387.8	414.9	390.7	389.3	29	365.7	365.9	366.5	363.7		
30	382.7	381.8	388.5	385.9	30	332.8	394.1	364.0	376.1		
31	395.7	412.7	429.5	411.8	31	372.3	368.5	395.5	368.5		
32	421.8	390.9	398.6	401.3	32	360.8	382.5	341.3	370.4		
33	389.5	386.5	398.9	392.1	33	359.9	369.9	373.0	369.0		
34	394.4	389.2	400.8	392.2	34	446.7	401.5	385.3	372.4		
35	390.4	408.1	451.4	396.7	35	409.8	372.9	376.7	373.0		
36	382.6	390.6	399.2	392.8	36	387.6	416.6	369.9	370.9		
37	387.2	392.9	406.6	391.0	37	369.7	372.1	400.4	379.8		
38	384.2	385.8	415.5	405.6	38	367.1	365.4	366.6	363.6		
39	383.0	403.1	388.9	391.1	39	367.8	367.9	381.9	372.9		
40	391.8	391.6	407.0	406.4	40	382.9	373.1	367.4	371.2		
				mean	391.4					mean	371.2
				stdev	12.4					stdev	15.4
				max	463.2					max	457.4
				cv%	3.2					cv%	4.1
				coeff. unif	97.9					coeff. unif	97.4

Appendix B-1. Experiment IIb Dripper Uniformity Test. (Continued)

Appendix B-1. Experiment IIb Dropper Uniformity Test. (Continued)

Test Date, 24 October, 1990

East Header

West Header

Mass of dropper output, less tare mass					Mass of dropper output, less tare mass						
Line	Row 1	Row 2	Row 3	Row 4	Line	Row 1	Row 2	Row 3	Row 4		
1	419.0	397.7	399.7	402.2	1	414.46	461.86	399.96	401.56		
2	409.9	399.5	397.7	401.3	2	403.26	402.96	406.26	403.46		
3	403.3	405.4	397.9	402.0	3	406.26	410.26	428.26	442.16		
4	405.3	401.1	401.6	403.4	4	403.56	406.96	401.46	406.06		
5	393.3	400.8	402.2	400.6	5	395.06	396.76	416.66	405.06		
6	397.8	401.0	406.2	404.7	6	407.26	398.06	399.06	406.36		
7	397.2	397.2	399.7	409.1	7	406.36	403.56	397.86	406.66		
8	402.8	402.1	404.6	406.4	8	412.96	401.46	403.76	402.66		
9	398.3	406.7	397.9	395.9	9	406.06	403.56	407.26	405.16		
10	407.0	396.1	445.4	406.4	10	406.96	398.26	403.36	411.26		
11	402.7	400.8	396.1	393.8	11	391.96	410.56	401.56	400.76		
12	405.8	415.0	406.1	403.2	12	407.36	403.46	400.26	400.26		
13	404.7	399.6	400.3	410.0	13	400.56	402.56	401.26	404.06		
14	399.6	399.6	392.7	397.0	14	402.06	401.26	404.56	401.96		
15	398.3	426.4	400.5	402.1	15	400.16	429.66	402.16	401.16		
16	401.5	395.5	405.3	400.9	16	422.36	396.26	400.96	399.96		
17	398.8	397.6	397.1	398.0	17	398.96	397.96	420.26	402.66		
18	405.4	402.9	393.3	397.1	18	395.26	399.06	416.56	404.46		
19	395.5	395.0	397.6	420.9	19	405.46	402.06	426.86	397.56		
20	406.3	399.8	394.3	395.4	20	406.46	396.46	396.16	406.16		
21	404.6	411.0	413.4	392.3	21	405.56	411.96	396.26	400.46		
22	398.1	395.1	403.7	399.1	22	404.06	399.06	451.06	399.66		
23	402.0	394.6	401.3	403.3	23	404.36	398.26	408.26	404.36		
24	399.6	393.3	401.1	389.0	24	403.86	413.56	399.36	398.06		
25	398.3	399.1	403.8	402.5	25	405.06	408.66	399.16	428.56		
26	398.7	400.0	396.0	400.7	26	408.96	401.16	398.86	398.46		
27	510.2	401.9	415.3	410.5	27	415.96	401.36	409.06	403.46		
28	404.6	401.4	398.4	404.5	28	419.66	426.96	403.06	403.76		
29	405.2	404.6	437.7	403.8	29	399.96	401.76	401.56	403.46		
30	399.5	396.7	400.1	400.0	30	410.36	398.56	426.76	403.36		
31	413.3	416.7	411.6	408.4	31	401.56	430.56	402.96	407.26		
32	403.5	406.3	398.3	415.5	32	405.96	403.16	409.86	393.66		
33	405.0	417.7	399.7	398.6	33	405.96	408.96	402.66	405.96		
34	407.5	419.1	395.6	401.0	34	405.06	404.66	410.26	409.36		
35	406.4	405.8	408.3	400.7	35	404.66	401.16	404.36	406.06		
36	397.9	400.5	400.2	410.6	36	402.96	398.56	418.76	404.86		
37	401.0	415.7	401.6	400.1	37	402.66	421.46	412.76	404.76		
38	407.8	410.1	396.7	401.3	38	399.96	403.96	403.36	405.06		
39	400.4	400.5	414.4	394.3	39	405.26	443.36	400.56	403.46		
40	400.3	410.6	398.0	398.5	40	423.26	402.86	417.26	423.76		
				mean	403.5					mean	406.6
				stdev	11.4					stdev	10.3
				max	510.2					max	461.9
				CV%	2.8					CV%	2.5
				coeff.unif.	98.5					coeff.unif.	98.3

Appendix B-1. Experiment IIb Dripper Uniformity Test. (Continued)

Appendix B-2. Tritium Scintillation Cocktail and Aliquot Volume Adjustments.

Introduction

Two different scintillation cocktails were used to analyze the tritium samples of experiment IIb. A unique set of counting efficiencies is associated with each cocktail where the scintillation response is a function of the cocktail formulation, the particle being counted and the liquid with which the cocktail is mixed. The cocktail used for the trench irrigation experiment IIb samples from days 0 through 184 was Aquasol universal LSC, a xylene-based product manufactured by Dupont New England Nuclear (p/n NEF-934, Boston, MA). After day 184 samples were prepared with Ready-Safe LSC (Beckman Instruments Inc., Fullerton, CA), a newer cocktail formulation with significantly higher counting efficiency than xylene based cocktails (Klein and Gershey, 1990). Ready-Safe was less expensive, more safely handled, and proved to mix more readily with aqueous sample to form a uniform gel than did Aquasol.

The amount of sample mixed with cocktail for experiment IIb tritium analyses was reduced when insufficient sample had been collected in the field to use the normal 0.5 ml aliquot size.

This volume varied from 0.1 to 0.5 ml by steps of 0.1 ml. The quenching characteristic of a scintillation gel is sensitive to the proportions of sample and cocktail. As sample aliquot size is reduced the resulting counts are disproportionately increased. Therefore, a vial counted with 0.1 ml of solution added to cocktail produces more than $1/5 = 20\%$ of the counts as when 0.5 ml of solution is used.

Two experiments were performed to elucidate the characteristics of quenching and counting efficiency of the two cocktails used in experiments IIa and IIb. The first experiment was done early in experiment IIb, before the switch from Aquasol cocktail was contemplated. Its purpose was to identify the character of quenching with different sample aliquot sizes. The second experiment was done just prior to the first use of Ready-Safe. Its purpose was not only to identify quenching characteristics of both cocktails with various aliquot sizes but to identify the differences in cocktail-specific counting efficiencies. These data produced simple normalization factors to allow all experiment IIb counting data to be expressed as equivalent counts of Aquasol-cocktail gels at a normal sample aliquot volume of 0.5 ml.

Appendix B-2. Tritium Scintillation Cocktail and Aliquot Volume Adjustments. (Continued)

Experiment 1: Aquasol

Tritium was used at three different concentrations. The most concentrated solution, about 0.2 mCi/L, was diluted serially to produce the other two solutions, 0.02 and 0.002 mCi/L, respectively. Since relative concentrations were sought rather than absolute tritium activity no attempt was made to correct observed counts for decay or known standards. Five aliquot volumes were used; 0.1, 0.2, 0.3, 0.4 and 0.5 ml. Each aliquot was used with each of the three solutions for seven replicate vials of each combination. The treatments for this experiment were therefore:

$$\begin{aligned} &\text{Concentration (3)} \times \text{Aliquot (5)} \\ &\times \text{Replication (7)} = 105, n \end{aligned}$$

Tritium was analyzed with a Beckman LS-1800 programmable liquid scintillation counter. Individual replications of sample were prepared for scintillation by pipetting the designated aliquot (0-100 μ l adjustable Eppendorf pipettor or 500 μ l Eppendorf pipettor, Brinkman Instruments, Inc., Westbury, NY) to 5 ml of scintillation cocktail in 8 ml Beckman Mini Poly-Q vials. Each vial was capped and placed in a rack with other vials. When the entire rack was filled it was vigorously shaken to mix the vials contents to form the desired gel. Vials were then transferred to a counting rack compatible with the counter. The counter was programmed to run in auto-count mode, with a single channel window of 0-400 nm and no internal standard. Counting time per vial was set to a maximum of 10 minutes. At the beginning

of a run a series of ten background vials was counted. These vials were prepared with 0.5 ml aliquots of un-traced distilled-deionized water in place of treatment solution in the vials.

The results are given in Table 1. The observed counts for the 0.5 ml aliquot treatment at the highest concentration of tritium are used to anchor the expected counts for the remainder of the treatments. Therefore, expected counts for 0.1 ml aliquot at the lowest concentration would be the baseline anchor counts $\times$ 0.01 dilution $\times$ 1/5 aliquot ratio. This treatment assumed that counts derived from tritium are linear across the entire range of measurement and that the dilutions of full-strength tritium were exact when making the medium-and low-concentration solutions.

Figure 1 illustrates the linear relationship between observed counts of 0.2, 0.02, and 0.002 mCi/L solutions at the same aliquot size and the predicted counts for each treatment. Each data point represents the mean of seven replications, less background counts. The intercepts for the regression models were forced through $Y = 0$. The strong linear nature of the scintillation response to tritium concentration is evident in the high values for individual determination coefficients. As the aliquot size is reduced the slope of the prediction equation increases, which indicates less quenching of β -emissions as the activity of tritium is decreased relative to scintillation cocktail. These data indicate that this characteristic was highly predictable.

Appendix B-2. Tritium Scintillation Cocktail and Aliquot Volume Adjustments. (Continued)

Experiment 1: Aquasol. Data expressed as counts per minute

Tritium Conc. Aliquot (ml)	0.2 mCi/L					0.02 mCi/L					0.002 mCi/L				
	0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1
Rep. I	37239	30647	23622	16761	8819	3785	3081	2444	1678	922	394	321	252	192	100
II	37452	30801	24060	16610	8970	3780	3076	2407	1668	905	388	319	255	179	102
III	37074	30807	23816	16669	8893	3777	3099	2416	1685	898	378	323	254	175	103
IV	37563	30536	24055	16613	8872	3735	3137	2409	1669	920	389	333	259	180	104
V	37179	30750	23778	16629	8848	3780	3107	2404	1695	915	390	326	247	183	101
VI	37253	31048	23802	16779	8866	3724	3091	2415	1673	924	407	331	248	177	98
VII	37413	30541	23796	16464	8927	3778	3094	2408	1686	888	387	324	252	178	103
Mean Counts	37310	30733	23847	16646	8885	3766	3098	2415	1679	910	390	325	252	181	102
Std Dev	171.23	179.20	157.91	105.86	50.51	24.97	20.17	13.61	9.99	13.65	8.77	5.12	4.12	5.62	2.07
CV %	0.46	0.58	0.66	0.64	0.57	0.66	0.65	0.56	0.59	1.50	2.25	1.57	1.63	3.11	2.04
Expected Counts	37310	29848	22386	14924	7462	3731	2985	2239	1492	746	373	298	224	149	75
Error	0.000	1.030	1.065	1.115	1.191	1.009	1.038	1.079	1.125	1.220	1.047	1.090	1.128	1.210	1.362

Treatments: Cocktail (1) x Tritium concentration (3) x Aliquot size (5) x Replication (7)

Cocktail NEN Aquasol Universal LSC
Tritium concentration 0.2, 0.02, 0.002 mCi/L
Aliquot size 0.5, 0.4, 0.3, 0.2, 0.1 ml

Appendix B-2. Tritium Scintillation Cocktail and Aliquot Volume Adjustments. (Continued)

Experiment 1: Predicted v Observed Counts for Tritium in Aquasol Cocktail

Appendix B-2. Tritium Scintillation Cocktail and Aliquot Volume Adjustments (Continued)

Experiment 2: Aquasol and Ready-Safe Cocktails

The procedures for experiment 1 were expanded to include treatments with a new cocktail, Ready-Safe. The number of replications was reduced to 4. The mechanics and tritium solutions used in experiment 2 remained the same. The new treatment regime was:

Concentration (3) x Aliquot (5) x
Replication (4) x Cocktail (2) = 120, n.

The results are given in Table 2. The observed counts for 0.5 ml aliquot volume at the highest concentration of tritium in *Aquasol cocktail* are used to anchor the expected counts for the remainder of the treatments. Therefore, expected counts for 0.1 ml aliquot at the lowest concentration would be the anchored baseline counts x 0.01 dilution x 1/5 aliquot ratio. The same assumptions as in experiment 1 were in force. As before, the variability about the treatment means was relatively low and did not suffer here from fewer replications.

Figure 2 illustrates the linear relationship between observed counts of 0.2, 0.02, and 0.002

mCi/L solutions at the same aliquot size and the counts for each treatment. Each data point represents the mean of four replications, less background counts. The intercepts for the linear regression models were forced through $Y = 0$. The highly linear nature of the scintillation response to tritium concentration was again evident, this time for both cocktails. With Ready Safe, the margin of improved counting efficiency over Aquasol tended to decrease as the aliquot size was reduced, from about 6-7 percent improved performance over Aquasol at 0.5, 0.4, and 0.3 ml aliquot sizes, to about 3% at 0.2 ml and less than 1% at 0.1 ml. These data indicate that the quenching characteristic was again highly predictable for both cocktails.

This data was used to make a simple correction factor for experiment IIb scintillation counts for tritium. This factor was used to normalize all count data for 0.5 ml aliquot volumes in Aquasol cocktail. Since the results for experiment 1 and experiment 2 Aquasol treatments were so similar, the experiment 2 data were used for all correction factors. These volume/cocktail correction factors, K_{vc} , (Table 3), were found by taking the inverse of each slope parameter from the individual regression models.

Table 3. Background adjusted correction factors

Aliquot Vol. (ml)	Correction Factor -----		
	Exp. 1 Aquasol	Exp. 1 Aquasol	Exp. 2 Ready-Safe
0.5	1.000	1.000	0.938
0.4	0.971	0.974	0.911
0.3	0.939	0.942	0.888
0.2	0.898	0.895	0.868
0.1	0.840	0.837	0.834

Experiment 2: Aquasol and Ready-Safe Cocktails. Data expressed as counts per minute.

Aquasol

Tritium Conc.		0.2 mCi/L					0.02 mCi/L					0.002 mCi/L				
Aliquot (ml)		0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1
Rep.	I	36118	29719	22869	15962	8607	3611	2953	2355	1625	854	391	314	245	175	98
	II	35916	29564	22930	16087	8683	3639	3022	N/A	1642	871	372	314		177	91
	III	36018	29676	22858	16085	8539	3634	3005	2348	1656	875	384	307	246	173	99
	IV	36003	29341	23114	16228	8566	3644	2968	2341	1618	887	367	303	246	167	99
Mean		36014	29575	22943	16091	8599	3632	2987	2348	1635	872	379	310	246	173	97
Std Dev		82.78	169.13	118.48	108.72	62.74	14.58	31.97	7.00	17.11	13.65	10.97	5.45	0.58	4.32	3.86
CV %		0.23	0.57	0.52	0.68	0.73	0.40	1.07	0.30	1.05	1.57	2.90	1.76	0.24	2.50	3.99
Expected counts		36014	28811	21608	14406	7203	3601	2881	2161	1441	720	360	288	216	144	72
Error		0.000	0.026	0.058	0.105	0.162	0.008	0.035	0.080	0.119	0.174	0.049	0.069	0.120	0.167	0.256

Ready Safe

Tritium Conc.		0.2 mCi/L					0.02 mCi/L					0.002 mCi/L				
Aliquot (ml)		0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1
Rep.	I	38370	31576	24295	16624	8703	3808	3217	2423	1668	889	393	339	256	182	96
	II	38411	31665	24231	16600	8551	3793	3200	2439	1694	865	381	342	256	176	97
	III	38468	31800	24321	16632	8606	3779	3164	2459	1678	888	394	335	261	184	103
	IV	38366	31463	24438	16482	8681	3779	3179	2405	1673	880	389	329	259	186	97
Mean		38404	31626	24321	16585	8635	3790	3190	2432	1678	881	389	336	258	182	98
Std Dev		47.42	142.44	86.53	69.67	69.85	13.84	23.28	23.00	11.27	11.09	5.91	5.62	2.45	4.32	3.20
CV %		0.12	0.45	0.36	0.42	0.81	0.37	0.73	0.95	0.67	1.26	1.52	1.67	0.95	2.37	3.26
Expected counts		38404	30723	23042	15362	7681	3840	3072	2304	1536	768	384	307	230	154	77
Error		0.000	0.029	0.053	0.074	0.111	-0.013	0.037	0.052	0.085	0.128	0.013	0.086	0.107	0.156	0.218

Treatments: Cocktail (2) x Tritium concentration (3) x Aliquot size (5) x Replication (4)

Cocktail   NEN Aquasol Universal LSC, Beckman Ready-Safe LSC
Tritium concentration   0.2, 0.02, 0.002 mCi/L
Aliquot vol.   0.5, 0.4, 0.3, 0.2, 0.1 ml

Appendix B-2. Tritium Scintillation Cocktail and Aliquot Volume Adjustments.
(Continued)

Experiment 2: Predicted v Observed Counts for Tritium in Aquasol and Ready-Safe Cocktails.

Appendix B-3. Tensimeter Calibration.

Soil tensions during experiment IIb were measured to the nearest millibar with one of two hand-held pressure transducer units (Soil Measurement Systems, Tucson, AZ). Both transducers contained identical electronics. The transducer normally used to take these readings was identified by its serial number, S/N 83063. A backup transducer was used occasionally, S/N 87662. Both units produced a reproducible and linear reading of applied tension during the calibration.

The operation and calibration of these units was checked periodically against regulated laboratory manometers. The maximum vacuum to the manometers was provided by a laboratory source about 425-450 mb strong. Tension to the manometers was regulated by a Moore model 44-20 pressure regulator (Moore Products Co., Springhouse, PA). Tensions from 0-40 mb were

routed through a vertical water-filled manometer, measured to the nearest 0.1 cm at the meniscus. Tensions above 40 mb were routed through a vertical mercury-filled manometer, again measured to the nearest 0.1 cm hg. The height of the mercury column was converted to cm water at the rate of 13.6 cm H₂O/cm mercury. Tensimeter readings were taken at set tension steps on the manometer through a septum stopper attached indirectly to the output of the regulator.

The following three tables provide the results from tensimeter calibration on three separate dates. A linear least-squares model was used to fit observed tension readings (cm H₂O) to source vacuum (cm H₂O). The results of the last calibration date are also provided in a plot which follows the tables.

Calibration Date: 7/27/90

S/N 87662		S/N 83063		
Source	Obs.	Source	Obs.	
0	0	0	0	Model: $Y = b + m * \text{Source}$
5	5	5	5	
20	22	20	20	<u>S/N 87662</u>
40	46	40	39	
85	97	80	79	
140	162	140	140	$Y = -0.2085 + 1.1493 * \text{Source}$
200	230	200	201	
300	345	300	301	
455	522	435	438	
				<u>S/N 83064</u>
				$Y = -0.6194 + 1.0070 * \text{Source}$
				$R^2 = 0.999985$
				$R^2 = 0.999984$

Appendix B-3. Tensimeter Calibration. (Continued)

Calibration Date: 10/9/90

S/N 87662		S/N 83064		
Source	Obs.	Source	Obs.	
0	0	0	0	Model: $Y = b + m * \text{source}$
5	5	5	5	
21	24	20	21	<u>S/N 87662</u> $Y = -0.6020 + 1.1512 * \text{Source}$ $R^2 = 0.999965$
41	48	40	40	
80	91	80	80	
120	136	120	119	
200	229	200	200	<u>S/N 83064</u> $Y = -0.1288 + 1.0018 * \text{Source}$ $R^2 = 0.99997$
301	345	310	309	
425	490	440	442	

Calibration Date: 12/12/90

S/N 87662		S/N 83064		
Source	Obs.	Source	Obs.	
0	0	0	4	Model: $Y = b + m * \text{source}$
4	4	10	10	
20	22	20	21	<u>S/N 87662</u> $Y = -0.8767 + 1.1444 * \text{Source}$ $R^2 = 0.99998$
40	44	40	40	
80	91	80	79	
136	153	54	54	
204	234	136	132	<u>S/N 83064</u> $Y = -0.2634 + 1.0029 * \text{Source}$ $R^2 = 0.99989$
272	310	204	207	
408	466	272	273	
476	544	408	410	
		474	474	

Appendix B-3. Tensimeter Calibration. (Continued)

Tensimeter Calibration of 12/12/90

Appendix B-4. Comparison of NMSU and University of Arizona Laboratory Results.

A small selection of samples from the Experiment IIb soil cores liquid extracts was sent to the Soil, Water and Plant Analyses Laboratory of the University of Arizona to verify earlier results obtained by technicians at New Mexico State University. Ten samples (identified by core section and segment number) had been analyzed at NMSU for nitrate, chloride, chromium and boron by methods described in section 5.2 of this report.

At the University of Arizona laboratory nitrate and chloride were analyzed by ion chromatography methods. Corresponding methods at NMSU were by spectrophotometric autoanalyzer and by chloridometer titration, respectively. Chromium and Boron were analyzed at the University of Arizona by inductively coupled plasma emission methods like at NMSU. The results of these comparative analyses are provided in the following tables.

Sample	NMSU	UA	NMSU	UA	NMSU	UA
100.0	0.015	0.015	1.0	0.01	0.01	0.01
200.0	0.015	0.015	1.0	0.01	0.01	0.01
300.0	0.015	0.015	0.01	0.01	0.01	0.01
400.0	0.015	0.015	0.01	0.01	0.01	0.01
500.0	0.015	0.015	0.01	0.01	0.01	0.01
600.0	0.015	0.015	0.01	0.01	0.01	0.01
700.0	0.015	0.015	0.01	0.01	0.01	0.01
800.0	0.015	0.015	0.01	0.01	0.01	0.01
900.0	0.015	0.015	0.01	0.01	0.01	0.01
1000.0	0.015	0.015	0.01	0.01	0.01	0.01

Sample	NMSU	UA	NMSU	UA	NMSU	UA
100.0	0.015	0.015	1.0	0.01	0.01	0.01
200.0	0.015	0.015	1.0	0.01	0.01	0.01
300.0	0.015	0.015	0.01	0.01	0.01	0.01
400.0	0.015	0.015	0.01	0.01	0.01	0.01
500.0	0.015	0.015	0.01	0.01	0.01	0.01
600.0	0.015	0.015	0.01	0.01	0.01	0.01
700.0	0.015	0.015	0.01	0.01	0.01	0.01
800.0	0.015	0.015	0.01	0.01	0.01	0.01
900.0	0.015	0.015	0.01	0.01	0.01	0.01
1000.0	0.015	0.015	0.01	0.01	0.01	0.01

**Appendix B-4. Comparison of NMSU and University of Arizona Laboratory Results.
(Continued)**

New Mexico State University, (ppm)

Sample ID	Nitrate	Chloride	Boron	Chromium
33-1	0.3	11.7	4.776	0.071
33-2	5.9	16.1	4.052	0.064
35-1	225.3	406.1	5.187	0.005
35-2	241.2	518.5	4.505	0.007
35-3	232.4	587.6	3.957	0.015
35-4	201.5	608.5	4.894	0.010
36-1	14.3	4.7	4.471	0.003
36-2	16.4	6.5	4.372	0.001
36-3	8.1	5.0	3.836	0.035
36-4	5.2	8.0	4.318	0.027

University of Arizona, (ppm)

Sample ID	Nitrate	Chloride	Boron	Chromium
33-1	1.2	7.1	5.120	0.094
33-2	4.3	9.1	4.520	0.084
35-1	247.0	396.0	5.500	-0.002
35-2	264.0	516.0	4.830	-0.002
35-3	241.0	588.0	4.150	-0.002
35-4	220.0	597.0	5.190	-0.002
36-1	15.9	6.1	5.130	0.003
36-2	20.3	7.2	4.900	-0.002
36-3	12.8	6.5	4.170	0.019
36-4	6.4	8.3	4.670	0.015

Difference between measurements, U/A - NMSU, (ppm)

Sample ID	Nitrate	Chloride	Boron	Chromium
33-1	0.9	-4.6	0.344	0.023
33-2	-1.6	-7.0	0.468	0.020
35-1	21.7	-10.1	0.313	-0.007
35-2	22.8	-2.5	0.325	-0.009
35-3	8.6	0.4	0.193	-0.017
35-4	18.5	-11.5	0.296	-0.012
36-1	1.6	1.4	0.659	0.000
36-2	3.9	0.7	0.528	-0.003
36-3	4.7	1.5	0.334	-0.016
36-4	1.2	0.3	0.352	-0.012

NRC TRENCH EXPERIMENT IIb - PUMPHOUSE RECORD

[illegible]

Comments:

