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**GEOCHEMICAL AND HYDROLOGIC
CHARACTERIZATION OF THE EFFLUENT DRAINING
FROM U12E, U12N, AND U12T TUNNELS,
AREA 12, NEVADA TEST SITE**

by
**Charles E. Russell
Lora Gillespie
David Gillespie**

MAY 1993

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CHARACTERIZATION OF THE EFFLUENT DRAINING FROM
U12E, U12N, AND U12T TUNNELS,
AREA 12, NEVADA TEST SITE**

by

Water Resources Center
Desert Research Institute
University and Community College System of Nevada

Publication No. 45105

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Las Vegas, Nevada

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INTRODUCTION

Objectives

The objective of the Tunnel Effluent Characterization Project was to characterize the tunnel effluents in terms of rate of discharge, pH, temperature, specific conductivity, turbidity, and aqueous chemistry. The parameters were monitored for one year to identify hazardous constituents within the effluent and to characterize temporal variations.

Site Description

Rainier Mesa, located in the north-central portion of the Nevada Test Site, is one of the primary locations where the United States conducts underground tests on the effects of nuclear weapons.

The majority of the devices tested within Rainier Mesa are detonated in tunnels mined into zeolitized tuffs. The zeolitized tuff is relatively impermeable and acts as a perching unit for meteoric water moving through the mesa down to the regional groundwater table. Groundwater traveling along faults accumulates in fractures, faults, and interstitial pores within the zeolitized tuff. Water in the vicinity of the cavity-chimney structure created by an underground nuclear detonation may come into contact with radionuclides released during the detonation. Tritium is the most mobile of all of these radionuclides.

The fractures containing this water may be intercepted during normal mining operations, creating artificial seeps within the tunnels. The water is drained, through pipes, out of the tunnels and into evaporation ponds at the base of the tunnel muckpiles. Only three of the tunnels have sufficient quantities of water for the discharge to reach the tunnel portals. These tunnels are U12n, U12e, and U12t tunnels.

The effluent from the tunnels is also affected by mining and support activities conducted within the tunnels. These activities may have or have had the potential to release heavy metals, volatile organics, semivolatile organics, and polychlorinated biphenyls into the tunnel effluent.

Effluent Sampling/Monitoring Locations

The sampling and monitoring station for U12n tunnel was located on the U12n access road at the base of the U12n tunnel muckpile (N891750 E639625 Nevada Central Coordinates). Effluent within U12n tunnel drained into sumps within the tunnel. Water from the sump was transferred via suction pump into a drain pipe. The drain pipe allowed groundwater to flow out the tunnel portal and beneath the muckpile. The drainage pipe emerged at the base of the muckpile and extended approximately 100 m before intersecting the monitoring station. The discharge from the monitoring station reentered the drain pipe and continued to flow approximately 300 m to the discharge ponds (Figure 1).

The sampling and monitoring station for U12e tunnel was located at the top of the U12e tunnel muckpile (N887875 E637920, Nevada Central Coordinates). Effluent within U12e

tunnel drained into sumps connected directly to the tunnel drain pipe. The drain pipe emerged from the tunnel portal and ran approximately 100 m along the surface to the monitoring station. The effluent drained back into the pipe after passing through the monitoring station. From this point, the pipe ran down the face of the muckpile and alongside the road for 250 m to the discharge ponds (Figure 2).

The sampling and monitoring station for U12t tunnel was located on a dirt road that ran parallel to the base of the U12t tunnel muckpile (N898000 E650000 Nevada Central Coordinates). Effluent from U12t tunnel drained into sumps within the tunnel. The water from the sump was transferred via suction pump into a drain pipe. The groundwater within the drain pipe flowed out the tunnel portal and beneath the muckpile. The pipe emerged at the base of the muckpile where it traveled approximately 10 m before intersecting the monitoring station. The discharge from the monitoring station reentered the drain pipe and continued to flow approximately 150 m to the discharge ponds (Figure 3).

Previous Samples

The tunnel ponds have been sampled by Reynolds Electrical & Engineering Company, Inc. (REECo) on a monthly basis for the past 21 years. Grab samples were routinely analyzed for tritium, plutonium, gross beta, and gamma spectroscopy. Results have consistently shown elevated tritium concentrations within the effluent. The summarized results of these analyses are contained in reports issued yearly by REECo. These reports are currently titled "Radiological Effluent and Onsite Area Monitoring Report for the Nevada Test Site." The published data have been pulled together into a table and series of graphs presented in Appendix 7.

In addition, one set of metal, organic, and radionuclide samples was acquired on August 7, 1987, from the effluents of U12e, U12n, and U12t tunnels. The results are summarized in Appendix 6. Elevated levels of tritium were detected in all of the effluent and methylene chloride was detected in U12t tunnel effluent.

Sample/System Design

The effluent characterization system was designed to measure mining effluent discharge, temperature, pH, EC, and turbidity. The equipment used at the effluent characterization stations, their operating ranges and accuracies are listed in Table 1. A schematic of the instrumentation and how they were connected is diagrammatically shown in Figure 4. The characterization system described in Table 1 and Figure 4 has several advantages. The power requirements for the system were minimal, allowing reliable operation from only three 12-volt, 1.5-amp solar panels. The datalogger allowed for the independent collection, processing, and compilation of data, and the dedicated telephone lines and modems allowed for the daily data retrieval. The instrumentation at the sites provided a cost-effective method of providing real-time monitoring data that required only monthly calibration.

The biggest problem of this system was the lack of an appropriately designed field sampler to collect, filter and preserve the environmental samples according to approved methods. An

electronically controlled discrete sampler was installed at the sites. The lack of an automated method to filter, acidify, cap and cool the bottles in the sampler negated its use for the collection of samples to characterize the effluent stream.

Data Storage and Processing

The field pH, EC, and temperature probes, and transducers supplied a continuous stream of data to the dataloggers. The datalogger sampled these data once every minute and determined an average value every hour. Turbidity of the stream was sampled once every 15 minutes and averaged once every hour. The hourly data for all parameters were stored in permanent memory. Once a day, the computer system at the Desert Research Institute (DRI) would call and initiate a transfer of the data collected for the last 24 hours. Once data were stored in the DRI computers, plots of the pH, temperature, discharge, EC and turbidity data for the past seven days of data were automatically created. These plots were used to identify data trends indicative of malfunctioning instrumentation. If malfunctions were noted, then the offending instrumentation was recalibrated or replaced.

QUALITY ASSURANCE OBJECTIVES

Continuously Monitored Parameters

Several data quality objectives were set prior to the start of the project. These include objectives for data precision, accuracy, and completeness. Data precision refers to the closeness of repeated measurements of the same quantity. It can be stated as the ratio of the standard deviation to the mean of replicate determinations expressed as a percentage. Data accuracy refers to the degree of difference between actual concentrations or levels in a water sample and the values that are measured during an analysis. Data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under optimal conditions. Data precision, accuracy, and completeness objectives are stated in Table 2.

Thirty data sets were chosen for the purpose of estimating data precision. These data sets were collected during periods of minimal variation. Each set consisted of four values, which were used to calibrate a single precision estimate. The 30 precision values were averaged together to determine the data precision for a given parameter collected from a single tunnel. The data precision estimates for all of the parameters measured from all of the tunnels are presented in Table 3.

A comparison of the data precision objectives from Table 2 to the data precision estimates from Table 3 shows that the temperature, pH, EC, discharge, and turbidity measurements from U12e, U12n, and U12t tunnel met the precision objectives established in Table 2, with the sole exception of the turbidity meter at U12n tunnel. One possible explanation for the turbidity meter at U12n tunnel failing to meet precision objectives is the rapidly varying turbidity of the effluent from that tunnel. This occurred at all times of day and night when mining was occurring. It may

be possible that some of the 30 data sets used to determine precision may have occurred simultaneous with mining. Another possibility is the poor reliability of the turbidity meters, which may have affected the precision of the instrument.

Data accuracy estimates were determined through calibration to known standards. Calibration activities were routinely conducted on a monthly basis and are described below. The field thermistor was checked against a National Institute of Standards and Technology thermometer. If the thermistor was in error by more than 0.015 C, a linear extrapolation was applied to the output to recalibrate the thermistor. Both the field EC meter and pH meter were checked monthly against portable EC and pH meters, which had been calibrated against laboratory standards. If the field EC measurements of the mining effluent were greater than three percent off of the calibrated portable meter, then the field EC meter data were recalibrated to the laboratory standards. If the field pH meter output differed from the portable pH meter by more than 0.2 pH units, then the field meter was recalibrated using the laboratory buffers. The transducer at each station was checked monthly against steel tape measurements of the water level within the flume. If the data output of the transducer differed by 0.61 cm from the measurement of the steel tape, then a linear extrapolation was applied to its output to recalibrate the transducer. The turbidity meter at each station was checked monthly for drift by placing two glass reference plates into the turbidity measurement chamber. Each of the reference plates had been previously placed within the turbidity meter and the light diffusion (or turbidity) values for the reference plates were known. If the values for each reference plate varied by more than 10 percent of the previous measurement, then recalibration of the turbidity meter was required. The turbidity meter was recalibrated by pouring a laboratory prepared 4000 Nephelometric Turbidity Unit standard into the measurement chamber and recalibrating the instrument. Once calibration of the meter was completed, the two glass reference plates were replaced into the meter and new reference values determined.

Although the field instruments were calibrated on a monthly basis, sometimes more frequent calibration was required. Anomalous trends within the data indicated if nonperiodic calibration was required. If an instrument required calibration two or three times in succession, then the instrument was repaired or replaced.

Quality assurance records were recorded during calibration and used to determine data accuracy. This was accomplished by comparing initial field measurements of temperature, EC, pH, discharge, and turbidity to recently calibrated portable field instrumentation. Field measurements were divided by the calibrated readings taken from the portable field instruments and multiplied by 100 to get an individual accuracy measurement for that instrument at that time. The accuracy estimates were averaged to determine the data accuracy for a particular meter for the entire characterization period. The results of this analysis are presented in Table 3. A comparison of the actual data accuracy contained in Table 3 to data accuracy objectives in Table 2 indicates that temperature and pH meters from all tunnels, EC from U12e and U12t tunnel, discharge from U12n and U12c tunnel and the turbidity from U12n tunnel met accuracy objectives stated in Table 2.

The EC meter at U12n tunnel was only 0.82 percent off of the accuracy objective. This small discrepancy may be due to the periodic fluctuation of the EC of the effluent at U12n tunnel outside the range of the standards used to calibrate the instrument. The EC meters were typically calibrated with 100, 500, and 1000 μ Siemen standards. The EC at U12n tunnel would infrequently fluctuate as high as 2588. If calibrations were conducted during these periods of high EC, a larger degree of error would be associated with the accuracy of the measurements. The discharge at U12t tunnel did not meet its accuracy objective. The most probable reason for the decreased accuracy was the relatively larger flume size used at U12t tunnel. The larger flows from this tunnel originally required a 4-inch flume versus the 2-inch flumes at U12n and U12e tunnel. The larger flume size at U12t tunnel corresponded with a decrease in data resolution and accuracy. The turbidity of the U12t tunnel did not meet accuracy objectives. The primary reason for this was the low turbidity of the effluent. The turbidity meter installed at U12t tunnel is capable of measuring turbidity ranging from 0 to 9999 NTU. The low turbidity at U12t tunnel was on the extreme edge of the measurement range for this meter. This is the most probable reason for the decreased accuracy of this meter at this location.

Data completeness for the continuously monitored data was assessed by determining the ratio of the actual number of data points collected that passed the quality criteria to the total possible number of data points that could be achieved under optimal conditions. The results of the analyses are presented in Table 3. A comparison of the actual data completeness contained in Table 3 to data completeness objectives in Table 2 indicates that temperature from all the effluent monitoring stations, pH at U12e tunnel, EC at U12e tunnel, and discharge at U12n tunnel achieved data completeness objectives.

Two reasons for removal of data from the data set were possible: equipment failure and instrumentation drift. The turbidity meters were the most prone to equipment failure, followed by the pH and then the EC meters. The meters most prone to drift were the transducers followed by the pH and the turbidity meters. The biggest problem of the continuous monitoring was the failure to achieve the majority of the data completeness objectives.

Geochemical Parameters

Field Quality Assurance Procedures

Several steps were incorporated into the field sampling activities to ensure the quality of geochemical samples. These included the use of a quality assurance manual, certified cleaning procedures for bottles, EPA approved preservation methods and holding times, chain-of-custody forms, bottle labels, analysis request forms, field logs, random sample numbering, field spikes, field blanks, matrix spikes, and matrix spike duplicates.

The quality assurance manual was established by DRI prior to the initiation of the field project (DRI, unpublished). This document specifies analytes, sample handling, preservation procedures, methods of analysis, and quality assurance procedures. These procedures were used throughout the project to ensure the validity of the samples taken. The documentation associated with quality assurance are archived in the DRI Water Resources Center quality assurance files.

All bottles used during the project were from I-Chem Corporation or Eagle-Pitcher Corporation. These bottles were pre-cleaned, tested, and certified by the manufacturer. The types of bottles used, volumes required, nature of preservatives and length of holding times are listed in Table 4.

All samples collected under this program were affixed with a sample label (Figure 5). Sample numbers were randomly determined prior to initiation of the sample. The purpose of the random numbering system was to prevent the analytical laboratories from determining the origin of individual samples. All samples were recorded into field logbooks during acquisition (Figure 6). The samples were also logged onto chain-of-custody (Figure 7) and analysis request forms (Figure 8). The field logbooks, chain-of-custody and analysis request forms are archived in the DRI quality assurance files.

Field blanks consisted of samples filled in the field with high pressure liquid chromatography reagent grade water. Field blanks were initially taken for all analytes. Following the first set of samples, field blanks were taken only for volatile organic analyses. The results of the analyses for the field blanks are archived in the DRI quality assurance files. Field blank results are included in this report for analytes exhibiting positive concentrations.

Field spikes were laboratory prepared ampules containing certified concentrations of contaminants. The field spikes used in this program were prepared by Environmental Research Associates of Arvada, Colorado, the same company that prepares the field spikes for the Environmental Protection Agency's Contract Laboratory Program.

The field spikes for this project were single blank spikes. Single blank spikes are spikes in which the type and nature of the contaminants within the spike are unknown to the laboratory personnel, yet their nature as a field spike is readily apparent. Double blank spikes are spikes in which the type and nature of the contaminants within the spike are unknown and the spike is submitted as a regular sample with its true nature hidden from laboratory personnel. Double blanks were not used following discussions with REECO organic laboratory personnel. Double blank spikes are identifiable by their unique color during extraction. Since they are so easily detected, the expense and perishable nature of the double blank spikes did not warrant their use. The results of the field spikes are presented in the initial portion of the Geochemical Results section of this report.

Matrix spike and matrix spike duplicates were quality assurance techniques used by laboratory and field operations. The purpose of the matrix spike is to determine if the water being sampled by the field technicians has dissolved or suspended material within it that may interfere with the extraction, analysis, and interpretation of the parameters of interest. A matrix spike is a sample collected in conjunction with routine samples and is preserved, handled, documented, and transported in exactly the same manner as a normal sample. Upon receipt in the laboratory, the matrix spike is tagged with known concentrations of an organic compound. The results indicate if something within the matrix of the sample is interfering with the anticipated results. A matrix spike duplicate is collected, handled, documented, and analyzed in exactly the same

manner as the matrix spike. The results of the matrix spike and matrix spike duplicate were used to evaluate laboratory consistency.

The date, location, and nature of field quality assurance samples are summarized in Table 5.

Laboratory Quality Assurance Procedures

Three laboratories were used to analyze the samples for this project. DRI's Water Analysis Laboratory was used to analyze for the inorganic constituents. REECo's Analytical Services Laboratories were used to analyze the radioactivity and tritium concentrations, and a separate REECo laboratory analyzed for organic species. The general chemical categories analyzed in this project, the Environmental Protection Agency (EPA) methods used, and the published accuracy, precision, and detection limits of the methods are presented on Table 6.

Quality assurance methods vary from laboratory to laboratory. The water laboratory at DRI utilizes four separate quality control methods during analysis. These include EPA control samples, standards, laboratory duplicates and laboratory spikes for all relevant analyses. EPA control samples are certified by the EPA to be of known concentration. The control samples are run with every batch of samples being analyzed for a specific analyte. Standards are laboratory prepared samples whose concentrations span the anticipated concentration range within the field samples. Standards are used to calibrate the analytical equipment. Duplicate analyses are run to determine if the analytical equipment is operating consistently. Spiked samples are samples spiked by the laboratory as an internal check on the accuracy of the method and equipment involved in the analyses. Records for the analysis and associated quality assurance methods are archived at the DRI Water Analysis Laboratory in Reno.

In addition to the internal quality assurance records, the DRI's water laboratory participates in three annual, state-wide, analytical studies to achieve certification with the EPA, State of Nevada, and the U.S. Geological Survey (USGS). The first two studies are the Water Pollution Study and the Water Supply Study. These studies are co-sponsored by the State of Nevada and the EPA for certification of laboratories in federal and state discharge permits and Safe Drinking Water Act analyses. The third study, entitled the USGS Analytical Evaluation Program, is a nationwide study that certifies laboratories for use in USGS work. The annual results of all three studies are maintained at the DRI's water laboratory in Reno.

The REECo Analytical Services Laboratories have very extensive quality assurance procedures. These procedures are spelled out in the REECo Analytical Services Department Quality Implementation Procedures (1992). In addition to internal EPA control samples, standards, laboratory duplicates and laboratory spikes, the organic laboratory participates in the EPA's Contract Laboratory Program. Although the laboratory does not contract to the EPA for samples, it has consistently qualified to do so during this study, with only one minor exception. This exception was rectified during the analysis of an EPA remedial Contract Laboratory sample.

Records of the quality assurance procedures for samples submitted to the REECo analytical laboratories are maintained in both the DRI quality assurance files and at the Analytical Services Laboratories in Mercury, Nevada.

Sampling Frequency

The schedule shown in Figure 9 summarizes when samples were taken at each of the tunnel complexes and when calibration and maintenance activities occurred at the monitoring stations. The intent of the the sample design was to determine if variation of geochemical properties occurred during the span of one year, utilizing different sampling frequencies to detect potential changes in the effluent during different activities being conducted in the tunnels. To satisfy these requirements, sampling of the tunnels spanned one year, the frequency of sampling was initially high and then dropped to monthly or quarterly, depending upon the tunnel and activity occurring within the tunnel.

The types of activity that may occur within the tunnel were defined as baseline, active, and testing activities. Periods of baseline activity were when the effluent of the tunnel was not actively affected by operations within the tunnel. These operations include mining, coring, and any other activity associated with routine mine expansion and maintenance. Active periods were when the aforementioned operations were occurring, and when the potential existed for impacting the tunnel discharge, pH, EC, temperature, and/or turbidity. Testing periods were activities associated with the detonation of nuclear devices within the tunnels.

Announced underground nuclear detonations were not conducted in any of the tunnel complexes during the period of the study. U12e tunnel was closed during the period of the study and all samples from this tunnel were representative of baseline conditions. U12t tunnel was normally inactive except for Tuesdays when a reentry team would discharge full sumps into the main discharge line. The periods of increased discharge are representative of active periods within U12t tunnel, with the remainder of the time representative of baseline conditions. During the month of December 1991, miners reentered U12t tunnel and sealed a drift from which 90 percent of all flow was emanating. Samples before and after this time are not directly comparable, yet both are representative of slightly differing baseline conditions. U12n tunnel was active throughout the period of study. There were periods of stabilized discharge that were probably representative of baseline conditions. The dates, times, sample names, and tunnel conditions when the samples were collected are summarized in Table 7.