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb - TENSIO METER READINGS

Date _____ 24 hr Time _____ By _____ Fill Date/By _____

Tensimeter ID _____ File Entry Date/By _____ Verify _____

	Raw	Air	F?		Raw	Air	F?		Raw	Air	F?
140	_____	_____	_____	840	_____	_____	_____	1440	_____	_____	_____
142	_____	_____	_____	842	_____	_____	_____	1442	_____	_____	_____
144	_____	_____	_____	844	_____	_____	_____	1444	_____	_____	_____
146	_____	_____	_____	846	_____	_____	_____	1446	_____	_____	_____
148	_____	_____	_____	848	_____	_____	_____	1448	_____	_____	_____
150	_____	_____	_____	850	_____	_____	_____	1450	_____	_____	_____
152	_____	_____	_____	852	_____	_____	_____	1452	_____	_____	_____
154	_____	_____	_____	854	_____	_____	_____	1454	_____	_____	_____
156	_____	_____	_____	856	_____	_____	_____	1456	_____	_____	_____
158	_____	_____	_____	858	_____	_____	_____	1458	_____	_____	_____
160	_____	_____	_____	860	_____	_____	_____	1460	_____	_____	_____
340	_____	_____	_____	1040	_____	_____	_____	1640	_____	_____	_____
342	_____	_____	_____	1042	_____	_____	_____	1642	_____	_____	_____
344	_____	_____	_____	1044	_____	_____	_____	1644	_____	_____	_____
346	_____	_____	_____	1046	_____	_____	_____	1646	_____	_____	_____
348	_____	_____	_____	1048	_____	_____	_____	1648	_____	_____	_____
350	_____	_____	_____	1050	_____	_____	_____	1650	_____	_____	_____
352	_____	_____	_____	1052	_____	_____	_____	1652	_____	_____	_____
354	_____	_____	_____	1054	_____	_____	_____	1654	_____	_____	_____
356	_____	_____	_____	1056	_____	_____	_____	1656	_____	_____	_____
358	_____	_____	_____	1058	_____	_____	_____	1658	_____	_____	_____
360	_____	_____	_____	1060	_____	_____	_____	1660	_____	_____	_____
640	_____	_____	_____	1240	_____	_____	_____	1840	_____	_____	_____
642	_____	_____	_____	1242	_____	_____	_____	1842	_____	_____	_____
644	_____	_____	_____	1244	_____	_____	_____	1844	_____	_____	_____
646	_____	_____	_____	1246	_____	_____	_____	1846	_____	_____	_____
648	_____	_____	_____	1248	_____	_____	_____	1848	_____	_____	_____
650	_____	_____	_____	1250	_____	_____	_____	1850	_____	_____	_____
652	_____	_____	_____	1252	_____	_____	_____	1852	_____	_____	_____
654	_____	_____	_____	1254	_____	_____	_____	1854	_____	_____	_____
656	_____	_____	_____	1256	_____	_____	_____	1856	_____	_____	_____
658	_____	_____	_____	1258	_____	_____	_____	1858	_____	_____	_____
660	_____	_____	_____	1260	_____	_____	_____	1860	_____	_____	_____

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb - TENSIO-METER READINGS (continued)

	Raw	Air	F?		Raw	Air	F?		Raw	Air	F?
2040	_____	_____	_____	2240	_____	_____	_____	2440	_____	_____	_____
2042	_____	_____	_____	2242	_____	_____	_____	2442	_____	_____	_____
2044	_____	_____	_____	2244	_____	_____	_____	2444	_____	_____	_____
2046	_____	_____	_____	2246	_____	_____	_____	2446	_____	_____	_____
2048	_____	_____	_____	2248	_____	_____	_____	2448	_____	_____	_____
2050	_____	_____	_____	2250	_____	_____	_____	2450	_____	_____	_____
2052	_____	_____	_____	2252	_____	_____	_____	2452	_____	_____	_____
2054	_____	_____	_____	2254	_____	_____	_____	2454	_____	_____	_____
2056	_____	_____	_____	2256	_____	_____	_____	2456	_____	_____	_____
2058	_____	_____	_____	2258	_____	_____	_____	2458	_____	_____	_____
2060	_____	_____	_____	2260	_____	_____	_____	2460	_____	_____	_____

Comments:

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb - SOLUTION SAMPLE COLLECTION & VOLUME

Date/By _____ Time: Begin _____ End _____ Vacuum (cm Hg) _____

File name _____ Entry Date/By _____ Verify Date/By _____

	tare	w/sample	w/diln.		tare	w/sample	w/diln.
241	-----	-----	-----	841	-----	-----	-----
243	-----	-----	-----	843	-----	-----	-----
245	-----	-----	-----	845	-----	-----	-----
247	-----	-----	-----	847	-----	-----	-----
249	-----	-----	-----	849	-----	-----	-----
251	-----	-----	-----	851	-----	-----	-----
253	-----	-----	-----	853	-----	-----	-----
255	-----	-----	-----	855	-----	-----	-----
257	-----	-----	-----	857	-----	-----	-----
259	-----	-----	-----	859	-----	-----	-----
441	-----	-----	-----	1041	-----	-----	-----
443	-----	-----	-----	1043	-----	-----	-----
445	-----	-----	-----	1045	-----	-----	-----
447	-----	-----	-----	1047	-----	-----	-----
449	-----	-----	-----	1049	-----	-----	-----
451	-----	-----	-----	1051	-----	-----	-----
453	-----	-----	-----	1053	-----	-----	-----
455	-----	-----	-----	1055	-----	-----	-----
457	-----	-----	-----	1057	-----	-----	-----
459	-----	-----	-----	1059	-----	-----	-----
641	-----	-----	-----	1241	-----	-----	-----
643	-----	-----	-----	1243	-----	-----	-----
645	-----	-----	-----	1245	-----	-----	-----
647	-----	-----	-----	1247	-----	-----	-----
649	-----	-----	-----	1249	-----	-----	-----
651	-----	-----	-----	1251	-----	-----	-----
653	-----	-----	-----	1253	-----	-----	-----
655	-----	-----	-----	1255	-----	-----	-----
657	-----	-----	-----	1257	-----	-----	-----
659	-----	-----	-----	1259	-----	-----	-----

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb - SOLUTION SAMPLE COLLECTION & VOLUME

(continued)

	tare	w/sample	w/diln.		tare	w/sample	w/diln.
1441	-----	-----	-----	2041	-----	-----	-----
1443	-----	-----	-----	2043	-----	-----	-----
1445	-----	-----	-----	2045	-----	-----	-----
1447	-----	-----	-----	2047	-----	-----	-----
1449	-----	-----	-----	2049	-----	-----	-----
1451	-----	-----	-----	2051	-----	-----	-----
1453	-----	-----	-----	2053	-----	-----	-----
1455	-----	-----	-----	2055	-----	-----	-----
1457	-----	-----	-----	2057	-----	-----	-----
1459	-----	-----	-----	2059	-----	-----	-----
1641	-----	-----	-----	2241	-----	-----	-----
1643	-----	-----	-----	2243	-----	-----	-----
1645	-----	-----	-----	2245	-----	-----	-----
1647	-----	-----	-----	2247	-----	-----	-----
1649	-----	-----	-----	2249	-----	-----	-----
1651	-----	-----	-----	2251	-----	-----	-----
1653	-----	-----	-----	2253	-----	-----	-----
1655	-----	-----	-----	2255	-----	-----	-----
1657	-----	-----	-----	2257	-----	-----	-----
1659	-----	-----	-----	2259	-----	-----	-----
1841	-----	-----	-----	2441	-----	-----	-----
1843	-----	-----	-----	2443	-----	-----	-----
1845	-----	-----	-----	2445	-----	-----	-----
1847	-----	-----	-----	2447	-----	-----	-----
1849	-----	-----	-----	2449	-----	-----	-----
1851	-----	-----	-----	2451	-----	-----	-----
1853	-----	-----	-----	2453	-----	-----	-----
1855	-----	-----	-----	2455	-----	-----	-----
1857	-----	-----	-----	2457	-----	-----	-----
1859	-----	-----	-----	2459	-----	-----	-----

Code Explanation & Comments:

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

AutoAnalyser Nitrate											
Project _____						Page ____ of ____					
Technician _____						Date: _____					
Standard _____						Entry Date/By _____					
Pos.	Sample	Dilution	Peak	Pos.	Sample	Dilution	Peak	Pos.	Sample	Dilution	Peak
1				28				15			
2				29				16			
3				30				17			
4				31				18			
5				32				19			
6				33				20			
7				34				21			
8				35				22			
9				36				23			
10				37				24			
11				38				25			
12				39				26			
13				40				27			
14				1				28			
15				2				29			
16				3				30			
17				4				31			
18				5				32			
19				6				33			
20				7				34			
21				8				35			
22				9				36			
23				10				37			
24				11				38			
25				12				39			
26				13				40			
27				14							

NRC AutoAnalyser Nitrate Analyses Form 9/91

CHLORIDOMETER CHLORIDE

Project

Date

Time

By

File: Name

Entry Date/By

Verify Date/By

Normal chloridometer mode:

Low

High

Background (me/l):

1

-2

3

4

5

6

7

8

9

1

Mean

Std Dev

CV

Sample ID # A me/I

Sample ID # A me/I

Sample ID # A me/I

Comments:

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb - TRITIUM REPEAT ANALYSES

Sample Date _____ Repeat Analyses Date _____ Technician _____

Entry Date/By _____ Verify Date/By _____

	P	A	S	Tare	+ Sln	+Add H2O	C		P	A	S	Tare	+ Sln	+Add H2O	C
241	-	-	-	-	-	-	-	841	-	-	-	-	-	-	-
243	-	-	-	-	-	-	-	843	-	-	-	-	-	-	-
245	-	-	-	-	-	-	-	845	-	-	-	-	-	-	-
247	-	-	-	-	-	-	-	847	-	-	-	-	-	-	-
249	-	-	-	-	-	-	-	849	-	-	-	-	-	-	-
251	-	-	-	-	-	-	-	851	-	-	-	-	-	-	-
253	-	-	-	-	-	-	-	853	-	-	-	-	-	-	-
255	-	-	-	-	-	-	-	855	-	-	-	-	-	-	-
257	-	-	-	-	-	-	-	857	-	-	-	-	-	-	-
259	-	-	-	-	-	-	-	859	-	-	-	-	-	-	-
441	-	-	-	-	-	-	-	1041	-	-	-	-	-	-	-
443	-	-	-	-	-	-	-	1043	-	-	-	-	-	-	-
445	-	-	-	-	-	-	-	1045	-	-	-	-	-	-	-
447	-	-	-	-	-	-	-	1047	-	-	-	-	-	-	-
449	-	-	-	-	-	-	-	1049	-	-	-	-	-	-	-
451	-	-	-	-	-	-	-	1051	-	-	-	-	-	-	-
453	-	-	-	-	-	-	-	1053	-	-	-	-	-	-	-
455	-	-	-	-	-	-	-	1055	-	-	-	-	-	-	-
457	-	-	-	-	-	-	-	1057	-	-	-	-	-	-	-
459	-	-	-	-	-	-	-	1059	-	-	-	-	-	-	-
641	-	-	-	-	-	-	-	1241	-	-	-	-	-	-	-
643	-	-	-	-	-	-	-	1243	-	-	-	-	-	-	-
645	-	-	-	-	-	-	-	1245	-	-	-	-	-	-	-
647	-	-	-	-	-	-	-	1247	-	-	-	-	-	-	-
649	-	-	-	-	-	-	-	1249	-	-	-	-	-	-	-
651	-	-	-	-	-	-	-	1251	-	-	-	-	-	-	-
653	-	-	-	-	-	-	-	1253	-	-	-	-	-	-	-
655	-	-	-	-	-	-	-	1255	-	-	-	-	-	-	-
657	-	-	-	-	-	-	-	1257	-	-	-	-	-	-	-
659	-	-	-	-	-	-	-	1259	-	-	-	-	-	-	-

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb - TRITIUM REPEAT ANALYSES (continued)

	P	A	S	Tare	+ Sln	+Add H2O	C		P	A	S	Tare	+ Sln	+Add H2O	C
1441	-	-	-	-	-	-	-	2041	-	-	-	-	-	-	-
1443	-	-	-	-	-	-	-	2043	-	-	-	-	-	-	-
1445	-	-	-	-	-	-	-	2045	-	-	-	-	-	-	-
1447	-	-	-	-	-	-	-	2047	-	-	-	-	-	-	-
1449	-	-	-	-	-	-	-	2049	-	-	-	-	-	-	-
1451	-	-	-	-	-	-	-	2051	-	-	-	-	-	-	-
1453	-	-	-	-	-	-	-	2053	-	-	-	-	-	-	-
1455	-	-	-	-	-	-	-	2055	-	-	-	-	-	-	-
1457	-	-	-	-	-	-	-	2057	-	-	-	-	-	-	-
1459	-	-	-	-	-	-	-	2059	-	-	-	-	-	-	-
1641	-	-	-	-	-	-	-	2241	-	-	-	-	-	-	-
1643	-	-	-	-	-	-	-	2243	-	-	-	-	-	-	-
1645	-	-	-	-	-	-	-	2245	-	-	-	-	-	-	-
1647	-	-	-	-	-	-	-	2247	-	-	-	-	-	-	-
1649	-	-	-	-	-	-	-	2249	-	-	-	-	-	-	-
1651	-	-	-	-	-	-	-	2251	-	-	-	-	-	-	-
1653	-	-	-	-	-	-	-	2253	-	-	-	-	-	-	-
1655	-	-	-	-	-	-	-	2255	-	-	-	-	-	-	-
1657	-	-	-	-	-	-	-	2257	-	-	-	-	-	-	-
1659	-	-	-	-	-	-	-	2259	-	-	-	-	-	-	-
1841	-	-	-	-	-	-	-	2441	-	-	-	-	-	-	-
1843	-	-	-	-	-	-	-	2443	-	-	-	-	-	-	-
1845	-	-	-	-	-	-	-	2445	-	-	-	-	-	-	-
1847	-	-	-	-	-	-	-	2447	-	-	-	-	-	-	-
1849	-	-	-	-	-	-	-	2449	-	-	-	-	-	-	-
1851	-	-	-	-	-	-	-	2451	-	-	-	-	-	-	-
1853	-	-	-	-	-	-	-	2453	-	-	-	-	-	-	-
1855	-	-	-	-	-	-	-	2455	-	-	-	-	-	-	-
1857	-	-	-	-	-	-	-	2457	-	-	-	-	-	-	-
1859	-	-	-	-	-	-	-	2459	-	-	-	-	-	-	-

Code Explanation & Comments:

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

NRC TRENCH EXPERIMENT IIb

NRC Trench Experiment IIb
Spring 1991 Transect Sample Log

Date _____

Y _____ m   Core Date _____
X _____ m   Z Interval _____ ft

Sample ID	Z (ft)	Backfill (cm)	Discard (cm)	Recovery (cm)	# Seg.	Segment Length (cm)	Segment Interval	Segment Mass (g)
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____
____	____	____	____	____	____	____	____	--1 _____ --2 _____ --3 _____ --4 _____

Form revised 5-22-91

**NRC Experiment IIb Redistribution
Spring 1991 Transect Samples**

Technician

Notes:

Appendix B-5. Experiment IIb Forms for field data collection. (Continued)

Spring 1991 Sample Treatment History Form

#	Seg.	Extr.	Nitrate	Chloride	EC	Cr/B	Tritium	to vials	Code	Redo
1	1									
1	2									
1	3									
1	4									
2	1									
2	2									
2	3									
2	4									
3	1									
3	2									
3	3									
3	4									
4	1									
4	2									
4	3									
4	4									
5	1									
5	2									
5	3									
5	4									
6	1									
6	2									
6	3									
6	4									
7	1									
7	2									
7	3									
7	4									
8	1									
8	2									
8	3									
8	4									
9	1									
9	2									
9	3									
9	4									

Appendix B-6. Experiment IIb Sample pH, Day 225.

The samples collected on day 225 (3/14/91) from the Experiment IIb solution samplers were evaluated for approximate pH in the field. Narrow range pH indicator strips (ColorpHast strips, EM Science, Gibbstown, NJ), pH 6.5-10.0 were dipped into the fresh solution of each sampler, allowed to develop pH-dependant color changes for about 1 minute and then compared to a color chart to determine pH. The color

comparisons were made in natural light conditions. The semi-quantitative nature of these strips allows pH resolution of 0.2 units between pH = 6.8-7.8 and 0.3 units above and below those limits. Some visual interpolations between those units were made when evaluating these samples. The following table lists the results for each solution sample collected on that day.

X ₂	Y ₂	Z ₂	pH	X ₂	Y ₂	Z ₂	pH	X ₂	Y ₂	Z ₂	pH
-2.26	0.5	0.5	7.4	1.84	0.5	2.0	7.5	-0.25	0.5	4.0	8.2
-1.75	0.5	0.5	7.5	2.24	0.5	2.0	7.6	0.25	0.5	4.0	8.4
-1.25	0.5	0.5	7.3	-2.25	0.5	2.5	8.0	0.75	0.5	4.0	8.4
-0.25	0.5	0.5	7.6	-1.75	0.5	2.5	8.0	1.25	0.5	4.0	8.2
0.25	0.5	0.5	7.6	-1.25	0.5	2.5	8.1	1.84	0.5	4.0	8.1
0.75	0.5	0.5	7.2	-0.75	0.5	2.5	7.6	-1.75	0.5	4.5	7.5
1.25	0.5	0.5	6.9	0.25	0.5	2.5	7.7	-1.25	0.5	4.5	7.3
1.84	0.5	0.5	7.3	1.25	0.5	2.5	7.7	-0.75	0.5	4.5	8.3
2.23	0.5	0.5	7.2	1.84	0.5	2.5	7.6	-0.25	0.5	4.5	8.1
-2.26	0.5	1.0	6.6	2.24	0.5	2.5	7.6	0.25	0.5	4.5	8.4
-1.75	0.5	1.0	7.6	-2.26	0.5	3.0	8.3	0.75	0.5	4.5	8.1
-0.75	0.5	1.0	7.3	-1.75	0.5	3.0	8.1	1.25	0.5	4.5	8.1
-0.25	0.5	1.0	7.1	-1.25	0.5	3.0	7.9	1.84	0.5	4.5	8.1
0.75	0.5	1.0	7.6	-0.75	0.5	3.0	8.4	2.24	0.5	4.6	8.1
1.25	0.5	1.0	7.4	-0.25	0.5	3.0	8.2	-1.75	0.5	5.0	7.2
1.84	0.5	1.0	7.5	0.25	0.5	3.0	8.1	-1.25	0.5	5.0	7.5
2.24	0.5	1.0	7.4	0.75	0.5	3.0	8.3	-0.75	0.5	5.0	7.6
-2.25	0.5	1.5	7.7	1.25	0.5	3.0	8.4	-0.25	0.5	5.0	8.2
-1.75	0.5	1.5	7.8	1.84	0.5	3.0	8.2	0.25	0.5	5.0	7.8
-1.25	0.5	1.5	7.7	2.24	0.5	3.0	7.6	0.75	0.5	5.0	7.7
-0.75	0.5	1.5	7.6	-2.25	0.5	3.5	7.7	1.25	0.5	5.0	7.6
-0.25	0.5	1.5	7.5	-1.75	0.5	3.5	7.7	-1.25	0.5	5.5	7.5
0.25	0.5	1.5	7.9	-1.25	0.5	3.5	7.8	-0.75	0.5	5.5	7.4
0.75	0.5	1.5	7.6	-0.75	0.5	3.5	8.3	-0.25	0.5	5.5	7.6
1.25	0.5	1.5	7.7	-0.25	0.5	3.5	8.1	0.25	0.5	5.5	7.6
1.84	0.5	1.5	7.6	0.25	0.5	3.5	8.7	0.75	0.5	5.5	7.5
2.24	0.5	1.5	7.5	0.75	0.5	3.5	8.4	1.25	0.5	5.5	7.3
-1.75	0.5	2.0	8.1	1.25	0.5	3.5	8.5	-1.25	0.5	6.0	7.3
-0.75	0.5	2.0	7.8	1.84	0.5	3.5	7.6	-0.75	0.5	6.0	7.3
-0.25	0.5	2.0	7.7	-2.25	0.5	4.0	7.8	-0.25	0.5	6.0	7.4
0.25	0.5	2.0	7.1	-1.75	0.5	4.0	8.1	0.25	0.5	6.0	7.4
0.75	0.5	2.0	7.7	-1.25	0.5	4.0	8.1				
1.25	0.5	2.0	7.6	-0.75	0.5	4.0	8.4				

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1958	1957	1956	1955	1954	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1894	1893	1892	1891	1890	1889	1888	1887	1886	1885	1884	1883	1882	1881	1880	1879	1878	1877	1876	1875	1874	1873	1872	1871	1870	1869	1868	1867	1866	1865	1864	1863	1862	1861	1860	1859	1858	1857	1856	1855	1854	1853	1852	1851	1850	1849	1848	1847	1846	1845	1844	1843	1842	1841	1840	1839	1838	1837	1836	1835	1834	1833	1832	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1793	1792	1791	1790	1789	1788	1787	1786	1785	1784	1783	1782	1781	1780	1779	1778	1777	1776	1775	1774	1773	1772	1771	1770	1769	1768	1767	1766	1765	1764	1763	1762	1761	1760	1759	1758	1757	1756	1755	1754	1753	1752	1751	1750	1749	1748	1747	1746	1745	1744	1743	1742	1741	1740	1739	1738	1737	1736	1735	1734	1733	1732	1731	1730	1729	1728	1727	1726	1725	1724	1723	1722	1721	1720	1719	1718	1717	1716	1715	1714	1713	1712	1711	1710	1709	1708	1707	1706	1705	1704	1703	1702	1701	1700	1699	1698	1697	1696	1695	1694	1693	1692	1691	1690	1689	1688	1687	1686	1685	1684	1683	1682	1681	1680	1679	1678	1677	1676	1675	1674	1673	1672	1671	1670	1669	1668	1667	1666	1665	1664	1663	1662	1661	1660	1659	1658	1657	1656	1655	1654	1653	1652	1651	1650	1649	1648	1647	1646	1645	1644	1643	1642	1641	1640	1639	1638	1637	1636	1635	1634	1633	1632	1631	1630	1629	1628	1627	1626	1625	1624	1623	1622	1621	1620	1619	1618	1617	1616	1615	1614	1613	1612	1611	1610	1609	1608	1607	1606	1605	1604	1603	1602	1601	1600	1599	1598	1597	1596	1595	1594	1593	1592	1591	1590	1589	1588	1587	1586	1585	1584	1583	1582	1581	1580	1579	1578	1577	1576	1575	1574	1573	1572	1571	1570	1569	1568	1567	1566	1565	1564	1563	1562	1561	1560	1559	1558	1557	1556	1555	1554	1553	1552	1551	1550	1549	1548	1547	1546	1545	1544	1543	1542	1541	1540	1539	1538	1537	1536	1535	1534	1533	1532	1531	1530	1529	1528	1527	1526	1525	1524	1523	1522	1521	1520	1519	1518	1517	1516	1515	1514	1513	1512	1511	1510	1509	1508	1507	1506	1505	1504	1503	1502	1501	1500	1499	1498	1497	1496	1495	1494	1493	1492	1491	1490	1489	1488	1487	1486	1485	1484	1483	1482	1481	1480	1479	1478	1477	1476	1475	1474	1473	1472	1471	1470	1469	1468	1467	1466	1465	1464	1463	1462	1461	1460	1459	1458	1457	1456	1455	1454	1453	1452	1451	1450	1449	1448	1447	1446	1445	1444	1443	1442	1441	1440	1439	1438	1437	1436	1435	1434	1433	1432	1431	1430	1429	1428	1427	1426	1425	1424	1423	1422	1421	1420	1419	1418	1417	1416	1415	1414	1413	1412	1411	1410	1409	1408	1407	1406	1405	1404	1403	1402	1401	1400	1399	1398	1397	1396	1395	1394	1393	1392	1391	1390	1389	1388	1387	1386	1385	1384	1383	1382	1381	1380	1379	1378	1377	1376	1375	1374	1373	1372	1371	1370	1369	1368	1367	1366	1365	1364	1363	1362	1361	1360	1359	1358	1357	1356	1355	1354	1353	1352	1351	1350	1349	1348	1347	1346	1345	1344	1343	1342	1341	1340	1339	1338	1337	1336	1335	1334	1333	1332	1331	1330	1329	1328	1327	1326	1325	1324	1323	1322	1321	1320	1319	1318	1317	1316	1315	1314	1313	1312	1311	1310	1309	1308	1307	1306	1305	1304	1303	1302	1301	1300	1299	1298	1297	1296	1295	1294	1293	1292	1291	1290	1289	1288	1287	1286	1285	1284	1283	1282	1281	1280	1279	1278	1277	1276	1275	1274	1273	1272	1271	1270	1269	1268	1267	1266	1265	1264	1263	1262	1261	1260	1259	1258	1257	1256	1255	1254	1253	1252	1251	1250	1249	1248	1247	1246	1245	1244	1243	1242	1241	1240	1239	1238	1237	1236	1235	1234	1233	1232	1231	1230	1229	1228	1227	1226	1225	1224	1223	1222	1221	1220	1219	1218	1217	1216	1215	1214	1213	1212	1211	1210	1209	1208	1207	1206	1205	1204	1203	1202	1201	1200	1199	1198	1197	1196	1195	1194	1193	1192	1191	1190	1189	1188	1187	1186	1185	1184	1183	1182	1181	1180	1179	1178	1177	1176	1175	1174	1173	1172	1171	1170	1169	1168	1167	1166	1165	1164	1163	1162	1161	1160	1159	1158	1157	1156	1155	1154	1153	1152	1151	1150	1149	1148	1147	1146	1145	1144	1143	1142	1141	1140	1139	1138	1137	1136	1135	1134	1133	1132	1131	1130	1129	1128	1127	1126	1125	1124	1123	1122	1121	1120	1119	1118	1117	1116	1115	1114	1113	1112	1111	1110	1109	1108	1107	1106	1105	1104	1103	1102	1101	1100	1099	1098	1097	1096	1095	1094	1093	1092	1091	1090	1089	1088	1087	1086	1085	1084	1083	1082	1081	1080	1079	1078	1077	1076	1075	1074	1073	1072	1071	1070	1069	1068	1067	1066	1065	1064	1063	1062	1061	1060	1059	1058	1057	1056	1055	1054	1053	1052	1051	1050	1049	1048	1047	1046	1045	1044	1043	1042	1041	1040	1039	1038	1037	1036	1035	1034	1033	1032	1031	1030	1029	1028	1027	1026	1025	1024	1023	1022	1021	1020	1019	1018	1017	1016	1015	1014	1013	1012	1011	1010	1009	1008	1007	1006	1005	1004	1003	1002	1001	1000	999	998	997	996	995	994	993	992	991	990	989	988	987	986	985	984	983	982	981	980	979	978	977	976	975	974	973	972	971	970	969	968	967	966	965	964	963	962	961	960	959	958	957	956	955	954	953	952	951	950	949	948	947	946	945	944	943	942	941	940	939	938	937	936	935	934	933	932	931	930	929	928	927	926	925	924	923	922	921	920	919	918	917	916	915	914	913	912	911	910	909	908	907	906	905	904	903	902	901	900	899	898	897	896	895	894	893	892	891	890	889	888	887	886	885	884	883	882	881	880	879	878	877	876	875	874	873	872	871	870	869	868	867	866	865	864	863	862	861	860	859	858	857	856	855	854	853	852	851	850	849	848	847	846	845	844	843	842	841	840	839	838	837	836	835	834	833	832	831	830	829	828	827	826	825	824	823	822	821	820	819	818	817	816	815	814	813	812	811	810	809	808	807	806	805	804	803	802	801	800	799	798	797	796	795	794	793	792	791	790	789	788	787	786	785	784	783	782	781	780	779	778	777	776	775	774	773	772	771	770	769	768	767	766	765	764	763	762	761	760	759	758	757	756	755	754	753	752	751	750	749	748	747	746	745	744	743	742	741	740	739	738	737	736	735	734	733	732	731	730	729	728	727	726	725	724	723	722	721	720	719	718	717	716	715	714	713	712	711	710	709	708	707	706	705	704	703	702	701	700	699	698	697	696	695

[illegible]

 

Appendix C-1. Experiment I Redistribution Cores II and III.

Introduction

On April 6, 1989, 594 days after the last irrigation of plot I, a 14.6 m deep borehole was made near the center of the 4 m by 9 m irrigated area ($X_1 = 0.46$ m, $Y_1 = 4.67$ m). A 2" diameter split-spoon sampler was used to collect continuous soil cores in 2' intervals. These samples were analyzed for water content, tritium, chloride ion, electrical conductivity and soil morphological features. The results of that work is discussed by Vinson, et al, 1989.

Another pair of cores was collected from plot I nearly a year later, on March 16, 1990, 938 days after the last irrigation. The purpose of these cores was to supplement the data collected from the center-of-plot borehole with borehole data from the edge and 2 meters outside of the irrigated area, while remaining near the center of the plot with respect to the Y-plane. These core samples were analyzed for volumetric water content, tritium, chloride ion and nitrate ion. The locations of these new boreholes are:

	X_1 (m)	Y_1 (m)	Z_{total} (m)
BoreholeII	2.02	4.95	15.22
Borehole III	4.00	5.00	15.19

The split-spoon apparatus used for the first "center" borehole was able to penetrate below about 8 meters depth with great difficulty. Also, the analyses of the soil cores and solution extracts revealed that some sample cross contamination across borehole depths had probably occurred, most likely during the periods when the split-spoon sampler was pulled from the borehole to recover a core segment or pushed back into the borehole to regain a previous depth. In an effort to correct these previous difficulties a different drilling method

was used to produce the Borehole II and Borehole III samples that we discussed here.

Borehole Drilling

A 6" hollow-stem CME rotary drill apparatus mounted on a drill truck (Southwest Engineering, Inc., Las Cruces, New Mexico) was used. The sampling tube, designed to collect uncontaminated cores, was lined with 3" OD. acrylic tubing (1/8" wall thickness) in 5' lengths (2 pieces, 2.5 feet long, joined with tape). A total of twenty 2.5' long core sections were collected from each borehole. A technician was stationed to monitor and measure drilling depths each time the sampling tube was pulled from the borehole. As each acrylic liner was extracted from the sample tube it was permanently marked to note sample depth and orientation, sealed at either end with several layers of Parafilm® paraffin wrap (American Can, Greenwich, CT), capped with acrylic end plates, and then protected from accidental disturbance with additional seals of cloth duct tape. As a precaution each segment was kept in a horizontal position to reduce any vertical displacement of materials within the liner. The core segments were kept out of direct sunlight while in the field. At the end of the field operations the cores were taken to the laboratory for refrigerated storage.

Sample Preparation

Only about 25 percent of the soil mass within the liners was used for analyses. Soil recovery was measured within each liner by gently tamping any loose soil at the ends of the liner to form a continuous column of soil and then measuring the length of column through the liner visually. The ratio of soil length within

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

the liner to the depth of soil drilled to fill the liner was used to assign depths to, core sub-samples.

A section of an individual core was selected for sampling and its assigned depth was based on the cumulative borehole depth at the top of the liner section plus the proportioned length of

the soil core and measured to the center of the sample. On average, core samples were centered at 0.35 m intervals along the depth of the boreholes. An average of 498 g of fresh soil was taken for each sub-sample. About half of this was used to determine oven-dry gravimetric moisture and the other half for making solution extracts. Because of the large sample size the samples were not pre-screened for non-representative sample fractions.

Gravimetric moisture was measured by placing a core sub-sample in a tared aluminum soil can, measuring the can mass to the nearest 0.01 g on a Sartorius E2000D balance (Brinkman Instrument, Inc., Westbury, NY), and then drying the sample in a laboratory convective oven at 105° C for 36-48 hours before re-weighing the can. A period longer than 24 hours was necessary to ensure equilibrium moisture contents (< 0.01 g/12 hr. mass change) for the large sample masses.

Volumetric water content was estimated from gravimetric water content by using soil bulk density data from the original trench characterization work (Wierenga et al., 1988, 1989, 1990). A grand mean value (1.67 Mg/m^3) of all bulk density values of cores used for site characterization, those collected from the north face of the trench during excavation, was universally used to calculate borehole sample volumetric water content.

Solution extracts were made by mixing fresh soil samples with distilled-deionized water. A

plastic beaker was tared to the nearest 0.01 g on the Sartorius balance. The fresh soil was added, re-weighed with the beaker, and then the balance was tared once again. Water was then added to the beaker, an amount equal to about 25 percent of the fresh weight of the soil before recording a final mass of the beaker and soil paste. The amount of diluent water added was varied, depending upon the moisture contained in the sub-sample and its texture. The goal of sample dilution was to add the least amount of water necessary to enable extraction of a sufficiently large sample to complete the chemical analyses, about 20 ml. Drier soil core sections and those with heavier textures (i.e., some samples with very high clay content) required more water.

The samples were then vigorously stirred with a metal spatula for about one minute. The beakers were covered with an acrylic plate which closely fit the beaker rim and allowed to stand for 20 minutes. The soil paste was briefly stirred once more during the standing period.

A Buchner funnel apparatus was used to extract the paste samples. A bank of 15 Buchner funnels was plumbed to a common vacuum source, about 425 mb strong. Each ceramic funnel was fit with a 5.5 cm-diameter disk of Whatman's #42 ashless filter paper. During filtration the rim of a paste filled Buchner funnel was covered to reduce evaporation. The effluent was collected in clean 13 dram polypropylene vials which were capped and then wrapped with Parafilm® before being placed in refrigerated storage.

Sample Analyses

The extracts were analyzed for tritium, chloride ion and nitrate ion. For tritium 0.5 ml aliquots of sample were mixed with 5.0 ml of Aquasol universal liquid scintillation cocktail (Dupont New England Nuclear, Boston, MA) in

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

"Mini-Q" 8 ml scintillation vials (Beckman Instruments, Inc., Fullerton, CA) and run as single replications with a Beckman model LS1800 scintillator in "auto-run" mode. Raw counts were taken for 20 minutes per sample within a single-channel counting window of 0-400 nm. No quenching factors were used in the counting routine. Tritium background was taken from vials prepared with untraced well water in place of extract.

Chloride was analyzed with a Buchler model 4-2500 chloridometer (Buchler Instruments, Inc., Ft. Lee, NJ) which utilizes timed Ag/AgCl titrimetry to determine chloride ion. Before using the instrument the silver electrodes were thoroughly cleaned with a commercial silver cleaner or re placed. The instrument was switched to high sensitivity mode, which provides a detection limit of about 0.3 me/l. Ten replicated readings each of 10 me/l and 60 me/l chloride standards were used to make a two-point calibration curve. Ten replications of background correction vials were prepared with distilled-deionized water and read. The high number of replications was used to ensure stable instrument performance before analyzing extracts. Sample titrations were performed with 0.10 to 1.00 ml volume aliquots, on the Cl⁻

concentration within the sample. Samples were read as single replications.

Nitrate analyses was performed with a Technicon AutoAnalyser II in the NMSU Soil & Water Testing Laboratory. This instrument determines nitrate by a colorimetric procedure; copperized cadmium column is used to reduce sample nitrate to nitrite in the presence of NH₄Cl. The resulting nitrite is treated with a

colorizing agent to form a pink color. A colorimeter is then used to measure absorbance of the colorized solution at 540 nm.

The sample extracts were first screened for approximate nitrate content by using nitrate test strips (EM Science Inc., Gibbstown, NJ). From these approximations the final sample dilutions to bring the samples into the working linear range (0-10 mg/l) of the AutoAnalyser were determined. Samples were diluted from 1x (full strength) to 100x with distilled-de ionized water in dilution steps of no more than 10x per dilution. The instrument was calibrated to a single point curve with a 1 mg/l N-NO₃ standard. The instrument was re-calibrated with two replications of nitrate standard for every 10 sample extracts in a sequence of run.

Appendix C-1. Experiment I Redistribution Cores II and III (Continued).

Results & Discussion

Figure C-1.1 shows the depth-distribution of volumetric water content and includes data from the earlier borehole at $X_1 = 0$ meters for comparison (mean $0.135 \text{ cm}^3/\text{cm}^3$). Water content was quite variable about a means of $0.138 \text{ cm}^3/\text{cm}^3$ at $X_1 = 2$ meters and $0.127 \text{ cm}^3/\text{cm}^3$ at $X_1 = 4$ meters with no clear trends or distinct wetting front of applied Experiment I water in evidence. Lower water contents, below 10 meters depth, are responsible for the relatively low 4 meter-mean value. High water contents between about $8 \frac{1}{2}$ and $9 \frac{1}{2}$ meters correspond to the abrupt appearance of a clay textured lens of soil that is common to all three boreholes at that depth.

Scintillation counts for tritium applied to the irrigation area (C_0) were adjusted for a 2.91 year period of decay between day 0 of Experiment I and April 23, 1990, the day that tritium samples were counted for this experiment:

$$N(t) = N_0 (1/2)^{t/t^{1/2}}$$

where

$N(t)$ = decay adjusted C_0

N_0 = original C_0 , $5 / 27 / 87, 7037$ counts

t = elapsed time, years

$t^{1/2}$ = tritium half - life, 12.3 years

This resulted in a calculated value of 0.1713 half-lives of tritium decay during the period. This value was used to adjust calculations for a mass balance of tritium recovered from the borehole located at $Y_1 = 2$ meters. Based upon an original applied tritium pulse, 1.76 cm/d applied for the first 10 days of Experiment I, about 7.22 cm of tritium was recovered from the borehole, about 41.1 percent. This compares to a 50.2 percent recovery from the borehole near the center of the plot, taken almost a year earlier

(Vinson et al., 1989). No tritium was found in samples collected at $Y_1 = 4$ meters.

Tritium data is presented as the observed concentration C relative to input tritium (C_0). In the 2 meter borehole the first appearance of tritium occurs about 4 meters in depth, peaks at the 8.55 meter mark, at $C/C_0 = 17.1\%$ and does not occur below about 10 meters in depth (Figure C-12). Compared to the 0-meter borehole, the leading front of tritium in the 2-meter borehole reached about the same depth but with the mien of great dispersion. This may be due to delayed lateral movement of tritium from the center of the irrigated area to the periphery.

Nitrate and chloride ion profiles are quite similar in appearance within the same borehole (Figures C-1.3 and C-1.4). At $Y_1 = 2$ meters the ions appear to have been effectively eluted from the profile to about 10 meters depth. From there the ion concentrations increase dramatically, to nearly the depth where the tritium plume becomes extinct. The concentrations of both ions peak at a depth of 11.53 meters.

At $Y_1 = 4$ meters the anions have been eluted to about 4 meters depth. They show a much more irregular concentration profile, with relatively high concentrations from 4 meters to about 13 meters depth where they begin to co-vary with ion concentrations in the 2 meter borehole.

Cumulative ion masses within the whole profile are much higher than in the 2 meter borehole which again may be due to salt additions from areas within the irrigated plot.

A curious spike in nitrate concentration occurs near the soil surface in both boreholes. This may be due to mineralization of soil organic matter over time in the moist soil environment unsaturated by the plot moisture barrier.

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Plot 1 Redistribution Cores - Volumetric Water Content

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Plot 1 Redistribution Cores - Tritium distribution

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Plot 1 Redistribution Cores - Chloride distribution

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Plot 1 Redistribution Cores - Nitrate distribution

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Experiment I Redistribution Cores - Solute Data and Volumetric Water Content

Y (m)	Depth (m)	Theta (cm ³ /cm ³)	Tritium (C/Co)	Chloride (me/l)	Nitrate (me/l)
0	0.00	0.132	0.000	2.34	N/A
0	0.20	0.127	0.000	2.58	N/A
0	0.44	0.174	0.000	0.84	N/A
0	0.69	0.164	0.000	1.68	N/A
0	0.90	0.160	0.000	4.56	N/A
0	1.14	0.154	0.000	6.54	N/A
0	1.39	0.140	0.000	3.42	N/A
0	1.59	0.117	0.000	2.55	N/A
0	1.66	0.139	0.000	2.07	N/A
0	1.88	0.125	0.000	4.31	N/A
0	2.15	0.099	0.000	3.87	N/A
0	2.34	0.090	0.000	5.49	N/A
0	2.57	0.099	0.000	3.82	N/A
0	2.84	0.149	0.000	1.59	N/A
0	3.10	0.109	0.000	3.09	N/A
0	3.31	0.179	0.000	2.10	N/A
0	3.52	0.179	0.000	1.42	N/A
0	3.65	0.152	0.000	1.38	N/A
0	3.85	0.135	0.000	1.53	N/A
0	4.09	0.137	0.000	0.90	N/A
0	4.28	0.135	0.000	1.17	N/A
0	4.48	0.130	0.000	2.89	N/A
0	4.72	0.145	0.000	1.10	N/A
0	4.90	0.119	0.000	2.96	N/A
0	4.97	0.135	0.000	2.02	N/A
0	5.11	0.157	0.000	1.75	N/A
0	5.27	0.122	0.000	2.89	N/A
0	5.45	0.162	0.000	1.74	N/A
0	5.67	0.167	0.000	1.95	N/A
0	5.86	0.140	0.000	3.37	N/A
0	6.04	0.119	0.000	5.06	N/A
0	6.26	0.117	0.020	2.91	N/A
0	6.47	0.104	0.000	4.76	N/A
0	6.56	0.162	0.029	1.99	N/A
0	6.70	0.132	0.039	2.94	N/A
0	6.85	0.114	0.029	3.67	N/A
0	7.03	0.132	0.061	3.44	N/A
0	7.26	0.129	0.070	2.61	N/A
0	7.48	0.124	0.112	3.07	N/A
0	7.66	0.140	0.145	3.43	N/A
0	7.89	0.120	0.182	2.12	N/A

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Experiment I Redistribution Cores - Solute Data and Volumetric Water Content

Y (m)	Depth (m)	Theta (cm ³ /cm ³)	Tritium (C/Co)	Chloride (me/l)	Nitrate (me/l)
00.0	0	8.03	0.134	0.019	3.40
00.3	0	8.21	0.109	0.146	4.36
00.6	0	8.44	0.205	0.250	4.17
00.9	0	8.62	0.149	0.240	5.11
01.2	0	8.80	0.152	0.194	7.87
01.5	0	9.03	0.200	0.183	5.92
01.8	0	9.33	0.197	0.080	4.77
02.1	0	9.57	0.209	0.024	9.22
02.4	0	9.83	0.147	0.000	20.89
02.7	0	10.01	0.147	0.000	23.12
03.0	0	10.25	0.097	0.000	78.02
03.3	0	10.51	0.067	0.000	60.94
03.6	0	10.79	0.135	0.000	58.81
03.9	0	11.07	0.117	0.000	84.29
04.2	0	11.26	0.169	0.000	58.13
04.5	0	11.46	0.117	0.005	59.24
04.8	0	11.65	0.117	0.000	47.94
05.1	0	11.90	0.134	0.000	54.76
05.4	0	12.12	0.107	0.000	46.81
05.7	0	12.37	0.129	0.000	44.65
06.0	0	12.69	0.089	0.000	12.30
06.3	0	12.94	0.162	0.000	17.50
06.6	0	13.22	0.114	0.000	21.09
06.9	0	13.49	0.072	0.000	22.77
07.2	0	13.74	0.072	0.006	18.64
07.5	0	14.01	0.073	0.000	14.45
07.8	0	14.31	0.109	0.000	17.92
08.1	0	14.60	0.152	0.003	11.60
08.4	2	0.05	0.127	0.001	0.35
08.7	2	0.27	0.143	0.001	0.41
09.0	2	0.60	0.128	0.001	0.34
09.3	2	0.99	0.182	0.000	0.35
09.6	2	1.31	0.133	0.000	0.31
09.9	2	1.64	0.111	0.000	0.29
10.2	2	2.05	0.100	0.000	0.30
10.5	2	2.45	0.086	0.001	1.33
10.8	2	2.88	0.104	0.001	1.19
11.1	2	3.28	0.135	0.001	0.24
11.4	2	3.65	0.198	0.001	0.28
11.7	2	4.02	0.154	0.002	0.55
12.0	2	4.38	0.143	0.003	0.43

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Experiment I Redistribution Cores - Solute Data and Volumetric Water Content

Y (m)	Depth (m)	Theta (cm ³ /cm ³)	Tritium (C/Co)	Chloride (me/l)	Nitrate (me/l)
2	4.80	0.130	0.013	0.63	0.63
2	5.15	0.165	0.027	0.64	0.88
2	5.51	0.146	0.029	0.77	0.86
2	5.87	0.163	0.048	0.54	1.06
2	6.30	0.199	0.083	1.28	1.07
2	6.65	0.146	0.109	2.04	1.51
2	7.00	0.127	0.106	1.76	1.32
2	7.36	0.121	0.111	0.48	1.16
2	7.81	0.133	0.133	1.13	0.96
2	8.18	0.125	0.164	1.65	0.99
2	8.55	0.118	0.171	1.62	0.91
2	8.93	0.185	0.111	2.54	1.06
2	9.38	0.181	0.013	2.75	1.22
2	9.75	0.137	0.004	4.40	1.91
2	10.12	0.141	0.003	5.52	2.30
2	10.48	0.113	0.001	13.79	4.75
2	10.87	0.171	0.001	41.96	14.67
2	11.20	0.110	0.000	51.25	16.06
2	11.53	0.134	0.001	68.95	19.91
2	11.87	0.128	0.000	57.40	14.68
2	12.30	0.121	0.001	48.26	10.14
2	12.64	0.131	0.000	54.88	8.49
2	12.99	0.179	0.000	9.67	0.88
2	13.46	0.129	0.000	13.20	1.97
2	13.69	0.069	0.002	13.55	1.84
4	0.04	0.127	0.001	0.52	15.17
4	0.34	0.135	0.000	0.18	4.82
4	0.65	0.144	0.001	0.03	5.38
4	0.97	0.164	0.001	0.29	4.23
4	1.29	0.168	0.001	0.02	2.38
4	1.65	0.140	0.000	0.20	2.23
4	2.00	0.124	0.000	0.30	2.51
4	2.35	0.127	0.000	0.45	2.33
4	2.70	0.140	0.000	0.23	2.28
4	3.20	0.152	0.001	0.49	1.18
4	3.49	0.159	0.000	0.66	1.34
4	3.79	0.158	0.001	1.06	1.44
4	4.08	0.151	0.001	2.71	2.70
4	4.38	0.110	0.001	17.23	10.71
4	4.71	0.179	0.002	17.61	11.05
4	5.01	0.174	0.002	22.51	16.33

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Experiment I Redistribution Cores - Solute Data and Volumetric Water Content

Y (m)	Depth (m)	Theta (cm ³ /cm ³)	Tritium (C/Co)	Chloride (me/l)	Nitrate (me/l)
4	5.33	0.093	0.001	36.22	7.58
4	5.64	0.133	0.000	58.32	30.04
4	5.95	0.115	0.001	68.16	9.70
4	6.33	0.106	0.001	42.23	25.48
4	6.65	0.151	0.001	64.70	12.84
4	6.97	0.138	0.001	68.02	24.82
4	7.30	0.126	0.002	73.75	21.43
4	7.74	0.129	0.001	55.23	16.40
4	8.09	0.130	0.000	51.99	18.79
4	8.43	0.155	0.000	52.03	19.78
4	8.78	0.214	0.001	60.29	12.22
4	9.23	0.229	0.001	65.37	14.67
4	9.52	0.154	0.000	68.69	14.33
4	9.81	0.102	0.000	62.20	3.83
4	10.10	0.122	0.001	94.56	17.98
4	10.40	0.108	0.000	75.37	11.33
4	10.72	0.103	0.001	54.16	9.26
4	11.04	0.081	0.001	50.06	9.22
4	11.36	0.099	0.002	49.46	7.67
4	11.68	0.077	0.001	39.88	6.05
4	12.00	0.065	0.001	29.34	4.00
4	12.37	0.046	0.000	34.72	4.54
4	12.71	0.067	0.001	11.06	1.39
4	13.05	0.085	0.001	9.28	1.23
4	13.39	0.157	0.001	30.94	3.85
4	13.80	0.076	0.001	10.49	1.37
4	14.13	0.085	0.000	10.42	1.37
4	14.47	0.064	0.001	7.00	1.10
4	14.80	0.187	N/A	N/A	N/A
4	15.09	0.112	0.000	14.58	1.93

Note: Data for core located at Y = 0 meters are reported by Vinson et al. (1989), included here for comparison with later cores (2 m and 4 m)

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Redistribution Cores II & III of 3/16/90 - Segment Drill Depth & Core Recovery

Core #1, X1 = 2.02 m, 3/16/90

Core Section#	Cumul. Sampler Depth (cm)	Increment Sampler Depth (cm)	Recovery Core length (less waste) (cm)	+Cutting tip Add 2" (cm)	Scale Ratio (depth/ recov.)
1,2	142.0	142.0	117.3	122.38	1.160
3,4	307.3	165.3	97.8	102.88	1.607
5,6	454.7	147.3	149.5	154.58	0.953
7,8	605.8	151.2	123.5	128.58	1.176
9,10	754.4	148.5	101.7	106.78	1.391
11,12	913.1	158.8	100.8	105.88	1.499
13,14	1061.7	148.6	138.5	143.58	1.035
15,16	1214.1	152.4	112.8	117.88	1.293
17,18	1369.1	154.9	102.9	107.98	1.435
19,20	1521.5	152.4	108.9	113.98	1.337
Avg		152.15	115.4	120.5	1.289
Stdev		6.150	17.261	17.261	0.207

Core #2, X1 = 4.00 m, 3/16/90

Core Section#	Cumul. Sampler Depth (cm)	Increment Sampler Depth (cm)	Recovery Core length (less waste) (cm)	+Cutting tip Add 2" (cm)	Scale Ratio (depth/ recov.)
1,2	132.1	142.0	114.8	119.88	1.185
3,4	299.7	167.6	119.5	124.58	1.346
5,6	452.1	152.4	117.9	122.98	1.239
7,8	604.5	152.4	123.4	128.48	1.186
9,10	756.9	152.4	121.7	126.78	1.202
11,12	909.3	152.4	114.9	119.98	1.270
13,14	1064.3	154.9	114.7	119.78	1.294
15,16	1216.7	152.4	113.5	118.58	1.285
17,18	1369.1	152.4	120.1	125.18	1.217
19,20*	1518.9	149.9	N/A	N/A	N/A
Avg		152.88	117.8	122.91	1.247
Stdev		5.920	3.540	3.540	0.055

*Core 2-20 sent to Tucson, unavailable for processing

Experiment I Redistribution Cores II & III of 3/16/90 - Supporting Data

Location Y1 (m)	Depth Z (m)	Moisture Determination			Sample Extraction			Nitrate Analyses			Raw NO3 (ppm)	3H2O Raw Tritium (cpm)	Chloride		Linear Coeff.
		Can Tare (g)	Can +Moist (g)	Can +ODS (g)	Beaker Tare (g)	Beaker +Moist (g)	Added Water (g)	Linear Scale (abs)	Sample Diln.	1 ppm Std. (abs)			No. Aliq.	Raw Cl (me/l)	
2.02	0.05	62.25	312.08	294.39	25.25	248.87	36.34	16.4	100	51.25	141.7	11.6	5	6.0	0.991
2.02	0.27	63.39	281.11	263.93	25.21	266.76	36.29	13.6	50	50.38	59.8	12	6	8.2	0.991
2.02	0.60	63.64	398.76	374.92	25.25	290.17	45.93	12.9	50	50.38	56.7	12	6	7.3	0.991
2.02	0.99	63.53	386.45	354.65	25.74	219.38	40.29	10.8	50	50.38	47.5	6	6	9.7	0.991
2.02	1.31	63.52	356.28	334.68	25.22	247.71	43.44	27.4	10	51.25	23.7	11	6	6.5	0.991
2.02	1.64	62.69	399.11	378.11	25.75	254.16	43.21	99.2	1	50.38	8.7	11	6	5.8	0.991
2.02	2.05	62.76	239.17	229.22	25.72	284.16	48.16	51.0	1	50.38	4.5	6	6	3.2	0.991
2.02	2.45	62.60	408.35	391.50	25.28	210.65	40.05	44.4	1	50.38	3.9	12	6	24.2	0.991
2.02	2.88	62.73	399.67	379.94	25.23	240.40	41.08	39.4	1	50.38	3.5	12	6	23.8	0.991
2.02	3.28	62.32	346.47	325.26	25.77	186.13	37.76	33.7	1	50.38	3.0	12	6	5.3	0.991
2.02	3.65	63.92	354.77	323.89	25.74	220.15	44.84	43.1	1	50.83	3.8	12	15	18.0	0.991
2.02	4.02	62.16	281.90	263.34	25.89	238.35	46.15	47.6	1	50.83	4.1	13	10	16.5	0.991
2.02	4.38	61.80	355.74	332.60	25.76	286.25	46.53	79.7	1	50.83	6.9	17	5	7.5	0.991
2.02	4.80	62.14	317.65	299.22	25.97	313.61	59.81	11.2	10	51.25	9.7	30	5	7.8	0.991
2.02	5.15	62.12	268.24	249.74	25.76	328.93	53.44	17.5	10	51.25	15.1	55	5	8.7	0.991
2.02	5.51	62.92	334.22	312.39	25.87	292.01	61.20	17.3	10	51.10	15.0	58	5	10.7	0.991
2.02	5.87	62.89	314.71	292.37	25.88	323.49	63.05	21.2	10	51.10	18.4	91	5	7.5	0.991
2.02	6.30	62.51	287.08	263.18	25.22	260.01	55.02	24.8	10	50.78	21.6	172	5	20.7	0.991
2.02	6.65	63.65	299.61	280.61	25.89	333.23	57.02	28.5	10	50.78	24.8	184	5	26.9	0.991
2.02	7.00	63.47	284.73	269.09	25.66	279.44	51.44	23.2	10	50.78	20.2	166	5	21.5	0.991
2.02	7.36	63.59	322.40	304.97	25.88	300.37	51.54	22.0	10	50.78	19.2	186	5	6.3	0.991
2.02	7.81	63.61	250.43	236.67	25.23	226.19	41.18	18.1	10	50.78	15.8	221	5	14.9	0.991
2.02	8.18	63.41	293.22	277.24	25.27	323.30	52.49	17.3	10	50.78	15.1	252	5	20.1	0.991
2.02	8.55	63.46	301.23	285.50	25.87	303.68	49.27	16.4	10	50.78	14.3	271	5	20.4	0.991
2.02	8.93	63.38	308.94	284.49	25.86	303.73	104.06	15.6	10	50.85	13.6	148	5	26.0	0.991
2.02	9.38	62.53	313.18	288.64	25.91	288.64	116.89	16.4	10	50.85	14.3	25	5	25.7	0.991
2.02	9.75	62.46	397.26	371.87	25.65	369.88	108.77	27.4	10	50.85	23.9	15	5	44.0	0.991
2.02	10.12	62.87	354.09	331.35	25.85	316.71	69.49	42.9	10	50.85	37.3	15	5	71.7	0.991