REAL TIME MONITORING RESULTS

A statistical summary of the temperature, discharge, pH, EC, and turbidity data from U12e, U12n, and U12t tunnels is presented in Table 8. Graphical representation of the data is presented in Figures 10 to 23. Data contained on the graphs that intersect the x axis were collected during periods of time when the data did not meet quality assurance objectives or instrumentation malfunctioned. These data were not incorporated into the statistical summaries. The data incorporated into the statistical summaries passed all quality assurance measures and are considered to be representative of tunnel conditions.

Temperature

The temperature data for U12e tunnel (Figure 10) comprised the most complete data set recorded during the project. The mean temperature was 13.85 ± 2.47 °C. U12e tunnel was closed during the period of monitoring for this project. Variances in the data were due to daily and annual environmental influences.

The mean temperature for U12n tunnel (Figure 11) was 14.18 ± 3.24 °C. Operationally, U12n tunnel was very active during the period of monitoring. The data record reflects variance due to environmental influence and mining activities. Daily variations were not as pronounced at U12n tunnel versus U12e tunnel. A possible explanation is the U12e tunnel drainage pipe may have been relatively more susceptible to environmental variations. The U12e tunnel drainage pipe sits on the top of a flat muckpile that is subject to a relatively greater exposure to environmental effects. In addition, the relatively smaller and slower flowing discharge in the U12e tunnel drainage pipe was more rapidly and effectively altered by environmental factors.

The mean temperature of the discharge from U12t tunnel (Figure 12) was 18.06 ± 2.71 °C. This mean temperature reflects two operational conditions within T tunnels. The first occurred from April 17, 1991 to December 11, 1991. This period was characterized by large flow emanating from the U12t extension drift. The effluent draining from this drift was plugged during mid-December 1991. The resultant lower discharge from the drift was cooler than the larger, previous flow. This is probably due to the relatively greater susceptibility of the smaller volumes to environmental effects. Daily variations were also much less during the high-flow period relative to the low-flow period. The mean temperature for the high-flow period was 20.10 ± 1.03 and the mean temperature for the low-flow period was 15.91 ± 2.23 (Table 9).

Another interesting trend can be seen in the temperature data during the high-flow period for U12t tunnel. Temperature during the period of mid-October 1991 did not appear to decrease by approximately one degree as occurred at U12n and U12e tunnels during the same period of time. Instead, the temperature appeared to remain stable. This trend may be due to the relative insensitivity of the large flows to environmental temperature variation.

Discharge

The mean discharge from U12e tunnel was 53.71 ± 7.80 l/min (Figure 13). Considerable variation occurred with the greatest variation from early December 1991 to early February 1992. The variability was not anticipated for a closed tunnel. Three calibrations were conducted just prior to and during this period of increased discharge and were within quality assurance standards. One possible explanation presents itself. The water running through the discharge line was colder and denser during this period than at any other time during monitoring. Temperature driven density differences were not accounted for when calculating the fluid moving through the flume.

Data completeness for discharge from U12e tunnel was only 68.7 percent of the amount of data intended to be collected. This was 11.3 percent short of the data completeness objective

for this parameter (Table 2). Table 10 contains statistical summaries of the raw data collected from U12e tunnel. These raw data have been edited for data collected during calibration and for data collected during instrument malfunction. The resulting data indicate a mean discharge of 69.91 ± 172.67 l/min. This value was useful as a comparison to the more accurate yet less complete mean discharge contained in Table 8. The large degree of variance in the raw data was due to episodes of instrument drift. The total amount of raw data was 99.9 percent of that which was anticipated to be collected. A 23 percent variation exists between the two estimates.

The nature of the discharge data taken from U12e tunnel appeared to change during early June 1992. The change in the data was due to a change in monitoring equipment. The original field monitoring probes used to determine stage within the flumes were Druck transducers. These transducers were prone to drift and required constant calibrations. The transducers were also affected by temperature driven density changes. An alternative method using Stevens floats and pulse generators for measuring stage in the flumes, was introduced at U12e and U12t tunnel. This instrumentation was less susceptible to temperature driven density changes and has proved reliable during long-term monitoring at other sites. Examination of both signals indicated that unexplained short-term variations were occurring in the discharge of U12e tunnel. The size of the variance is a factor of 0.2 of the mean.

The mean discharge from U12n tunnel was 127.61 ± 26.06 l/min (Figure 14). An even larger degree of variance was seen in the discharge of U12n tunnel relative to the variance in U12e tunnel discharge. This variation was probably due to mining activities. The variation was sometimes greater than three times the mean. In addition, a very slowly decreasing trend was seen in the discharge over the course of the year. This may have been indicative of either more mining activity in the tunnels during the early part of the study or the result of a steady decline in baseline discharge. The Stevens floats and pulse generators were not installed at U12n tunnel. This was done to provide complete data similarity between the characterization data and data collected by DRI, starting May 1992, in support of the Defense Nuclear Agency's efforts to obtain and comply with a State of Nevada Temporary Discharge Permit.

The mean discharge from U12t tunnel was 253.29 ± 142.27 l/min (Figure 15). Periodic increases in discharge were seen superimposed on the background trend. The periodic increases in discharge were due to weekly entries by REEC personnel into the tunnel to empty sumps that had been slowly filling up with water draining from isolated seeps. These sumps were not normally connected to the effluent drainage system. The discharge was increased by as much as 175 l/min during drainage. The discharge of U12t tunnel was drastically affected by plugging the U12t extension drift on December 11, 1992. The pre-plug flows averaged 336.74 ± 50.88 and the post-plug flows averaged 37.07 ± 51.59 l/min.

A large portion of data was lost due to problems during calibration and efforts to install smaller flumes capable of measuring the decreased flow following the plugging of the U12t extension drift. The raw data presented in Table 10 comprise a less accurate yet more complete data set. Data completeness for the mean discharge from Table 8 was 50.0 percent. The mean

value for the raw data from T tunnel was 254.93 ± 188.72 l/min and the data completeness was 74.8 percent (Table 10). The raw data set has a 0.06 percent variance from the calibrated and quality assured data set. The raw data set indicated that the discharge was relatively consistent for periods of time longer than that summarized in Table 8.

pH

The mean pH of the discharge from U12e tunnel was 8.47 ± 0.21 (Figure 16). The data exhibited an increase in pH from April 17, 1991 to January 3, 1992. pH measurements at the monitoring stations were temperature compensated. The reason for the increase in pH is unknown.

The mean pH of the discharge from U12n tunnel was 8.60 ± 0.92 (Figure 17). The record was fairly consistent except for some variance during mid to late July 1991, and from late December 1991 to early January 1992. The variation in pH of the discharge appeared to be periodic with a frequency of approximately 24 hours. The variance usually occurred during the night. There were two possible explanations for this; mining activities were periodically flushing acidic solutions into the discharge of U12n tunnel, or the voltage of the batteries powering the pH probe dropped to low levels. The variance is not thought to be representative of actual tunnel conditions.

The pH data summary for U12n tunnel given in Table 8 represents only 72 percent of the complete data set. The non-quality assured data set given in Table 9 has a mean pH of 8.61 ± 1.02 . This data set had 95.1 percent data completeness and was within 99.9 percent of the quality assured mean pH. Although the non-quality assured data set was less accurate, it was representative of a greater portion of the record.

The mean pH of the discharge from U12t tunnel was 7.64 ± 0.65 (Figure 18). The drop in discharge that occurred on December 10, 1991 had a significant effect on pH. The mean pH of the effluent, prior to the change in discharge, was 7.70 ± 0.24 . The mean pH of the effluent for two months following the drop in discharge was 6.51 ± 1.02 . The drop in discharge corresponded to an increase in pH followed by a drop of almost one pH unit. The reason for the temporary initial rise was unknown. Similarly, the temporary rise in pH that occurred during late November 1991 was also unknown. A possible explanation for the temporary drop in pH from mid-December 1991 to early February 1992 may be the partial exposure of the pH probes to the atmosphere during the decreased flow. Measurements from periods later than February 1992 appeared to have recovered to approximately original levels.

The quality assured data set was only 70 percent complete. The non-quality assured data summary for U12t tunnel pH was 93.2 percent complete. The mean value of this data set was 7.19 ± 1.19 ; although the accuracy of the data set was less, it represented a greater period of record than the quality assured data summary from Table 8.

The pH of the effluent from U12t tunnel appeared to be only marginally affected by the weekly increase in discharge created by draining the isolated sumps to the main discharge line.

Electrical Conductivity

The mean EC of the discharge from U12e tunnel was $333.69 \pm 23.28 \mu\text{S}$ (Figure 19). The majority of the signal appeared to be consistent except for the month of August 1991, mid-October, and November 1991. The August 1991 period was characterized by EC measurements that were as much as $80 \mu\text{S}$ less than the mean measurement. Field calibration prior to (July 25, 1991) and following the August low measurements (September 5, 1991) were within calibration objectives. The reason for the variation is unknown.

The mean EC of the discharge from U12n tunnel was $356.12 \pm 60.31 \mu\text{S}$ (Figure 20). The EC data from the U12n tunnel effluent was chiefly characterized by periodic increases in the conductivity of the fluid. Visual observations and turbidity measurements indicated the fluid was often affected by mining activities, causing fluctuations in EC as well as temperature and turbidity. The EC during periods of tunnel activity increased by a factor of seven or more.

The completeness of the quality assured data base for the EC of the discharge emanating from U12n tunnel was only 66.2 percent. The non-quality assured data summary for the EC from U12n tunnel was 99.8 percent complete. The mean value of the non-quality assured data set was $353.33 \pm 104.50 \mu\text{S}$. Although not as accurate as the data summary contained in Table 8, the non-quality assured data were more complete and were used to indicate fairly constant conditions for the majority of the study duration.

The mean EC of the discharge from U12t tunnel was $448.13 \pm 169.68 \mu\text{S}$ (Figure 21). The two major features of this data record were the changes in conductivity created by the weekly purging of the sumps and the December 1991 decrease in flow. The mean EC for the period of high flow, extending from April 17 to December 10, 1992 was $275.75 \pm 31.64 \mu\text{S}$. The mean EC for the period of low flow, extending from December 10, 1992 to July 28, 1992 was $610.31 \pm 26.13 \mu\text{S}$. It is obvious that the seeps supplying the sumps and currently draining from U12t tunnel contain larger amounts of dissolved solids than the groundwater draining from the U12t extension drift.

The quality assured data summary for the EC measured from the effluent draining from U12t tunnel and contained in Table 8 was only 70.9 percent complete. The mean value for the non-quality assured data summary for the EC measured at U12t tunnel was $432.35 \pm 168.78 \mu\text{S}$, which although less accurate, was constant over 92.2 percent of the record.

Turbidity

Turbidity was not monitored at U12e tunnel. The U12e tunnel was closed during the period of this study. Variations in turbidity were neither expected nor observed at the tunnel complex during the monitoring period. The turbidity of the complex was approximately that of U12t tunnel (2 to 5 NTU).

The mean turbidity of the discharge from U12n tunnel was $91.71 \pm 198.06 \text{ NTU}$ (Figure 22). The major element of this signal was the periodic increases of turbidity up to an order of

magnitude greater than that of the mean signal. The most probable cause for this increase was the large suspended solid load of the effluent draining from mining and coring operations conducted within the tunnel.

The length of the quality assured record summarized in Table 8 for the turbidity of the U12n tunnel effluent was only 44.5 percent complete. This was due to the relatively poor reliability of the turbidity meters in a remote locale. The non-quality assured record for the turbidity of the U12n tunnel is summarized in Table 10. The mean value was 131.14 ± 468.54 NTU. This value was representative of 65.8 percent of the record, although the accuracy of this estimate was less than the accuracy of the relevant estimate in Table 8.

The mean turbidity of the discharge from U12t tunnel was 2.27 ± 1.74 NTU (Figure 23). There were two relatively minor elements of this signal. The first element consisted of the increase in turbidity caused by the weekly discharging of the sumps into the discharge line. This action caused only a minor increase in the turbidity of the discharge. The second element consisted of an increase in turbidity due to the decrease in the overall flow of the effluent caused by plugging the U12t extension drift. The increase in turbidity was minor. The mean turbidity for the high-flow period of discharge was 1.52 ± 0.38 NTU. The mean turbidity for the low-flow period of discharge was 4.50 ± 2.21 NTU.

The completeness of this data record, 35.6 percent, was the poorest of the entire project. The limited data recovery was due to poor instrument reliability in the field and the drastic change in the quantity of effluent draining from U12t tunnel. A slightly larger record exists for the non-qualified data set. The mean value summarized in Table 10 was 34.06 ± 193.32 NTU. This data set, while representative of 54.3 percent of the record, was up to 15 times the mean value of the quality assured data.

Comparison to State Regulations

It was not the original intention of the authors to compare the data collected under this program to various regulatory standards. The primary reason for this was the lack of guidance from a regulatory agency such as the State of Nevada Department of Environmental Protection (DEP) or the EPA as to which standards were relevant and applicable. It was the authors' intent to conduct a characterization of the effluent that would be useful to any future remedial or regulatory actions regarding effluent draining from the tunnel complexes.

The opportunity to apply the data collected under this program to regulatory problems came sooner than suspected. A minor modification during January 1992 to the ponds containing the water draining from U12n tunnel caused the Nevada DEP to cite the Department of Energy and the Defense Nuclear Agency with modifying an existing treatment facility without permission from the state. Following negotiations, a temporary discharge permit was granted for the discharge from U12n tunnel. The data being collected by DRI for this project were included as a requirement for the temporary permit. On the back of the temporary permit was a copy of the State of Nevada's Drinking Water Standards. Although not cited in the permit, these

standards may have been included as an informal standard with which to compare the effluent. In light of this development, the relevant Drinking Water Standards for pH and turbidity are given in Table 11. None of the other Drinking Water Standards were monitored during the characterization period.

The results indicate that the Drinking Water Standard for pH is routinely surpassed at U12e and U12n tunnel and occasionally surpassed at U12t tunnel. The turbidity standard is routinely surpassed at both U12n and U12t tunnels.

GEOCHEMICAL RESULTS

Evaluation of Laboratories and Methods

The laboratories involved in the analyses of the samples were subjected to three types of quality assurance checks. These consisted of 1) control spikes used to assess the accuracy of the participating laboratory, 2) matrix spike and matrix spike duplicate analysis used to assess precision, and 3) field blanks used to determine if contaminants were being derived from the sample bottles and handling procedures. The analytical quality assurance objectives for accuracy and precision are given in Table 6. The completeness objectives for all of the geochemical parameters were 90 percent. The names of the laboratories used in this project, the types of analysis conducted and the contact for each laboratory are given in Table 12.

Control Spikes

Control spikes were samples prepared by Environmental Resource Associates of Arvada, Colorado, for the purpose of evaluating the analytical techniques of laboratories involved in the EPA's Contract Laboratory Program. Single blind control spikes (samples that contain unknown contaminants at unknown concentrations, yet whose identity as a control spike is readily discernible) were purchased for the purpose of evaluating the accuracy of the laboratories involved in the analysis of ionic and trace metals, volatile and semivolatile organics, and polychlorinated biphenyls (PCBs). Radionuclide control spikes were not submitted to the appropriate analytical laboratory owing to the difficulty in procuring this type of quality control sample.

Two sets of control spikes were submitted to each laboratory. The results of the trace metal, ionic, volatile organic, semivolatile organic, and PCB control spikes are presented in Table 13. The accuracy for each analytical procedure as determined by dividing the analytical laboratory's estimated concentration by the reported value from the supplier of the control spike and converting this value to a percentage. Accuracy values in excess of 100 percent were normalized to percentage values of less than 100 percent for the purpose of statistical summaries. If the analytical laboratory did not detect an analyte that was present in the control spike, then a 0 percent accuracy value was assigned for that analysis, even if the presence of the contaminant was below the detection limit used by the laboratory. If the analytical laboratory detected a contaminant that was not present in the control spike, then the accuracy value was 0 percent. If

an analyte was not present in the control spike and not detected by the analytical laboratory, then an accuracy value of 100 percent was assigned to the analysis. If the analysis detected an analyte that was present in the control spike, yet determined its concentration to be less than one-half of the actual control spike concentration, then a negative accuracy value was reported. Accuracy estimates in Table 13 are expressed in such a way that 100 percent accuracy is perfect accuracy. However, accuracy objectives in Table 6 are normalized to 0, where perfect accuracy is ≥ 0 percent. Further discussions are based upon normalization of the accuracy estimates determined from the study and the accuracy objectives in Table 6. The estimates are normalized by subtracting the accuracy estimate in Table 6 from the value of 100.

A comparison of the normalized values from Tables 13 and Table 6 indicates that only the analyses for cobalt, copper, silver, and potassium achieved the accuracy objectives for both control spikes. The analysis for cadmium, lead, mercury, nickel, zinc, and sodium achieved the accuracy objective for at least one of the control spikes. The remaining parameters did not achieve the accuracy objectives for either of the control spikes. The accuracy objectives stated in Table 6 were the most precise that EPA could achieve through all of its method evaluation experiments. A histogram of the accuracy achieved for trace metal and cation analysis is presented in Figure 24. The mean accuracy value for the trace metals and cations was 95.55 ± 4.79 percent. All analyses, except one, that of mercury, achieved an accuracy of greater than 80 percent, which is the minimum acceptable accuracy objective for this study. For this reason, the accuracy of the trace metals and cation analysis was acceptable for this project.

A comparison of Table 13 and Table 6 indicates that, for the volatile organic analysis, all parameters achieved an accuracy greater than 82 percent, except for one of the analyses of Acetone, 1,1-Dichloroethene, 1,1-Dichloroethane, 1,2-Dichloroethene (total), 2-Butanone, cis-1,3-Dichloropropene, Xylene (total), 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, and 1,4-Dichlorobenzene. The 82 percent accuracy objective was the lowest accuracy accepted by the EPA during method evaluation. It should be noted that the February 28, 1992 control spike was actually analyzed by Sierra Technical Services, a contract laboratory for REECO's Analytical Services Laboratory. A histogram of the accuracy achieved for volatile organic analysis is presented in Figure 25. The mean accuracy achieved during volatile organic analysis was 84.33 ± 36.91 percent. The only negative accuracy was one determined for 1,4-Dichlorobenzene. Analysis of all volatile organics appears to be acceptable in terms of accuracy except for those parameters previously listed.

A comparison of Table 13 and Table 6 indicates that at least one of the analyses for the two base/neutral and acid semivolatile organic control spikes achieved the minimum accuracy objective of 20 percent, except for the analyses of Phenol and Pentachlorophenol. Neither of the analyses for Phenol and Pentachlorophenol achieved the 20 percent accuracy objective. In addition, only one of the analyses for 1,3-Dichlorobenzene, 1,2-Dichlorobenzene, Hexachloroethane, Isophorone, 1,2,4-Trichlorobenzene, 2,4,6-Trichlorophenol, 2,4,5-Trichlorophenol, 2,4-Dinitrophenol, Benzo (a) anthracene, Chrysene, and 4-Hydroxy-4-Methylpentenone achieved the 20 percent accuracy objective. The 20 percent

accuracy objective was the lowest accuracy accepted by the EPA during method evaluation of base/neutral semivolatile organic analyses. As previously stated, the 20 percent accuracy objective was determined by subtracting the 80 percent value reported in Table 6 for this analysis from the value of 100. The 20 percent accuracy objective was arbitrarily chosen for the acid semivolatile analysis, as no accuracy standards have been identified for these analyses. A histogram of the accuracy achieved during semivolatile organic analysis is presented in Figure 26. The mean accuracy achieved during semivolatile organic analysis was 79.54 ± 49.27 percent. The seven negative accuracy values presented in Figure 26 consist of Phenol, 1,3-Dichlorobenzene, 1,2-Dichlorobenzene, Hexachloroethane, 1,2,4-Trichlorobenzene, 2,4,6-Trichlorophenol, and Pentachlorophenol. Analysis of all semivolatile organics appears to be acceptable in terms of accuracy except for those of the previously listed parameters.