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Experiment I Redistribution Cores II & III of 3/16/90 - Supporting Data

Location Y1 (m)	Depth Z (m)	Moisture Determination			Sample Extraction			Nitrate Analyses			Raw NO3 (ppm)	3H2O Raw Tritium (cpm)	Chloride		Linear Coeff.
		Can Tare (g)	Can +Moist (g)	Can +ODS (g)	Beaker Tare (g)	Beaker +Moist (g)	Added Water (g)	Linear Scale (abs)	Sample Diln.	1 ppm Std. (abs)			No. Allq.	Raw Cl (me/l)	
2.02	10.48	62.73	328.94	312.03	25.88	208.64	45.23	19.4	50	51.10	84.0	12	5	195.0	0.991
2.02	10.87	62.05	245.81	228.76	25.85	232.66	50.20	28.6	100	51.10	247.8	12	5	566.4	0.991
2.02	11.20	62.25	306.28	291.26	25.21	299.71	53.43	26.5	100	51.10	229.6	4	1	117.5	0.995
2.02	11.53	62.48	273.91	258.25	25.25	298.28	55.40	33.3	100	51.05	288.8	12	1	160.4	0.995
2.02	11.87	62.12	301.84	284.72	25.25	283.33	46.06	30.0	100	51.05	260.2	11	1	163.2	0.995
2.02	12.30	63.53	328.96	311.01	25.74	198.07	40.14	23.5	100	51.05	203.8	13	1	155.6	0.995
2.02	12.64	63.07	274.13	258.73	25.22	236.12	45.28	16.3	100	51.05	141.4	10	1	146.5	0.995
2.02	12.99	63.34	386.79	355.48	25.75	205.00	44.36	27.5	10	51.05	23.8	11	1	42.2	0.995
2.02	13.46	65.18	282.56	267.02	25.72	217.33	59.03	31.1	10	51.05	27.0	10	1	29.0	0.995
2.02	13.69	63.55	318.20	308.16	25.28	231.40	53.30	21.6	10	51.05	18.7	12	1	22.1	0.995
4.00	0.04	63.39	330.10	311.21	25.21	239.57	55.69	29.0	100	51.05	251.5	12	5	6.9	0.995
4.00	0.34	62.25	289.10	272.08	25.25	169.73	46.03	19.7	50	51.05	85.4	10	5	2.6	0.995
4.00	0.65	63.64	306.61	287.28	25.25	314.72	70.19	17.7	50	51.05	76.7	11	5	0.3	0.995
4.00	0.97	63.53	325.06	301.63	25.74	284.40	59.89	18.2	50	51.10	78.8	12	10	8.8	0.995
4.00	1.29	63.52	332.42	307.80	25.22	155.37	42.86	13.2	50	51.10	57.2	12	10	0.6	0.995
4.00	1.65	62.69	345.84	323.96	25.75	187.04	49.13	10.4	50	51.10	45.0	11	10	6.5	0.995
4.00	2.00	62.76	324.95	306.80	25.72	263.57	51.88	9.8	50	51.10	42.5	10	10	8.1	0.995
4.00	2.35	62.60	336.63	317.20	25.28	278.35	45.62	10.5	50	51.10	45.5	8	10	14.0	0.995
4.00	2.70	62.73	342.98	321.30	25.23	322.82	63.34	44.1	10	51.10	38.2	11	10	6.3	0.995
4.00	3.20	62.32	338.65	315.58	25.77	259.43	48.08	29.0	10	51.10	25.1	12	10	16.8	0.995
4.00	3.49	63.92	298.14	277.77	25.74	239.60	49.15	30.0	10	51.10	26.0	11	10	20.4	0.995
4.00	3.79	62.16	342.99	318.71	25.89	228.21	46.08	37.6	10	51.10	32.6	13	10	38.4	0.995
4.00	4.08	61.80	317.04	295.88	25.76	288.65	58.06	11.0	50	51.10	47.6	12	10	76.6	0.995
4.00	4.38	62.14	338.86	321.70	25.97	248.14	50.05	20.6	100	51.30	177.8	11	10	458.8	0.995
4.00	4.71	62.12	336.82	310.22	25.76	234.70	51.99	28.7	100	51.30	247.7	14	10	633.4	0.995
4.00	5.01	62.92	311.22	287.76	25.87	235.62	50.09	40.0	100	51.30	345.2	14	10	763.2	0.995
4.00	5.33	62.89	342.27	327.49	25.88	253.36	51.33	25.3	50	51.10	109.6	11	10	839.9	0.995
4.00	5.64	62.51	307.70	289.61	25.22	253.04	50.38	60.3	100	51.30	520.4	8	10	1620.4	0.995

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Experiment I Redistribution Cores II & III of 3/16/90 - Supporting Data

Location Y1 (m)	Depth Z (m)	Moisture Determination			Sample Extraction			Nitrate Analyses				3H2O Raw Tritium (cpm)	Chloride		
		Can Tare (g)	Can +Moist (g)	Can +ODS (g)	Beaker Tare (g)	Beaker +Moist (g)	Added Water (g)	Linear Scale (abs)	Sample Diln.	1 ppm Std. (abs)	Raw NO3 (ppm)		No. Aliq.	Raw Cl (me/l)	Linear Coeff.
4.00	5.95	63.65	304.37	288.82	25.89	301.30	60.04	30.1	50	51.10	130.4	12	1	147.0	0.995
4.00	6.33	63.47	336.78	320.53	25.66	260.22	54.93	43.8	100	51.30	378.0	12	1	100.5	0.995
4.00	6.65	63.59	294.78	275.65	25.88	259.46	54.84	50.5	50	50.95	219.4	12	1	177.3	0.995
4.00	6.97	63.61	304.70	286.30	25.23	287.85	59.92	44.5	100	51.30	384.0	11	1	168.8	0.995
4.00	7.30	63.41	316.33	298.58	25.27	337.26	77.81	30.3	100	51.25	261.7	12	1	144.5	0.995
4.00	7.74	63.46	350.25	329.75	25.87	243.53	48.56	36.8	100	51.25	317.9	13	1	171.7	0.995
4.00	8.09	63.38	346.29	325.87	25.86	259.49	57.36	37.4	100	51.25	323.1	8	1	143.4	0.995
4.00	8.43	62.53	307.16	286.35	25.91	246.60	49.02	45.0	100	51.25	388.7	4	1	164.0	0.995
4.00	8.78	62.46	307.31	279.52	25.65	306.76	91.35	22.4	100	51.25	193.5	12	1	153.2	0.995
4.00	9.23	62.87	316.55	286.00	25.85	315.82	125.66	22.8	100	51.25	196.9	11	1	140.8	0.995
4.00	9.52	62.73	304.91	284.44	25.88	238.22	55.10	29.7	100	51.25	256.6	11	1	197.2	0.995
4.00	9.81	62.05	337.13	321.28	25.85	237.21	44.86	15.0	50	51.25	64.8	11	1	168.7	0.995
4.00	10.10	62.25	285.12	269.92	25.21	297.35	61.64	54.0	50	51.25	233.2	12	1	196.8	0.995
4.00	10.40	62.48	379.75	360.56	25.25	252.74	57.38	42.6	50	51.15	184.4	8	1	196.8	0.995
4.00	10.72	62.12	354.10	337.09	25.25	213.85	36.91	43.6	50	51.15	188.7	12	1	177.0	0.995
4.00	11.04	63.53	362.83	348.98	25.74	251.40	48.40	30.5	50	51.15	132.0	11	1	114.9	0.995
4.00	11.36	63.07	301.23	287.86	25.22	294.45	59.65	21.1	50	51.15	91.3	12	1	94.4	0.995
4.00	11.68	63.34	333.64	321.70	25.75	256.49	52.70	16.6	50	51.15	71.8	11	1	76.0	0.995
4.00	12.00	65.18	440.26	426.19	25.72	243.46	43.98	71.5	10	51.15	61.9	11	1	72.8	0.995
4.00	12.37	63.55	292.60	286.40	25.28	264.98	47.56	38.4	10	51.15	33.2	2	1	40.8	0.995
4.00	12.71	66.19	393.71	381.16	25.23	160.40	36.12	26.5	10	51.15	22.9	12	1	29.2	0.995
4.00	13.05	62.58	392.92	376.84	25.77	200.58	50.35	22.1	10	51.15	19.1	12	1	23.2	0.995
4.00	13.39	58.71	312.56	290.72	25.74	298.52	58.07	80.6	10	51.25	69.6	12	1	89.7	0.995
4.00	13.80	60.11	349.55	336.92	25.89	196.91	41.93	46.9	5	50.95	20.4	11	1	25.0	0.995
4.00	14.13	59.76	324.26	311.38	25.76	186.41	43.50	23.4	10	51.25	20.2	8	1	24.6	0.995
4.00	14.47	63.61	398.21	385.80	25.97	219.02	49.01	16.5	10	51.25	14.3	11	1	14.5	0.995
4.00	14.80	63.41	338.05	310.45	25.76	291.55	72.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.00	15.09	59.91	293.94	279.27	25.87	334.77	94.49	19.7	10	51.25	17.0	4	1	20.6	0.995

Appendix C-1. Experiment I Redistribution Cores II and III. (Continued)

Appendix C-2. "A" Profile Pre-Leaching Chloride and Nitrate.

Introduction

During the original trench excavation work 1986 an extensive collection of loose soil samples was taken from the soil profile along the north side. These samples were used to characterize moisture release profiles for 0-15 bars of tension (Wierenga et al, 1988 and 1989). Individual samples were usually less than 0.5 kg in mass and in many cases were depleted during the laboratory procedures.

After the collapse of the south trench wall during Experiment I a new shoring structure was built within the trench to prevent further damage to the intact trench walls during planned irrigation experiments. This structure prevented ready access to the trench soil facies. Therefore, before construction began, a second complete set of soil samples was collected along the north face of the trench as a sample bank for future study of pre-leaching soil conditions. This appendix reports the pre-leaching levels of chloride and nitrate in the soil profile at the "A" profile (layer A) transect on the trench face, at $X = 3.25$ m from the northwest corner of the trench, from extractions made of these "banked" samples.

Soil Sampling

The second series of loose soil samples, designated as series II, were collected in March, 1988 in an attempt to duplicate the locations of the original soil samples in X and Z directions. It was not possible to duplicate original locations in Y: the original (series I) collection was made from a soil shelf which served as a walkway and sampling platform along the north side of the trench. This shelf was gradually sloughed away to access deeper locations as the

trench was excavated. The series I samples were taken from the center of this shelf, which was approximately 120 cm wide. Series II samples were taken from the trench face itself ($Y = 0$ m), approximately $Y + 60$ cm from the original samples.

For the series II collection (layers A, B, and C) the interval in Z was slightly different from the original collection. For example, the original profile "A" samples were taken in 13 cm increments in Z to the bottom of the trench (6.2 m) for a total of 48 samples. For the series II collection of profile "A", the subset of samples considered in this appendix, 40 samples were collected on 15 cm intervals to a depth of 6 m. Positions in X were identical to the series I collection, at $X = 3.25$ m ($X_2 = -0.78$ m).

About 0.8 kg of each sample was collected as loose soil and several representative peds. Samples were placed in pre-labeled plastic bags and stored at room temperature. Since the samples were collected from the exposed trench face they were relatively dry and did not require further drying before storage

Sample Preparation

Approximately 150 grams of each loose sample (peds excluded) were sieved on October 23, 1989. Samples were sieved through a 2 mm square mesh wire sieve (W.S. Tyler, Inc., Mentor, OH). Fractions larger than 2 mm were ground gently in a mortar and pestle and then sieved again.

Approximately 25% of the mass of some samples would not pass through the sieve. This coarse material was discarded. To avoid exposing new un-weathered mineral facies no attempt was made to crush very hard clods. The

Appendix C-2. "A" Profile Pre-Leaching Chloride and Nitrate. (Continued)

sieved samples were placed in paper bags and allowed to air dry until further processing.

On November 2, 1989 sub-samples of individual air-dry soil (35-41 g each) were gravimetrically diluted (Sartorius E2000D balance, Brinkman Instrument, Inc., Westbury, NY) with distilled-deionized water to approximate a 1:1 dilution. Each of these soil/water slurries was briefly stirred and then allowed to stand covered for about 20 minutes. Each slurry was then extracted on a Buchner funnel apparatus with a vacuum source about 400 mb strong. The effluent was collected in 13 dram polypropylene vials which were capped and wrapped with Parafilm® for refrigerated storage.

For each sample a second sub-sample, approximately 34-56 g of air dry soil, was oven-dried for 24 hours at 105°C to determine the residual moisture content for the calculations of sample dilution. These data were recorded to the nearest milligram.

Chemical Analyses

Chloride was analyzed with a Buchler model 4-2500 chloridometer (Buchler Instruments, Inc., Ft. Lee, NJ) which utilizes timed Ag/AgCl titrimetry to determine solution Cl⁻ content. Before using the instrument the silver electrodes were cleaned with a commercial silver cleaner or replaced. The instrument was switched to high sensitivity mode, which provided a detection limit of about 0.2 me/l. A series of standard readings was taken with 0.1 ml aliquots of 10 me/L and 60 me/L NaCl solutions to make a two point calibration curve. Eight replications of each solution were read to ensure nominal instrument operation. Eight background correction vials were prepared with 0.1 ml

aliquots of distilled-deionized water. Sample titrations were performed with single replications of 0.10 ml aliquots.

Nitrate analysis was performed with a Technicon AutoAnalyser II (Technicon Industrial Systems, Terrytown, NY) in the NMSU Soil & Water Testing Laboratory. The sample extracts were first screened for approximate nitrate content by using nitrate test strips (EM Science Inc., Gibbstown, NJ). From these approximations the final dilutions to bring the samples into the working linear range (0-10 mg/l) of the AutoAnalyser were determined. Samples were diluted from 1x (full strength) to 100x with distilled-de ionized water in dilution steps of no more than 10x per step. The instrument was calibrated to a single point curve with two to four replications of a 1 mg/L N NO₃ standard and updated with two replications of nitrate standard for every 10 sample extracts in the sequence of runs.

Data Reduction

The chemical analysis data were manipulated to estimate the pre leaching solution levels of chloride and nitrate in the "A" profile as in-situ solution contents and on a dry soil weight basis. For the soil solution values neutron probe measurements were used to estimate volumetric moisture contents within an "undisturbed" profile. The first neutron probe readings from plot II, taken on May 17, 1988, provided the moisture content data. Values from a single access tube, that closest to the wall of the trench, at X₂ = 0 m and Y₂ = 1.09 m, was used to provide the estimated moisture content for the "A" profile samples. Neutron probe soil moisture content values were linearly interpolated to match with the depths of "A" profile samples. The neutron probe

Appendix C-2. "A" Profile Pre-Leaching Chloride and Nitrate (continued).

measurements were separated from the soil samples by a linear distance of about 1.34 m and in time by about 3 months. An estimated term for sample bulk density was found by matching series II sample collection depths with linearly interpolated values of bulk density for the layer "A" soil cores, those collected during the original trench excavation work.

The raw chemical analyses data were adjusted for the dilution of samples by the amount of water added to make the extraction pastes, the air dry (initial) moisture contents and the estimated gravimetric water contents provided by neutron probe measurements and the bulk density of layer "A" cores. The reduced data are presented as in-situ solution contents of ions on the day of neutron probe measurement (me/L) and as (less speculative) ion contents on the basis of oven-dry soil mass (ppm), which do not utilize the neutron probe or bulk density estimates.

Discussion of Results

The distribution of chloride and nitrate are presented as a dry soil mass proportion in Figure C-2a and as a concentration of the in-situ soil solution on the day of neutron probe measurement in Figure C-2b. Both expressions of the data are quite similar; most local ion concentration peaks and troughs occur at the same depths and pairs of chloride and nitrate ion concentrates in the same sample covary in a similar pattern. The most notable features of both plots are local peak concentrations at the 3.0 m and 4.5 m depths. These peaks correspond

to abrupt increases in clay and calcium carbonate content between 3.18 and 3.31 m depths and increased calcium carbonate content between 4.48 and 4.61 m depths as observed in the original series I samples (Wierenga et al, 1989).

When chloride and nitrate ions are plotted against each other on a scatter diagram a clear relationship is evident (Figure C-2c). On this diagram data points along the positive slope generally corresponds with increasing depth. Almost all of those data which appear dispersed above the main cluster are associated with local concentration maxima for both anions (Figure C-2b).

Another interesting view of these data are presented in Figure C-2d. Here, the ratio of chloride to nitrate is quite variable to about 2 m depth corresponding to the approximate depth of a lithologic discontinuity, at 1.7 m depth. This has been identified as the morphological boundary between the Isaacks' Ranch and Jornada II soil units (Wierenga et al, 1989 and Nash, 1990). Below 2 m depth the Cl/NO_3 ratio steadily increases. Given a long term net downward movement of solutes in the profile, these data suggest that nitrate mobility has been restricted relative chloride on the whole, or selectively added to or removed from portions of the profile by plants or biological transformation. In the absence of significant net downward movement of these ions, i.e., conditions of little recharge, the present-day ion distributions may represent stable historical concentrations following periods of profile accretion.

Appendix C-2. "A" Profile Pre-Leaching Chloride and Nitrate. (Continued)

Sample ID	Depth, Z (m)	EXTRACTION VALUES		— OD MOISTURE CONTENT —			Est. Layer A Db (Mg/m3)	Est. Tube 0 Theta (cm3/cm3)
		Air-Dry Soil (g)	Diluent Added Water (g)	CAN TARE (g)	CAN + Air-Dry (g)	CAN + Oven-Dry (g)		
A-1	0.15	35.00	34.97	62.049	102.305	101.956	1.76	0.073
2	0.30	35.14	35.25	63.650	102.511	102.183	1.64	0.083
3	0.45	35.07	35.10	62.334	101.349	100.996	1.53	0.110
4	0.60	35.85	35.76	63.344	105.370	105.038	1.72	0.112
5	0.75	35.19	35.66	62.241	103.171	102.911	1.68	0.101
6	0.90	35.95	35.78	59.744	99.643	99.402	1.88	0.083
7	1.05	35.21	35.22	60.460	101.511	101.281	1.84	0.067
8	1.20	35.64	36.85	62.824	101.102	100.881	1.79	0.053
10	1.50	35.30	35.24	59.679	99.584	99.344	1.71	0.097
11	1.65	36.46	36.77	62.128	100.594	100.399	1.72	0.090
12	1.80	40.58	40.48	59.911	98.693	98.527	1.75	0.086
13	1.95	40.45	41.14	62.410	100.852	100.641	1.79	0.086
14	2.10	40.46	40.54	60.111	100.256	100.088	1.73	0.073
15	2.25	40.39	40.87	59.643	104.034	103.728	1.74	0.054
16	2.40	41.17	41.19	63.177	106.764	106.572	1.74	0.057
17	2.55	41.10	41.21	63.275	102.274	102.099	1.77	0.059
18	2.70	41.20	41.24	62.814	102.497	102.350	1.74	0.058
19	2.85	40.72	40.98	63.438	103.126	102.855	1.78	0.060
20	3.00	40.05	39.90	59.682	99.642	99.199	1.79	0.063
21	3.15	40.08	40.09	65.073	105.931	105.473	1.75	0.094
22	3.30	40.14	40.09	61.650	104.244	103.844	1.64	0.107
23	3.45	40.26	40.24	62.702	99.471	99.252	1.70	0.084
24	3.60	40.04	40.08	64.309	114.087	113.752	1.76	0.069
25	3.75	40.06	40.02	63.024	100.128	99.903	1.71	0.059
26	3.90	40.09	40.05	59.918	100.214	100.048	1.66	0.066
27	4.05	40.01	40.19	63.392	120.728	120.157	1.67	0.070
28	4.20	40.06	40.04	62.272	106.610	106.316	1.71	0.069
29	4.35	40.08	40.15	63.421	103.632	103.372	1.64	0.065
30	4.50	40.37	40.44	62.832	94.412	94.119	1.78	0.059
31	4.65	40.21	40.25	63.632	100.239	100.028	1.66	0.069
32	4.80	40.22	40.25	59.426	106.634	106.405	1.66	0.074
33	4.95	40.09	40.13	62.511	100.299	100.093	1.62	0.069
34	5.10	40.38	40.65	62.131	94.690	94.551	1.64	0.067
35	5.25	40.01	40.13	59.967	98.904	98.757	1.73	0.066
36	5.40	40.00	40.05	62.743	100.722	100.568	1.61	0.068
37	5.55	40.19	40.16	62.467	97.058	96.939	1.62	0.070
38	5.70	40.04	40.01	62.590	104.888	104.735	1.70	0.070
39	5.85	40.11	40.26	60.250	92.331	92.201	1.68	0.066
40	6.00	40.21	40.17	58.693	93.925	93.760	1.56	0.061

Appendix C-2. "A" Profile Pre-Leaching Chloride and Nitrate. (Continued)

Sample ID	Depth, Z (m)	H2O content in-situ sample (g)	Liquid Dilution Factor	Solid Dilution Factor	CHLORIDE			
					Raw Reading (me/l)	Raw Corrected (me/l)	Dry-soil Basis (g/Mg)	Soil Solution basis (me/l)
A-1	0.15	1.44	25.21	1.02	4.53	0.26	9	6.6
2	0.30	1.75	21.12	1.02	4.70	0.43	15	9.0
3	0.45	2.50	15.05	1.02	4.91	0.63	23	9.5
4	0.60	2.31	16.50	1.01	4.57	0.30	11	4.9
5	0.75	2.10	18.00	1.03	4.78	0.51	18	9.1
6	0.90	1.58	23.66	1.01	4.93	0.65	23	15.4
7	1.05	1.28	28.61	1.01	4.47	0.20	7	5.8
8	1.20	1.05	36.15	1.05	4.94	0.66	25	23.9
10	1.50	2.00	18.66	1.01	6.04	1.74	62	32.5
11	1.65	1.91	20.28	1.02	5.87	1.57	57	31.9
12	1.80	1.98	21.44	1.01	5.69	1.40	50	30.0
13	1.95	1.93	22.29	1.03	6.13	1.83	67	40.8
14	2.10	1.71	24.76	1.01	5.71	1.42	51	35.1
15	2.25	1.24	33.97	1.03	6.37	2.07	75	70.2
16	2.40	1.35	31.46	1.01	7.02	2.70	97	85.1
17	2.55	1.37	31.08	1.01	7.86	3.53	126	109.6
18	2.70	1.37	31.01	1.01	6.72	2.41	86	74.7
19	2.85	1.35	31.28	1.02	8.91	4.56	165	142.6
20	3.00	1.39	29.73	1.02	10.47	6.09	220	181.0
21	3.15	2.13	19.81	1.02	9.23	4.87	177	96.5
22	3.30	2.60	16.41	1.02	7.85	3.52	127	57.7
23	3.45	1.98	21.35	1.01	7.11	2.79	100	59.6
24	3.60	1.57	26.49	1.01	7.95	3.62	130	95.8
25	3.75	1.38	29.97	1.01	7.92	3.59	128	107.5
26	3.90	1.59	26.19	1.01	7.73	3.40	121	89.1
27	4.05	1.67	25.06	1.02	8.80	4.45	162	111.5
28	4.20	1.60	26.01	1.01	9.04	4.69	168	121.8
29	4.35	1.57	26.56	1.01	9.35	4.99	179	132.5
30	4.50	1.33	31.48	1.02	13.51	9.07	328	285.6
31	4.65	1.67	25.14	1.01	13.35	8.91	320	224.1
32	4.80	1.79	23.52	1.01	11.94	7.53	270	177.1
33	4.95	1.70	24.66	1.01	11.51	7.11	255	175.3
34	5.10	1.64	25.86	1.02	14.18	9.73	350	251.6
35	5.25	1.51	27.51	1.01	12.15	7.74	277	212.8
36	5.40	1.69	24.69	1.01	12.33	7.91	283	195.4
37	5.55	1.73	24.25	1.01	13.47	9.03	322	219.0
38	5.70	1.63	25.48	1.01	12.70	8.28	295	210.9
39	5.85	1.57	26.57	1.01	12.97	8.54	306	226.9
40	6.00	1.55	26.90	1.01	14.17	9.72	347	261.5

Chloride background = 42.65 * 0.1 me/l

10 me/l Chloride standard = 104.1 * 0.1 me/l

Appendix C-2. "A" Profile Pre-Leaching Chloride and Nitrate. (Continued)

Sample ID	Depth, Z (m)	NITRATE				
		Raw Reading (scale)	Sample Dilution (x)	Raw Corrected (ppm)	Dry-soil Basis (g/Mg)	Soil Solution basis (me/l)
A-1	0.15	35.00	10	31	31	12.8
2	0.30	29.50	10	26	26	9.0
3	0.45	14.25	10	12	13	3.1
4	0.60	13.25	10	12	12	3.2
5	0.75	13.75	10	12	12	3.6
6	0.90	13.00	10	11	11	4.5
7	1.05	44.50	1	4	4	1.8
8	1.20	24.25	10	21	22	12.7
10	1.50	45.50	10	40	40	12.3
11	1.65	59.50	10	52	53	17.5
12	1.80	62.50	10	55	55	19.4
13	1.95	33.50	40	117	121	43.3
14	2.10	89.00	10	78	79	32.0
15	2.25	31.00	40	108	111	61.1
16	2.40	53.50	40	187	189	97.7
17	2.55	56.00	40	196	198	101.0
18	2.70	40.00	40	140	141	72.0
19	2.85	56.75	40	199	203	103.0
20	3.00	69.00	40	241	246	119.0
21	3.15	51.00	40	178	183	58.6
22	3.30	34.50	40	121	123	32.9
23	3.45	22.00	40	77	78	27.3
24	3.60	29.00	40	101	103	44.6
25	3.75	30.00	40	105	106	52.2
26	3.90	24.00	40	84	85	36.5
27	4.05	36.00	40	126	129	52.4
28	4.20	33.25	40	116	118	50.2
29	4.35	37.50	40	131	133	57.8
30	4.50	64.25	40	225	229	117.4
31	4.65	60.00	40	210	213	87.5
32	4.80	50.00	40	175	177	68.3
33	4.95	42.50	40	149	151	60.8
34	5.10	60.75	40	213	216	91.2
35	5.25	45.00	40	157	159	71.8
36	5.40	46.50	40	163	164	66.6
37	5.55	50.00	40	175	176	70.4
38	5.70	43.50	40	152	153	64.3
39	5.85	39.75	40	139	141	61.3
40	6.00	46.00	40	161	162	71.8

Nitrate conversion: 4.427 ppm NO₃ = 50.6 (linear scale), 11.43/ppm

Appendix C-2a. "A" Profile Pre-Leaching Chloride and Nitrate.

Appendix C-2b. "A" Profile Pre-Leaching Chloride and Nitrate.

Appendix C-2c. "A" Profile Pre-Leaching Chloride and Nitrate.

Appendix C-2d. "A" Profile Pre-Leaching Chloride and Nitrate.

Appendix C-3. Evaporative Loss from 20 ml Glass Scintillation Vials.

For long-term liquid sample storage 20 ml capacity glass scintillation w/vials with foil lined screw-on caps were used. These vials were chosen over polypropylene vials to reduce evaporative sample loss during storage. On August 10, 1990 six new vials were partially filled with distilled-deionized water and then capped. Three of the vial caps were then wrapped with 2 layers of Paraffilm® wrap

(Am. Nat'l. Can, Greenwich, CT). Then all the vials were weighed to the nearest mg with a Sartorius E2000D balance. All 6 vials were stored upright on a laboratory bench. Periodically the vials were reweighed. On October 17, 1991 the vials were reweighed and then placed in refrigerated storage until a final reweighing on March 11, 1992. The following tables illustrate the results of this trial:

Temperature	21° C					2° C	
Date	8/10/90	8/15/90	10/17/91	loss/day		3/11/92	loss/day
Day	0	5	433	of day 0		579	of day 433
Vial Mass	(g)	(g)	(g)	(g)		(g)	(g)
With Parafilm							
Replication I	22.401	22.401	22.047	0.00082		21.989	0.00040
Replication II	22.625	22.625	22.202	0.00098		22.138	0.00044
Replication III	21.753	21.753	21.398	0.00082		21.347	0.00035
Treatment Mean (g)	22.260	22.260	21.882			21.825	
Mean Loss (g)	0	0	0.377			0.058	
Loss per day (g)			0.00087			0.00039	
Without Parafilm							
Replication I	20.998	20.993	18.588	0.00555		18.307	0.00192
Replication II	21.399	21.387	18.334	0.00705		17.707	0.00429
Replication III	21.453	21.432	18.052	0.00781		17.746	0.00210
Treatment Mean (g)	21.283	21.271	18.325			17.920	
Mean Loss (g)	0.000	0.013	2.959			0.405	
Loss per day (g)		0.00253	0.00683			0.00277	

All vials kept at room temperature from 8/10/90 to 10/17/90, refrigerated thereafter

Summary: Evaporative loss per day, (g)

	Temperature	
	21° C.	2° C.
With Parafilm wrap	0.0009	0.0004
Unwrapped	0.0068	0.0028

Appendix C-4. Facilities Maps of Trench Site and Ranch Headquarters.

TRENCH SITE WATER UTILITIES

**Appendix C-4. Facilities Maps of Trench Site and Ranch Headquarters.
(Continued)**

RANCH HOUSE UTILITIES

Appendix C-5a. Experiment IIa Redistribution Cores Data.

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
5	-1.5	0.0	7-Jun-90	1.66	0.062	0.103	0.000	42	10	0.006	1.3
5	-1.5	0.2	7-Jun-90	1.66	0.063	0.105	0.000	97	21	0.013	2.7
5	-1.5	0.4	13-Jun-90	1.67	0.081	0.136	0.000	69	21	0.005	1.3
5	-1.5	0.6	11-Jun-90	1.68	0.086	0.144	0.000	45	15	0.000	0.0
5	-1.5	0.8	13-Jun-90	1.68	0.048	0.080	0.002	117	19	0.009	1.4
5	-1.5	1.0	7-Jun-90	1.69	0.068	0.114	0.003	32	9	0.005	1.2
5	-1.5	1.2	6-Jun-90	1.69	0.066	0.112	0.006	96	25	0.005	1.3
5	-1.5	1.4	13-Jun-90	1.70	0.081	0.138	0.013	19	6	0.000	0.0
5	-1.5	1.6	5-Jun-90	1.70	0.068	0.115	0.025	161	38	0.006	1.3
5	-1.5	1.8	5-Jun-90	1.71	0.064	0.110	0.049	25	6	0.006	1.3
5	-1.5	2.0	11-Jul-90	1.71	0.050	0.086	0.063	109	16	1.485	209.4
5	-1.5	2.2	11-Jul-90	1.72	0.048	0.083	0.068	59	12	0.659	131.1
5	-1.5	2.4	11-Jul-90	1.72	0.049	0.084	0.051	84	17	0.467	88.0
5	-1.5	2.6	11-Jul-90	1.73	0.047	0.082	0.034	153	33	0.346	70.3
5	-1.5	2.8	11-Jul-90	1.74	0.058	0.101	0.018	279	70	0.283	66.1
5	-1.5	3.0	11-Jul-90	1.75	0.057	0.100	0.009	344	75	0.377	76.9
5	-1.0	0.0	7-Jun-90	1.66	0.104	0.172	0.003	254	91	0.004	1.3
5	-1.0	0.2	12-Jun-90	1.66	0.068	0.114	0.003	56	15	0.005	1.3
5	-1.0	0.4	7-Jun-90	1.67	0.082	0.137	0.000	52	12	0.000	0.0
5	-1.0	0.6	13-Jun-90	1.68	0.086	0.144	0.000	61	20	0.004	1.3
5	-1.0	0.8	13-Jun-90	1.68	0.063	0.106	0.001	12	3	0.000	0.0
5	-1.0	1.0	13-Jun-90	1.69	0.050	0.084	0.001	241	48	0.007	1.3
5	-1.0	1.2	12-Jun-90	1.69	0.061	0.103	0.000	55	15	0.005	1.2
5	-1.0	1.4	7-Jun-90	1.70	0.069	0.117	0.019	186	41	0.007	1.4
5	-1.0	1.6	5-Jun-90	1.70	0.072	0.122	0.042	96	22	0.007	1.4
5	-1.0	1.8	5-Jun-90	1.71	0.076	0.129	0.070	70	19	0.011	2.7
5	-1.0	2.0	11-Jul-90	1.71	0.073	0.124	0.104	18	5	0.725	196.2

Appendix C-5a. Experiment IIa Redistribution Cores Data. (Continued)

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
5	-1.0	2.2	11-Jul-90	1.72	0.083	0.142	0.100	53	15	0.503	132.6
5	-1.0	2.4	11-Jul-90	1.72	0.054	0.093	0.086	61	13	0.452	90.2
5	-1.0	2.6	11-Jul-90	1.73	0.057	0.099	0.048	208	48	0.257	56.0
5	-1.0	2.8	11-Jul-90	1.74	0.050	0.087	0.025	190	41	0.307	61.5
5	-1.0	3.0	11-Jul-90	1.75	0.058	0.102	0.013	266	54	0.364	68.9
5	0.0	0.0	8-Jun-90	1.66	0.020	0.034	0.020		17	0.017	1.3
5	0.0	0.2	12-Jun-90	1.66	0.067	0.112	0.005	53	15	0.005	1.3
5	0.0	0.4	11-Jun-90	1.67	0.091	0.152	0.004	49	16	0.004	1.3
5	0.0	0.6	8-Jun-90	1.68	0.074	0.123	0.006	4	1	0.006	1.3
5	0.0	0.8	12-Jun-90	1.68	0.079	0.133	0.012	31	9	0.004	1.3
5	0.0	1.0	11-Jun-90	1.69	0.061	0.103	0.028	46	12	0.005	1.2
5	0.0	1.2	8-Jun-90	1.69	0.058	0.098	0.080	80	17	0.006	1.3
5	0.0	1.4	13-Jun-90	1.70	0.071	0.121	0.116	65	17	0.005	1.3
5	0.0	1.6	13-Jun-90	1.70	0.087	0.148	0.134	72	20	0.005	1.4
5	0.0	1.8	5-Jun-90	1.71	0.062	0.107	0.139	299	58	0.008	1.4
5	0.0	2.0	11-Jul-90	1.71	0.052	0.089	0.208	66	14	0.444	88.1
5	0.0	2.2	11-Jul-90	1.72	0.042	0.072	0.137	140	24	0.409	66.6
5	0.0	2.4	11-Jul-90	1.72	0.046	0.080	0.089	245	51	0.289	56.9
5	0.0	2.6	11-Jul-90	1.73	0.048	0.083	0.040	338	78	0.299	64.5
5	0.0	2.8	11-Jul-90	1.74	0.049	0.084	0.021	482	108	0.369	77.5
5	0.0	3.0	11-Jul-90	1.75	0.040	0.071	0.011	651	134	0.436	84.3
5	1.0	0.0	11-Jun-90	1.66	0.059	0.098	0.051	45	13	0.023	6.0
5	1.0	0.2	7-Jun-90	1.66	0.071	0.119	0.068	79	21	0.032	7.9
5	1.0	0.4	11-Jun-90	1.67	0.085	0.142	0.064	38	12	0.033	10.2
5	1.0	0.6	11-Jun-90	1.68	0.079	0.133	0.072	115	40	0.063	20.6
5	1.0	0.8	7-Jun-90	1.68	0.088	0.148	0.119	110	32	0.055	14.9
5	1.0	1.0	11-Jun-90	1.69	0.083	0.139	0.104	116	39	0.055	17.4

Appendix C-5a. Experiment IIa Redistribution Cores Data. (Continued)

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
5	1.0	1.2	7-Jun-90	1.69	0.056	0.094	0.167	214	45	0.147	28.9
5	1.0	1.4	13-Jun-90	1.70	0.059	0.100	0.146	141	32	0.276	59.3
5	1.0	1.6	5-Jun-90	1.70	0.075	0.128	0.146	252	68	0.231	58.1
5	1.0	1.8	5-Jun-90	1.71	0.066	0.112	0.162	135	32	0.207	46.2
5	1.0	2.0	5-Jun-90	1.71	0.071	0.122	0.154	156	39	0.213	50.4
5	1.0	2.2	11-Jul-90	1.72	0.049	0.085	0.061	232	54	0.258	56.2
5	1.0	2.4	11-Jul-90	1.72	0.054	0.093	0.021	463	101	0.514	105.7
5	1.0	2.6	11-Jul-90	1.73	0.050	0.087	0.007	695	145	0.607	119.1
5	1.0	2.8	11-Jul-90	1.74	0.045	0.078	0.004	882	160	0.800	136.3
5	1.0	3.0	11-Jul-90	1.75	0.042	0.074	0.002	1070	197	0.769	133.1
5	1.5	0.2	13-Jun-90	1.66	0.064	0.107	0.018	43	11	0.011	2.6
5	1.5	0.4	11-Jun-90	1.67	0.093	0.155	0.020	27	11	0.019	7.2
5	1.5	0.6	7-Jun-90	1.68	0.078	0.131	0.031	47	16	0.047	14.7
5	1.5	0.8	12-Jun-90	1.68	0.088	0.148	0.029	65	21	0.084	25.7
5	1.5	1.0	12-Jun-90	1.69	0.060	0.101	0.027	176	44	0.092	21.4
5	1.5	1.2	13-Jun-90	1.69	0.068	0.115	0.018	108	33	0.104	29.4
5	1.5	1.4	11-Jun-90	1.70	0.072	0.123	0.015	58	20	0.092	29.8
5	1.5	1.6	5-Jun-90	1.70	0.039	0.067	0.027	295	40	0.043	5.5
5	1.5	1.8	5-Jun-90	1.71	0.069	0.117	0.013	331	74	0.046	9.7
5	1.5	2.0	5-Jun-90	1.71	0.049	0.084	0.014	370	74	0.103	19.2
5	1.5	2.2	11-Jul-90	1.72	0.049	0.085	0.004	835	188	0.525	110.9
5	1.5	2.6	11-Jul-90	1.73	0.053	0.091	0.000	1169	273	0.541	118.8
5	1.5	2.8	11-Jul-90	1.74	0.045	0.079	0.001	1307	289	0.573	118.9
5	1.5	3.0	11-Jul-90	1.75	0.038	0.066	0.001	1305	228	0.792	129.9
5.1	-0.5	0.0	12-Jun-90	1.66	0.074	0.122	0.009	68	19	0.010	2.6
5.1	-0.5	0.2	8-Jun-90	1.66	0.060	0.100	0.005	69	16	0.006	1.3
5.1	-0.5	0.4	8-Jun-90	1.67	0.087	0.146	0.002	138	38	0.000	0.0

Appendix C-5a. Experiment IIa Redistribution Cores Data. (Continued)

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
5.1	-0.5	0.6	11-Jun-90	1.68	0.097	0.163	0.002	21	8	0.000	0.0
5.1	-0.5	0.8	11-Jun-90	1.68	0.073	0.123	0.001	54	16	0.005	1.3
5.1	-0.5	1.0	11-Jun-90	1.69	0.057	0.097	0.003	205	48	0.011	2.5
5.1	-0.5	1.2	12-Jun-90	1.69	0.073	0.124	0.010	64	21	0.004	1.2
5.1	-0.5	1.4	13-Jun-90	1.70	0.075	0.127	0.019	54	13	0.000	0.0
5.1	-0.5	1.6	11-Jul-90	1.70	0.069	0.117	0.060	36	10	0.690	175.8
5.1	-0.5	1.8	11-Jul-90	1.71	0.061	0.105	0.104	31	8	0.843	198.5
5.1	-0.5	2.0	11-Jul-90	1.71	0.064	0.109	0.147	43	12	0.372	97.3
5.1	-0.5	2.2	11-Jul-90	1.72	0.056	0.096	0.000	79	18	0.313	68.3
5.1	-0.5	2.4	11-Jul-90	1.72	0.048	0.084	0.092	132	29	0.325	67.7
5.1	-0.5	2.6	11-Jul-90	1.73	0.058	0.100	0.063	150	37	0.285	66.2
5.1	-0.5	2.8	11-Jul-90	1.74	0.057	0.099	0.036	155	40	0.238	57.7
5.1	0.5	0.0	12-Jun-90	1.66	0.045	0.075	0.017	189	33	0.008	1.3
5.1	0.5	0.2	12-Jun-90	1.66	0.076	0.126	0.016	31	9	0.005	1.3
5.1	0.5	0.4	7-Jun-90	1.67	0.090	0.151	0.027	21	7	0.005	1.3
5.1	0.5	0.6	11-Jun-90	1.68	0.072	0.120	0.031	53	14	0.005	1.3
5.1	0.5	0.8	12-Jun-90	1.68	0.062	0.104	0.081	43	11	0.005	1.3
5.1	0.5	1.0	7-Jun-90	1.69	0.063	0.106	0.136	55	13	0.006	1.3
5.1	0.5	1.2	7-Jun-90	1.69	0.063	0.106	0.184	136	32	0.012	2.6
5.1	0.5	1.4	12-Jun-90	1.70	0.057	0.097	0.218	78	21	0.047	12.1
5.1	0.5	1.6	5-Jun-90	1.70	0.075	0.128	0.217	70	22	0.062	18.5
5.1	0.5	1.8	11-Jul-90	1.71	0.058	0.099	0.227	47	11	0.457	99.6
5.1	0.5	2.0	11-Jul-90	1.71	0.045	0.077	0.109	71	12	0.688	108.5
5.1	0.5	2.2	11-Jul-90	1.72	0.056	0.096	0.131	167	37	0.268	56.2
5.1	0.5	2.4	11-Jul-90	1.72	0.056	0.097	0.078	209	46	0.282	58.0
5.1	0.5	2.6	11-Jul-90	1.73	0.053	0.092	0.032	309	69	0.283	59.3
5.1	0.5	2.8	11-Jul-90	1.74	0.049	0.085	0.014	402	87	0.398	80.9

Appendix C-5a. Experiment IIa Redistribution Cores Data. (Continued)

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
9	-1.5	0.0	12-Jun-90	1.66	0.054	0.089	0.024	293	60	0.013	2.6
9	-1.5	0.2	13-Jun-90	1.66	0.062	0.103	0.032	67	18	0.015	3.7
9	-1.5	0.4	12-Jun-90	1.67	0.079	0.133	0.042	95	28	0.069	19.3
9	-1.5	0.6	11-Jun-90	1.68	0.082	0.138	0.032	43	12	0.069	18.5
9	-1.5	0.8	7-Jun-90	1.68	0.067	0.113	0.049	128	26	0.146	28.4
9	-1.5	1.0	11-Jun-90	1.69	0.078	0.131	0.033	77	24	0.128	37.6
9	-1.5	1.2	13-Jun-90	1.69	0.069	0.116	0.039	154	40	0.268	64.8
9	-1.5	1.4	12-Jun-90	1.70	0.071	0.120	0.025	156	45	0.253	68.9
9	-1.5	1.6	5-Jun-90	1.70	0.053	0.090	0.018	217	42	0.119	21.4
9	-1.5	2.0	11-Jul-90	1.71	0.045	0.078	0.005	730	133	0.787	134.2
9	-1.5	2.2	11-Jul-90	1.72	0.047	0.082	0.002	908	176	0.778	141.9
9	-1.5	2.4	11-Jul-90	1.72	0.042	0.072	0.001	766	151	0.764	141.2
9	-1.5	2.6	11-Jul-90	1.73	0.029	0.050	0.001	1072	155	1.026	139.3
9	-1.5	2.8	11-Jul-90	1.74	0.031	0.054	-0.001	894	153	0.900	144.3
9	-1.0	0.0	7-Jun-90	1.66	0.054	0.089	0.058	94	18	0.082	14.7
9	-1.0	0.2	12-Jun-90	1.66	0.070	0.116	0.084	57	15	0.048	11.7
9	-1.0	0.4	8-Jun-90	1.67	0.076	0.127	0.131	209	52	0.088	20.5
9	-1.0	0.6	13-Jun-90	1.68	0.070	0.118	0.135	112	28	0.116	26.7
9	-1.0	0.8	12-Jun-90	1.68	0.077	0.130	0.167	104	30	0.138	37.4
9	-1.0	1.0	13-Jun-90	1.69	0.071	0.120	0.170	142	35	0.185	42.8
9	-1.0	1.2	12-Jun-90	1.69	0.073	0.123	0.168	139	36	0.264	64.6
9	-1.0	1.4	7-Jun-90	1.70	0.067	0.113	0.128	147	44	0.318	88.2
9	-1.0	1.6	5-Jun-90	1.70	0.042	0.072	0.099		40	0.552	49.6
9	-1.0	1.8	5-Jun-90	1.71	0.084	0.143	0.033	201	54	0.132	33.2
9	-1.0	2.0	11-Jul-90	1.71	0.060	0.102	0.028	494	119	0.421	95.3
9	-1.0	2.2	11-Jul-90	1.72	0.048	0.082	0.011	560	122	0.496	101.2
9	-1.0	2.4	11-Jul-90	1.72	0.038	0.065	0.005	591	132	0.473	99.0

Appendix C-5a. Experiment IIa Redistribution Cores Data. (Continued)

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
9	-1.0	2.6	11-Jul-90	1.73	0.034	0.059	0.003	955	179	0.641	112.8
9	-1.0	2.8	11-Jul-90	1.74	0.040	0.069	0.002	1164	226	0.661	120.6
9	-1.0	3.0	11-Jul-90	1.75	0.074	0.129	0.001	574	176	0.403	115.8
9	-0.5	0.0	8-Jun-90	1.66	0.033	0.055	0.027	281	36	0.055	6.6
9	-0.5	0.2	7-Jun-90	1.66	0.056	0.094	0.051	61	12	0.007	1.3
9	-0.5	0.4	11-Jun-90	1.67	0.077	0.129	0.072	61	19	0.004	1.3
9	-0.5	0.6	11-Jun-90	1.68	0.087	0.146	0.080	163	54	0.008	2.5
9	-0.5	0.8	12-Jun-90	1.68	0.071	0.119	0.171	49	13	0.010	2.6
9	-0.5	1.0	13-Jun-90	1.69	0.057	0.095	0.233	91	20	0.032	6.5
9	-0.5	1.2	12-Jun-90	1.69	0.081	0.137	0.236	77	27	0.094	30.6
9	-0.5	1.4	12-Jun-90	1.70	0.058	0.099	0.259	146	42	0.234	63.4
9	-0.5	1.6	5-Jun-90	1.70	0.054	0.092	0.142	182	42	0.312	67.7
9	-0.5	1.8	5-Jun-90	1.71	0.075	0.128	0.094	234	54	0.318	69.1
9	-0.5	2.0	11-Jul-90	1.71	0.056	0.095	0.044	235	58	0.207	48.2
9	-0.5	2.2	11-Jul-90	1.72	0.049	0.084	0.020	289	67	0.298	64.6
9	-0.5	2.4	11-Jul-90	1.72	0.050	0.086	0.008	465	96	0.456	88.0
9	-0.5	2.6	11-Jul-90	1.73	0.041	0.071	0.005	785	155	0.590	109.7
9	-0.5	2.8	11-Jul-90	1.74	0.046	0.081	0.004	972	198	0.609	116.3
9	0.0	0.0	7-Jun-90	1.66	0.036	0.061	0.012	205	30	0.019	2.6
9	0.0	0.2	7-Jun-90	1.66	0.063	0.105	0.024	114	23	0.007	1.4
9	0.0	0.4	7-Jun-90	1.67	0.118	0.197	0.031	27	11	0.003	1.3
9	0.0	0.6	13-Jun-90	1.68	0.081	0.135	0.101	37	11	0.005	1.3
9	0.0	0.8	11-Jun-90	1.68	0.075	0.126	0.126	49	14	0.010	2.6
9	0.0	1.0	12-Jun-90	1.69	0.108	0.183	0.172	72	28	0.064	23.1
9	0.0	1.2	13-Jun-90	1.69	0.068	0.116	0.194	135	32	0.154	34.7
9	0.0	1.4	31575	1.70	0.070	0.119	0.185	185	49	0.195	49.0
9	0.0	1.6	31567	1.70	0.074	0.126	0.143	204	52	0.227	53.9

Appendix C-5a. Experiment IIa Redistribution Cores Data. (Continued)

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
9	0.0	1.8	31603	1.71	0.048	0.082	0.087	197	43	0.286	58.1
9	0.0	2.0	31603	1.71	0.051	0.088	0.045	233	52	0.311	65.0
9	0.0	2.2	31603	1.72	0.053	0.090	0.019	368	83	0.346	73.7
9	0.0	2.4	31603	1.72	0.053	0.092	0.008	496	113	0.402	86.3
9	0.0	2.6	31603	1.73	0.066	0.115	0.003	559	144	0.391	94.9
9	0.0	2.8	31603	1.74	0.055	0.096	0.003	662	156	0.475	105.1
9	0.5	0.0	31574	1.66	0.017	0.028	0.042		37	0.041	3.6
9	0.5	0.2	31575	1.66	0.038	0.063	0.052	142	24	0.016	2.5
9	0.5	0.4	31574	1.67	0.071	0.119	0.081	68	19	0.010	2.6
9	0.5	0.6	31569	1.68	0.077	0.129	0.129	65	20	0.013	3.8
9	0.5	0.8	31574	1.68	0.066	0.110	0.200	123	32	0.037	8.9
9	0.5	1.0	31569	1.69	0.078	0.131	0.193	87	22	0.073	17.7
9	0.5	1.2	31570	1.69	0.065	0.110	0.220	118	29	0.222	50.7
9	0.5	1.4	31574	1.70	0.074	0.125	0.150	185	58	0.432	127.1
9	0.5	1.6	31603	1.70	0.066	0.113	0.083	150	39	0.200	49.6
9	0.5	1.8	31603	1.71	0.066	0.112	0.051	137	42	0.161	45.9
9	0.5	2.0	31603	1.71	0.053	0.091	0.024	171	45	0.259	63.7
9	0.5	2.2	31603	1.72	0.047	0.080	0.014	391	77	0.549	101.4
9	0.5	2.4	31603	1.72	0.028	0.048	0.012		75	1.562	142.4
9	0.5	2.6	31603	1.73	0.051	0.088	0.004	575	128	0.586	122.2
9	1.0	0.0	31569	1.66	0.057	0.094	0.081	59	13	0.056	11.6
9	1.0	0.2	31575	1.66	0.065	0.108	0.066	95	22	0.049	10.6
9	1.0	0.4	31574	1.67	0.090	0.151	0.083	96	33	0.163	52.1
9	1.0	0.6	31574	1.68	0.087	0.145	0.084	103	31	0.185	52.6
9	1.0	0.8	31575	1.68	0.071	0.119	0.026	70	19	0.005	1.3
9	1.0	1.0	31569	1.69	0.095	0.161	0.075	188	62	0.201	61.9
9	1.0	1.2	31569	1.69	0.081	0.137	0.058	119	35	0.177	49.3

Y (m)	X (m)	Z (m)	Extract Date	Est. Db (g/cm3)	Water Content		Relative Tritium (C/Co)	Chloride Content		Bromide Content	
					Grav. (g/cm3)	Volume (cm3/cm3)		Solution (ppm)	Dry soil (ppm)	Relative (C/Co)	Dry soil (ppm)
9	1.0	1.4	31570	1.70	0.064	0.108	0.052	411	85	0.334	65.1
9	1.0	1.6	31567	1.70	0.104	0.176	0.023	140	42	0.240	67.7
9	1.0	1.8	31567	1.71	0.085	0.144	0.017			0.246	53.8
9	1.0	2.0	31603	1.71	0.017	0.029	0.026		113	1.234	85.7
9	1.0	2.2	31603	1.72	0.044	0.076	0.002	633	125	0.625	115.9
9	1.0	2.4	31603	1.72	0.040	0.069	0.001	967	189	0.645	118.2
9	1.0	2.6	31603	1.73	0.039	0.068	0.001	1106	203	0.746	128.4
9	1.0	2.8	31603	1.74	0.035	0.062	0.001	1131	189	0.825	129.6
9	1.0	3.0	31603	1.75	0.028	0.050	0.001	1218	174	0.988	132.9
9	1.5	0.0	31569	1.66	0.050	0.083	0.014	202	42	0.046	8.9
9	1.5	0.2	31573	1.66	0.053	0.088	0.019	57	13	0.022	4.9
9	1.5	0.4	31573	1.67	0.072	0.121	0.024	93	28	0.022	6.2
9	1.5	0.6	31574	1.68	0.079	0.132	0.018	66	22	0.016	4.9
9	1.5	0.8	31575	1.68	0.155	0.260	0.008	22	10	0.003	1.4
9	1.5	1.0	31573	1.69	0.085	0.143	0.010	31	11	0.007	2.4
9	1.5	1.2	31574	1.69	0.068	0.115	0.006	136	40	0.013	3.7
9	1.5	1.4	31573	1.70	0.082	0.140	0.004			0.042	17.2
9	1.5	1.6	31567	1.70	0.078	0.133	0.004	176	44	0.130	30.5
9	1.5	1.8	31567	1.71	0.073	0.125	0.003	153	36	0.108	23.7
9	1.5	2.0	31603	1.71	0.058	0.099	0.001	390	84	0.565	114.1
9	1.5	2.2	31603	1.72	0.048	0.082	0.000	853	179	0.664	131.1
9	1.5	2.4	31603	1.72	0.040	0.068	0.000	1229	253	0.631	122.2
9	1.5	2.6	31603	1.73	0.043	0.074	0.001	1215	207	0.906	145.1
9	1.5	2.8	31603	1.74	0.037	0.065	-0.001	1355	229	0.842	133.4
9	1.5	3.0	31603	1.75	0.022	0.039	0.002		131	1.834	157.1

Appendix C-5b. Experiment IIa Neutron Probe Water and Tritium Contour Data.