A comparison of Table 13 and Table 6 indicates that all of the analysis for the PCBs, with the exception of Aroclor-1260, achieved the accuracy objective of 66 percent. The 66 percent accuracy objective was the lowest accuracy accepted by the EPA during method evaluation. The mean accuracy achieved during PCB analyses was 96.78 ± 10.74 percent. Analysis of all of the PCBs, except for Aroclor-1260, appears to be acceptable in terms of accuracy.

Precision

The precision of the laboratories analyzing the organic constituents was evaluated through the use of matrix spikes and matrix spike duplicates. The original purpose of matrix spikes and matrix spike duplicates was to determine if geochemical constituents within the samples would mask or interfere with the analyses for volatile organics, semivolatile organics, and PCBs. Interference or masking of potential contaminants did not appear to be a problem with samples derived from the tunnel effluent. A second use for matrix spike and matrix spike duplicates was as duplicate samples for evaluation of analytical precision. The matrix spike and matrix spike duplicate are acquired from one sample point at almost identical times. The water within the samples are essentially duplicate samples that can be compared to each other for estimates of precision. The radiological, trace metal, and cation analysis did not have the duplicate samples required for precision evaluation.

Precision was determined by calculating the ratio of the matrix spike versus the matrix spike duplicate, normalizing the estimate to less or equal to one, summing all of the ratios and determining a mean and standard deviation for each analytical method. Analytes which were undetected in both the matrix spike and matrix spike duplicate were assigned a precision of 100. Detection of an analyte in one sample, but not the other, was assigned a precision value of zero. Table 14 presents the mean and standard deviation precision estimate for each method.

The precision objectives for volatile organic analyses were estimated to range from ± 16 –65 percent by the EPA (Table 6). Analytical precision results from this project ranged from 0 to 100 percent (with perfect precision 100 percent; however, in Table 6, perfect precision was ± 0 percent). The precision estimates and objectives were normalized by taking the precision estimates from Table 14, dividing by 100, subtracting from one, and multiplying by 100 to be

compatible with the plus or minus precision estimates stated in Table 6. The volatile organic analytes that exceeded the precision objectives at least once were chloromethane, bromomethane, vinyl chloride, methylene chloride, acetone, and 1,2-dichloroethane. None of the mean precision estimates for any of these volatile organics exceeded the precision objectives. Precision for the analyses of volatile organics were acceptable for the purpose of this report.

The precision objective for base/neutral semivolatile organic analysis ranged from ± 13 –105 percent (Table 6). Acid semivolatile organic precision estimates were not developed for that class of compound. Analytical precision results from this project ranged from ± 0 –100 percent. None of the mean precision estimates exceeded the precision objectives, although several analyses of bis (2-Ethylhexyl)phthalate came close. For the purpose of this report, all semivolatile analyses were acceptable in terms of precision.

The precision objective for PCBs ranged from ± 21 –79 percent (Table 6). Analytical precision results were ± 0 percent. None of the PCB analysis exceeded precision objectives.

Field Blanks

Field blanks consisted of reagent grade water (high pressure liquid chromatography water) that was transported to the field, bottled, and sent to the laboratory for analysis. Positive results indicate a potential contaminant problem with the bottles and/or the analytical process. A statistical summary of the field blank results are presented in Table 15. The results will be used to evaluate the validity of samples where analyses indicated the presence, in the effluent, of specific analytes.

Completeness

Completeness for geochemical parameters was calculated by determining the ratio of the actual number of analyses received by the total number of analyses planned prior to sampling. The results for data completeness are given in Table 16. The only parameter that did not achieve the data completeness objective of 90 percent was the radionuclide analyses for U12n tunnel. This parameter was only 0.4 percent below the objective. The majority of the geochemical parameters met or exceeded the completeness objectives of this study.

Gross Ionic Chemistry

Few of the dissolved ionic species are subject to regulatory standards, however, a close examination of the data can reveal information as to the geochemical similarity of the effluent over time.

The major ionic chemistry and specific anions sampled from U12e tunnel effluent are summarized in Table 17. The concentrations of the major anions and cations (Na, K, Ca, Mg, HCO_3 , CO_3 , SO_4 , and Cl) were calculated into relative percentages and plotted on Figure 27. This type of plot is called a trilinear or Piper diagram. The purpose of the plot is to determine if the concentrations of the major cations and anions are changing over time. Changes in relative

concentrations are indicated by the sample points plotting in different locations on the plot. All of the U12e tunnel samples plot on the same location on the piper diagram. This indicates that the geochemical processes affecting the water in U12e tunnel remained relatively constant throughout the period of the study. It is also indicative of water from different sources (affected by different chemical processes) not being detected in the effluent.

Only a few of the major ions are included in the regulatory standard that was deemed appropriate for the tunnel effluent by the Nevada DEP. The standards are presented in Table 18. A comparison of Table 17 and Table 18 indicates that none of the major ionic species and specific anions sampled from the U12e tunnel effluent surpassed the regulatory standards.

A comparison of the mean pH for U12e tunnel derived from continuous monitoring (Table 8) and from the geochemical samples (Table 17) reveals only a 1.3 percent discrepancy. A comparison of the mean EC for U12e tunnel derived from continuous monitoring (Table 8) and from the geochemical samples (Table 17) reveals only a 4.5 percent discrepancy. These comparisons are an independent verification of the field monitoring and analytical techniques used during this project.

A statistical summary of the major ionic chemistry and specific anions sampled from the U12n tunnel effluent is presented in Table 19. The trilinear diagram for the U12n tunnel effluent data is presented in Figure 28. The major ionic chemistry exhibited considerable variation with respect to carbonate concentrations and smaller variations in sulfate and chloride concentrations. The variation may be due to increases of bicarbonate and/or carbonate originating from grouting operations or the introduction of water in the tunnel that originated from outside sources. Typical mining and grouting operations utilize larger amounts of water than what the tunnels are capable of supplying. Water originating from nearby wells are used in conjunction with water draining from tunnel seeps during periods of construction.

The ionic chemistry data can be categorized into activity-affected and nonactivity-affected samples. A nonactivity-affected sample is one where the temperature, pH, discharge, EC, and turbidity were within one standard deviation of the mean. These samples were interpreted to represent water samples that consist primarily of water emanating from seeps within the tunnel. Activity-affected samples were those collected when pH, temperature, EC, discharge, or turbidity were greater than one standard deviation from the mean value. These samples were interpreted to represent effluent that is actively being affected by construction or the introduction of water originating from nearby wells. Figure 29 is a trilinear diagram of nonaffected-samples from U12n tunnel. Figure 30 is a trilinear diagram of affected-samples from U12n tunnel. Although there is some overlap of the two types of samples, it is clear that the nonaffected-samples exhibited less variation and were probably more representative of actual tunnel conditions.

A comparison of Table 18 and Table 19 indicates that for the period of sampling, only pH exceeded the State of Nevada Drinking Water Standards. A plot of the pH versus time is on Figure 31. The plot indicates that pH exceeded the state standard during the majority of the time.

A comparison of the mean pH for U12n tunnel derived from continuous monitoring (Table 8) and from the geochemical samples (Table 19) revealed only a 0.5 percent discrepancy. Similarly, a comparison of the mean EC for U12n tunnel derived from continuous monitoring (Table 8) and from the geochemical samples (Table 19) revealed only a 1.3 percent discrepancy.

A statistical summary of the major ionic chemistry and specific anions sampled from the U12t tunnel effluent is presented in Table 20. The trilinear diagram for the U12t tunnel effluent data is presented in Figure 32. Variation can be seen in the geochemical signature of the effluent. Two additional piper diagrams (Figure 33 and Figure 34) have been used to divide the samples into two sets, one that represents the high-flow conditions of April 17, 1991 to December 10, 1991 and the second set that represents low-flow conditions from December 11, 1991 to July 28, 1992. Figure 33, which represents high-flow conditions, exhibits a small degree of variation within the 14 samples comprising the data base. The two samples plotted on Figure 34 have significantly higher levels of sodium and potassium and lesser amounts of bicarbonate relative to the low-flow samples. The two samples in Figure 34 represent the current conditions within U12t tunnel.

A comparison of Table 18 and Table 20 indicates that none of the ionic species exceeded the State of Nevada Drinking Water Standards.

A comparison of the mean pH for U12t tunnel derived from continuous monitoring (Table 8) and from the geochemical samples (Table 20) revealed only a 3.2 percent discrepancy. Similarly, a comparison of the mean EC for U12t tunnel derived from continuous monitoring (Table 8) and from the geochemical samples (Table 20) revealed a 40.3 percent discrepancy. The large variation of EC between the two estimates was probably due to the timing of when the majority of samples were taken. The majority of the geochemical samples (14 out of 16) were acquired during high-flow conditions when EC averaged approximately 275 μ s (Table 9). The majority of the continuously monitored EC were acquired during the period of low flow when EC averaged approximately 610 μ s (Table 9).

Metals

The trace metals sampled in the U12e tunnel effluent are summarized in Table 21. Overall, the trace element concentrations were very low. The only element that exceeded the State of Nevada Drinking Water Standards for metals (Table 22) was iron (Figure 35). The maximum detectable limits for iron concentrations stated in the Safe Drinking Water Act are based on aesthetic qualities of the water (taste, color, and odor) rather than health effects. The mean iron concentration of U12e tunnel effluent was 0.59 ± 0.21 mg/l. The variation in the concentration over time covered a four-fold range. The variations were not explainable.

The trace metals sampled in the U12n tunnel effluent are summarized in Table 23. The trace element concentrations within the effluent were very low, with none of the elements exceeding State of Nevada Drinking Water Standards at any time.

The trace metals sampled in the U12t tunnel effluent are summarized in Table 24. The trace element concentrations were very low, with none of the elements exceeding State of Nevada Drinking Water Standards at any time.

Volatile Organics

The results of the volatile organic analyses sampled from U12e tunnel effluent are presented in Table 25. A number of volatile organic parameters were detected at least once in samples acquired from the effluent. These parameters include chloromethane, bromomethane, vinyl chloride, chloroethane, methylene chloride, acetone, 1,1-dichloroethene, 1,2-dichloroethene (total) and xylene (total). Only once was there a concentration of an organic chemical (methylene chloride) within the effluent greater than the detection limits of the analytical methods. This means that the majority of all of the reported concentrations in Table 25 are qualitative estimates only. A second point is that only the volatile organics chloromethane, bromomethane, vinyl chloride, and methylene chloride were found within effluent samples in greater numbers than their associated laboratory blanks. The temporal variability of all volatile organics detected one or more times in U12e effluent is presented in Appendix 3A.

The results of the volatile organic analyses of samples from U12n tunnel effluent are presented in Table 26. A number of volatile organic parameters were detected at least once in samples acquired from the effluent. These parameters include chloromethane, bromomethane, vinyl chloride, chloroethane, methylene chloride, acetone, 1,1-dichloroethene, 1,2-dichloroethene (total), 2-butanone, 1,1,1-trichloroethane, 4-methyl-2-pentanone, tetrachloroethene, and m,p-xylene. All of these volatile organics, except for 1,1-dichloroethene, were found within effluent samples in greater numbers than their associated laboratory blanks. The temporal variability of all volatile organics detected one or more times in the U12n effluent is presented and discussed in Appendix 3B.

The results of the volatile organic analyses of samples from U12t tunnel effluent are presented in Table 27. A number of volatile organic parameters were detected at least once in samples acquired from the effluent. These parameters include chloromethane, bromomethane, vinyl chloride, chloroethane, methylene chloride, acetone, 1,1-dichloroethene, 1,2-dichloroethene (total), 2-butanone, 1,1,1-trichloroethane, benzene, and m,p-xylene. All of these volatile organic chemicals, except for 1,2-dichloroethene (total), were found within effluent samples in greater numbers than their associated laboratory blanks. The temporal variability of all volatile organics detected one or more times in the U12n effluent is presented in Appendix 3C.

The majority of the volatile organic analyses presented in Tables 25, 26, and 27 were not detected or did not exceed the the concentration of the associated laboratory and field blanks. Those analyses whose concentration exceeded the associated blanks are discussed in Appendix 3A, 3B, and 3C. Of those analytes discussed in the appendices, only seven exceeded the detection limit of the associated method. The analyte, dates on which detection limit was exceeded, concentration, and tunnel from which it was discharged are listed in Table 28. The sample

analyses for the three chemicals were generally acceptable except for the January 13, 1992 occurrences of methylene chloride in U12n and U12e tunnel effluent. Recoveries of several internal standards used to calibrate the laboratory equipment did not meet EPA standards on the day those sample were analyzed. All analyses made during that run are to be considered quantitative estimates only. In addition, volatile organic analysis matrix spikes and matrix spike duplicate samples from U12n tunnel, also taken on January 13, 1992, did not exceed detection limits of the method, even though the two samples were virtually identical to the regular sample reported in Table 28.

The opinion of the authors is that it is questionable whether or not the analytes presented in Table 28 were present in the various tunnel effluents on the noted dates. If they were, sources for the volatile organics are quite common. Acetone is a common solvent for fats, oils, waxes, resins, rubber, plastics, lacquers, varnishes, and rubber cements. 2-butanone, also known as methyl ethyl ketone, is a fairly common solvent. Methylene chloride is a common degreasing and cleaning solvent and concentrations detected at or below the detection limit within the effluent may actually be due to the analytical method. EPA does not consider the detection of up to 50 µg/L in samples to be a problem for common laboratory solvents such as methylene chloride (REECo analyst's notes for VOA sample No. 74970, 14263, and 17115, May 25, 1992).

It is important to note that the concentration levels of the volatile organics found in the tunnel effluent are very low and are discontinuous, indicating a sporadic and dilute source. The samples containing various chemicals detected in U12n tunnel effluent (Table 28) were analyzed in terms of whether the tunnel was active or if just baseline flows were occurring. The results indicated that none of the detected volatile organic parameters were consistently detected during baseline or active flow. Detections occurred sporadically, pointing to either isolated occurrences of the volatile organic parameters being injected into the water, or sporadic occurrences of laboratory contamination. A similar analysis of the detected parameters in the U12t tunnel effluent was conducted in terms of the high-flow versus low-flow periods. All of the detected parameters occurred during the high-flow period. This may be an indication that volatile organics detected in the U12t tunnel effluent may have been emanating from the U12t extension drift. However, if one looks at the relative number of samples taken during each period, (2 samples for low flow and 14 samples for high flow) it seems intuitively obvious that any detections would be biased toward the high-flow period, even if the detections were due to random laboratory contamination.

Semivolatile Organics

The results of the semivolatile organic analyses of samples from U12e tunnel effluent are presented in Table 29. Five semivolatile organic parameters were detected at least once in samples acquired from the effluent. These parameters include N-Nitroso-Di-n-propylamine, Di-n-butylphthalate, butylbenzylphthalate, bis (2-ethylhexyl) phthalate and, Di-n-octylphthalate. The temporal variability of all semivolatile organics detected one or more times in U12e effluent is presented in Appendix 4A.

The results of the semivolatile organic analyses of samples from U12n tunnel effluent are presented in Table 30. Five semivolatile organic parameters were detected at least once in samples acquired from the effluent. These parameters include N-Nitroso-Di-n-propylamine, Di-n-butylphthalate, butylbenzylphthalate, bis (2-ethylhexyl) phthalate and, Di-n-octylphthalate. The temporal variability of all semivolatile organics detected one or more times in U12n effluent is presented in Appendix 4B.

The results of the semivolatile organic analyses of samples from U12t tunnel effluent are presented in Table 31. Four semivolatile organic parameters were detected at least once in samples acquired from the effluent. These parameters include N-Nitroso-Di-n-propylamine, Di-n-butylphthalate, butylbenzylphthalate, and bis (2-ethylhexyl) phthalate. The temporal variability of all semivolatile organics detected one or more times in U12t effluent is presented in Appendix 4C.

The majority of the semivolatile organic analyses presented Tables 29, 30, and 31 did not exceed the the concentration of the associated laboratory and field blanks. Those analyses whose concentration exceeded the associated blanks are presented and discussed in Appendices 4A, 4B, and 4C. Of those analytes, only three exceeded the detection limit of the associated method. The analyte, dates on which detection limit was exceeded, concentration, and tunnel from which it was discharged are listed in Table 32. The sample analyses for the two chemicals were plagued with problems. The June 23, 1991 analysis of N-nitroso-di-n-propylamine had its hold times exceeded. The U12n samples of bis (2-ethylhexyl) phthalate taken on July 8, 1991, January 13, May 12, and June 9, 1992 either had the hold times exceeded or problems with surrogate recoveries. The August 5, 1991 bis (2-ethylhexyl) phthalate sample from U12t tunnel also had problems associated with surrogate recovery. The aforementioned samples should be considered qualitative estimates only.

In addition, the matrix spike and matrix spike duplicate results for bis (2-ethylhexyl) phthalate exhibit considerable variation (Table 33). The variation in the duplicate samples indicates a low level of precision and accuracy for this analysis. The stated accuracy for bis (2-ethylhexyl) phthalate ranged from 90.8 to 98.7 percent (Table 13). The precision for this analysis averaged 48 percent.

It is important to note that the concentration levels of the semivolatile organics found in the tunnel effluent were low and discontinuous, indicating a sporadic and dilute source. The various chemicals detected in U12n tunnel effluent (Table 32) were analyzed in terms of whether the tunnel was active or if just baseline flows were occurring. The results indicated that none of the detected semivolatile organic parameters were consistently detected during baseline or active flow. Detections occurred sporadically, pointing to either isolated occurrences of the volatile organic parameters being injected into the water or sporadic occurrences of laboratory contamination. A similar analysis for the parameters in U12t tunnel was conducted in terms of the high-flow versus low-flow periods. All of the detected parameters occurred during the high-flow period. This may be an indication that volatile organics detected in the U12t tunnel

effluent may have been emanating from the U12t extension drift. However, if one looks at the relative number of samples taken during each period, (2 samples for low flow and 14 samples for high-flow) most random detections would occur during the high-flow period due to the greater number of associated samples.

The analyte bis (2-Ethylhexyl) phthalate was considered to be present in the U12n tunnel effluent on the noted dates, with the exception of those dates on which analyses were indicated to be qualitative in nature. Bis (2-ethylhexyl) phthalate is used as a plasticizer and in vacuum pumps. N-nitroso-di-n-propylamine is listed by Montgomery and Welkom (1989) as a research chemical. If actually present, the concentrations and occurrence of bis (2-Ethylhexyl) phthalate are low and sporadic.

Unknown Semivolatiles

Anomalous spikes were often detected during the semivolatile analyses. The anomalous spikes were the results of semivolatile organic chemicals being detected by the gas chromatograph mass spectrometer used during analyses. The identities of these semivolatile organics were usually unknown, as the required calibration standards for these particular chemicals were not included in the analytical method (8240). As such, the concentrations were quantitative estimates. Additional work, which was beyond the scope of this project, would have been required to identify these chemicals.

Table 34 is a list of unknown semivolatile organics detected in the U12e tunnel effluent. Each chemical is identified by a retention time. The retention time is the number of minutes the chemical requires to travel through the column of the gas chromatograph. The retention time is fairly consistent for a specific chemical, however, some variability can be expected. For this reason, parameters that are detected more than once were given a range in retention times. The range in retention times was arbitrarily chosen. A given range may actually consist of one or more chemicals.

The temporal variability of the unknown semivolatile parameters detected in the discharge emanating from the U12e tunnel portal is presented in Appendix 4D. Table 35 lists the retention times, dates, and concentrations of those parameters that were present in concentrations greater than their associated blanks. If an unknown semivolatile organic exceeds the concentration of its associated laboratory and field blanks, it is considered to be present in the effluent on the day it was detected. However, the infrequent detection of these parameters, and the qualitative nature of the analysis does not lend a substantial amount of reliability to the analyses.

The temporal variability of the unknown semivolatile parameters detected in the discharge emanating from the U12n tunnel portal is presented in Appendix 4E and Table 36. Table 37 lists the retention times, dates, and concentrations of those parameters that were present in concentrations greater than their associated blanks.

The temporal variability of the unknown semivolatile parameters detected in the discharge emanating from the U12t tunnel portal is presented in Appendix 4F and Table 38. Table 39 lists

the retention times, dates, and concentrations of those parameters that were present in concentrations greater than their associated blanks.

The analyses presented in Tables 35, 37, and 39 consist of retention times, dates, and concentrations of unknown semivolatile organic species that exceeded their associated laboratory and field blanks. The results shown on this table rarely exceed concentrations of greater than 50 µg/L or exceeded associated laboratory blanks by more than 40 µg/l. The uncertainty associated with the analyses, the lack of standards with which to identify the compounds, the relatively low concentrations and/or small separation between the sample and associated blanks, and their sporadic occurrence create a great deal of uncertainty with these analyses. If these chemicals are present in the tunnel effluent, they occur sporadically and in low concentrations.

The unknown semivolatile organics detected in the U12n tunnel effluent (Table 39) were analyzed in terms of whether the tunnel was active or if just baseline flows were occurring. The results indicated that none of the unknown semivolatile organic parameters were consistently detected during baseline or active flow. A similar analysis for the parameters in U12t tunnel was conducted in terms of the high-flow versus low-flow periods. The unknown semivolatile organics were detected primarily during the period of high flow, when the majority of the samples were taken. There is no evidence that the type of activity occurring in either U12n or U12t tunnel had affected the concentration or occurrence of unknown semivolatile organics within the effluent streams.

Polychlorinated Biphenyls

Sixteen samples from U12t tunnel, 15 samples from U12e tunnel, and 27 samples from U12n tunnel were collected during the period of June 17, 1991 to May 12, 1992, for analysis for PCBs. Analytes consisted of Aroclor-1016; Aroclor-1221; Aroclor-1232; Aroclor-1242; Aroclor-1248; Aroclor-1254; and Aroclor-1260. At no time were these analytes detected in any of the tunnel effluent streams. Detection limits for analytes were 0.065 µg/l.

Tritium and Ionizing Radiation

The temporal variability of tritium concentrations and levels of ionizing radiation in U12e tunnel effluent are summarized in Table 40 and graphically displayed in Appendix 5A. Tritium concentrations remained fairly constant throughout the monitoring period at levels of approximately 2.00×10^{-3} µC/ml or 6.25×10^5 tritium units. Federal and State drinking water regulations allow for only 2.00×10^{-5} µC/ml for drinking water. Concentrations in U12e tunnel effluent exceed this by over a factor of 100. The results of a June 12, 1986 grab sample by REECO showed tritium concentrations in the U12e tunnel effluent to be 2.42×10^{-3} µC/ml, a slightly greater concentration than that detected during this study (Appendix 6).

Gamma radiation varied by no more than a factor of two during the period of characterization and averaged 1.62×10^{-7} µC/ml. Detected concentrations were typically no more than 1.5×10^{-7} µC/ml. The levels of gamma radiation were very small and were below detection during the June 12, 1986 sampling.

Gross alpha radiation varied by no more than a factor of two during the period of characterization and averaged 2.44×10^{-8} $\mu\text{C}/\text{ml}$. Detected concentrations were typically no more than 2.0×10^{-8} $\mu\text{C}/\text{ml}$. The levels of gross alpha radiation were very small. Gross alpha levels were 4.6×10^{-8} $\mu\text{C}/\text{ml}$ during the June 12, 1986 sampling (Appendix 6). This level is slightly greater than that detected during this study.

Gross beta radiation varied by almost an order of magnitude during the period of characterization, averaging 7.03×10^{-8} $\mu\text{C}/\text{ml}$. Detected concentrations were as much as 1.1×10^{-7} $\mu\text{C}/\text{ml}$. Although the variability is considerable, the levels of gross beta radiation remain quite small. Gross beta levels were 2.82×10^{-7} $\mu\text{C}/\text{ml}$ during the June 12, 1986 sampling (Appendix 6). This level was over a factor of two greater than that detected during the characterization period.

The temporal variability of tritium concentrations and levels of ionizing radiation in U12n tunnel effluent are summarized in Table 41 and presented in Appendix 5B. Tritium concentrations were relatively constant during the monitoring period with a mean concentration of 3.12×10^{-4} $\mu\text{C}/\text{ml}$ or 97,500 tritium units. Concentrations of tritium exceeded federal and state Safe Drinking Water Standards for the majority of the U12n tunnel samples. The results of the June 12, 1986 grab sample showed tritium concentrations in the U12n tunnel effluent to be 7.83×10^{-4} $\mu\text{C}/\text{ml}$ (Appendix 6). This concentration was approximately two times the level of tritium detected during this study.

Gamma radiation was usually not detectable in the U12n tunnel effluent. The mean level was 1.76×10^{-7} $\mu\text{C}/\text{ml}$. The lower limit of uncertainty associated with each of the analyses never exceeded the detection limit of the analyses. Gamma radiation was below detection during the June 12, 1986 sampling (Appendix 6).

Levels of gross alpha radiation average 2.79×10^{-8} $\mu\text{C}/\text{ml}$ within the U12n tunnel effluent. The levels were fairly constant except for two periods (Appendix 5B, Figure 131), during which an increase of an order of magnitude was observed. Gross alpha levels were 1.4×10^{-7} $\mu\text{C}/\text{ml}$ during the June 12, 1986 sampling (Appendix 6). This level is almost an order of magnitude greater than that detected during the characterization period.

Levels of gross beta radiation average 3.31×10^{-8} $\mu\text{C}/\text{ml}$ within the U12n tunnel effluent. The levels were fairly constant except for three periods (Appendix 5B, Figure 132), during which temporary increases of up to an order of magnitude were detected. Gross beta levels were 4.20×10^{-7} $\mu\text{C}/\text{ml}$ during the June 12, 1986 sampling (Appendix 6). This level is almost an order of magnitude greater than that detected during the characterization period.

The temporal variability of tritium concentrations and levels of ionizing radiation in U12t tunnel effluent are summarized in Table 42 and graphically displayed in Appendix 5C. Tritium concentrations remained fairly constant throughout the monitoring period, averaging 6.46×10^{-3} $\mu\text{C}/\text{ml}$ or 2.01×10^6 tritium units. Tritium concentrations increased by a factor of 5 following the decrease in T tunnel discharge. The final concentrations were 3.76×10^{-2} $\mu\text{C}/\text{ml}$.

Federal and State drinking water acts allow only 2.00×10^{-5} $\mu\text{C}/\text{ml}$ for drinking water. Final concentrations in U12t tunnel effluent exceed this by over a factor of 1800 times. The results of the June 12, 1986 grab sample showed tritium concentrations in the U12t tunnel effluent to be 2.61×10^{-1} $\mu\text{C}/\text{ml}$ (Appendix 6). This concentration is approximately an order of magnitude greater than the tritium concentrations emanating from U12t tunnel at the end of this study.

Gamma radiation varied by no more than a factor of two during the period of characterization and averaged 1.43×10^{-7} $\mu\text{C}/\text{ml}$. Detected concentrations were typically no more than 3×10^{-7} $\mu\text{C}/\text{ml}$. Gamma spectral analysis conducted on June 12, 1986 indicated the presence of I-131 (9.71×10^{-4} $\mu\text{C}/\text{ml}$), Rh-106 (5.53×10^{-5} $\mu\text{C}/\text{ml}$), Ru-103 (4.01×10^{-4} $\mu\text{C}/\text{ml}$), and Sb-124 (1.79×10^{-5} $\mu\text{C}/\text{ml}$) (Appendix 6). Although the gamma spectra were not used for this report, the total gamma count for the June 1986 analysis was greater than that during the characterization period by over three orders of magnitude.

Levels of gross alpha radiation averaged 1.10×10^{-8} $\mu\text{C}/\text{ml}$ within the U12n tunnel effluent. The levels were fairly constant except for one period (Appendix 5C, Figure 135), during which an increase of a factor of five was observed. Gross alpha levels were less than 1.4×10^{-7} $\mu\text{C}/\text{ml}$ during the June 12, 1986 sampling (Appendix 6). This level was greater than the levels reported during the characterization period.

Gross beta radiation varied by almost an order of magnitude during the period of characterization, and averaged 3.22×10^{-7} $\mu\text{C}/\text{ml}$. Detected concentrations have been as much as 1.41×10^{-6} $\mu\text{C}/\text{ml}$. The highest levels were encountered after the discharge in U12t tunnel was reduced. The higher levels of beta radiation following the decrease in discharge may be considered an environmental problem. Gross beta levels were 1.54×10^{-3} $\mu\text{C}/\text{ml}$ during the June 12, 1986 sampling (Appendix 6). This level is almost three orders of magnitude greater than that detected during the end of the characterization period.

Tritium is the primary radionuclide of concern in the discharge from all three tunnel complexes, with beta radioactivity in the U12t tunnel discharge a potential additional concern. A comparison of Tables 40, 41, 42 and a data summary of historical records in Appendix 6 and 7 reveal that radiological measurements collected during the characterization period are equal to or less than that of previous samples acquired up to 27 years prior.

DISCUSSION/CONCLUSIONS

The results of the intensive geochemical characterization of the tunnel effluent discharging from U12n, U12e, and U12t tunnels revealed that tritium was the only hazardous material present in all of the tunnel effluents. Concentrations of tritium averaged from 15 to 1800 times that of federal and state standards. A second, potential problem was the concentration of gross beta levels in the U12t tunnel effluent. Detected concentrations have been as much as 1.41×10^{-6} $\mu\text{C}/\text{ml}$ in the U12t tunnel effluent. Minute concentrations of volatile organic and semivolatile organic species were detected in the various effluent streams, however, the extremely small

quantities, sporadic occurrences, and association of these chemicals with those used in analytical laboratories suggest that they may be false positives. This may not be the case with concentrations of bis (2-Ethylhexyl) phthalate in U12n tunnel effluent (Appendix 4B, Figure 77). Bis (2-Ethylhexyl) phthalate was detected 11 times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 18, 21, July 5, 8, 11, August 19, September 9, 1991, January 13, February 28, May 12, and June 9, 1992. The detected concentrations were 24, 60, 10, 21, 42, 3, 3, 32, 16, 11, and 310 $\mu\text{g/l}$, respectively. The concentrations detected on June 18, 21, July 8, 11, 1991, January 13, February 28, May 12, and June 9, 1992 exceeded the detection limit of the method. Bis (2-Ethylhexyl) phthalate is the only organic chemical found routinely in any of the tunnel effluents in concentrations greater than that of the detection limits and associated field and laboratory blanks. If bis (2-Ethylhexyl) phthalate is actually present, the concentrations are low and occurrences sporadic.

RECOMMENDATIONS

The presence of tritium in tunnel effluent streams presents a difficult challenge in terms of remediation. Two possible courses of action present themselves. The first is the use of evaporation ponds to volatilize the tritium to the atmosphere. Volatilization can be accomplished through the use of solar energy and/or fossil fuel heaters. Such ponds typically contain double liners and are monitored for leaks. The ponds would have to be large enough to treat 114.8 million liters per year (405,250 ft^3 per year).

A second alternative is to prevent discharge from reaching the tunnel portals. This would require the emplacement of enhanced recharge basins within specific portals or the blocking of flowing sections of the tunnels with grout bulkheads. Assuming the bulkheads were not degraded by chemical reactions with the effluent, and were not circumvented by fracture flow around the bulkheads, groundwater would then reenter the groundwater flow system and continue to travel southward toward regional discharge areas in the Amargosa Desert. Observed tritium concentrations of 3.76×10^7 pCi/l would require 11 half-lives to pass (approximately 140 years) prior to tritium concentrations decaying to federal and state standards. This simple calculation does not account for dilution of the tritium, which would certainly occur during transport. Groundwater flow on the Nevada Test Site appears to take thousands of years to reach regional discharge areas (Winograd and Thordarson, 1975). This transit time should allow adequate time for decay of tritium to acceptable levels.

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APPENDIX 1

Tables from Text

Table 1. Effluent Characterization Instrumentation.

Type of Instrument	Manufacturer ¹	Operating Range	Accuracy
Temperature	Campbell Thermistor	-33 to 48°C	± 0.2°C
pH	TBI	3 to 10 pH units	± 1%
Discharge	Druck Transducer	0 to 1 psi	± 1%
EC	Barnstead	10 to 10,000 µsiemens	± 1%
Turbidity	Hach	0 to 9999 NTU	± 1 NTU
Data logger	Campbell	1 megabyte memory	NA
Modem & Computers	Sun	NA	NA

¹The use of trade names does not constitute an endorsement on the behalf of the Desert Research Institute.

Table 2. Data Precision, Accuracy, and Completeness Objectives.

	Parameter - Percentage				
	Temperature	pH	EC	Discharge	Turbidity
Precision*	95	95	95	95	90
Accuracy*	95	90	90	90	80
Completeness	90	80	80	80	80

*Precision and accuracy based on laboratory checks of instrumentation and prior field experience

Table 3. Data Precision, Accuracy, and Completeness Estimates for the Data Collected.

	Precision	Accuracy	Completeness
U12n			
Temperature	99.25	98.73	99.47
Discharge	97.55	92.80	89.70
pH	99.18	98.30	72.01
EC	99.25	89.14	66.26
Turbidity	82.51	91.66	44.48
U12i			
Temperature	99.84	99.46	93.33
Discharge	98.56	87.53	49.99
pH	99.93	93.51	70.20
EC	94.90	95.62	70.89
Turbidity	94.02	64.92	35.59
U12e			
Temperature	99.08	98.86	99.68
Discharge	99.45	90.31	68.73
pH	99.72	97.64	81.81
EC	99.93	97.39	83.09

Table 4. List of Analytes, Bottles, Preservative, Holding Times and Analytical Laboratories.

Parameter	Volume Required (ml)	Container	Preservative	Time	Laboratory
VOA	(2) 40 ml vials	Teflon lined lid with septum - VOA vial	Eliminate free air space, Cool to 4°C, add 4 drops concentrated HCL per 40 ml vial	14 days	REEC0
Semi-VOA	1000	Amber glass only with Teflon lined cap	Eliminate free air space	7 days	REEC0
Metals	1000	Polyethylene	Filter on-site HNO ₃ to pH < 2, Cool to 4°C	6 months	DRI
Anions, TDS, EC, pH, Alk, SiO ₂	1000	Polyethylene	Filter and Cool to 4°C	28 days	DRI
Total Phosphate and Ammonia	250	Polyethylene	H ₂ SO ₄ to pH < 2, Cool to 4°C	28 days	DRI
PCBs	1000	Amber glass only with Teflon lined cap	Eliminate free air space	7 days	REEC0
Gross alpha, beta, gamma spectroscopy	1 gallon	Polyethylene	HNO ₃ to pH < 2	6 months	REEC0
Tritium	1000	Flint glass	Cool to 4°C	None	REEC0

Table 5. Date, Location, and Nature of QA Samples Collected under the Project.

Date	Location and Sample Name	Nature of Sample
06/17/91	N Tunnel - U12n	Matrix spike and matrix spike duplicates for VOA, SVOA, and PCBs
	T Tunnel - U12i	Matrix spike and matrix spike duplicates for VOA, SVOA, and PCBs. Field blanks for VOA, SVOA, PCB, metals, anions, nutrients, tritium, and radionuclides
	E Tunnel - U12e	Matrix spike and matrix spike duplicates for VOA, SVOA, and PCBs
06/18/91	E Tunnel VOA-trip PCB-trip Anions-trip Tritium-trip SVOA-trip Metals-trip Nutrients-trip Radionuclide-trip	Field blanks for VOA, SVOA, PCB, metals, anions, nutrients, tritium, radionuclides
06/19/91	T Tunnel VOA-trip PCB-trip Anions-trip Tritium-trip VOA-field PCB-field Anions-field Tritium-field SVOA-trip Metals-trip Nutrients-trip Radionuclide-trip SVOA-field Metals-field Nutrients-field Radionuclide-field	Field blanks for VOA, SVOA, PCB, metals, anions, nutrients, tritium, radionuclides
06/26/91	N Tunnel - VOA-field, SVOA-field, PCB-field	Field blanks for VOA, SVOA, PCB
06/29/91	T Tunnel - VOA-field, SVOA-field	Field blanks for VOA, SVOA
07/02/91	N Tunnel - VOA field blank	Field blanks for VOA
07/05/91	T Tunnel - 55947-MS, 55977 MSD, VOA field blank	Field blanks for VOA, matrix spike and matrix spike duplicate for VOA, SVOA, PCB
07/08/91	N Tunnel - VOA field blank, 78997-MS, 78997-MSD	Field blank for VOA, matrix spike and matrix spike duplicate for VOA, SVOA, PCB
07/11/91	T Tunnel - VOA field blank E Tunnel - 95400-MS, 95400-MSD	Field blank for VOA Matrix spike and matrix spike duplicate
07/17/91	N Tunnel - VOA field blank	Field blank for VOA
07/23/91	N Tunnel - VOA field blank	Field blank for VOA
07/29/91	N Tunnel - VOA field blank, 525, 535, 525	Field blank for VOA Control spikes for VOA, SVOA, metals, PCBs
08/05/91	N Tunnel - VOA field blank	Field blank for VOA
08/19/91	N Tunnel - VOA field blank	Field blank for VOA
09/09/91	T Tunnel - VOA field blank	Field blank for VOA
10/08/91	E Tunnel - VOA field blank	Field blank for VOA
11/25/91	N Tunnel - U12n-MS, U12n-MSD E Tunnel - VOA field blank	Matrix spike and matrix spike duplicate for VOA, SVOA, PCB Field blank for VOA

Table 5. Continued.

Date	Location and Sample Name	Nature of Sample
02/28/92	N Tunnel - 45285 field blank, 537, 541, 539, 9943, 410	Field blank for VOA Control spikes for VOA, SVOA, PCB, trace metals, cations
05/12/92	E Tunnel - VOA field blank, U12e-MS, U12e-MSD	Field blank for VOA, matrix spike and matrix spike duplicate for VOA, SVOA, PCB
06/09/92	N Tunnel - VOA field blank	Field blank for VOA
08/11/92	E Tunnel - VOA field blank	Field blank for VOA

No QA samples were taken for the following sample dates: 06/29/91, 06/21/91, 06/22/91, 06/23/91, 12/31/91, 1/13/92, and 04/09/1992.

12/13/91 samples were taken from U12t Tunnel following drastic decrease in discharge. Health and safety samples only.

Table 6. Chemicals Sampled During the Tunnel Effluent Characterization Project, Method of Extraction/Preparation, Cleanup, and Analysis, Accuracy and Precision Objectives, and Detection Limits.