Neutron Probe Water at Y = 6 m & = 10 m, Days 78 & 655

Day	Y (m)	X (m)	Z (m)	Theta	Y (m)	X (m)	Z (m)	Theta
78	6	-4	0.25	0.099	10	-4	0.25	0.11
78	6	-4	0.5	0.094	10	-4	0.5	0.097
78	6	-4	0.75	0.077	10	-4	0.75	0.077
78	6	-4	1	0.072	10	-4	1	0.066
78	6	-4	1.25	0.074	10	-4	1.25	0.043
78	6	-4	1.5	0.076	10	-4	1.5	0.052
78	6	-4	1.75	0.069	10	-4	1.75	0.053
78	6	-4	2	0.063	10	-4	2	0.053
78	6	-4	2.25	0.041	10	-4	2.25	0.051
78	6	-4	2.5	0.041	10	-4	2.5	0.057
78	6	-4	2.75	0.053	10	-4	2.75	0.055
78	6	-4	3	0.071	10	-4	3	0.044
78	6	-4	3.25	0.119	10	-4	3.25	0.07
78	6	-4	3.5	0.084	10	-4	3.5	0.078
78	6	-4	3.75	0.081	10	-4	3.75	0.052
78	6	-4	4	0.086	10	-4	4	0.055
78	6	-4	4.25	0.094	10	-4	4.25	0.1
78	6	-4	4.5	0.115	10	-4	4.5	0.128
78	6	-4	4.75	0.079	10	-4	4.75	0.094
78	6	-4	5	0.064	10	-4	5	0.066
78	6	-4	5.25	0.069	10	-4	5.25	0.055
78	6	-4	5.5	0.079	10	-4	5.5	0.06
78	6	-4	5.75	0.065	10	-4	5.75	0.072
78	6	-4	6	0.063	10	-4	6	0.074
78	6	-3	0.25	0.113	10	-3	0.25	0.11
78	6	-3	0.5	0.12	10	-3	0.5	0.113
78	6	-3	0.75	0.099	10	-3	0.75	0.101
78	6	-3	1	0.088	10	-3	1	0.075
78	6	-3	1.25	0.064	10	-3	1.25	0.056
78	6	-3	1.5	0.055	10	-3	1.5	0.063
78	6	-3	1.75	0.06	10	-3	1.75	0.066
78	6	-3	2	0.043	10	-3	2	0.058
78	6	-3	2.25	0.035	10	-3	2.25	0.053
78	6	-3	2.5	0.044	10	-3	2.5	0.054
78	6	-3	2.75	0.05	10	-3	2.75	0.056
78	6	-3	3	0.078	10	-3	3	0.045
78	6	-3	3.25	0.074	10	-3	3.25	0.094
78	6	-3	3.5	0.074	10	-3	3.5	0.085
78	6	-3	3.75	0.086	10	-3	3.75	0.088
78	6	-3	4	0.088	10	-3	4	0.109
78	6	-3	4.25	0.094	10	-3	4.25	0.099

**Appendix C-5b. Experiment IIa Neutron Probe Water and Tritium Contour Data.
(Continued)**

Observed Tritium, Solution Samplers (Y = 0.5 m), days 78 & 429

Day	X (m)	Z (m)	C/Co	Day	X (m)	Z (m)	C/Co
78	-1.25	0.5	0	429	0.75	0.5	0.105
78	-0.75	0.5	0.054	429	1.25	0.5	0.057
78	0.25	0.5	0.011	429	0.25	1	0.198
78	0.75	0.5	0.391	429	0.75	1	0.268
78	-0.75	1	0.07	429	1.25	1	0.084
78	-0.25	1	0.192	429	-1.25	1.5	0.007
78	0.25	1	0.627	429	-0.75	1.5	0.093
78	0.75	1	0.689	429	-0.25	1.5	0.11
78	1.25	1	0	429	0.25	1.5	0.115
78	-1.25	1.5	0	429	0.75	1.5	0.194
78	-0.75	1.5	0.001	429	1.25	1.5	0.038
78	-0.25	1.5	0	429	-1.25	2	0.001
78	0.25	1.5	0	429	-0.75	2	0.01
78	0.75	1.5	0	429	-0.25	2	0.021
78	1.25	1.5	0	429	0.25	2	0.014
78	-1.25	2	0	429	0.75	2	0.018
78	-0.75	2	0	429	1.25	2	0.003
78	-0.25	2	0	429	-1.25	2.5	0
78	0.25	2	0	429	-0.25	2.5	0.003
78	0.75	2	0.001	429	0.25	2.5	0.002
78	0.25	2.5	0	429	0.75	2.5	0.001
78	-0.5	0.25	0.005	429	1.25	2.5	0
78	0	0.25	0.003				
78	0.5	0.25	0.006				
78	-0.5	0.75	0.506				
78	0	0.75	0.115				
78	0.5	0.75	0.205				

Appendix C-6. Construction of Narrow-Profile Ceramic Devices.

Introduction

This document describes the procedures used to construct small-diameter (1/4" nominal ID) ceramic devices for use as tensiometers or solution samplers. These have served as the primary ceramic devices in a variety of lysimeter experiments at the Jornada trench site of the NMSU college ranch. The small-diameter device differs from the more familiar 1/2" ID PVC device in that these are designed for installation into a vertical soil wall.

The small diameter device has a 90° elbow at one end which forms a sealed chamber continuous with the straight PVC and ceramic cup. When installed elbow-up into a vertical soil face and filled with water the air bubble in the elbow is more easily accessed with the tensiometer needle.

Since first conceived several design changes have been made including changes in the cements used, the ceramic and plastic raw materials used, and the methods for fabricating and fitting parts. The current product is more durable and more dependable.

The following procedure is used for making a standard device, approximately 1.4 cm outside diameter and 90 cm long. In use, this device is inserted about 82 cm into soil material at a 10° angle from horizontal into a pre-drilled hole.

Materials

PVC pipe: Schedule 40 clear, 1/4" nominal (OD Excelon, US Plastics Corp. (Lima, OH), p/n 34100.

Ceramic cups: 1 bar High-Flow, 1.0 cm OD* 10 cm long, 0.16 cm wall, Soil Moisture Equip. Corp. (Santa Barbara, CA), p/n 652X04-BIM3.

Acrylic tubing: 5/8" OD, 1/2" ID, local purchase.

Copper elbows: 90° plumbing, 5/8" X 1/2", local hardware purchase.

Normal cements:

1) JB Weld 2-part epoxy aB Weld Co., Sulphur Springs, TX), local hardware purchase.

2) Clear PVC pipe cleaner and cement, local hardware purchase. Note: Not all cements are compatible with all PVC plastics. May substitute methyl-ethyl ketone (MEK) for pipe cleaner.

3) Clear 2-part ceramic epoxy, Soil Moisture Equipment Corp. (Santa Barbara, CA), available in 8 oz. through 1 gallon sizes.

Appendix C-6. Construction of Narrow-Profile Ceramic Devices. (Continued)

Methods

1) Cut the PVC pipe to length. Cut with a PVC pipe cutting tool or with a hacksaw while the pipe is clamped securely in a vice. Eighty-three cm is the standard length. For installation directly below the walkways in the trench add an additional 5 cm to length, to 88 cm.

2) Ream about 1.5 cm into one end of the PVC to accept a ceramic cup. The PVC pipe and the 1/2" variable speed drill used to make the hole are mounted securely in a special jig in the laboratory to properly align the drill bit relative to the PVC pipe. It is *extremely important* that the hole is drilled centered and straight into the PVC. If not, the finished device is considerably weakened and the ceramic device becomes more likely to break during installation.

Use a *sharp* 27/64" cobalt-alloy drill bit (1.072 cm) available locally from a hardware store. Special drill bits for acrylic are less effective and difficult to find in the correct diameter. Expect the drill bit to dull quickly.

Because of the heat produced during drilling, the bit will wallow a larger hole than expected. To control warp and glazing in the plastic it is important to cool the PVC and remove cuttings during the drilling. This can be accomplished by directing a stream of water from a wash bottle at the area being drilled while frequently removing the cuttings from the hole. If pressurized air is available a nozzle can be fashioned to force air through the PVC from the end opposite that being drilled. This will cool the plastic and help force cuttings out of the hole.

Proceed slowly. The drill motor should be set to about 500 rpm (fast speed). Drilling should take about 30 seconds for the 1.5 cm-deep hole.

3) Lathe the other end of the PVC to accept the 1/2" end of the copper elbow. Use a sharp bit to remove about 0.010" to 0.020" from the outside diameter of the pipe, about 2 cm into the length of the PVC. The amount of material removed will vary since the ID of copper elbows varies from lot to lot. Start by taking a small amount of material first. Keep an elbow handy to check the fit on the PVC. It should fit snugly.

4) Cut acrylic tubing to 6 cm lengths. This can be done with an acrylic cutting tool or, carefully, with a hacksaw (and a *sharp* blade). Debur the cut surfaces with a de-burring tool or knife. Bevel the inside edge of one end to about 30° with a routing bit. A beveled surface will accept a rubber septum stopper more easily. Chuck the acrylic carefully since this material is easily fractured.

5) Cement the un-beveled end of the acrylic tubing into the copper elbow. Mix the JB Weld epoxy components with equal parts by weight. Apply a thin layer of epoxy to both surfaces to be bonded and insert the acrylic into the elbow. A small bead of cement should form around the outside rim of the joint. Too little cement will not seal the joint. Note: Other epoxy cements, e.g. that sold by Soil Moisture Equipment Corp., have an unfavorable oxidation reaction with copper over time which renders the bond useless. Most other epoxies are somewhat water soluble and will soften with time.

6) Seal the pores of the open end of the ceramic cup with epoxy and heat treat. By pre-sealing the pores of the cup it can be cemented to the PVC pipe without forming seal-breaking air pockets. Note: Before handling cups, wrap all but the last 3 cm of surface in tissue and tape in place. This will protect the surface of the cup from absorbing oils from the skin. Use Soil Moisture Equipment Corp. 2-part

Appendix C-6. Construction of Narrow-Profile Ceramic Devices. (Continued)

epoxy cement mixed as equal parts by volume. With a foam brush apply an even thin coat of cement to the last 1 cm of outside cup surface. Allow the cement to be absorbed by the pores of the cup for about 15 minutes and reapply if necessary. Allow to dry for 24 hours. Heat the cup at 110F to 150F for about 4 hours.

7) Cement the copper elbow to the PVC. Use equal parts by weight of the two JB Weld components. Apply a uniform coat of cement to the inside surface of the 5/8" end of the elbow and to the outside lathed surface of the PVC pipe. A good joint will form a bead of cement about the rim of the elbow.

8) Cement the ceramic cup into the PVC. *Quickly* dip the open end of the cup and the reamed end of the PVC pipe into the PVC pipe cleaner (or MEK). Apply a layer of PVC cement to the outside surface of the end of the cup and to the inside surface of the PVC. Insert the cup into the PVC with a twisting motion. Ensure that the cup is firmly seated straight into the pipe and that no air bubble are visible through the PVC. If any bubbles can be seen it will be necessary to re-seat the cup with more cement. Care must be taken not to use too much cement.

Excess cement and a sloughed layer of PVC may block the opening of the cup when the cup is pushed into the pipe. Ensure that the cup extends straight out from the PVC. Allow the cup to dry for at least 48 hours.

9) Test the ceramic device for leaks to about 450 cm water head. Though the high-flow cups are rated for a bubble pressure of 1 bar, regions within individual cups may be less restrictive. Most cups will hold at least 450 cm pressure. Remove the protective tissue from the cup and immerse the entire cup-end of the device into water. Allow the pores to fill with water for about 1/2 to 1 minute. Seal the acrylic end of the device with an appropriate (13 X 20) rubber septum stopper. With a regulated supply of pressurized air apply 32-36 cm Hg pressure into the sealed system. This can be accomplished with a 26 gauge needle, connected to the pressure source and pushed through the septum. Hold the cup end of the device under water and carefully watch for the formation of air bubbles about the cemented joint. Slowly rotate the cup to observe all cemented surfaces. It may take 30 seconds or more for slow leaks to appear. In like fashion, place the copper elbow end of the device under water and observe for bubbles.

Appendix C-7. NRC Trench Wall Ceramic Device Installation.

Introduction

Installation methods for trench wall devices have evolved through several improvements. A 1/2" standard drill and drill bit was used to complete the hole drilling. Since the OD of the PVC tubing is 0.540" it was necessary to use a great deal of force to push the ceramic device to its' final position. It was often necessary to jet some water into the drilled hole and ream this "mudhole" many times with a masonry bit to soften the trench wall soil for insertion of the device. In hard soil 2 persons working all day could expect to complete the installation of 5 to 7 devices in a day.

The present method of installation is a great improvement. A hammer drill facilitates much faster and easier drilling. A 1/2" bit is used to drill a pilot hole in the soil. This hole is finished with a 9/16" bit to enlarge all but the final 8 cm of hole length for easier insertion of the device. A mud slurry using finely sieved native materials is used to create a more reliable soil/ceramic contact. With these improvements two persons can now usually install 15 to 20 devices in a day, regardless of soil hardness.

Materials

Makita 3/4", 6A hammer drill, 2 speed, reversible, local purchase

Black and Decker 1/2" variable speed drill, reversible, heavy duty

Bosch 1/2" carbide masonry bit, 18" medium speed parabolic flutes, machined to chuck into 1/2" straight shank drill, silver soldered to 1/2" steel bar to a total length of 105 cm (campus PSL machine shop for adding extension to bit), local purchase

9/16" carbide masonry bit, 16" medium speed standard flutes, 18" length overall, silver soldered to 1/2" steel bar to a total length of 105 cm (campus PSL), Hayden Twist Drill & Tool, Warren, MI, p/n 161-18

9/16" carbide masonry bit, 20" high speed shallow flutes, extended to 105 cm by campus PSL, local purchase

9/16" wood bit, 8" overall length, medium speed aggressive flutes, local purchase

Protractor for setting and maintaining 10° hole angle during drilling, local purchase

Shop-Vac with 1/2" OD and 3/8" OD acrylic tubing "straws" for vacuuming cuttings from drilled holes, local purchase

Native soil materials, air dried, chipped (NMSU Soil and Water Testing Lab) and sieved through 80 mesh screen. Note: For soils at the trench an 80 mesh sieve is the maximum, any larger opening size will make mud slurry difficult to push through a 3/8" slurry "straw"

Distilled-deionized water for making mud slurry

3/8" OD acrylic tubing x 1 m long, connected to approx. 20 cm of Tygon tubing for making a mud slurry "straw", local purchase

3/8" x 1/2" ax-handle wedges, for securing devices to wooden wall of trench, local purchase

Appendix C-7. NRC Trench Wall Ceramic Device Installation. (Continued)

Procedure

Drilling a hole through the wood and the pilot hole through soil requires two persons. One person operates the drill while the second measures the drill bit angle and monitors that the bit is maintained at that angle throughout the drilling process. When the pilot hole is completed ($\frac{1}{2}$ " bit to the bottom of the hole one person can finish the drilling and installation of ceramic devices.

First drill through the wood structure with a 9/16" wood drill. The hammer drill is not required for this. Use a protractor to set and monitor a 10° angle several times during the drilling. Place the protractor directly on the flutes of the drill and take measurements while the drill is stopped.

The pilot hole is drilled with a $\frac{1}{2}$ " masonry bit to the bottom of the hole. It is very important that the bit angle is monitored closely, possibly 5 or 6 pauses to measure with the protractor, for at least the first one-half of the length of this hole. As the drilled hole becomes deeper corrections of the drilling angle become more difficult. Use the hammer drill set to high speed with hammering action turned on. It is common for the drill bit to become lodged in the hole as cuttings collect behind the flutes of the bit. At these times it is important not to load the drill motor when the bit will not turn. Reverse the direction of the bit to dislodge it and begin again. When the bit begins to labor it is best to ream the hole to carry cuttings out. Sometimes it is necessary to switch drill speed to "low" to increase torque. When the pilot hole is drilled to length use the 3/8" vacuum straw and Shop-Vac to remove cuttings from the hole. For an 86 cm length hole the straw should be inserted no further than 78 cm to leave native cuttings in the

portion of the hole where the ceramic cup will seat.

Moisture Equipment Corp. 2-part epoxy cement mixed as equal parts by volume. With a foam brush apply an even thin coat of cement to the last 1 cm of outside cup surface. Allow the cement to be absorbed by the pores of the cup for about 15 minutes and reapply if necessary. Allow to dry for 24 hours. Heat the cup at 110F to 150F for about 4 hours.

The pilot hole is finished with the deep/medium speed fluted 9/16" masonry bit. For an 86 cm pilot hole this bit is not used any deeper than 78 cm to avoid over-reaming the hole for the diameter of the ceramic. The larger diameter hole which is made with this bit allows easier installation of ceramic devices. The hammer drill is used in the same manner as with the $\frac{1}{2}$ " bit. It is not necessary to use the protractor. When the 9/16" hole is completed the $\frac{1}{2}$ " acrylic straw and Shop-Vac are used to remove cuttings from the hole. Again, do not vacuum to the end of the hole.

Usually it is necessary to alternate the $\frac{1}{2}$ " bit (to the end of the hole, 86 cm) with the 9/16" bit (to 78 cm deep) several times before the hole is finished. The standard drill is usually powerful enough to use at this point. Between each bit change it is helpful to vacuum the cuttings. The hole is finished when the ceramic device can easily be inserted into position without undue torque (< approx. 10 ft. lbs.).

A mud slurry is made from 80 mesh-sieved native soil materials taken from about the same depth in the trench at which the ceramic cup is to be placed. In a wide mouth plastic bottle mix approx. 3 parts water with 5 parts dry sieved soil (by weight), cap and shake the bottle vigorously. The slurry should have viscosity

Appendix C-7. NRC Trench Wall Ceramic Device Installation. (Continued)

approximating honey. Use the acrylic slurry straw to draw 15 ml of slurry (mark position on tubing for 15 ml) into the straw. Crimp the Tygon tubing and push the straw to the end of the hole. Blow through the Tygon and slowly withdraw the straw approx. 5 cm to place the mud in the last 5 cm of the hole. Promptly insert the ceramic device into the hole and seat the cup in the mud.

When the cup is seated in the mud is important that the mud/cup interface is not disturbed.

Since the PVC tubing is about $\frac{1}{2}$ " diameter and is placed within a $\frac{9}{16}$ " diameter hole the device should be protected from accidental disturbance. Use an ax handle wedge to shim the PVC tubing against the wood. Insert the wedge between the PVC and wood under the tubing and gently hammer the wedge into place. When finished it should not be possible to twist the device by hand. The wedge should not be hammered flush with the wood but instead protrude from the wood so that it may be easily pulled with pliers in case the device needs to be removed.

Appendix C-7. NRC Trench Wall Ceramic Device Installation. (Continued)

Appendix C-8. Soils and Geomorphology at the Las Cruces Trench Site.

Physiography

The trench site is in the Basin and Range Province of southern New Mexico which is characterized by broad desert basins between discontinuous mountain ranges. The trench site is at an elevation of about 1357 m (4450 ft.) on the eastern Piedmont slope of Summerford Mountain, the most northern peak of the Dona Ana Mountains. The general boundary between the arid (less than 25 cm rain per year) and semiarid zones for this area is considered to be at an elevation of 1524 m (5000 ft.) (Gile et al, 1981).

Although the trench site is presently in an arid climatic regime, fossil data and evidence of perennial lakes in nearby basins suggest times of more effective moisture in southern New Mexico during the Pleistocene (Martin and Mehringer, 1965; Hawley et al, 1976; Van Devender, 1977). Times of more effective moisture (i.e., more precipitation and lower evaporation) probably correspond to glacial advances in the Northern Hemisphere. For example, Reeves (1973) described a cool-moist interval (the Tahoka pluvial) on the southern High Plains that dates from 15,000 to 22,500 years B.P., which is roughly the time of the last full glacial advance, the Wisconsin. Climatic conditions in this region prior to the last full glacial are poorly documented (Gile et al, 1981).

Geology

The Basin and Range Province of southern New Mexico is dominated by the Rio Grande Rift zone which is one of the four best developed intracontinental rift zones in the world (Kues et al, 1986). The rift zone is characterized by extensional tectonics, block faulted mountain ranges, crustal thinning, shallow seismic activity, volcanism, and basins filled with thick sediments eroded from adjacent mountains.

The trench site has been emplaced within soils and sediments derived mainly from Summerford Mountain which is a laccolith (i.e., an igneous intrusion that has displaced adjacent sedimentary rocks). The laccolith is monzonitic to syenitic in composition and solidified 35 m.y. BP. (Hawley et al, 1975). The dominant minerals contained in the laccolith are microcline, plagioclase, orthoclase, quartz, augite, biotite, hornblende, sphene, apatite, magnetite, and zircon (Hurlbut and Klein, 1977).

Soils and Geomorphology

The trench site extends downward through the Isaacks' Ranch and Jornada II deposits into what can probably be classified as the Camp Rice Formation, Jornada I surface (L.H. Gile, personal communication). Their approximate ages are 8,000-15,000 years, 25,000-150,000 years, and 250,000-400,000 years, respectively.

Appendix C-8. Soils and Geomorphology at the Las Cruces Trench Site. (Continued)

The Jornada I surface is exposed approximately 3.1 m below the top of the trench. Soils of the Jornada I surface reflect a very long time of landscape stability (Gile et al, 1981). These soils are generally underlain by a sequence of buried soils within the Camp Rice Formation. The trench site contains at least two buried soils beneath the Jornada I surface which can be identified by separate calcic horizons. A well defined argillic horizon marks the top of the Jornada I surface; the A horizon appears to have been truncated when overlying material was deposited.

The Jornada II surface is exposed approximately 1.4 m below the top of the trench. The Jornada II deposit is nearly continuous within the trench except where it has been truncated on the north and south walls by an arroyo associated with the Isaacks' Ranch deposit. The Jornada II surface can be identified by its stage III (Gile et al, 1966) calcic horizon. Apparently, the A and B horizons associated with the Jornada II soil were truncated by the deposition of Isaacks' Ranch.

Isaacks' Ranch was deposited after a period of landscape stability and soil formation represented by the Jornada II surface (Gile et al, 1981). The deposition of Isaacks' Ranch probably accompanied a climatic change, as did the deposition of Jornada II, Jornada I, and the buried soils associated with the Camp Rice Formation. During times of more effective moisture plants cover the landscape and prevent erosion. Soil formation is more effective during these wetter conditions because more water is available for leaching. When the climate again became arid, plant cover must have decreased while erosion increased, especially during summer thunderstorms.

Each of the deposits exhibit a fining-upward

sequence (i.e., coarser particles at depth grading upward to finer particles). The deposits are lithologically similar (Gile et al, 1981) except that Isaacks' Ranch contains less carbonate (stage II), reflecting its younger age, than the underlying deposits which contain stage III carbonate accumulation.

Geochemistry

Gile et al (1981) reported that the general soil mineral composition of the Desert Project is dominated by quartz, feldspars, and biotite in the sand and silt fraction. The clay mineralogy of soils in the Desert Project as reported by Gile et al. (1981) contain kaolinite, mica and small amounts of chlorite and montmorillonite.

Monger et al (1987) studied the mineralogy of soils in the southern portion of the Jornada Basin derived from similar parent material as the soils at the trench site and found that quartz, K-feldspar, plagioclase, and authigenic calcite dominated the bulk (< 2 mm) mineralogy with minor amounts of biotites and opaques. They found the clay mineralogy was dominated by quartz, kaolinite, illite, and authigenic calcite with minor amounts of feldspars, chlorite, and smectites.

Based on the above discussion of soil mineralogy the chemical species most likely to be found in the soil solution are Ca^{++} , K^{+} , Na^{+} , Mg^{++} , $\text{Si}(\text{OH}_4)$, Fe^{+++} , Al^{+++} , H^{+} , OH^{-} , and CO_3^{--} . Because of the highly reactive nature of Fe^{+++} and Al^{+++} , these species should quickly precipitate as oxides of, in the case of Al^{+++} , be incorporated into clay mineral structures.