Chemical ¹	Method			Accuracy ²	Precision ^{2,4}	Detection Limits (µg/L)
	Extraction/ Preparation	Cleanup	Analysis ³			
Volatile Organic Compounds ⁵						
Volatile Organics	5030	N/A	8240 (624)	± 0-18%	± 16-65%	5-100
Semivolatile Organic Compounds						
Base/Neutral	3520	3640	8270 (625)	± 1-80%	± 13-105%	10-50
PCBs	3520	3640	8080 (608)	± 3-34%	± 21-79%	ND-.065
Metals						
Aluminum	3005	N/A	6010	± 0.6% ⁸	± 5.6%	45
Antimony	3005	N/A	7041	ND	ND	3
Arsenic	3005	N/A	3062-85 ¹⁰	ND	ND	2
Barium	3005	N/A	6010	ND	ND	5
Beryllium	3005	N/A	6010	± 2.2%	± 5.2%	0.3
Cadmium	3005	N/A	7131	± 1%	± 3.2%	0.1
Calcium	3005	N/A	6010	ND	ND	10
Chromium	3005	N/A	6010	± 0.6%	± 3.8%	7
Cobalt	3005	N/A	6010	± 2.4%	± 10%	7
Copper	3005	N/A	6010	± 6.0%	± 5.1%	6
Iron	3005	N/A	6010	± 1.0%	± 3.0%	7
Lead	3005	N/A	7421	± 5%	± 3.7%	1
Lithium	3005	ND	3425-85 ¹¹	ND	ND	5
Magnesium	3005	N/A	7450	± 1%	± 4.7%	1
Manganese	3005	N/A	6010	± 1%	± 3.3%	2
Mercury	245.1	N/A	245.1 ¹²	± 11%	± 15%	0.2
Nickel	3005	N/A	6010	± 2.0%	± 5.8%	15
Potassium	3005	N/A	7610	± 2.0%	± 8.1%	10
Selenium	3005	N/A	3667-85 ¹³	± 5%	± 4.1%	2
Silver	3005	N/A	272.1 ¹⁴	± 10.6%	± 8.8%	10
Sodium	3005	N/A	273.1 ¹²	± 1%	± 1.3%	2
Thallium	3005	N/A	7841	ND	ND	1
Vanadium	3005	N/A	6010	± 0.5%	± 1.1%	8
Zinc	3005	N/A	6010	± 0.5%	± 5.6%	2
Anions (SDWA) ^{6,7}						
Chloride	N/A	N/A	325.1	± 3%	± 1%	1000
Fluoride	N/A	N/A	340.2	± 2.5%	± 11%	100
NH ₃	N/A	N/A	350.1	± 1%	± 1%	10
Nitrate-N	N/A	N/A	353.2	± 3%	± 17%	10-100
Nitrite-N	N/A	N/A	353.2	ND	ND	10
Total Phosphate	N/A	N/A	365.2	ND	ND	10
Sulfate	N/A	N/A	300.0	± 2%	± 2%	500

Table 6. Continued.

Chemical ¹	Method			Accuracy ²	Precision ^{2,4}	Detection Limits (µg/L)
	Extraction/ Preparation	Cleanup	Analysis ³			
Radionuclides ⁹						
Gross Alpha	N/A	N/A	9310	± 14%	± 20%	3pCi/L
Gross Beta	N/A	N/A	9310	± 1%	± 12%	3pCi/L
Gamma Spect	N/A	N/A	ND	ND	ND	40pCi/L
Tritium	N/A	N/A	ND	ND	ND	400pCi/L
Miscellaneous						
EC	N/A	N/A	120.1	± 3.6%	± 7.7%	1 µmhos/cm
pH	N/A	N/A	150.1	± 0.2%	± 2.1%	0.1 pH unit
Alkalinity (HCO ₃ +CO ₃)	N/A	N/A	1-2030-78 ¹⁴	ND	ND	ND
SiO ₂	N/A	N/A	370.1	± 7.3%	± 10.1%	2000
TDS	N/A	N/A	1-2700-78 ¹⁴	ND	ND	ND

NA - not applicable.

ND - no data available.

¹All chemicals are on the EPA RCRA priority pollutant list.

²Chemical specific.

³Numbers in parentheses are equivalent EPA Method from "Methods for Chemical Analysis of Water and Wastes, EPA 600/4-82-055, December 1982.

⁴Precision is based on one standard deviation of the analysis of an interlaboratory standard.

⁵Many of the compounds detected in methods 603, 604, 606, 608, 609, 610, and 612 are detectable with 625 and 624.

⁶Required under Safe Drinking Water Act.

⁷Only EPA method is stated - not required under RCRA.

⁸Stated precision and accuracies are the most stringent recorded by EPA. Concentrations close to the detection limit will be more inaccurate and more imprecise.

⁹REECo methods, precision, and accuracy for Gamma Spectroscopy and Tritium analysis were not available during completion of the draft report.

¹⁰ASTM Method I-3062-85.

¹¹ASTM Method I-3425-85.

¹²EPA-600/4-79-020.

¹³ASTM Method I-3667-85.

¹⁴USGS Water resources investigation methods for determining inorganic substances in water and fluvial sediments.

Table 7. Sample Dates, Sample Names, and Associated Tunnel Condition.

Date	Time	Sample Name	Tunnel Condition	Date	Time	Sample Name	Tunnel Condition
U12n Tunnel				U12t Tunnel			
06/17/91	1600	05193	Active	06/17/91	1045	96723	Baseline
06/18/91	1500	16158	Active	06/18/91	1345	96169	Baseline
06/19/91	1430	41518	Active	06/19/91	1020	96678	Baseline
06/20/91	1345	58496	Active	06/20/91	1230	47329	Baseline
06/21/91	1330	94319	Active	06/21/91	0930	38143	Baseline
06/22/91	1400	94405	Baseline	06/22/91	0930	83510	Baseline
06/23/91	1300	39140	Baseline	06/23/91	0930	98898	Tunnel sumps activated
06/26/91	1000	76609	Active	06/29/91	0930	04406	Baseline
06/29/91	1145	34203	Baseline	07/05/91	1045	55997	Baseline
07/02/91	1100	19810	Active	07/11/91	1000	95911	Baseline
07/05/91	1415	13303	Baseline	08/05/91	1330	59368	Baseline
07/08/91	0930	78997	Active	09/09/91	1240	75670	Baseline
07/11/91	1415	45866	Active	10/08/91	1500	73516	Tunnel sumps activated
07/17/91	1100	45446	Active	11/25/91	0945	94958	Baseline
07/23/91	1115	71785	Active	12/31/91	1115	21739	Baseline - discharge from the U12t extension drift
07/29/91	1130	80710	Active	01/13/92	0945	93859	Baseline - discharge from the U12t extension drift
08/05/91	0930	78783	Active	05/12/92	1330	14236	Tunnel sumps activated minus discharge from the U12t extension drift
08/19/91	1200	52552	Active	U12e Tunnel			
09/09/91	1700	01894	Active	06/17/91	1330	38742	Baseline
10/08/91	0830	11744	Active	06/18/91	1000	01449	Baseline
11/25/91	1415	70020	Baseline	06/19/91	1240	89533	Baseline
01/13/92	1120	25580	Active	06/20/91	1000	74163	Baseline
02/28/92	1015	45285	Active	06/21/91	1100	92837	Baseline
04/09/92	0930	37836	Active	06/22/91	1045	69008	Baseline
05/12/92	1130	74970	Active	06/23/91	1030	92404	Baseline
06/09/92	1030	64602	Baseline	06/29/91	1045	45369	Baseline
07/14/92	0945	59011	Active	07/5/91	1130	16729	Baseline
				07/11/91	1145	95400	Baseline
				08/05/91	1140	36981	Baseline
				09/09/91	1130	37705	Baseline
				10/08/91	1100	67830	Baseline
				11/25/91	1115	32789	Baseline
				01/13/92	1330	60127	Baseline
				05/12/92	1015	17115	Baseline

Table 8. Statistical Summary of Temperature, pH, EC, Discharge, and Turbidity from E, N, and T Tunnels from April 17, 1991 to July 28, 1992.

	Mean	Median	Standard Deviation	Range	# of Samples
E Tunnel					
Temperature °C	13.85	14.11	2.47	1.73-22.73	11,220
Discharge (L/min)	53.71	51.85	7.80	40.38-108.00	7,736
pH	8.47	8.47	0.21	7.70-8.91	8,547
EC (µs)	333.69	337.70	23.28	236.8-381.5	9,353
Turbidity (NTU)	NA	NA	NA	NA	NA
N Tunnel					
Temperature °C	14.18	14.18	3.242	7.68-33.18	11,196
Discharge (L/min)	127.61	127.10	26.06	40.84-441.60	10,097
pH	8.60	8.69	0.92	0.38-11.81	8,106
EC (µs)	356.12	353.30	60.32	206.30-2588.00	7,458
Turbidity (NTU)	91.71	25.98	198.06	0.00-3072.0	5,007
T Tunnel*					
Temperature °C	18.06	19.04	2.707	11.78-25.08	10,505
Discharge (L/min)	253.29	311.70	142.27	0.00-648.80	5,627
pH	7.64	7.71	0.65	3.32-11.09	7,902
EC (µs)	448.13	554.90	169.68	215.20-792.00	7,979
Turbidity (NTU)	2.27	1.55	1.74	0.00-18.02	4,006

*See text for further statistics describing flow conditions monitored for U12i Tunnel.

Table 9. Statistical Summary of Temperature, pH, EC, Discharge, and Turbidity from High and Low Flow Periods at T Tunnel.

	Mean	Median	Standard Deviation	Range	# of Samples
T Tunnel – High Flow					
Temperature °C	20.10	20.42	1.031	14.19–25.08	5,385
Discharge (L/min)	336.74	346.70	50.88	125.4–648.8	4,060
pH	7.70	7.70	0.24	3.31–11.09	5,061
EC (µs)	275.75	273.10	31.64	215.2–792.0	3,859
Turbidity (NTU)	1.52	1.46	0.38	0.00–6.18	2,986
T Tunnel – Low Flow					
Temperature °C	15.91	15.48	2.23	11.78–23.84	5,113
Discharge (L/min)	37.07	51.59	34.16	0.00–247.40	1,567
pH	7.51	8.21	1.02	3.35–9.68	2,832
EC (µs)	610.31	609.80	26.13	468.7–689.1	4,111
Turbidity (NTU)	4.50	4.30	2.21	0.00–18.02	1,020

Table 10. Statistical Summary of All Calibrated and Non-Calibrated Temperature, pH, EC, Discharge, and Turbidity from E, N, and T Tunnels from April 17, 1991 to July 28, 1992.

	Mean	Median	Standard Deviation	# of Samples
E Tunnel				
Temperature °C	13.89	14.12	2.47	11,253
Discharge (L/min)	69.91	51.45	172.67	11,244
pH	8.40	8.38	0.25	11,250
EC (µs)	334.69	338.10	22.15	11,253
Turbidity (NTU)	NA	NA	NA	NA
N Tunnel				
Temperature °C	14.20	14.21	3.24	11,242
Discharge (L/min)	133.27	127.20	170.20	11,187
pH	8.61	8.69	1.02	10,707
EC (µs)	353.33	352.50	104.50	11,234
Turbidity (NTU)	131.14	25.99	468.54	7,408
T Tunnel*				
Temperature °C	18.06	19.04	2.71	10,498
Discharge (L/min)	254.93	295.20	188.72	8,426
pH	7.19	7.62	1.19	10,491
EC (µs)	432.35	338.60	168.78	10,377
Turbidity (NTU)	34.06	1.46	193.32	6,115

Table 11. Comparison of Continuously Monitored Parameters to State of Nevada Drinking Water Standards.

Parameter ¹	State Standard	U12e Tunnel		U12n Tunnel		U12l Tunnel	
		Mean	Range ³	Mean	Range ³	Mean	Range ³
pH	6.5–8.5 ²	8.47	7.70–8.91	8.60	0.38–11.81	7.64	3.32–11.09
Turbidity	1 NTU	NA ⁴		91.71	0.0–3072	2.27	0.0–18.02

¹Standards do not exist or do not apply to EC, temperature, and discharge

²pH is expressed as a range

³All values taken from the quality assured data in Table 8

⁴Turbidity not collected at U12e Tunnel

Table 12. Laboratories Responsible for Analyses of Water Samples Collected.

Laboratory	Laboratory Director	Analysis Conducted	Laboratory Address
Water Analysis Laboratory Desert Research Institute	Jim Heidker	Ionic Chemistry Trace Metals	7010 Dandini Blvd. Reno, NV 89512 (702) 673-7300
Analytical Services Department Reynolds Electrical & Engineering Co., Inc.	Jerry Dugas	Volatile Organics Semivolatile Organics PCB	P.O. Box 98521 Las Vegas, NV 89193 (702) 295-7997
Analytical Services Department Reynolds Electrical & Engineering Co., Inc.	Howard Hawthorne	Tritium Gross Alpha Gross Beta Gamma Spectrum	P.O. Box 98521 Las Vegas, NV 89193 (702) 295-7472

Table 13. Results for Control Spike Analyses (Estimated Accuracy).

Parameter	Range – % Correct
Trace Metals and Cations	
Al	96.09 – 96.39
Sb	87.10 – 99.02
As	96.97 – 97.58
Ba	96.62 – 98.24
Be	93.95 – 98.75
Cd	97.30 – 99.12
Cr	94.00 – 99.06
Co	97.70 – 99.07
Cu	95.83 – 99.71
Fe	96.96 – 98.20
Pb	86.67 – 95.93
Mn	97.22 – 98.22
Hg	75.00 – 92.22
Mo	96.0 ¹
Ni	94.59 – 99.75
Se	87.50 – 89.25
Ag	89.83 – 93.26
Sr	—
Tl	88.79 – 98.96
V	90.60 – 99.33
Zn	98.32 – 100.0
Ca	94.34 – 97.85
Mg	95.52 – 98.88
K	98.39 – 99.20
Na	97.85 – 99.86
Volatile Organics	
Chloromethane	100
Bromomethane	100
Vinyl Chloride	0 – 100
Chlorethane	100
Methylene Chloride	85.08 – 96.59
Acetone	37.09 – 100
Carbon Disulfide	100
1,1-Dichloroethene	0 – 100
1,1-Dichloroethane	100
1,2-Dichloroethene (total)	0 – 100
Chloroform	90.0 – 91.70
1,2-Dichloroethane	89.11 – 92.08

¹Single values indicate either a single analysis or duplicate result

Table 13. Continued.

Parameter	Range - % Correct
Volatile Organics	
2-Butanone	0 - 88.26
1,1,1-Trichloroethane	95.65 - 98.0
Carbon Tetrachloride	90.0 - 98.70
Vinyl Acetate	100
Bromodichloromethane	82.83 - 90.0
1,2-Dichloropropane	100
cis-1,3-Dichloropropene	0 - 100
Trichloroethene	89.35 - 94.75
Dibromochloromethane	85.58 - 90.0
1,1,2-Trichloroethane	100
Benzene	94.0 - 98.5
trans-1,3-Dichloropropene	97.3 - 100
Bromoform	85.29 - 88.90
4-Methyl-2-Pentanone	100
2-Hexanone	100
Tetrachloroethene	97.02 - 98.40
1,1,2,2-Tetrachloroethane	89.79 - 100
Toluene	91.02 - 96.51
Chlorobenzene	93.33 - 97.89
Ethylbenzene	99.0 - 99.78
Styrene	100
m,p-Xylene	100
Xylene (total)	100
1,2-Dichlorobenzene	89.05
1,3-Dichlorobenzene	41.35
1,4-Dichlorobenzene	-123.0
Semivolatile Organics	
Phenol	-69.70 - -29.0
bis (2-Chloroethyl) ether	100
2-Chlorophenol	100
1,3-Dichlorobenzene	-11.54 - 100
1,4-Dichlorobenzene	100
Benzyl alcohol	100
1,2-Dichlorobenzene	-97.5 - 65.91
2-Methylphenol	62.5 - 94.12
bis (2-chloroisopropyl) ether	100
4-Methylphenol	84.71 - 100
N-Nitroso-Di-n-propylamine	100
Hexachloroethane	-34.39 - 100

Table 13. Continued.

Parameter	Range - % Correct
Semivolatile Organics (continued)	
Nitrobenzene	100
Isophorone	19.79 - 100
2-Nitrophenol	94.62 - 100
2,4-Dimethylphenol	100
Benzoic acid	100
bis (2-Chloroethoxy) methane	100
2,4-Dichlorophenol	100
1,2,4-Trichlorobenzene	-5.76 - 66.49
Naphthalene	47.46 - 99.10
4-Chloroaniline	70.0 - 100
Hexachlorobutadiene	42.45 - 100
4-Chloro-3-methylphenol	98.86 - 100
2-Methylnaphthalene	33.33 - 59.09
Hexachlorocyclopentadiene	100
2,4,6-Trichlorophenol	-221.36 - 99.49
2,4,5-Trichlorophenol	0 - 100
2-Chloronaphthalene	88.18 - 100
2-Nitroaniline	100
Dimethylphthalate	100
Acenaphthylene	100
2,6-Dinitrotoluene	72.92 - 100
3-Nitroaniline	100
Acenaphthene	100
2,4-Dinitrophenol	0 - 100
4-Nitrophenol	100
Dibenzofuran	65.15 - 73.93
2,4-Dinitrotoluene	61.38 - 80.64
Diethylphthalate	100
4-Chlorophenyl-phenylether	100
Fluorene	100
4-Nitroaniline	100
4,6-Dinitro-2-methylphenol	100
N-Nitrosodiphenylamine	100
4-Bromophenyl-phenylether	100
Hexachlorobenzene	89.09 - 100
Pentachlorophenol	-131.58 - 0.0
Phenanthrene	100
Anthracene	100
Di-n-butylphthalate	58.75 - 100
Fluoranthene	100

Table 13. Continued.

Parameter	Range - % Correct
Semivolatile Organics (continued)	
Pyrene	99.61 - 100
Butylbenzylphthalate	100
3,3-Dichlorobenzidine	100
Benzo(a)anthracene	0 - 90.0
Chrysene	0 - 92.59
bis(2-Ethylhexyl)phthalate	90.81 - 98.75
Di-n-octylphthalate	100
Benzo(h)fluoranthene	100
Benzo(k)fluoranthene	100
Benzo(a)pyrene	100
Indeno(1,2,3-cd)pyrene	100
Dibenz(a,h)anthracene	100
Benzo(g,h,i)perylene	100
Unknown	0 - 100
Aroclor-1016	100
Aroclor-1221	100
Aroclor-1232	100
Aroclor-1242	100
Aroclor-1248	95.33 - 100
Aroclor-1254	100
Aroclor-1260	59.70 - 100

Table 14. Precision Estimates for all Organic Analyses.

Parameter	Mean	Standard Deviation	Range - % Correct
Volatile Organics			
Chloromethane	77.91	40.74	33 - 100
Bromomethane	73.75	45.65	0 - 100
Vinyl Chloride	60.71	50.51	0 - 100
Chlorethane	100	0	100
Methylene Chloride	86.6	29.8	43 - 100
Acetone	75.0	46.29	0 - 100
Carbon Disulfide	100	0	100
1,1-Dichloroethene	100	0	100
1,1-Dichloroethane	100	0	100
1,2-Dichloroethene (total)	96.88	8.84	75 - 100
Chloroform	100	0	100
1,2-Dichloroethane	87.50	35.36	0 - 100
2-Butanone	100	0	100
1,1,1-Trichloroethane	100	0	100
Carbon Tetrachloride	100	0	100
Vinyl Acetate	100	0	100
Bromodichloromethane	100	0	100
1,2-Dichloropropane	100	0	100
cis-1,3-Dichloropropene	100	0	100
Trichloroethene	100	0	100
Dibromochloromethane	100	0	100
1,1,2-Trichloroethane	100	0	100
Benzene	100	0	100
trans-1,3-Dichloropropene	100	0	100
Bromoform	100	0	100
4-Methyl-2-Pentanone	100	0	100
2-Hexanone	100	0	100
Tetrachloroethene	100	0	100
1,1,2,2-Tetrachloroethane	100	0	100
Toluene	100	0	100
Chlorobenzene	100	0	100
Ethylbenzene	100	0	100
Styrene	100	0	100
m,p-Xylene	93.7	17.6	50 - 100
Xylene (total)	100	0	100

Table 14. Continued.

Parameter	Mean	Standard Deviation	Range - % Correct
Semivolatile Organics			
Phenol	100	0	100
bis (2-Chloroethyl) ether	100	0	100
2-Chlorophenol	100	0	100
1,3-Dichlorobenzene	91.67	11.51	71.74 - 98.51
1,4-Dichlorobenzene	100	0	100
Benzyl alcohol	100	0	100
1,2-Dichlorobenzene	100	0	100
2-Methylphenol	100	0	100
bis (2-chloroisopropyl) ether	100	0	100
4-Methylphenol	100	0	100
N-Nitroso-Di-n-propylamine	100	0	100
Hexachloroethane	100	0	100
Nitrobenzene	100	0	100
Isophorone	100	0	100
2-Nitrophenol	100	0	100
2,4-Dimethylphenol	100	0	100
Benzoic acid	100	0	100
bis (2-Chloroethoxy) methane	100	0	100
2,4-Dichlorophenol	100	0	100
1,2,4-Trichlorobenzene	100	0	100
Naphthalene	100	0	100
4-Chloroaniline	100	0	100
Hexachlorobutadiene	100	0	100
4-Chloro-3-methylphenol	100	0	100
2-Methylnaphthalene	100	0	100
Hexachlorocyclopentadiene	100	0	100
2,4,6-Trichlorophenol	100	0	100
2,4,5-Trichlorophenol	100	0	100
2-Chloronaphthalene	100	0	100
2-Nitroaniline	100	0	100
Dimethylphthalate	100	0	100
Acenaphthylene	100	0	100
2,6-Dinitrotoluene	100	0	100
3-Nitroaniline	100	0	100
Acenaphthene	100	0	100
2,4-Dinitrophenol	100	0	100
4-Nitrophenol	100	0	100
Dibenzofuran	100	0	100
2,4-Dinitrotoluene	100	0	100

Table 14. Continued.

Parameter	Mean	Standard Deviation	Range - % Correct
Semivolatile Organics (continued)			
Diethylphthalate	100	0	100
4-Chlorophenyl-phenylether	100	0	100
Fluorene	100	0	100
4-Nitroaniline	100	0	100
4,6-Dinitro-2-methylphenol	100	0	100
N-Nitrosodiphenylamine	100	0	100
4-Bromophenyl-phenylether	100	0	100
Hexachlorobenzene	100	0	100
Pentachlorophenol	100	0	100
Phenanthrene	100	0	100
Anthracene	100	0	100
Di-n-butylphthalate	100	0	100
Fluoranthene	100	0	100
Pyrene	100	0	100
Butylbenzylphthalate	100	0	100
3,3-Dichlorobenzidine	100	0	100
Benzo(a)anthracene	100	0	100
Chrysene	100	0	100
bis(2-Ethylhexyl)phthalate	48.68	46.84	0 - 100
Di-n-octylphthalate	100	0	100
Benzo(b)fluoranthene	100	0	100
Benzo(k)fluoranthene	100	0	100
Benzo(a)pyrene	100	0	100
Indeno(1,2,3-cd)pyrene	100	0	100
Dibenz(a,h)anthracene	100	0	100
Benzo(g,h,i)perylene	100	0	100
Unknown	100	0	100
Aroclor-1016	100	0	100
Aroclor-1221	100	0	100
Aroclor-1232	100	0	100
Aroclor-1242	100	0	100
Aroclor-1248	100	0	100
Aroclor-1254	100	0	100
Aroclor-1260	100	0	100

Table 15. Results of Field Blank Analyses.

	Mean Value of Field Blanks (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, Anions				
EC	3.0 μ S	0.0	3.0	3
SiO ₂	<1.0	0.0	<1.0	3
pH	5.34 (pH units)	0.34	5.58 - 4.95	3
HCO ₃	<5.0	0.0	<5.0	3
CO ₃	0.0	0.0	0.0	3
Cl	0.72	0.10	0.78 - 0.60	3
SO ₄	0.2	0.0	0.2	3
NO ₃	<0.04	0.0	<0.04	3
Na	0.27	0.06	0.3 - 0.2	3
K	0.13	0.06	0.2 - 0.1	3
Ca	0.1	0.0	0.1	3
Mg	<0.1	0.0	<0.1	3
TDS	<4.0	0.0	<4.0	3
Br	<0.02	0.0	<0.02	3
F	<0.05	0.0	<0.05	3
NH ₄	0.003	0.006	0.10 - <0.005	3
NO ₂	<0.01	0.0	<0.01	3
TPO ₄	<0.005	0.0	<0.005	3
Al	0.047	0.021	0.07 - 0.03	3
Sb	<0.001	0.0	<0.001	3
As	<0.002	0.0	<0.002	3
Ba	0.001	0.001	0.002 - <0.002	3
Be	<0.001	0.0	<0.001	3
Cd	<0.001	0.0	<0.001	3
Cr	<0.01	0.0	<0.02 - <0.01	3
Co	<0.01	0.0	<0.01	3
Cu	0.022	0.003	0.024 - 0.019	3
Fe	0.067	0.098	0.18 - 0.01	3
Pb	0.004	0.002	0.006 - 0.002	3
Li	<0.005	0.0	<0.005	3
Mn	<0.005	0.0	<0.005	3
Hg	<0.0002	0.0	<0.0002	3
Ni	<0.01	0.0	<0.01	3
Se	<0.002	0.0	<0.002	3
Ag	<0.005	0.0	<0.005	3
Tl	<0.001	0.0	<0.001	3
V	<0.02	0.0	<0.02	3
Zn	0.012	0.001	0.013 - 0.011	3

Table 15. Continued.

Parameter Name	# of field blanks in which parameter was detected	Concentration of the detected values (µg/L)	Total # of samples	Detection limit (µg/L)
Volatile Organics Analysis				
Chloromethane	6	7.0 ± 2.2	19	10
Bromomethane	4	5.8 ± 6.3	19	10
Vinyl Chloride	5	6.6 ± 2.5	19	10
Chloroethane	3	7.7 ± 4.0	19	10
Methylene Chloride	18	57.9 ± 216.4	19	10
Acetone	16	18.7 ± 15.0	19	10
Carbon Disulfide	1	0.1 ± 0.0	19	5
1,1-Dichloroethene	5	3.8 ± 0.8	19	5
1,1-Dichloroethane	0	0.0 ± 0.0	19	5
1,2-Dichloroethene (total)	6	2.6 ± 1.5	19	5
Chloroform	8	1.5 ± 1.4	19	5
1,2-Dichloroethane	0	0.0 ± 0.0	19	5
2-Butanone	2	16.0 ± 17.0	19	10
1,1,1-Trichloroethane	2	0.1 ± 0.0	19	5
Carbon Tetrachloride	0	0.0 ± 0.0	19	5
Vinyl Acetate	0	0.0 ± 0.0	19	10
Bromodichloromethane	0	0.0 ± 0.0	19	5
1,2-Dichloropropane	0	0.0 ± 0.0	19	5
cis-1,3-Dichloropropene	0	0.0 ± 0.0	19	5
Trichloroethene	0	0.0 ± 0.0	19	5
Dibromochloromethane	0	0.0 ± 0.0	19	5
1,1,2-Trichloroethane	0	0.0 ± 0.0	19	5
Benzene	2	0.1 ± 0.0	19	5
trans-1,3-Dichloropropene	0	0.0 ± 0.0	19	5
Bromoform	0	0.0 ± 0.0	19	5
4-Methyl-2-Pentanone	0	0.0 ± 0.0	19	10
2-Hexanone	1	8.0 ± 0.0	19	10
Tetrachloroethene	0	0.0 ± 0.0	19	5
1,1,2,2-Tetrachloroethane	0	0.0 ± 0.0	19	5
Toluene	2	0.25 ± 0.2	19	5
Chlorobenzene	0	0.0 ± 0.0	19	5
Ethylbenzene	2	0.55 ± 0.1	19	5
Styrene	0	0.0 ± 0.0	19	5
m,p-Xylene	10	2.2 ± 1.5	19	5
Xylene (total)	2	0.75 ± 0.4	19	5

Unknown Volatile Parameters

Retention Time	Estimated Concentration	# of Time Detected	# of Samples
4.18	7.0	1	19
7.02	7.0	1	19
7.85	9.0	1	19

Table 15. Continued.

Parameter Name	# of field blanks in which parameter was detected	Concentration of the detected values (µg/L)	Total # of samples	Detection limit (µg/L)
Semivolatile Organics Analysis				
Phenol	0	0.0 ± 0.0	5	10
bis (2-Chloroethyl) ether	0	0.0 ± 0.0	5	10
2-Chlorophenol	0	0.0 ± 0.0	5	10
1,3-Dichlorobenzene	0	0.0 ± 0.0	5	10
1,4-Dichlorobenzene	0	0.0 ± 0.0	5	10
Benzyl alcohol	0	0.0 ± 0.0	5	10
1,2-Dichlorobenzene	0	0.0 ± 0.0	5	10
2-Methylphenol	0	0.0 ± 0.0	5	10
bis (2-chloroisopropyl) ether	0	0.0 ± 0.0	5	10
4-Methylphenol	0	0.0 ± 0.0	5	10
N-Nitroso-Di-n-propylamine	1	10.0 ± 0.0	5	10
Hexachloroethane	0	0.0 ± 0.0	5	10
Nitrobenzene	0	0.0 ± 0.0	5	10
Isophorone	0	0.0 ± 0.0	5	10
2-Nitrophenol	0	0.0 ± 0.0	5	10
2,4-Dimethylphenol	0	0.0 ± 0.0	5	10
Benzoic acid	0	0.0 ± 0.0	5	50
bis (2-Chloroethoxy) methane	0	0.0 ± 0.0	5	10
2,4-Dichlorophenol	0	0.0 ± 0.0	5	10
1,2,4-Trichlorobenzene	0	0.0 ± 0.0	5	10
Naphthalene	0	0.0 ± 0.0	5	10
4-Chloroaniline	0	0.0 ± 0.0	5	10
Hexachlorobutadiene	0	0.0 ± 0.0	5	10
4-Chloro-3-methylphenol	0	0.0 ± 0.0	5	10
2-Methylnaphthalene	0	0.0 ± 0.0	5	10
Hexachlorocyclopentadiene	0	0.0 ± 0.0	5	10
2,4,6-Trichlorophenol	0	0.0 ± 0.0	5	10
2,4,5-Trichlorophenol	0	0.0 ± 0.0	5	50
2-Chloronaphthalene	0	0.0 ± 0.0	5	10
2-Nitroaniline	0	0.0 ± 0.0	5	50
Dimethylphthalate	1	1.0 ± 0.0	5	10
Acenaphthylene	0	0.0 ± 0.0	5	10
2,6-Dinitrotoluene	0	0.0 ± 0.0	5	10
3-Nitroaniline	0	0.0 ± 0.0	5	10
Acenaphthene	0	0.0 ± 0.0	5	10
2,4-Dinitrophenol	0	0.0 ± 0.0	5	10
4-Nitrophenol	0	0.0 ± 0.0	5	10
Dibenzofuran	0	0.0 ± 0.0	5	10
2,4-Dinitrotoluene	0	0.0 ± 0.0	5	10
Diethylphthalate	0	0.0 ± 0.0	5	10
4-Chlorophenyl-phenylether	0	0.0 ± 0.0	5	10
Fluorene	0	0.0 ± 0.0	5	10
4-Nitroaniline	0	0.0 ± 0.0	5	10

Table 15. Continued.

Parameter Name	# of field blanks in which parameter was detected	Concentration of the detected values (µg/L)	Total # of samples	Detection limit (µg/L)
Semivolatile Organics Analysis (continued)				
4,6-Dinitro-2-methylphenol	0	0.0 ± 0.0	5	10
N-Nitrosodiphenylamine (1)	0	0.0 ± 0.0	5	10
4-Bromophenyl-phenylether	0	0.0 ± 0.0	5	10
Hexachlorobenzene	0	0.0 ± 0.0	5	10
Pentachlorophenol	0	0.0 ± 0.0	5	50
Phenanthrene	0	0.0 ± 0.0	5	10
Anthracene	0	0.0 ± 0.0	5	10
Di-n-butylphthalate	3	0.8 ± 0.2	5	10
Fluoranthene	0	0.0 ± 0.0	5	10
Pyrene	0	0.0 ± 0.0	5	10
Butylbenzylphthalate	0	0.0 ± 0.0	5	10
3,3-Dichlorobenzidine	0	0.0 ± 0.0	5	10
Benzo(a)anthracene	0	0.0 ± 0.0	5	10
Chrysene	0	0.0 ± 0.0	5	10
bis(2-Ethylhexyl)phthalate	2	1.7 ± 1.9	5	10
Di-n-octylphthalate	0	0.0 ± 0.0	5	10
Benzo(b)fluoranthene	0	0.0 ± 0.0	5	10
Benzo(k)fluoranthene	0	0.0 ± 0.0	5	10
Benzo(a)pyrene	0	0.0 ± 0.0	5	10
Indeno(1,2,3-cd)pyrene	0	0.0 ± 0.0	5	10
Dibenz(a,h)anthracene	0	0.0 ± 0.0	5	10
Benzo(g,h,i)perylene	0	0.0 ± 0.0	5	10
Unknown Semivolatile Parameters				
7.85 - 7.88	3	8.3	5	NA
8.24	1	2.0	5	NA
PCBs Organics Analysis				
Aroclor-1016	0	0.0 ± 0.0	4	0.065
Aroclor-1221	0	0.0 ± 0.0	4	0.065
Aroclor-1232	0	0.0 ± 0.0	4	0.065
Aroclor-1242	0	0.0 ± 0.0	4	0.065
Aroclor-1248	0	0.0 ± 0.0	4	0.065
Aroclor-1254	0	0.0 ± 0.0	4	0.065
Aroclor-1260	0	0.0 ± 0.0	4	0.065
Radionuclides (µCi/ml)				
Tritium	2	1.68 ± 10 ⁻⁷	3	variable
Gamma Spec.	0	ND ⁺	3	variable
Gross Alpha	2	1.71 ± 10 ⁻⁹	3	variable
Gross Beta	2	8.8 ± 10 ⁻¹⁰	3	variable

*Not detected

**Below background

Table 16. Data Completeness for Analytical Samples.

Sample Location	Sample Type	# of Planned Samples (a)*	# of Samples Actually Taken (b)**	# of Analyses Received (c)	Completeness Data (c/a)*100
U12n	VOA	29	27	27	93%
	SVOA			27	93%
	Metals			27	63%
	Radionuclides			26-27***	89.6%
	PCB			27	93%
U12c	VOA	12	16	16	133%
	SVOA			16	133%
	Metals			16	133%
	Radionuclides			13-16***	100%
	PCB				133%
U12t	VOA	16	16	16	100%
	SVOA			15	93%
	Metals			16	100%
	Radionuclides			17++	106%
	PCB			16	100%

*from original, unpublished sample schedule

**not including spikes and duplicates

++Additional radionuclide sample taken for health and safety reasons

***Range given as certain radionuclide parameters were lost whereas other were not

Table 17. Statistical Summary of Dissolved Ionic Species in U12c Tunnel Effluent, Sampled from April 17, 1991 to July 28, 1992.

	Mean (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, and Anions				
EC	349.31 μ S	3.69	355 - 341	16
SiO ₂	42.23	0.30	42.8 - 41.7	16
pH	8.36 (pH units)	0.08	8.47 - 8.16	16
HCO ₃	171.94	4.38	178 - 163	16
CO ₃	1.94	1.80	5.1 - 0.5	16
Cl	9.47	0.77	12.3 - 8.9	16
SO ₄	24.94	0.79	26.5 - 23.8	16
NO ₃	2.31	0.28	2.75 - 1.68	16
Na	74.31	1.44	76.7 - 71.6	16
K	3.42	0.45	5.01 - 3.10	16
Ca	5.97	0.28	6.63 - 5.65	16
Mg	0.54	0.03	0.58 - 0.49	16
TDS	262.6	8.1	282 - 248	16
Br	0.20	0.47	2.0 - 0.06	16
F	0.30	0.06	0.36 - 0.08	16
NH ₄	0.001	0.003	0.008 - <0.005	16
NO ₂	0.01	0.01	0.03 - <0.01	16
TPO ₄	0.073	0.005	0.090 - 0.070	16

Table 18. State of Nevada Drinking Water Standards for Relevant Measures of Gross Chemistry.

Parameter	Standard (mg/L)
pH	6.5 – 8.5
TDS	1000
Magnesium	150
Sulfate	500
Chloride	400
Nitrate as N	10
Fluoride	4.0

Table 19. Statistical Summary of Dissolved Ionic Species in U12n Tunnel Effluent, Sampled from April 17, 1991 to July 28, 1992.

	Mean (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, and Anions				
EC	360.89 μ S	38.16	474 – 324	27
SiO ₂	53.72	1.70	58.1 – 50.4	27
pH	8.65 (pH units)	0.25	9.22 – 8.26	27
HCO ₃	134.02	17.85	158.0 – 96.7	27
CO ₃	9.99	7.34	27.8 – 0.0	27
Cl	11.96	3.36	20.7 – 8.9	27
SO ₄	37.01	15.50	95.8 – 22.1	27
NO ₃	3.14	1.12	7.31 – 1.59	27
Na	64.90	6.04	84.3 – 58.5	27
K	8.07	0.97	11.0 – 7.05	27
Ca	11.89	2.35	16.70 – 8.74	27
Mg	0.73	0.12	0.93 – 0.53	27
TDS	261.4	28.02	337 – 234	27
Br	0.29	0.52	1.8 – 0.0	27
F	0.21	0.07	0.36 – 0.07	27
NH ₄	0.016	0.050	0.260 – <0.005	27
NO ₂	0.04	0.08	0.40 – <0.005	27
TPO ₄	0.173	0.026	0.630 – 0.026	27

Table 20. Statistical Summary of Dissolved Ionic Species in U12t Tunnel Effluent, Sampled from April 17, 1991 to July 28, 1992.

	Mean (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, and Anions				
EC	312.25 μ S	114.50	645 – 266	16
SiO ₂	56.60	3.75	59.0 – 44.6	16
pH	7.89 (pH units)	0.22	8.44 – 7.58	16
HCO ₃	121.94	24.62	188 – 109	16
CO ₃	0.33	1.30	5.2 – 0.0	16
Cl	10.29	0.81	12.5 – 9.3	16
SO ₄	38.49	33.73	141.0 – 24.5	16
NO ₃	4.08	0.93	4.96 – 1.59	16
Na	48.88	28.13	124.0 – 36.4	16
K	6.91	1.88	13.6 – 5.9	16
Ca	12.94	1.92	14.70 – 6.17	16
Mg	2.23	0.60	2.55 – 0.41	16
TDS	231.5	75.84	454 – 198	16
Br	0.24	0.42	1.8 – 0.10	16
F	0.12	0.03	0.21 – 0.06	16
NH ₄	<0.005	0.003	0.011 – <0.005	16
NO ₂	0.01	0.01	0.02 – <0.01	16
TPO ₄	0.058	0.011	0.093 – 0.050	16

Table 21. Statistical Summary of Dissolved Metals in U12c Tunnel Effluent, Sampled from April 17, 1991 to July 28, 1992.