Appendix C-8. Soils and Geomorphology at the Las Cruces Trench Site. (Continued)

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Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ila	Ilb	Event	Date	I	Ila	Ilb	Event
5/11/87	-16				6/30/87	34			
5/12/87	-15				7/1/87	35			
5/13/87	-14				7/2/87	36			
5/14/87	-13				7/3/87	37			
5/15/87	-12				7/4/87	38			
5/16/87	-11				7/5/87	39			
5/17/87	-10				7/6/87	40			
5/18/87	-9				7/7/87	41			
5/19/87	-8				7/8/87	42			
5/20/87	-7				7/9/87	43			
5/21/87	-6				7/10/87	44			
5/22/87	-5				7/11/87	45			
5/23/87	-4				7/12/87	46			
5/24/87	-3				7/13/87	47			
5/25/87	-2				7/14/87	48			
5/26/87	-1				7/15/87	49			
5/27/87	0			begin irrigation I	7/16/87	50			
5/28/87	1				7/17/87	51			
5/29/87	2				7/18/87	52			
5/30/87	3				7/19/87	53			
5/31/87	4				7/20/87	54			
6/1/87	5				7/21/87	55			
6/2/87	6				7/22/87	56			
6/3/87	7				7/23/87	57			
6/4/87	8				7/24/87	58			
6/5/87	9				7/25/87	59			
6/6/87	10			end tracer pulse I	7/26/87	60			
6/7/87	11				7/27/87	61			
6/8/87	12				7/28/87	62			
6/9/87	13				7/29/87	63			
6/10/87	14				7/30/87	64			
6/11/87	15				7/31/87	65			
6/12/87	16				8/1/87	66			
6/13/87	17				8/2/87	67			
6/14/87	18				8/3/87	68			
6/15/87	19				8/4/87	69			
6/16/87	20				8/5/87	70			
6/17/87	21				8/6/87	71			
6/18/87	22				8/7/87	72			
6/19/87	23				8/8/87	73			
6/20/87	24				8/9/87	74			
6/21/87	25				8/10/87	75			
6/22/87	26				8/11/87	76			
6/23/87	27				8/12/87	77			
6/24/87	28				8/13/87	78			
6/25/87	29				8/14/87	79			
6/26/87	30				8/15/87	80			
6/27/87	31				8/16/87	81			
6/28/87	32				8/17/87	82			
6/29/87	33				8/18/87	83			

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	IIa	IIb	Event	Date	I	IIa	IIb	Event
8/19/87	84				10/8/87	134			
8/20/87	85				10/9/87	135			
8/21/87	86			trench wall collapse	10/10/87	136			
8/22/87	87			(end I irrigation)	10/11/87	137			
8/23/87	88				10/12/87	138			
8/24/87	89				10/13/87	139			
8/25/87	90				10/14/87	140			
8/26/87	91				10/15/87	141			
8/27/87	92				10/16/87	142			
8/28/87	93				10/17/87	143			
8/29/87	94				10/18/87	144			
8/30/87	95				10/19/87	145			
8/31/87	96				10/20/87	146			
9/1/87	97				10/21/87	147			
9/2/87	98				10/22/87	148			
9/3/87	99				10/23/87	149			
9/4/87	100				10/24/87	150			
9/5/87	101				10/25/87	151			
9/6/87	102				10/26/87	152			
9/7/87	103				10/27/87	153			
9/8/87	104				10/28/87	154			
9/9/87	105				10/29/87	155			
9/10/87	106				10/30/87	156			
9/11/87	107				10/31/87	157			
9/12/87	108				11/1/87	158			
9/13/87	109				11/2/87	159			
9/14/87	110				11/3/87	160			
9/15/87	111				11/4/87	161			
9/16/87	112				11/5/87	162			
9/17/87	113				11/6/87	163			
9/18/87	114				11/7/87	164			
9/19/87	115				11/8/87	165			
9/20/87	116				11/9/87	166			
9/21/87	117				11/10/87	167			
9/22/87	118				11/11/87	168			
9/23/87	119				11/12/87	169			
9/24/87	120				11/13/87	170			
9/25/87	121				11/14/87	171			
9/26/87	122				11/15/87	172			
9/27/87	123				11/16/87	173			
9/28/87	124				11/17/87	174			
9/29/87	125				11/18/87	175			
9/30/87	126				11/19/87	176			
10/1/87	127				11/20/87	177			
10/2/87	128				11/21/87	178			
10/3/87	129				11/22/87	179			
10/4/87	130				11/23/87	180			
10/5/87	131				11/24/87	181			
10/6/87	132				11/25/87	182			
10/7/87	133				11/26/87	183			

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics Indicates solution sample collection days</i>									
bold Indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	IIa	IIb	Event	Date	I	IIa	IIb	Event
11/27/87	184				1/16/88	234			
11/28/87	185				1/17/88	235			
11/29/87	186				1/18/88	236			
11/30/87	187				1/19/88	237			
12/1/87	188				1/20/88	238			
12/2/87	189				1/21/88	239			
12/3/87	190				1/22/88	240			
12/4/87	191				1/23/88	241			
12/5/87	192				1/24/88	242			
12/6/87	193				1/25/88	243			
12/7/87	194				1/26/88	244			
12/8/87	195				1/27/88	245			
12/9/87	196				1/28/88	246			
12/10/87	197				1/29/88	247			
12/11/87	198				1/30/88	248			
12/12/87	199				1/31/88	249			
12/13/87	200				2/1/88	250			
12/14/87	201				2/2/88	251			
12/15/87	202				2/3/88	252			
12/16/87	203				2/4/88	253			
12/17/87	204				2/5/88	254			
12/18/87	205				2/6/88	255			
12/19/87	206				2/7/88	256			
12/20/87	207				2/8/88	257			
12/21/87	208				2/9/88	258			
12/22/87	209				2/10/88	259			
12/23/87	210				2/11/88	260			
12/24/87	211				2/12/88	261			
12/25/87	212				2/13/88	262			
12/26/87	213				2/14/88	263			
12/27/87	214				2/15/88	264			
12/28/87	215				2/16/88	265			
12/29/87	216				2/17/88	266			
12/30/87	217				2/18/88	267			
12/31/87	218				2/19/88	268			
1/1/88	219				2/20/88	269			
1/2/88	220				2/21/88	270			
1/3/88	221				2/22/88	271			
1/4/88	222				2/23/88	272			
1/5/88	223				2/24/88	273			
1/6/88	224				2/25/88	274			
1/7/88	225				2/26/88	275			
1/8/88	226				2/27/88	276			
1/9/88	227				2/28/88	277			
1/10/88	228				2/29/88	278			
1/11/88	229				3/1/88	279			
1/12/88	230				3/2/88	280			
1/13/88	231				3/3/88	281			
1/14/88	232				3/4/88	282			
1/15/88	233				3/5/88	283			

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	IIa	IIb	Event	Date	I	IIa	IIb	Event
3/6/88	284				4/25/88	334			
3/7/88	285				4/26/88	335			
3/8/88	286				4/27/88	336			
3/9/88	287				4/28/88	337			
3/10/88	288				4/29/88	338			
3/11/88	289				4/30/88	339			
3/12/88	290				5/1/88	340			
3/13/88	291				5/2/88	341			
3/14/88	292				5/3/88	342			
3/15/88	293				5/4/88	343			
3/16/88	294				5/5/88	344			
3/17/88	295				5/6/88	345			
3/18/88	296				5/7/88	346			
3/19/88	297				5/8/88	347			
3/20/88	298				5/9/88	348			
3/21/88	299				5/10/88	349			
3/22/88	300				5/11/88	350			
3/23/88	301				5/12/88	351			
3/24/88	302				5/13/88	352			
3/25/88	303				5/14/88	353			
3/26/88	304				5/15/88	354			
3/27/88	305				5/16/88	355			
3/28/88	306				5/17/88	356	-82		
3/29/88	307				5/18/88	357	-81		
3/30/88	308				5/19/88	358	-80		
3/31/88	309				5/20/88	359	-79		
4/1/88	310				5/21/88	360	-78		
4/2/88	311				5/22/88	361	-77		
4/3/88	312				5/23/88	362	-76		
4/4/88	313				5/24/88	363	-75		
4/5/88	314				5/25/88	364	-74		
4/6/88	315				5/26/88	365	-73		
4/7/88	316				5/27/88	366	-72		
4/8/88	317				5/28/88	367	-71		
4/9/88	318				5/29/88	368	-70		
4/10/88	319				5/30/88	369	-69		
4/11/88	320				5/31/88	370	-68		
4/12/88	321				6/1/88	371	-67		
4/13/88	322				6/2/88	372	-66		
4/14/88	323				6/3/88	373	-65		
4/15/88	324				6/4/88	374	-64		
4/16/88	325				6/5/88	375	-63		
4/17/88	326				6/6/88	376	-62		
4/18/88	327				6/7/88	377	-61		
4/19/88	328				6/8/88	378	-60		
4/20/88	329				6/9/88	379	-59		
4/21/88	330				6/10/88	380	-58		
4/22/88	331				6/11/88	381	-57		
4/23/88	332				6/12/88	382	-56		
4/24/88	333				6/13/88	383	-55		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ila	Ilb	Event	Date	I	Ila	Ilb	Event
6/14/88	384	-54			8/3/88	434	-4		
6/15/88	385	-53			8/4/88	435	-3		
6/16/88	386	-52			8/5/88	436	-2		
6/17/88	387	-51			8/6/88	437	-1		
6/18/88	388	-50			8/7/88	438	0		
6/19/88	389	-49			8/8/88	439	1		begin Ila irrigation
6/20/88	390	-48			8/9/88	440	2		
6/21/88	391	-47			8/10/88	441	3		
6/22/88	392	-46			8/11/88	442	4		
6/23/88	393	-45			8/12/88	443	5		
6/24/88	394	-44			8/13/88	444	6		
6/25/88	395	-43			8/14/88	445	7		
6/26/88	396	-42			8/15/88	446	8		
6/27/88	397	-41			8/16/88	447	9		
6/28/88	398	-40			8/17/88	448	10		
6/29/88	399	-39			8/18/88	449	11		end Ila tracer pulse
6/30/88	400	-38			8/19/88	450	12		
7/1/88	401	-37			8/20/88	451	13		
7/2/88	402	-36			8/21/88	452	14		
7/3/88	403	-35			8/22/88	453	15		
7/4/88	404	-34			8/23/88	454	16		
7/5/88	405	-33			8/24/88	455	17		
7/6/88	406	-32			8/25/88	456	18		
7/7/88	407	-31			8/26/88	457	19		
7/8/88	408	-30			8/27/88	458	20		
7/9/88	409	-29			8/28/88	459	21		
7/10/88	410	-28			8/29/88	460	22		
7/11/88	411	-27			8/30/88	461	23		
7/12/88	412	-26			8/31/88	462	24		
7/13/88	413	-25			9/1/88	463	25		
7/14/88	414	-24			9/2/88	464	26		
7/15/88	415	-23			9/3/88	465	27		
7/16/88	416	-22			9/4/88	466	28		
7/17/88	417	-21			9/5/88	467	29		
7/18/88	418	-20			9/6/88	468	30		
7/19/88	419	-19			9/7/88	469	31		
7/20/88	420	-18			9/8/88	470	32		
7/21/88	421	-17			9/9/88	471	33		
7/22/88	422	-16			9/10/88	472	34		
7/23/88	423	-15			9/11/88	473	35		
7/24/88	424	-14			9/12/88	474	36		
7/25/88	425	-13			9/13/88	475	37		
7/26/88	426	-12			9/14/88	476	38		
7/27/88	427	-11			9/15/88	477	39		
7/28/88	428	-10			9/16/88	478	40		
7/29/88	429	-9			9/17/88	479	41		
7/30/88	430	-8			9/18/88	480	42		
7/31/88	431	-7			9/19/88	481	43		
8/1/88	432	-6			9/20/88	482	44		
8/2/88	433	-5			9/21/88	483	45		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ila	Ilb	Event	Date	I	Ila	Ilb	Event
9/22/88	484	46			11/11/88	534	96		
9/23/88	485	47			11/12/88	535	97		
9/24/88	486	48			11/13/88	536	98		
9/25/88	487	49			11/14/88	537	99		
9/26/88	488	50			11/15/88	538	100		
9/27/88	489	51			11/16/88	539	101		
9/28/88	490	52			11/17/88	540	102		
9/29/88	491	53			11/18/88	541	103		
9/30/88	492	54			11/19/88	542	104		
10/1/88	493	55			11/20/88	543	105		
10/2/88	494	56			11/21/88	544	106		
10/3/88	495	57			11/22/88	545	107		
10/4/88	496	58			11/23/88	546	108		
10/5/88	497	59			11/24/88	547	109		
10/6/88	498	60			11/25/88	548	110		
10/7/88	499	61			11/26/88	549	111		
10/8/88	500	62			11/27/88	550	112		
10/9/88	501	63			11/28/88	551	113		
10/10/88	502	64			11/29/88	552	114		
10/11/88	503	65			11/30/88	553	115		
10/12/88	504	66			12/1/88	554	116		
10/13/88	505	67			12/2/88	555	117		
10/14/88	506	68			12/3/88	556	118		
10/15/88	507	69			12/4/88	557	119		
10/16/88	508	70			12/5/88	558	120		
10/17/88	509	71			12/6/88	559	121		
10/18/88	510	72			12/7/88	560	122		
10/19/88	511	73			12/8/88	561	123		
10/20/88	512	74			12/9/88	562	124		
10/21/88	513	75		end Ila irrigation	12/10/88	563	125		
10/22/88	514	76			12/11/88	564	126		
10/23/88	515	77			12/12/88	565	127		
10/24/88	516	78		cf probe	12/13/88	566	128		
10/25/88	517	79			12/14/88	567	129		
10/26/88	518	80			12/15/88	568	130		
10/27/88	519	81			12/16/88	569	131		
10/28/88	520	82			12/17/88	570	132		
10/29/88	521	83			12/18/88	571	133		
10/30/88	522	84			12/19/88	572	134		
10/31/88	523	85			12/20/88	573	135		
11/1/88	524	86			12/21/88	574	136		
11/2/88	525	87			12/22/88	575	137		
11/3/88	526	88			12/23/88	576	138		
11/4/88	527	89			12/24/88	577	139		
11/5/88	528	90			12/25/88	578	140		
11/6/88	529	91			12/26/88	579	141		
11/7/88	530	92			12/27/88	580	142		
11/8/88	531	93			12/28/88	581	143		
11/9/88	532	94			12/29/88	582	144		
11/10/88	533	95			12/30/88	583	145		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days				Experiment days					
Date	I	Ila	Ilb	Event	Date	I	Ila	Ilb	Event
12/31/88	584	146			2/19/89	634	196		
1/1/89	585	147			2/20/89	635	197		
1/2/89	586	148			2/21/89	636	198		
1/3/89	587	149			2/22/89	637	199		
1/4/89	588	150			2/23/89	638	200		
1/5/89	589	151			2/24/89	639	201		
1/6/89	590	152			2/25/89	640	202		
1/7/89	591	153			2/26/89	641	203		
1/8/89	592	154			2/27/89	642	204		
1/9/89	593	155			2/28/89	643	205		
1/10/89	594	156			3/1/89	644	206		
1/11/89	595	157			3/2/89	645	207		
1/12/89	596	158			3/3/89	646	208		
1/13/89	597	159			3/4/89	647	209		
1/14/89	598	160			3/5/89	648	210		
1/15/89	599	161			3/6/89	649	211		
1/16/89	600	162			3/7/89	650	212		
1/17/89	601	163			3/8/89	651	213		
1/18/89	602	164			3/9/89	652	214		
1/19/89	603	165			3/10/89	653	215		
1/20/89	604	166			3/11/89	654	216		
1/21/89	605	167			3/12/89	655	217		
1/22/89	606	168			3/13/89	656	218		
1/23/89	607	169			3/14/89	657	219		
1/24/89	608	170			3/15/89	658	220		
1/25/89	609	171			3/16/89	659	221		
1/26/89	610	172			3/17/89	660	222		
1/27/89	611	173			3/18/89	661	223		
1/28/89	612	174			3/19/89	662	224		
1/29/89	613	175			3/20/89	663	225		
1/30/89	614	176			3/21/89	664	226		
1/31/89	615	177			3/22/89	665	227		
2/1/89	616	178			3/23/89	666	228		
2/2/89	617	179			3/24/89	667	229		
2/3/89	618	180			3/25/89	668	230		
2/4/89	619	181			3/26/89	669	231		
2/5/89	620	182			3/27/89	670	232		
2/6/89	621	183			3/28/89	671	233		
2/7/89	622	184			3/29/89	672	234		
2/8/89	623	185			3/30/89	673	235		
2/9/89	624	186			3/31/89	674	236		
2/10/89	625	187			4/1/89	675	237		
2/11/89	626	188			4/2/89	676	238		
2/12/89	627	189			4/3/89	677	239		
2/13/89	628	190			4/4/89	678	240		
2/14/89	629	191			4/5/89	679	241		
2/15/89	630	192			4/6/89	680	242		Exp I deep core #1
2/16/89	631	193			4/7/89	681	243		
2/17/89	632	194			4/8/89	682	244		
2/18/89	633	195			4/9/89	683	245		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ia	Iib	Event	Date	I	Ia	Iib	Event
4/10/89	684	246		6 new access	5/30/89	734	296		
4/11/89	685	247		tubes, to #43	5/31/89	735	297		
4/12/89	686	248			6/1/89	736	298		
4/13/89	687	249			6/2/89	737	299		
4/14/89	688	250			6/3/89	738	300		
4/15/89	689	251			6/4/89	739	301		
4/16/89	690	252			6/5/89	740	302		
4/17/89	691	253			6/6/89	741	303		
4/18/89	692	254			6/7/89	742	304		
4/19/89	693	255			6/8/89	743	305		
4/20/89	694	256			6/9/89	744	306		
4/21/89	695	257			6/10/89	745	307		
4/22/89	696	258			6/11/89	746	308		
4/23/89	697	259			6/12/89	747	309		
4/24/89	698	260			6/13/89	748	310		
4/25/89	699	261			6/14/89	749	311		
4/26/89	700	262			6/15/89	750	312		
4/27/89	701	263			6/16/89	751	313		
4/28/89	702	264			6/17/89	752	314		
4/29/89	703	265			6/18/89	753	315		
4/30/89	704	266			6/19/89	754	316		
5/1/89	705	267			6/20/89	755	317		
5/2/89	706	268			6/21/89	756	318		
5/3/89	707	269			6/22/89	757	319		
5/4/89	708	270			6/23/89	758	320		
5/5/89	709	271			6/24/89	759	321		
5/6/89	710	272			6/25/89	760	322		
5/7/89	711	273			6/26/89	761	323		
5/8/89	712	274			6/27/89	762	324		
5/9/89	713	275			6/28/89	763	325		
5/10/89	714	276			6/29/89	764	326		
5/11/89	715	277			6/30/89	765	327		
5/12/89	716	278			7/1/89	766	328		
5/13/89	717	279			7/2/89	767	329		
5/14/89	718	280			7/3/89	768	330		
5/15/89	719	281			7/4/89	769	331		
5/16/89	720	282			7/5/89	770	332		
5/17/89	721	283			7/6/89	771	333		
5/18/89	722	284			7/7/89	772	334		
5/19/89	723	285			7/8/89	773	335		
5/20/89	724	286			7/9/89	774	336		
5/21/89	725	287			7/10/89	775	337		
5/22/89	726	288			7/11/89	776	338		
5/23/89	727	289			7/12/89	777	339		
5/24/89	728	290			7/13/89	778	340		
5/25/89	729	291			7/14/89	779	341		
5/26/89	730	292			7/15/89	780	342		
5/27/89	731	293			7/16/89	781	343		
5/28/89	732	294			7/17/89	782	344		
5/29/89	733	295			7/18/89	783	345		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ila	Ilb	Event	Date	I	Ila	Ilb	Event
7/19/89	784	346			9/7/89	834	396		
7/20/89	785	347			9/8/89	835	397		
7/21/89	786	348			9/9/89	836	398		
7/22/89	787	349			9/10/89	837	399		
7/23/89	788	350			9/11/89	838	400		
7/24/89	789	351			9/12/89	839	401		
7/25/89	790	352			9/13/89	840	402		
7/26/89	791	353			9/14/89	841	403		
7/27/89	792	354			9/15/89	842	404		
7/28/89	793	355			9/16/89	843	405		
7/29/89	794	356			9/17/89	844	406		
7/30/89	795	357			9/18/89	845	407		
7/31/89	796	358			9/19/89	846	408		
8/1/89	797	359			9/20/89	847	409		
8/2/89	798	360			9/21/89	848	410		
8/3/89	799	361			9/22/89	849	411		
8/4/89	800	362			9/23/89	850	412		
8/5/89	801	363			9/24/89	851	413		
8/6/89	802	364			9/25/89	852	414		
8/7/89	803	365			9/26/89	853	415		
8/8/89	804	366			9/27/89	854	416		
8/9/89	805	367			9/28/89	855	417		
8/10/89	806	368			9/29/89	856	418		
8/11/89	807	369			9/30/89	857	419		
8/12/89	808	370			10/1/89	858	420		
8/13/89	809	371			10/2/89	859	421		
8/14/89	810	372			10/3/89	860	422		
8/15/89	811	373			10/4/89	861	423		
8/16/89	812	374			10/5/89	862	424		
8/17/89	813	375			10/6/89	863	425		
8/18/89	814	376			10/7/89	864	426		
8/19/89	815	377			10/8/89	865	427		
8/20/89	816	378			10/9/89	866	428		
8/21/89	817	379			10/10/89	867	429		
8/22/89	818	380			10/11/89	868	430		
8/23/89	819	381			10/12/89	869	431		
8/24/89	820	382			10/13/89	870	432		
8/25/89	821	383			10/14/89	871	433		
8/26/89	822	384			10/15/89	872	434		
8/27/89	823	385			10/16/89	873	435		
8/28/89	824	386			10/17/89	874	436		
8/29/89	825	387			10/18/89	875	437		
8/30/89	826	388			10/19/89	876	438		
8/31/89	827	389			10/20/89	877	439		
9/1/89	828	390			10/21/89	878	440		
9/2/89	829	391			10/22/89	879	441		
9/3/89	830	392			10/23/89	880	442		
9/4/89	831	393			10/24/89	881	443		
9/5/89	832	394			10/25/89	882	444		
9/6/89	833	395			10/26/89	883	445		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ia	Ib	Event	Date	I	Ia	Ib	Event
10/27/89	884	446			12/16/89	934	496		
10/28/89	885	447			12/17/89	935	497		
10/29/89	886	448			12/18/89	936	498		
10/30/89	887	449			12/19/89	937	499		
10/31/89	888	450			12/20/89	938	500		
11/1/89	889	451			12/21/89	939	501		
11/2/89	890	452			12/22/89	940	502		
11/3/89	891	453			12/23/89	941	503		
11/4/89	892	454			12/24/89	942	504		
11/5/89	893	455			12/25/89	943	505		
11/6/89	894	456			12/26/89	944	506		
11/7/89	895	457			12/27/89	945	507		
11/8/89	896	458			12/28/89	946	508		
11/9/89	897	459			12/29/89	947	509		
11/10/89	898	460			12/30/89	948	510		
11/11/89	899	461			12/31/89	949	511		
11/12/89	900	462			1/1/90	950	512		
11/13/89	901	463			1/2/90	951	513		
11/14/89	902	464			1/3/90	952	514		
11/15/89	903	465			1/4/90	953	515		
11/16/89	904	466			1/5/90	954	516		
11/17/89	905	467			1/6/90	955	517		
11/18/89	906	468			1/7/90	956	518		
11/19/89	907	469			1/8/90	957	519		
11/20/89	908	470			1/9/90	958	520		
11/21/89	909	471			1/10/90	959	521		
11/22/89	910	472			1/11/90	960	522		
11/23/89	911	473			1/12/90	961	523		
11/24/89	912	474			1/13/90	962	524		
11/25/89	913	475			1/14/90	963	525		
11/26/89	914	476			1/15/90	964	526		
11/27/89	915	477			1/16/90	965	527		
11/28/89	916	478			1/17/90	966	528		
11/29/89	917	479			1/18/90	967	529		
11/30/89	918	480			1/19/90	968	530		
12/1/89	919	481			1/20/90	969	531		
12/2/89	920	482			1/21/90	970	532		
12/3/89	921	483			1/22/90	971	533		
12/4/89	922	484			1/23/90	972	534		
12/5/89	923	485			1/24/90	973	535		
12/6/89	924	486			1/25/90	974	536		
12/7/89	925	487			1/26/90	975	537		
12/8/89	926	488			1/27/90	976	538		
12/9/89	927	489			1/28/90	977	539		
12/10/89	928	490			1/29/90	978	540		
12/11/89	929	491			1/30/90	979	541		
12/12/89	930	492			1/31/90	980	542		
12/13/89	931	493			2/1/90	981	543		
12/14/89	932	494			2/2/90	982	544		
12/15/89	933	495			2/3/90	983	545		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ia	Iib	Event	Date	I	Ia	Iib	Event
2/4/90	984	546			3/26/90	1034	596		
2/5/90	985	547			3/27/90	1035	597		
2/6/90	986	548			3/28/90	1036	598		
2/7/90	987	549			3/29/90	1037	599		
2/8/90	988	550			3/30/90	1038	600		
2/9/90	989	551			3/31/90	1039	601		
2/10/90	990	552			4/1/90	1040	602		
2/11/90	991	553			4/2/90	1041	603		
2/12/90	992	554			4/3/90	1042	604		
2/13/90	993	555			4/4/90	1043	605		
2/14/90	994	556			4/5/90	1044	606		
2/15/90	995	557			4/6/90	1045	607		
2/16/90	996	558			4/7/90	1046	608		
2/17/90	997	559			4/8/90	1047	609		
2/18/90	998	560			4/9/90	1048	610		
2/19/90	999	561			4/10/90	1049	611		
2/20/90	1000	562			4/11/90	1050	612		
2/21/90	1001	563			4/12/90	1051	613		
2/22/90	1002	564			4/13/90	1052	614		
2/23/90	1003	565			4/14/90	1053	615		
2/24/90	1004	566			4/15/90	1054	616		
2/25/90	1005	567			4/16/90	1055	617		
2/26/90	1006	568			4/17/90	1056	618		
2/27/90	1007	569			4/18/90	1057	619		
2/28/90	1008	570			4/19/90	1058	620		
3/1/90	1009	571			4/20/90	1059	621		
3/2/90	1010	572			4/21/90	1060	622		
3/3/90	1011	573			4/22/90	1061	623		
3/4/90	1012	574			4/23/90	1062	624		
3/5/90	1013	575			4/24/90	1063	625		
3/6/90	1014	576			4/25/90	1064	626		
3/7/90	1015	577			4/26/90	1065	627		
3/8/90	1016	578			4/27/90	1066	628		
3/9/90	1017	579			4/28/90	1067	629		
3/10/90	1018	580			4/29/90	1068	630		
3/11/90	1019	581			4/30/90	1069	631		
3/12/90	1020	582			5/1/90	1070	632		
3/13/90	1021	583			5/2/90	1071	633		
3/14/90	1022	584			5/3/90	1072	634		
3/15/90	1023	585			5/4/90	1073	635		
3/16/90	1024	586		Exp I deep cores #2,3	5/5/90	1074	636		
3/17/90	1025	587			5/6/90	1075	637		
3/18/90	1026	588			5/7/90	1076	638		
3/19/90	1027	589			5/8/90	1077	639		
3/20/90	1028	590			5/9/90	1078	640		
3/21/90	1029	591			5/10/90	1079	641		
3/22/90	1030	592			5/11/90	1080	642		
3/23/90	1031	593			5/12/90	1081	643		
3/24/90	1032	594			5/13/90	1082	644		
3/25/90	1033	595			5/14/90	1083	645		

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>Italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	Ia	Ib	Event	Date	I	Ia	Ib	Event
5/15/90	1084	646			7/4/90	1134	696		
5/16/90	1085	647			7/5/90	1135	697		
5/17/90	1086	648			7/6/90	1136	698		
5/18/90	1087	649			7/7/90	1137	699		
5/19/90	1088	650			7/8/90	1138	700		
5/20/90	1089	651			7/9/90	1139	701		Exp Ia soil cores
5/21/90	1090	652			7/10/90	1140	702		(To 3 m deep)
5/22/90	1091	653			7/11/90	1141	703		
5/23/90	1092	654			7/12/90	1142	704		
5/24/90	1093	655			7/13/90	1143	705		
5/25/90	1094	656			7/14/90	1144	706		
5/26/90	1095	657			7/15/90	1145	707		
5/27/90	1096	658			7/16/90	1146	708		
5/28/90	1097	659			7/17/90	1147	709		
5/29/90	1098	660			7/18/90	1148	710		
5/30/90	1099	661		Exp Ia soil cores	7/19/90	1149	711		
5/31/90	1100	662		(To 1.6 m deep)	7/20/90	1150	712		
6/1/90	1101	663			7/21/90	1151	713		
6/2/90	1102	664			7/22/90	1152	714		
6/3/90	1103	665			7/23/90	1153	715		
6/4/90	1104	666			7/24/90	1154	716		
6/5/90	1105	667			7/25/90	1155	717		
6/6/90	1106	668			7/26/90	1156	718		
6/7/90	1107	669			7/27/90	1157	719		
6/8/90	1108	670			7/28/90	1158	720		
6/9/90	1109	671			7/29/90	1159	721		
6/10/90	1110	672			7/30/90	1160	722		
6/11/90	1111	673			7/31/90	1161	723		
6/12/90	1112	674			8/1/90	1162	724	0	begin Ib irrigation
6/13/90	1113	675			8/2/90	1163	725	1	
6/14/90	1114	676			8/3/90	1164	726	2	
6/15/90	1115	677			8/4/90	1165	727	3	
6/16/90	1116	678			8/5/90	1166	728	4	
6/17/90	1117	679			8/6/90	1167	729	5	
6/18/90	1118	680			8/7/90	1168	730	6	
6/19/90	1119	681			8/8/90	1169	731	7	
6/20/90	1120	682			8/9/90	1170	732	8	
6/21/90	1121	683			8/10/90	1171	733	9	
6/22/90	1122	684			8/11/90	1172	734	10	
6/23/90	1123	685			8/12/90	1173	735	11	
6/24/90	1124	686			8/13/90	1174	736	12	
6/25/90	1125	687			8/14/90	1175	737	13	
6/26/90	1126	688			8/15/90	1176	738	14	
6/27/90	1127	689			8/16/90	1177	739	15	end tracer pulse #1
6/28/90	1128	690			8/17/90	1178	740	16	
6/29/90	1129	691			8/18/90	1179	741	17	
6/30/90	1130	692			8/19/90	1180	742	18	
7/1/90	1131	693			8/20/90	1181	743	19	
7/2/90	1132	694			8/21/90	1182	744	20	
7/3/90	1133	695			8/22/90	1183	745	21	

Appendix C-9. Chronology of Las Cruces Trench Site Experimental Events.