	Mean (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, and Anions				
Al	0.76	0.25	1.3 – 0.34	16
Sb	0.0001	0.0005	0.002 – <0.001	16
As	0.0001	0.0005	0.002 – <0.002	16
Ba	0.009	0.003	0.017 – 0.006	16
Be	<0.001	<0.001	<0.001	16
Cd	0.0002	0.0007	0.003 – <0.001	16
Cr	<0.01	<0.01	0.02 – <0.01	16
Co	<0.01	<0.01	<0.01	16
Cu	0.015	0.030	0.129 – <0.005	16
Fe	0.59	0.21	1.0 – 0.24	16
Pb	0.002	0.002	0.008 – <0.001	16
Li	0.019	0.002	0.024 – 0.016	16
Mn	0.006	0.003	0.01 – <0.005	16
Hg	<0.0002	<0.0002	<0.0002	16
Ni	0.001	0.005	0.02 – <0.01	16
Se	<0.002	<0.002	<0.002	16
Ag	<0.005	<0.005	<0.005	16
Tl	<0.001	<0.001	0.001 – <0.001	16
V	<0.02	<0.02	<0.02	16
Zn	0.010	0.006	0.026 – <0.005	16

Table 22. State of Nevada Drinking Water Standards for Metals.

Parameter	Standard (mg/L)
Arsenic, As	0.05
Iron, Fe	0.3 – 0.60
Manganese	0.05 – 0.1
Copper, Cu	1.0
Zinc, Zn	5.0
Barium, Ba	1.0
Cadmium, Cd	0.010
Chromium, Cr	0.05
Lead, Pb	0.05
Mercury, Hg	0.002
Selenium, Se	0.01
Silver, Ag	0.05

Table 23. Statistical Summary of Dissolved Metals in U12n Tunnel Effluent, Sampled from April 17, 1991 to July 28, 1992.

	Mean (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, and Anions				
Al	0.184	0.03	0.63 – 0.03	27
Sb	0.001	0.002	0.008 – <0.001	27
As	0.006	0.004	0.010 – 0.004	27
Ba	0.006	0.007	0.031 – <0.002	27
Be	<0.001	<0.001	<0.001	27
Cd	0.0003	<0.001	0.003 – <0.001	27
Cr	<0.01	<0.01	0.02 – <0.01	27
Co	<0.01	<0.01	<0.01	27
Cu	0.015	0.058	0.303 – <0.005	27
Fe	0.131	0.095	0.40 – 0.03	27
Pb	0.0001	<0.001	0.003 – <0.001	27
Li	0.024	0.003	0.032 – 0.019	27
Mn	0.0004	<0.005	0.006 – <0.005	27
Hg	<0.0002	<0.0002	<0.0002	27
Ni	<0.01	<0.01	<0.01	27
Se	<0.002	<0.002	<0.002	27
Ag	<0.005	<0.005	<0.005	27
Tl	0.0002	<0.001	0.002 – <0.001	27
V	<0.02	<0.02	<0.02	27
Zn	0.004	<0.005	0.016 – <0.005	27

Table 24. Statistical Summary of Dissolved Metals in U12t Tunnel Effluent, Sampled from April 17, 1991 to July 28, 1992.

	Mean (mg/L)	Standard Deviation	Range	# of Samples
Metals, Cations, and Anions				
Al	0.084	0.04	0.17 – 0.03	16
Sb	0.0003	<0.001	0.003 – <0.001	16
As	0.006	0.008	0.029 – 0.002	16
Ba	0.003	0.003	0.013 – <0.002	16
Be	<0.001	<0.001	<0.001	16
Cd	<0.001	<0.001	<0.001	16
Cr	<0.01	<0.01	0.02 – <0.01	16
Co	<0.01	<0.01	<0.01	16
Cu	0.005	<0.005	0.038 – <0.005	16
Fe	0.06	0.01	0.14 – <0.01	16
Pb	0.0002	0.04	0.003 – <0.001	16
Li	0.013	0.0007	0.030 – 0.006	16
Mn	<0.005	0.007	<0.005	16
Hg	<0.0002	<0.0002	<0.0002	16
Ni	<0.01	<0.01	<0.01	16
Se	<0.002	<0.002	<0.002	16
Ag	<0.005	<0.005	<0.005	16
Tl	<0.001	<0.001	<0.001	16
V	<0.02	<0.02	<0.02	16
Zn	<0.011	0.005	0.020 – <0.005	16

Table 25. Concentration of Volatile Organic Parameters Sampled from the Effluent Draining Out of U12c Tunnel Portal.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)	# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Volatile Organics Analysis					
Chloromethane	3	7.7 ± 1.2	1	16	10
Bromomethane	4	4.8 ± 2.9	2	16	10
Vinyl Chloride	3	6.7 ± 1.2	2	16	10
Chloroethane	1	7.0 ± 0.0	1	16	10
Methylene Chloride	16	3.6 ± 3.6	13	16	10
Acetone	2	2.5 ± 2.1	2	16	10
Carbon Disulfide	0	0.0 ± 0.0	0	16	5
1,1-Dichloroethene	7	3.0 ± 0.0	7	16	5
1,1-Dichloroethane	0	0.0 ± 0.0	0	16	5
1,2-Dichloroethene (total)	7	3.3 ± 0.5	7	16	5
Chloroform	0	0.0 ± 0.0	0	16	5
1,2-Dichloroethane	0	0.0 ± 0.0	0	16	5
2-Butanone	0	0.0 ± 0.0	0	16	10
1,1,1-Trichloroethane	0	0.0 ± 0.0	0	16	5
Carbon Tetrachloride	0	0.0 ± 0.0	0	16	5
Vinyl Acetate	0	0.0 ± 0.0	0	16	10
Bromodichloromethane	0	0.0 ± 0.0	0	16	5
1,2-Dichloropropane	0	0.0 ± 0.0	0	16	5
cis-1,3-Dichloropropene	0	0.0 ± 0.0	0	16	5
Trichloroethene	0	0.0 ± 0.0	0	16	5
Dibromochloromethane	0	0.0 ± 0.0	0	16	5
1,1,2-Trichloroethane	0	0.0 ± 0.0	0	16	5
Benzene	0	0.0 ± 0.0	0	16	5
trans-1,3-Dichloropropene	0	0.0 ± 0.0	0	16	5
Bromoform	0	0.0 ± 0.0	0	16	5
4-Methyl-2-Pentanone	0	0.0 ± 0.0	0	16	10
2-Hexanone	0	8.0 ± 0.0	0	16	10
Tetrachloroethene	0	0.0 ± 0.0	0	16	5
1,1,2,2-Tetrachloroethane	0	0.0 ± 0.0	0	16	5
Toluene	0	0.0 ± 0.0	0	16	5
Chlorobenzene	0	0.0 ± 0.0	0	16	5
Ethylbenzene	0	0.0 ± 0.0	0	16	5
Styrene	0	0.0 ± 0.0	0	16	5
m,p-Xylene	0	0.0 ± 0.0	0	16	5
Xylene (total)	1	1.0 ± 0.0	1	16	5

Table 26. Concentration of Volatile Organic Parameters Sampled from the Effluent Draining Out of U12n Tunnel Portal.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)	# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Volatile Organics Analysis					
Chloromethane	6	5.0 ± 2.6	2	27	10
Bromomethane	6	4.8 ± 3.5	3	27	10
Vinyl Chloride	7	4.9 ± 2.3	3	27	10
Chloroethane	2	4.0 ± 4.2	1	27	10
Methylene Chloride	24	4.1 ± 4.4	21	27	10
Acetone	7	10.0 ± 7.6	4	27	10
Carbon Disulfide	0	0.0 ± 0.0	0	27	5
1,1-Dichloroethene	7	3.1 ± 0.4	7	27	5
1,1-Dichloroethane	0	0.0 ± 0.0	0	27	5
1,2-Dichloroethene (total)	9	3.1 ± 1.1	8	27	5
Chloroform	0	0.0 ± 0.0	0	27	5
1,2-Dichloroethane	0	0.0 ± 0.0	0	27	5
2-Butanone	2	37.0 ± 21.2	0	27	10
1,1,1-Trichloroethane	2	6.0 ± 2.8	0	27	5
Carbon Tetrachloride	0	0.0 ± 0.0	0	27	5
Vinyl Acetate	0	0.0 ± 0.0	0	27	10
Bromodichloromethane	0	0.0 ± 0.0	0	27	5
1,2-Dichloropropane	0	0.0 ± 0.0	0	27	5
cis-1,3-Dichloropropene	0	0.0 ± 0.0	0	27	5
Trichloroethene	0	0.0 ± 0.0	0	27	5
Dibromochloromethane	0	0.0 ± 0.0	0	27	5
1,1,2-Trichloroethane	0	0.0 ± 0.0	0	27	5
Benzene	0	0.0 ± 0.0	0	27	5
trans-1,3-Dichloropropene	0	0.0 ± 0.0	0	27	5
Bromoform	0	0.0 ± 0.0	0	27	5
4-Methyl-2-Pentanone	1	1.0 ± 0.0	0	27	10
2-Hexanone	0	0.0 ± 0.0	0	27	10
Tetrachloroethene	1	4.0 ± 0.0	0	27	5
1,1,2,2-Tetrachloroethane	0	0.0 ± 0.0	0	27	5
Toluene	0	0.0 ± 0.0	0	27	5
Chlorobenzene	0	0.0 ± 0.0	0	27	5
Ethylbenzene	0	0.0 ± 0.0	0	27	5
Styrene	0	0.0 ± 0.0	0	27	5
m,p-Xylene	4	1.5 ± 0.6	2	27	5
Xylene (total)	0	0.0 ± 0.0	0	27	5

Table 27. Concentration of Volatile Organic Parameters Sampled from the Effluent Draining Out of U12t Tunnel Portal.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)	# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Volatile Organics Analysis					
Chloromethane	7	6.0 ± 2.2	2	16	10
Bromomethane	5	4.8 ± 4.2	3	16	10
Vinyl Chloride	7	4.7 ± 2.3	3	16	10
Chloroethane	1	2.0 ± 0.0	1	16	10
Methylene Chloride	15	3.9 ± 2.2	13	16	10
Acetone	2	10.5 ± 10.6	1	16	10
Carbon Disulfide	0	0.0 ± 0.0	0	16	5
1,1-Dichloroethene	6	2.6 ± 1.0	5	16	5
1,1-Dichloroethane	0	0.0 ± 0.0	0	16	5
1,2-Dichloroethene (total)	8	3.2 ± 1.1	8	16	5
Chloroform	0	0.0 ± 0.0	0	16	5
1,2-Dichloroethane	0	0.0 ± 0.0	0	16	5
2-Butanone	0	0.0 ± 0.0	0	16	10
1,1,1-Trichloroethane	1	4.0 ± 0.0	0	16	5
Carbon Tetrachloride	0	0.0 ± 0.0	0	16	5
Vinyl Acetate	0	0.0 ± 0.0	0	16	10
Bromodichloromethane	0	0.0 ± 0.0	0	16	5
1,2-Dichloropropane	0	0.0 ± 0.0	0	16	5
cis-1,3-Dichloropropene	0	0.0 ± 0.0	0	16	5
Trichloroethene	0	0.0 ± 0.0	0	16	5
Dibromochloromethane	0	0.0 ± 0.0	0	16	5
1,1,2-Trichloroethane	0	0.0 ± 0.0	0	16	5
Benzene	1	0.2 ± 0.0	0	16	5
trans-1,3-Dichloropropene	0	0.0 ± 0.0	0	16	5
Bromoform	0	0.0 ± 0.0	0	16	5
4-Methyl-2-Pentanone	0	0.0 ± 0.0	0	16	10
2-Hexanone	0	0.0 ± 0.0	0	16	10
Tetrachloroethene	0	0.0 ± 0.0	0	16	5
1,1,2,2-Tetrachloroethane	0	0.0 ± 0.0	0	16	5
Toluene	0	0.0 ± 0.0	0	16	5
Chlorobenzene	0	0.0 ± 0.0	0	16	5
Ethylbenzene	0	0.0 ± 0.0	0	16	5
Styrene	0	0.0 ± 0.0	0	16	5
m,p-Xylene	4	1.75 ± 1.0	1	16	5
Xylene (total)	0	0.0 ± 0.0	0	16	5

Table 28. Volatile Organic Analytes whose Concentration Exceeded the Detection Limit of the Method and those of the Associated Blanks.

Analyte	TUNNEL		
	U12c	U12n	U12t
Methylene Chloride	Jan. 13, 1992 (17 µg/L)	Jan. 13, 1992 (20 µg/L)+ July 14, 1992 (14 µg/L)	
Acetone		June 26, 1991 (26 µg/L)	Sept. 9, 1991 (52 µg/L)
2-butanone		Sept. 9, 1991 (18 µg/L) April 9, 1992 (22 µg/L)	

+not detected above detection limit for MS and MSD

Table 29. Concentration of Semivolatile Organic Parameters Sampled from the Effluent Discharging Out of U12c Tunnel Portal.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)			# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Semivolatile Organics Analysis							
Phenol	0	0.0	±	0.0	0	16	10
bis (2-Chloroethyl) ether	0	0.0	±	0.0	0	16	10
2-Chlorophenol	0	0.0	±	0.0	0	16	10
1,3-Dichlorobenzene	0	0.0	±	0.0	0	16	10
1,4-Dichlorobenzene	0	0.0	±	0.0	0	16	10
Benzyl alcohol	0	0.0	±	0.0	0	16	10
1,2-Dichlorobenzene	0	0.0	±	0.0	0	16	10
2-Methylphenol	0	0.0	±	0.0	0	16	10
bis (2-chloroisopropyl) ether	0	0.0	±	0.0	0	16	10
4-Methylphenol	0	0.0	±	0.0	0	16	10
N-Nitroso-Di-n-propylamine	1	14.0	±	0.0	0	16	10
Hexachloroethane	0	0.0	±	0.0	0	16	10
Nitrobenzene	0	0.0	±	0.0	0	16	10
Isophorone	0	0.0	±	0.0	0	16	10
2-Nitrophenol	0	0.0	±	0.0	0	16	10
2,4-Dimethylphenol	0	0.0	±	0.0	0	16	10
Benzoic acid	0	0.0	±	0.0	0	16	50
bis (2-Chloroethoxy) methane	0	0.0	±	0.0	0	16	10
2,4-Dichlorophenol	0	0.0	±	0.0	0	16	10
1,2,4-Trichlorobenzene	0	0.0	±	0.0	0	16	10
Naphthalene	0	0.0	±	0.0	0	16	10
4-Chloroaniline	0	0.0	±	0.0	0	16	10
Hexachlorobutadiene	0	0.0	±	0.0	0	16	10
4-Chloro-3-methylphenol	0	0.0	±	0.0	0	16	10
2-Methylnaphthalene	0	0.0	±	0.0	0	16	10
Hexachlorocyclopentadiene	0	0.0	±	0.0	0	16	10
2,4,6-Trichlorophenol	0	0.0	±	0.0	0	16	10
2,4,5-Trichlorophenol	0	0.0	±	0.0	0	16	50
2-Chloronaphthalene	0	0.0	±	0.0	0	16	10
2-Nitroaniline	0	0.0	±	0.0	0	16	50
Dimethylphthalate	0	0.0	±	0.0	0	16	10
Acenaphthylene	0	0.0	±	0.0	0	16	10
2,6-Dinitrotoluene	0	0.0	±	0.0	0	16	10

Table 29. Continued.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)	# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Semivolatile Organics Analysis (continued)					
3-Nitroaniline	0	0.0 ± 0.0	0	16	50
Acenaphthene	0	0.0 ± 0.0	0	16	10
2,4-Dinitrophenol	0	0.0 ± 0.0	0	16	50
4-Nitrophenol	0	0.0 ± 0.0	0	16	50
Dibenzofuran	0	0.0 ± 0.0	0	16	10
2,4-Dinitrotoluene	0	0.0 ± 0.0	0	16	10
Diethylphthalate	0	0.0 ± 0.0	0	16	10
4-Chlorophenyl-phenylether	0	0.0 ± 0.0	0	16	10
Fluorene	0	0.0 ± 0.0	0	16	10
4-Nitroaniline	0	0.0 ± 0.0	0	16	50
4,6-Dinitro-2-methylphenol	0	0.0 ± 0.0	0	16	50
N-Nitrosodiphenylamine (1)	0	0.0 ± 0.0	0	16	10
4-Bromophenyl-phenylether	0	0.0 ± 0.0	0	16	10
Hexachlorobenzene	0	0.0 ± 0.0	0	16	10
Pentachlorophenol	0	0.0 ± 0.0	0	16	50
Phenanthrene	0	0.0 ± 0.0	0	16	10
Anthracene	0	0.0 ± 0.0	0	16	10
Di-n-butylphthalate	1	7.0 ± 0.0	1	16	10
Fluoranthene	0	0.0 ± 0.0	0	16	10
Pyrene	0	0.0 ± 0.0	0	16	10
Butylbenzylphthalate	1	0.5 ± 0.0	0	16	10
3,3-Dichlorobenzidine	0	0.0 ± 0.0	0	16	20
Benzo(a)anthracene	0	0.0 ± 0.0	0	16	10
Chrysene	0	0.0 ± 0.0	0	16	10
bis(2-Ethylhexyl)phthalate	8	9.1 ± 6.0	4	16	10
Di-n-octylphthalate	1	0.8 ± 0.0	0	16	10
Benzo(b)fluoranthene	0	0.0 ± 0.0	0	16	10
Benzo(k)fluoranthene	0	0.0 ± 0.0	0	16	10
Benzo(a)pyrene	0	0.0 ± 0.0	0	16	10
Indeno(1,2,3-cd)pyrene	0	0.0 ± 0.0	0	16	10
Dibenz(a,h)anthracene	0	0.0 ± 0.0	0	16	10
Benzo(g,h,i)perylene	0	0.0 ± 0.0	0	16	10

Table 30. Concentration of Semivolatile Organic Parameters Sampled from the Effluent Discharging Out of U12n Tunnel Portal.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)			# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Semivolatile Organics Analysis							
Phenol	0	0.0	±	0.0	0	27	10
bis (2-Chloroethyl) ether	0	0.0	±	0.0	0	27	10
2-Chlorophenol	0	0.0	±	0.0	0	27	10
1,3-Dichlorobenzene	0	0.0	±	0.0	0	27	10
1,4-Dichlorobenzene	0	0.0	±	0.0	0	27	10
Benzyl alcohol	0	0.0	±	0.0	0	27	10
1,2-Dichlorobenzene	0	0.0	±	0.0	0	27	10
2-Methylphenol	0	0.0	±	0.0	0	27	10
bis (2-chloroisopropyl) ether	0	0.0	±	0.0	0	27	10
4-Methylphenol	0	0.0	±	0.0	0	27	10
N-Nitroso-Di-n-propylamine	4	14.0	±	2.4	0	27	10
Hexachloroethane	0	0.0	±	0.0	0	27	10
Nitrobenzene	0	0.0	±	0.0	0	27	10
Isophorone	0	0.0	±	0.0	0	27	10
2-Nitrophenol	0	0.0	±	0.0	0	27	10
2,4-Dimethylphenol	0	0.0	±	0.0	0	27	10
Benzoic acid	0	0.0	±	0.0	0	27	50
bis (2-Chloroethoxy) methane	0	0.0	±	0.0	0	27	10
2,4-Dichlorophenol	0	0.0	±	0.0	0	27	10
1,2,4-Trichlorobenzene	0	0.0	±	0.0	0	27	10
Naphthalene	0	0.0	±	0.0	0	27	10
4-Chloroaniline	0	0.0	±	0.0	0	27	10
Hexachlorobutadiene	0	0.0	±	0.0	0	27	10
4-Chloro-3-methylphenol	0	0.0	±	0.0	0	27	10
2-Methylnaphthalene	0	0.0	±	0.0	0	27	10
Hexachlorocyclopentadiene	0	0.0	±	0.0	0	27	10
2,4,6-Trichlorophenol	0	0.0	±	0.0	0	27	10
2,4,5-Trichlorophenol	0	0.0	±	0.0	0	27	50
2-Chloronaphthalene	0	0.0	±	0.0	0	27	10
2-Nitroaniline	0	0.0	±	0.0	0	27	50
Dimethylphthalate	1	1.0	±	0.0	0	27	10
Acenaphthylene	0	0.0	±	0.0	0	27	10
2,6-Dinitrotoluene	0	0.0	±	0.0	0	27	10