<i>italics indicates solution sample collection days</i>									
bold indicates neutron probe reading days									
Experiment days					Experiment days				
Date	I	IIa	IIb	Event	Date	I	IIa	IIb	Event
8/23/90	1184	746	22		10/13/90	1235	797	73	
8/24/90	1185	747	23		10/15/90	1237	799	75	
8/25/90	1186	748	24		10/19/90	1241	803	79	
8/26/90	1187	749	25		10/22/90	1244	806	82	
8/27/90	1188	750	26		10/26/90	1248	810	86	
8/28/90	1189	751	27		10/29/90	1251	813	89	
8/29/90	1190	752	28		11/2/90	1255	817	93	
8/30/90	1191	753	29	begin tracer pulse #2	11/5/90	1258	820	96	
8/31/90	1192	754	30		11/9/90	1262	824	100	
9/1/90	1193	755	31		11/12/90	1265	827	103	
9/2/90	1194	756	32		11/21/90	1274	836	112	
9/3/90	1195	757	33		11/28/90	1281	843	119	
9/4/90	1196	758	34		12/5/90	1288	850	126	
9/5/90	1197	759	35		12/12/90	1295	857	133	
9/6/90	1198	760	36		12/14/90	1297	859	135	
9/7/90	1199	761	37		12/19/90	1302	864	140	
9/8/90	1200	762	38		12/26/90	1309	871	147	
9/9/90	1201	763	39		1/2/91	1316	878	154	
9/10/90	1202	764	40		1/18/91	1332	894	170	
9/11/90	1203	765	41		2/1/91	1346	908	184	
9/12/90	1204	766	42		2/7/91	1352	916	190	add 6 access tubes
9/13/90	1205	767	43		2/8/91	1353	917	191	add 6 access tubes
9/14/90	1206	768	44	end tracer pulse #2	2/15/91	1360	922	198	
9/15/90	1207	769	45		3/1/91	1374	936	212	
9/16/90	1208	770	46		3/7/91	1380	942	218	
9/17/90	1209	771	47		3/14/91	1387	949	225	
9/18/90	1210	772	48		4/11/91	1415	977	253	
9/19/90	1211	773	49		4/12/91	1416	978	254	
9/20/90	1212	774	50		5/9/91	1443	1005	281	
9/21/90	1213	775	51		5/21/91	1455	1017	293	Exp. IIb soil cores
9/22/90	1214	776	52		6/7/91	1472	1034	310	
9/23/90	1215	777	53		7/12/91	1507	1069	345	
9/24/90	1216	778	54		9/13/91	1570	1132	408	
9/25/90	1217	779	55		9/20/91	1577	1139	415	
9/26/90	1218	780	56		1/8/92	1687	1249	525	
9/27/90	1219	781	57						
9/28/90	1220	782	58						
9/29/90	1221	783	59						
9/30/90	1222	784	60						
10/1/90	1223	785	61						
10/2/90	1224	786	62						
10/3/90	1225	787	63						
10/4/90	1226	788	64						
10/5/90	1227	789	65						
10/6/90	1228	790	66						
10/7/90	1229	791	67						
10/8/90	1230	792	68						
10/9/90	1231	793	69						
10/10/90	1232	794	70	end IIb Irrigation					
10/12/90	1234	796	72						

Appendix C-10. Location of Experimental Assets.

All measures described in meters

Irrigation Plot I Corners				
Corner	X1	Y1	X	Y
SE	-1.98	8.98	15.14	-13.79
NE	-1.98	0.00	15.16	-4.81
SW	1.98	8.98	11.18	-13.78
NW	1.98	0.00	11.20	-4.80

Irrigation Plot II Corners				
Corner	X2	Y2	X	Y
SE	0.63	0.01	4.66	0.01
NE	0.48	11.98	4.51	11.98
SW	-0.59	-0.01	3.44	-0.01
NW	-0.74	11.96	3.29	11.96

Experiment I Deep Cores			
No.	X1	Y1	Z
1	-0.46	4.67	14.60
2	2.02	4.95	15.22
3	4.00	5.00	15.19

Experiment IIa Soil Cores			
No.	Y2	X2	Z
1	5	-1.5	3.0
2	5	-1.0	3.0
3	5.09	-0.5	2.8
4	5	0.0	3.0
5	5.09	0.5	2.8
6	5	1.0	3.0
7	5	1.5	3.0
8	9	-1.5	2.8
9	9	-1.0	3.0
10	9	-0.5	2.8
11	9	0.0	2.8
12	9	0.5	2.6
13	9	1.0	3.0
14	9	1.5	3.0

Experiment IIb Soil Cores			
No.	Y2	X2	Z
1	5	-2.75	6.25
2	5	-2.25	6.29
3	5	-1.75	6.21
4	5	-1.25	6.21
5	5	-0.70	6.29
6	5	-0.25	6.29
7	5	0.25	6.29
8	5	0.75	6.29
9	5	1.25	6.29
10	5	1.75	6.29
11	5	2.25	6.25
12	5	2.75	6.29
13	9	-2.75	6.25
14	9	-2.25	6.29
15	9	-1.75	6.26
16	9	-1.25	6.21
17	9	-0.75	6.29
18	9	-0.25	6.29
19	9	0.25	6.29
20	9	0.75	6.29
21	9	1.25	6.29
22	9	1.75	6.29
23	9	2.25	6.29
24	9	2.75	6.29

Appendix C-10. Location of Experimental Assets. (Continued)

Plot II Neutron Probe Access Tubes (described in meters)

Tube No.	X2	Y2	X	Y
0	0.00	1.09	4.03	1.09
7	-5.98	2.02	-1.95	2.02
8	-4.98	2.03	-0.96	2.03
9	-3.97	2.03	0.06	2.03
10	-3.01	2.02	1.02	2.02
11	-2.01	2.03	2.01	2.03
12	-1.00	2.04	3.03	2.04
13	-0.04	2.03	3.98	2.03
14	1.02	1.99	5.04	1.99
15	2.02	2.02	6.05	2.02
16	2.99	2.02	7.01	2.02
17	3.97	2.04	7.99	2.04
18	4.97	2.05	9.00	2.05
19	6.00	2.05	10.03	2.05
20	-0.01	4.03	4.02	4.03
27	-6.03	6.09	-2.00	6.09
28	-5.00	6.05	-0.97	6.05
29	-3.99	6.04	0.03	6.04
30	-3.02	6.05	1.01	6.05
31	-2.06	6.02	1.97	6.02
32	-1.04	6.05	2.99	6.05
33	-0.04	6.03	3.99	6.03
34	0.95	6.05	4.98	6.05
35	1.95	6.03	5.97	6.03
36	2.95	6.05	6.98	6.05
37	3.94	6.07	7.96	6.07
38	4.93	6.07	8.96	6.07
39	5.94	6.11	9.97	6.11
40	-0.08	8.03	3.94	8.03
47	-6.06	10.03	-2.03	10.03
48	-5.06	10.02	-1.03	10.02
49	-4.06	10.08	-0.03	10.08
50	-3.09	10.05	0.94	10.05
51	-2.10	10.01	1.93	10.01
52	-1.08	10.06	2.94	10.06
53	-0.08	10.02	3.94	10.02
54	0.91	10.04	4.93	10.04
55	1.91	10.04	5.94	10.04
56	2.92	10.04	6.95	10.04
57	3.88	10.06	7.91	10.06
58	4.88	10.07	8.91	10.07
59	5.89	10.10	9.92	10.10
60	-0.18	12.04	3.85	12.04
70	-1.01	12.58	3.02	12.58
71	0.72	12.51	4.75	12.51
80	-0.18	13.04	3.85	13.04
90	-0.17	13.99	3.85	13.99
100	-0.14	15.02	3.89	15.02
110	-0.18	16.02	3.84	16.02

Appendix C-10. Location of Experimental Assets. Continued)

Plot II Tensiometers (described in meters)

ID	X2	Y2	Z	X	Y	Exp Ila ID
142	-2.11	0.5	0.25	1.92	0.5	N/A
144	-1.5	0.5	0.25	2.53	0.5	'A1'
146	-1	0.5	0.25	3.03	0.5	'13'
148	-0.5	0.5	0.25	3.53	0.5	'14'
150	0	0.5	0.25	4.03	0.5	'15'
152	0.5	0.5	0.25	4.53	0.5	'16'
154	1	0.5	0.25	5.03	0.5	'17'
156	1.5	0.5	0.25	5.53	0.5	'A2'
158	2	0.5	0.25	6.03	0.5	N/A
342	-2.11	0.5	0.75	1.92	0.5	N/A
344	-1.5	0.5	0.75	2.53	0.5	'B1'
346	-1	0.5	0.75	3.03	0.5	'18'
348	-0.5	0.5	0.75	3.53	0.5	'19'
350	0	0.5	0.75	4.03	0.5	'20'
352	0.5	0.5	0.75	4.53	0.5	'21'
354	1	0.5	0.75	5.03	0.5	'22'
356	1.5	0.5	0.75	5.53	0.5	'B2'
358	2	0.5	0.75	6.03	0.5	N/A
642	-2.11	0.5	1.5	1.92	0.5	N/A
644	-1.5	0.5	1.5	2.53	0.5	'23'
646	-1	0.5	1.5	3.03	0.5	'24'
648	-0.5	0.5	1.5	3.53	0.5	'25'
650	0	0.5	1.5	4.03	0.5	'26'
652	0.5	0.5	1.5	4.53	0.5	'27'
654	1	0.5	1.5	5.03	0.5	'28'
656	1.5	0.5	1.5	5.53	0.5	'29'
658	2	0.5	1.5	6.03	0.5	N/A
842	-2.11	0.5	2	1.92	0.5	N/A
844	-1.5	0.5	2	2.53	0.5	'30'
846	-1	0.5	2	3.03	0.5	'31'
848	-0.5	0.5	2	3.53	0.5	'32'
850	0	0.5	2	4.03	0.5	'33'
852	0.5	0.5	2	4.53	0.5	'34'
854	1	0.5	2	5.03	0.5	'35'
856	1.5	0.5	2	5.53	0.5	'36'
858	2	0.5	2	6.03	0.5	N/A
1042	-2.11	0.5	2.5	1.92	0.5	N/A
1044	-1.5	0.5	2.5	2.53	0.5	'37'
1046	-1	0.5	2.5	3.03	0.5	'38'
1048	-0.5	0.5	2.5	3.53	0.5	'39'
1050	0	0.5	2.5	4.03	0.5	'40'
1052	0.5	0.5	2.5	4.53	0.5	'41'

Appendix C-10. Location of Experimental Assets. (Continued)

Plot II Tensiometers (described in meters)

ID	X2	Y2	Z	X	Y	Exp IIa ID
1054	1	0.5	2.5	5.03	0.5	'42'
1056	1.5	0.5	2.5	5.53	0.5	'43'
1058	2	0.5	2.5	6.03	0.5	N/A
1242	-2.11	0.5	3	1.92	0.5	N/A
1244	-1.5	0.5	3	2.53	0.5	'44'
1246	-1	0.5	3	3.03	0.5	'45'
1248	-0.5	0.5	3	3.53	0.5	'46'
1250	0	0.5	3	4.03	0.5	'47'
1252	0.5	0.5	3	4.53	0.5	'48'
1254	1	0.5	3	5.03	0.5	'49'
1256	1.5	0.5	3	5.53	0.5	'50'
1258	2	0.5	3	6.03	0.5	N/A
1442	-2.11	0.5	3.5	1.92	0.5	N/A
1444	-1.5	0.5	3.5	2.53	0.5	'51'
1446	-1	0.5	3.5	3.03	0.5	'52'
1448	-0.5	0.5	3.5	3.53	0.5	'53'
1450	0	0.5	3.5	4.03	0.5	'54'
1452	0.5	0.5	3.5	4.53	0.5	'55'
1454	1	0.5	3.5	5.03	0.5	'56'
1456	1.5	0.5	3.5	5.53	0.5	'57'
1458	2	0.5	3.5	6.03	0.5	N/A
1642	-2.11	0.5	4	1.92	0.5	N/A
1644	-1.5	0.5	4	2.53	0.5	N/A
1646	-1	0.5	4	3.03	0.5	N/A
1648	-0.5	0.5	4	3.53	0.5	N/A
1650	0	0.5	4	4.03	0.5	N/A
1652	0.5	0.5	4	4.53	0.5	N/A
1654	1	0.5	4	5.03	0.5	N/A
1656	1.5	0.5	4	5.53	0.5	N/A
1658	2	0.5	4	6.03	0.5	N/A
1842	-2.11	0.5	4.5	1.92	0.5	N/A
1844	-1.5	0.5	4.5	2.53	0.5	N/A
1846	-1	0.5	4.5	3.03	0.5	N/A
1848	-0.5	0.5	4.5	3.53	0.5	N/A
1850	0	0.5	4.5	4.03	0.5	N/A
1852	0.5	0.5	4.54	4.53	0.5	N/A
1854	1	0.5	4.54	5.03	0.5	N/A
1856	1.5	0.5	4.54	5.53	0.5	N/A
1858	2	0.5	4.58	6.03	0.5	N/A
2042	-2.11	0.5	5	1.92	0.5	N/A
2044	-1.5	0.5	5	2.53	0.5	N/A
2046	-1	0.5	5	3.03	0.5	N/A

Appendix C-10. Location of Experimental Assets. (Continued)

Plot II Tensiometers (described in meters)

ID	X2	Y2	Z	X	Y	Exp IIa ID
2048	-0.5	0.5	5	3.53	0.5	N/A
2050	0	0.5	5	4.03	0.5	N/A
2052	0.5	0.5	5	4.53	0.5	N/A
2054	1	0.5	5	5.03	0.5	N/A
2056	1.5	0.5	5	5.53	0.5	N/A
2058	2	0.5	5	6.03	0.5	N/A
2242	-2.11	0.5	5.5	1.92	0.5	N/A
2244	-1.5	0.5	5.5	2.53	0.5	N/A
2246	-1	0.5	5.5	3.03	0.5	N/A
2248	-0.5	0.5	5.5	3.53	0.5	N/A
2250	0	0.5	5.5	4.03	0.5	N/A
2252	0.5	0.5	5.5	4.53	0.5	N/A
2254	1	0.5	5.5	5.03	0.5	N/A
2256	1.5	0.5	5.5	5.53	0.5	N/A
2258	2	0.5	5.5	6.03	0.5	N/A
2442	-2.11	0.5	6	1.92	0.5	N/A
2444	-1.5	0.5	6	2.53	0.5	N/A
2446	-1	0.5	6	3.03	0.5	N/A
2448	-0.5	0.5	6	3.53	0.5	N/A
2450	0	0.5	6	4.03	0.5	N/A
2452	0.5	0.5	6	4.53	0.5	N/A
2454	1	0.5	6	5.03	0.5	N/A
2456	1.5	0.5	6	5.53	0.5	N/A
2458	2	0.5	6	6.03	0.5	N/A

Appendix C-10. Location of Experimental Assets. (Continued)

Plot II Solution Samplers (described in meters)

ID	X2	Y2	Z	X	Y	Exp IIa ID
241	-2.26	0.5	0.5	1.77	0.5	N/A
243	-1.75	0.5	0.5	2.28	0.5	N/A
245	-1.25	0.5	0.5	2.78	0.5	'1'
247	-0.75	0.5	0.5	3.28	0.5	'2'
249	-0.25	0.5	0.5	3.78	0.5	'3'
251	0.25	0.5	0.5	4.28	0.5	'4'
253	0.75	0.5	0.5	4.78	0.5	'5'
255	1.25	0.5	0.5	5.28	0.5	'6'
257	1.84	0.5	0.5	5.87	0.5	'43'
259	2.23	0.5	0.5	6.26	0.5	N/A
441	-2.26	0.5	1	1.77	0.5	N/A
443	-1.75	0.5	1	2.28	0.5	N/A
445	-1.25	0.5	1	2.78	0.5	'7'
447	-0.75	0.5	1	3.28	0.5	'8'
449	-0.25	0.5	1	3.78	0.5	'9'
451	0.25	0.5	1	4.28	0.5	'10'
453	0.75	0.5	1	4.78	0.5	'11'
455	1.25	0.5	1	5.28	0.5	'12'
457	1.84	0.5	1	5.87	0.5	'44'
459	2.24	0.5	1	6.27	0.5	N/A
641	-2.25	0.5	1.5	1.78	0.5	N/A
643	-1.75	0.5	1.5	2.28	0.5	N/A
645	-1.25	0.5	1.5	2.78	0.5	'13'
647	-0.75	0.5	1.5	3.28	0.5	'14'
649	-0.25	0.5	1.5	3.78	0.5	'15'
651	0.25	0.5	1.5	4.28	0.5	'16'
653	0.75	0.5	1.5	4.78	0.5	'17'
655	1.25	0.5	1.5	5.28	0.5	'18'
657	1.84	0.5	1.5	5.87	0.5	'45'
659	2.24	0.5	1.5	6.27	0.5	N/A
841	-2.25	0.5	2	1.78	0.5	N/A
843	-1.75	0.5	2	2.28	0.5	N/A
845	-1.25	0.5	2	2.78	0.5	'19'
847	-0.75	0.5	2	3.28	0.5	'20'
849	-0.25	0.5	2	3.78	0.5	'21'
851	0.25	0.5	2	4.28	0.5	'22'
853	0.75	0.5	2	4.78	0.5	'23'
855	1.25	0.5	2	5.28	0.5	'24'
857	1.84	0.5	2	5.87	0.5	'46'
859	2.24	0.5	2	6.27	0.5	N/A

Appendix C-10. Location of Experimental Assets. (Continued)

Plot II Solution Samplers (described in meters)

ID	X2	Y2	Z	X	Y	Exp IIa ID
1041	-2.25	0.5	2.5	1.78	0.5	N/A
1043	-1.75	0.5	2.5	2.28	0.5	N/A
1045	-1.25	0.5	2.5	2.78	0.5	'25'
1047	-0.75	0.5	2.5	3.28	0.5	'26'
1049	-0.25	0.5	2.5	3.78	0.5	'27'
1051	0.25	0.5	2.5	4.28	0.5	'28'
1053	0.75	0.5	2.5	4.78	0.5	'29'
1055	1.25	0.5	2.5	5.28	0.5	'30'
1057	1.84	0.5	2.5	5.87	0.5	'47'
1059	2.24	0.5	2.5	6.27	0.5	N/A
1241	-2.26	0.5	3	1.77	0.5	N/A
1243	-1.75	0.5	3	2.28	0.5	N/A
1245	-1.25	0.5	3	2.78	0.5	'31'
1247	-0.75	0.5	3	3.28	0.5	'32'
1249	-0.25	0.5	3	3.78	0.5	'33'
1251	0.25	0.5	3	4.28	0.5	'34'
1253	0.75	0.5	3	4.78	0.5	'35'
1255	1.25	0.5	3	5.28	0.5	'36'
1257	1.84	0.5	3	5.87	0.5	'48'
1259	2.24	0.5	3	6.27	0.5	N/A
1441	-2.25	0.5	3.5	1.78	0.5	N/A
1443	-1.75	0.5	3.5	2.28	0.5	N/A
1445	-1.25	0.5	3.5	2.78	0.5	'37'
1447	-0.75	0.5	3.5	3.28	0.5	'38'
1449	-0.25	0.5	3.5	3.78	0.5	'39'
1451	0.25	0.5	3.5	4.28	0.5	'40'
1453	0.75	0.5	3.5	4.78	0.5	'41'
1455	1.25	0.5	3.5	5.28	0.5	'42'
1457	1.84	0.5	3.5	5.87	0.5	'49'
1459	2.25	0.5	3.5	6.28	0.5	N/A
1641	-2.25	0.5	4	1.78	0.5	N/A
1643	-1.75	0.5	4	2.28	0.5	N/A
1645	-1.25	0.5	4	2.78	0.5	N/A
1647	-0.75	0.5	4	3.28	0.5	N/A
1649	-0.25	0.5	4	3.78	0.5	N/A
1651	0.25	0.5	4	4.28	0.5	N/A
1653	0.75	0.5	4	4.78	0.5	N/A
1655	1.25	0.5	4	5.28	0.5	N/A
1657	1.84	0.5	4	5.87	0.5	N/A
1659	2.26	0.5	4	6.29	0.5	N/A

Appendix C-10. Location of Experimental Assets. (Continued)

Plot II Solution Samplers (described in meters)

ID	X2	Y2	Z	X	Y	Exp IIa ID
1841	-2.25	0.5	4.5	1.78	0.5	N/A
1843	-1.75	0.5	4.5	2.28	0.5	N/A
1845	-1.25	0.5	4.5	2.78	0.5	N/A
1847	-0.75	0.5	4.5	3.28	0.5	N/A
1849	-0.25	0.5	4.5	3.78	0.5	N/A
1851	0.25	0.5	4.54	4.28	0.5	N/A
1853	0.75	0.5	4.54	4.78	0.5	N/A
1855	1.25	0.5	4.54	5.28	0.5	N/A
1857	1.84	0.5	4.54	5.87	0.5	N/A
1859	2.24	0.5	4.58	6.27	0.5	N/A
2041	-2.25	0.5	5	1.78	0.5	N/A
2043	-1.75	0.5	5	2.28	0.5	N/A
2045	-1.25	0.5	5	2.78	0.5	N/A
2047	-0.75	0.5	5	3.28	0.5	N/A
2049	-0.25	0.5	5	3.78	0.5	N/A
2051	0.25	0.5	5	4.28	0.5	N/A
2053	0.75	0.5	5	4.78	0.5	N/A
2055	1.25	0.5	5	5.28	0.5	N/A
2057	1.84	0.5	5	5.87	0.5	N/A
2059	2.24	0.5	5	6.27	0.5	N/A
2241	-2.25	0.5	5.5	1.78	0.5	N/A
2243	-1.75	0.5	5.5	2.28	0.5	N/A
2245	-1.25	0.5	5.5	2.78	0.5	N/A
2247	-0.75	0.5	5.5	3.28	0.5	N/A
2249	-0.25	0.5	5.5	3.78	0.5	N/A
2251	0.25	0.5	5.5	4.28	0.5	N/A
2253	0.75	0.5	5.5	4.78	0.5	N/A
2255	1.25	0.5	5.5	5.28	0.5	N/A
2257	1.84	0.5	5.5	5.87	0.5	N/A
2259	2.25	0.5	5.5	6.28	0.5	N/A
2441	-2.25	0.5	6	1.78	0.5	N/A
2443	-1.75	0.5	6	2.28	0.5	N/A
2445	-1.25	0.5	6	2.78	0.5	N/A
2447	-0.75	0.5	6	3.28	0.5	N/A
2449	-0.25	0.5	6	3.78	0.5	N/A
2451	0.25	0.5	6	4.28	0.5	N/A
2453	0.75	0.5	6	4.78	0.5	N/A
2455	1.25	0.5	6	5.28	0.5	N/A
2457	1.84	0.5	6	5.87	0.5	N/A
2459	2.25	0.5	6	6.28	0.5	N/A

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R. Cady, NRC Project Manager

11. ABSTRACT (200 words or less)

Three water flow and solute transport experiments were performed as part of a comprehensive field trench study near Las Cruces, New Mexico to test deterministic and stochastic models of vadose zone flow and transport. This report presents partial results from the third experiment (experiment IIB). Experiments IIA and b were conducted on the North side of the trench, on a plot 1.22 m wide by 12 m long, perpendicular to the trench. The area was drip irrigated during two time periods with water containing a variety of tracers. The water front was measured with tensiometers and neutron probes. Solute fronts were determined from soil solutions through suction samplers and from disturbed samples. Experiment IIB results show predominantly downward water movement through the layered unsaturated soil. Tritium plumes were only half as deep and half as wide as the water plumes at 310 days after the start of the experiment. Chromium, applied as Cr(VI), moved similar to tritium, but with a loss of mass due to reduction of Cr(VI) to Cr(III). Chloride and nitrate, initially present at high concentrations in the soil solution, were displaced by the irrigation water. The extensive data presented should serve well as a data base for model testing.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

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