Table 30. Continued.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)			# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Semivolatile Organics Analysis (continued)							
3-Nitroaniline	0	0.0	±	0.0	0	27	50
Acenaphthene	0	0.0	±	0.0	0	27	10
2,4-Dinitrophenol	0	0.0	±	0.0	0	27	50
4-Nitrophenol	0	0.0	±	0.0	0	27	50
Dibenzofuran	0	0.0	±	0.0	0	27	10
2,4-Dinitrotoluene	0	0.0	±	0.0	0	27	10
Diethylphthalate	0	0.0	±	0.0	0	27	10
4-Chlorophenyl-phenylether	0	0.0	±	0.0	0	27	10
Fluorene	0	0.0	±	0.0	0	27	10
4-Nitroaniline	0	0.0	±	0.0	0	27	50
4,6-Dinitro-2-methylphenol	0	0.0	±	0.0	0	27	50
N-Nitrosodiphenylamine (1)	0	0.0	±	0.0	0	27	10
4-Bromophenyl-phenylether	0	0.0	±	0.0	0	27	10
Hexachlorobenzene	0	0.0	±	0.0	0	27	10
Pentachlorophenol	0	0.0	±	0.0	0	27	50
Phenanthrene	0	0.0	±	0.0	0	27	10
Anthracene	0	0.0	±	0.0	0	27	10
Di-n-butylphthalate	1	0.5	±	0.0	1	27	10
Fluoranthene	0	0.0	±	0.0	0	27	10
Pyrene	0	0.0	±	0.0	0	27	10
Butylbenzylphthalate	1	0.4	±	0.0	0	27	10
3,3-Dichlorobenzidine	0	0.0	±	0.0	0	27	20
Benzo(a)anthracene	0	0.0	±	0.0	0	27	10
Chrysene	0	0.0	±	0.0	0	27	10
bis(2-Ethylhexyl)phthalate	14	39.9	±	76.5	8	27	10
Di-n-octylphthalate	1	0.2	±	0.0	0	27	10
Benzo(b)fluoranthene	0	0.0	±	0.0	0	27	10
Benzo(k)fluoranthene	0	0.0	±	0.0	0	27	10
Benzo(a)pyrene	0	0.0	±	0.0	0	27	10
Indeno(1,2,3-cd)pyrene	0	0.0	±	0.0	0	27	10
Dibenz(a,h)anthracene	0	0.0	±	0.0	0	27	10
Benzo(g,h,i)perylene	0	0.0	±	0.0	0	27	10

Table 31. Concentration of Semivolatile Organic Parameters Sampled from the Effluent Discharging Out of U12t Tunnel Portal.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)			# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Semivolatile Organics Analysis							
Phenol	0	0.0	±	0.0	0	15	10
bis (2-Chloroethyl) ether	0	0.0	±	0.0	0	15	10
2-Chlorophenol	0	0.0	±	0.0	0	15	10
1,3-Dichlorobenzene	0	0.0	±	0.0	0	15	10
1,4-Dichlorobenzene	0	0.0	±	0.0	0	15	10
Benzyl alcohol	0	0.0	±	0.0	0	15	10
1,2-Dichlorobenzene	0	0.0	±	0.0	0	15	10
2-Methylphenol	0	0.0	±	0.0	0	15	10
bis (2-chloroisopropyl) ether	0	0.0	±	0.0	0	15	10
4-Methylphenol	0	0.0	±	0.0	0	15	10
N-Nitroso-Di-n-propylamine	1	14.0	±	0.0	0	15	10
Hexachloroethane	0	0.0	±	0.0	0	15	10
Nitrobenzene	0	0.0	±	0.0	0	15	10
Isophorone	0	0.0	±	0.0	0	15	10
2-Nitrophenol	0	0.0	±	0.0	0	15	10
2,4-Dimethylphenol	0	0.0	±	0.0	0	15	10
Benzoic acid	0	0.0	±	0.0	0	15	50
bis (2-Chloroethoxy) methane	0	0.0	±	0.0	0	15	10
2,4-Dichlorophenol	0	0.0	±	0.0	0	15	10
1,2,4-Trichlorobenzene	0	0.0	±	0.0	0	15	10
Naphthalene	0	0.0	±	0.0	0	15	10
4-Chloroaniline	0	0.0	±	0.0	0	15	10
Hexachlorobutadiene	0	0.0	±	0.0	0	15	10
4-Chloro-3-methylphenol	0	0.0	±	0.0	0	15	10
2-Methylnaphthalene	0	0.0	±	0.0	0	15	10
Hexachlorocyclopentadiene	0	0.0	±	0.0	0	15	10
2,4,6-Trichlorophenol	0	0.0	±	0.0	0	15	10
2,4,5-Trichlorophenol	0	0.0	±	0.0	0	15	50
2-Chloronaphthalene	0	0.0	±	0.0	0	15	10
2-Nitroaniline	0	0.0	±	0.0	0	15	50
Dimethylphthalate	1	1.0	±	0.0	0	15	10
Acenaphthylene	0	0.0	±	0.0	0	15	10
2,6-Dinitrotoluene	0	0.0	±	0.0	0	15	10

Table 31. Continued.

Parameter Name	# of samples in which parameter was detected	Concentration of the detected values (µg/L)	# of these samples whose blank also contained the parameter	Total # of samples	Detection limit
Semivolatile Organics Analysis (continued)					
3-Nitroaniline	0	0.0 ± 0.0	0	15	50
Acenaphthene	0	0.0 ± 0.0	0	15	10
2,4-Dinitrophenol	0	0.0 ± 0.0	0	15	50
4-Nitrophenol	0	0.0 ± 0.0	0	15	50
Dibenzofuran	0	0.0 ± 0.0	0	15	10
2,4-Dinitrotoluene	0	0.0 ± 0.0	0	15	10
Diethylphthalate	0	0.0 ± 0.0	0	15	10
4-Chlorophenyl-phenylether	0	0.0 ± 0.0	0	15	10
Fluorene	0	0.0 ± 0.0	0	15	10
4-Nitroaniline	0	0.0 ± 0.0	0	15	50
4,6-Dinitro-2-methylphenol	0	0.0 ± 0.0	0	15	50
N-Nitrosodiphenylamine (1)	0	0.0 ± 0.0	0	15	10
4-Bromophenyl-phenylether	0	0.0 ± 0.0	0	15	10
Hexachlorobenzene	0	0.0 ± 0.0	0	15	10
Pentachlorophenol	0	0.0 ± 0.0	0	15	50
Phenanthrene	0	0.0 ± 0.0	0	15	10
Anthracene	0	0.0 ± 0.0	0	15	10
Di-n-butylphthalate	1	1.0 ± 0.0	0	15	10
Fluoranthene	0	0.0 ± 0.0	0	15	10
Pyrene	0	0.0 ± 0.0	0	15	10
Butylbenzylphthalate	1	0.6 ± 0.0	0	15	10
3,3-Dichlorobenzidine	0	0.0 ± 0.0	0	15	20
Benzo(a)anthracene	0	0.0 ± 0.0	0	15	10
Chrysene	0	0.0 ± 0.0	0	15	10
bis(2-Ethylhexyl)phthalate	4	15.9 ± 24.9	1	15	10
Di-n-octylphthalate	0	0.0 ± 0.0	0	15	10
Benzo(b)fluoranthene	0	0.0 ± 0.0	0	15	10
Benzo(k)fluoranthene	0	0.0 ± 0.0	0	15	10
Benzo(a)pyrene	0	0.0 ± 0.0	0	15	10
Indeno(1,2,3-cd)pyrene	0	0.0 ± 0.0	0	15	10
Dibenz(a,h)anthracene	0	0.0 ± 0.0	0	15	10
Benzo(g,h,i)perylene	0	0.0 ± 0.0	0	15	10

Table 32. Semivolatile Organic Analyte whose Concentration Exceeded the Detection Limit of the Method and those of the Associated Blanks.

Analyte	TUNNEL		
	U12c	U12n	U12t
Bis(2-Ethylhexyl) phthalate	June 18, 1991 (12 µg/L)	June 18, 1991 (24 µg/L)	August 5, 1991 (53 µg/L)*
	June 20, 1991 (11 µg/L)	June 21, 1991 (60 µg/L)	
	Jan. 13, 1992 (17 µg/L)	July 8, 1991 (21 µg/L)*	
		July 11, 1991 (42 µg/L)	
		Jan. 13, 1992 (32 µg/L)*	
		Feb. 28, 1992 (16 µg/L)	
		May 12, 1992 (12 µg/L)*	
		June 9, 1992 (310 µg/L)*	
N-nitroso-di-n-propylemine		June 18, 1991 (13 µg/L)	
		June 23, 1991 (16 µg/L)*	

*results are to be considered qualitative – see text.

Table 33. Comparison of U12n Tunnel Effluent Concentrations of Bis(2-Ethylhexyl)phthalate versus the Concentration of Their Associated Matrix Spike and Matrix Spike Duplicates.

Date	Effluent Result (µg/L)	Matrix Spike Result (µg/L)	Matrix Spike Duplicate Result (µg/L)
July 8, 1991	21	0	35
January 13, 1992	32	40	7.0

Table 34. Concentration of Unknown Semivolatile Organics Detected in Effluent Discharging from the U12e Tunnel Portal.

UNKNOWN SEMIVOLATILE PARAMETERS				
Range of retention time	Mean concentration (µg/L)	# of times detected	Total analyses conducted	# of samples whose blank also contained the parameter
5.19 – 5.27	14.0	1	16	0
5.89 – 6.07	70.0	1	16	1
6.51 – 6.88	80.0	3*	16	2
7.61 – 7.67	20.0	1	16	0
7.83 – 8.14	18.4	7	16	7
8.20 – 8.45	12.3	9	16	9
8.64 – 8.78	27.3	3	16	2
9.45 – 9.69	45.0	2*	16	1
10.44 – 10.66	31.0	1	16	1
12.07	20.0	1	16	0
13.19 – 13.22	10.0	1	16	1
38.68	9.0	1	16	0
40.32 – 41.66	8.0	1	16	2

*Includes replicate analyses

Table 35. Unknown Semivolatile Organics from U12e Tunnel Effluent that Exceeded the Concentration of their Associated Blanks.

Retention Time	Date	Concentration (µg/L)	Laboratory Blank Concentration (µg/L)
5.19 – 5.27	06/22/91	14	ND
6.51 – 6.88	11/25/91	60	40
7.61 – 7.67	10/08/91	20	0
7.83 – 8.14	06/21/91	27	26
8.20 – 8.45	06/22/91	10	9
	07/11/91	26	19
8.64 – 8.78	07/05/91	9	0
	10/08/91	50	10
9.45 – 9.69	10/08/91	70	20
12.07	10/08/91	20	0
38.68 – 39.90	11/25/91	9	0

ND – No laboratory blanks run

Table 36. Concentration of Unknown Semivolatile Organics Detected in Effluent Discharging from the U12n Tunnel Portal.

UNKNOWN SEMIVOLATILE PARAMETERS				
Range of retention time	Mean concentration (µg/L)	# of times detected	Total analyses conducted	# of samples whose blank also contained the parameter
5.89 – 6.07	220.0	1	27	1
6.51 – 6.88	75.0	4	27	3
7.83 – 8.14	32.3	3	27	2
8.20 – 8.45	25.14	7	27	6
8.64 – 8.78	21.0	5	27	2
9.14 – 9.18	2.0	1	27	0
9.45 – 9.69	31.0	2	27	1
10.44 – 10.66	29.02*	4*	27	3
10.97 – 11.07	24.0	2	27	1
15.29 – 15.69	10.5	2	27	1
31.10 – 31.26	7.0	2	27	0
33.97	10.0	1	27	0
35.09 – 35.92	10.0	1	27	1
36.51 – 36.70	14.0*	2	27	0
37.24 – 37.92	30.0*	2	27	0
38.68 – 39.90	80.0	1	27	1
40.32 – 41.66	20.0	1	27	1
46.27 – 47.22	10.0	2	27	1

*Includes replicate analyses

Table 37. Unknown Semivolatile Organics from U12n Tunnel Effluent that Exceeded the Concentration of Their Associated Blanks.

Retention Time	Date	Concentration (µg/L)	Laboratory Blank Concentration (µg/L)
5.89 – 6.07	09/09/91	220	190
6.51 – 6.88	08/19/91	16	0
7.83 – 8.14	11/25/91	50	40
	07/08/91	76	13
8.20 – 8.45	07/11/91	23	19
	09/09/91	30	0
	11/25/91	20	10
8.64 – 8.78	07/02/91	47	39
	07/05/91	9	0
	08/19/91	11	0
	09/09/91	8	0
	10/08/91	30	10
9.14 – 9.18	06/17/91	2	0*
	07/29/91	42	0*
	10/08/91	20	0*
10.44 – 10.66	06/19/91	31 (2nd run)	21
10.97 – 11.07	06/20/91	33	0
	07/11/91	15	13
15.29 – 15.69	06/20/91	8	0
	07/11/91	13	12
31.10 – 31.26	09/09/91	10	0
	07/14/92	4	0
33.97	09/09/91	10	0*
35.09 – 35.92	09/09/91	10	9
36.51 – 36.70	09/09/91	8 (1st run)	0*
		20 (2nd run)	0*
37.24 – 37.92	09/09/91	20 (1st run)	0*
		40 (2nd run)	0*
38.68 – 39.90	09/09/91	80	10

*No laboratory blanks run

Table 38. Concentration of Unknown Semivolatile Organics Detected in Effluent Discharging from the U12t Tunnel Portal.

UNKNOWN SEMIVOLATILE PARAMETERS				
Range of retention time	Mean concentration (µg/L)	# of times detected	Total analyses conducted	# of samples whose blank also contained the parameter
5.19 – 5.27	20.0	1	15	0
6.51 – 6.88	75.0	2	15	2
7.83 – 8.14	11.7	6	15	5
8.20 – 8.45	23.4	5	15	4
8.64 – 8.78	11.0	3	15	2
10.44 – 10.66	30.0	1	15	1
10.97 – 11.07	15.0	1	15	1
14.02	10.0	1	15	0
15.29 – 15.69	14.0	1	15	1
44.71 – 45.57	30.0	1	15	0

Table 39. Unknown Semivolatile Organics from U12t Tunnel Effluent that Exceeded the Concentration of Their Associated Blanks.

Retention Time	Date	Concentration (µg/L)	Laboratory Blank Concentration (µg/L)
5.19 – 5.27	09/09/91	20	0*
7.83 – 8.14	06/29/91	3	0
8.20 – 8.45	07/05/91	15	13
	07/11/91	23	19
	09/09/91	30	0
	11/25/91	40	10
	07/05/91	11	0
10.97 – 11.07	07/11/91	15	13
14.02	10/08/91	10	0*
15.29 – 15.69	07/11/91	14	12
44.71 – 45.57	08/05/91	30	0

*No laboratory blanks run

Table 40. Summary of Tritium Concentrations and Levels of Ionizing Radiation within U12c Tunnel Effluent during the Period of June 17, 1991 through May 12, 1992.

	Mean concentration of detected samples ($\mu\text{Ci/ml}$)	Standard Deviation	Range	# of detected samples	Total # of samples
Tritium	2.15×10^{-3}	1.75×10^{-4}	2.30×10^{-3} to 1.54×10^{-3}	16	16
Gamma Spec.	1.62×10^{-7}	9.49×10^{-8}	3.14×10^{-7} to ND ⁺	13	16
Gross Alpha	2.44×10^{-8}	1.63×10^{-8}	8.50×10^{-8} to 1.14×10^{-8}	16	16
Gross Beta	7.03×10^{-8}	3.09×10^{-8}	1.10×10^{-7} to Bkgd ⁺⁺	15	16

⁺Not detected

⁺⁺Below background

Table 41. Summary of Tritium Concentrations and Levels of Ionizing Radiation within U12n Tunnel Effluent during the Period of June 17, 1991 through July 28, 1992.

	Mean concentration of detected samples ($\mu\text{Ci/ml}$)	Standard Deviation	Range	# of detected samples	Total # of samples
Tritium	3.12×10^{-4}	1.09×10^{-4}	5.47×10^{-4} to 4.20×10^{-5}	27	27
Gamma Spec.	1.76×10^{-7}	5.94×10^{-8}	2.73×10^{-7} to ND ⁺	5	27
Gross Alpha	2.79×10^{-8}	4.20×10^{-8}	1.78×10^{-7} to 4.19×10^{-9}	26	26
Gross Beta	3.31×10^{-8}	4.76×10^{-8}	2.05×10^{-7} to <Bkgd ⁺⁺	23	26

⁺Not detected

⁺⁺Below background

Table 42. Summary of Tritium Concentrations and Levels of Ionizing Radiation within U12t Tunnel Effluent during the Period of June 17, 1991 through May 12, 1992.

	Mean concentration of detected samples ($\mu\text{Ci/ml}$)	Standard Deviation	Range	# of detected samples	Total # of samples
Tritium	6.46×10^{-3}	1.75×10^{-3}	3.76×10^{-2} to 2.60×10^{-3}	17	17
Gamma Spec.	1.43×10^{-7}	1.54×10^{-7}	4.51×10^{-7} to ND ⁺	9	17
Gross Alpha	1.10×10^{-8}	1.60×10^{-8}	7.34×10^{-8} to 3.72×10^{-9}	17	17
Gross Beta	3.22×10^{-7}	3.48×10^{-7}	1.41×10^{-6} to Bkgd ⁺⁺	16	17

⁺Not detected

⁺⁺Below background

APPENDIX 2

Figures from Text

Figure 1. U12n tunnel effluent discharge layout.

Figure 2. U12e tunnel effluent discharge layout.

Figure 3. U12t tunnel effluent discharge layout.

Figure 4. Schematic of instrumentation outlay for U12n tunnel.

Water Resources Center-DRI	
Sample # _____	Date _____
Location _____	Time _____
Well No. _____	Temp. _____
Preservative _____	Sample Type _____
Collected By _____	Filt/Unfilt _____
Depth _____	
Sampling Device _____	
Remarks _____	

Figure 5. Sample bottle label.

Field Parameters Log Sheet

Turbidity:

Air Temp:

2-7

Figure 6. Sample log sheet for the Tunnel Effluent Characterization Project.

2 of 2

CHAIN-OF-CUSTODY RECORD

[illegible]

Figure 7. Sample chain-of-custody form for the Tunnel Effluent Characterization Project.

ANALYSIS REQUEST FORM

Date of Receipt: _____

Person Receiving Samples: _____

[illegible]

Figure 8. Sample analysis request sheet for the Tunnel Effluent Characterization Project.

1991												1992						
Tunnel	Ju	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul				
U12n	17*, 18, 19, 20, 21, 22, 23, 26, 29	2, 5, 8, 11, 17, 23, 29	5, 19	9	8	25		13	29		9	12	9					
U12t	17, 18, 19, 20, 21, 22, 23, 29	5, 11	5	9	8	25	12**	13				12						
U12e	17, 18, 19, 20, 21, 22, 23, 29	5, 11	5	9	8	25		13				12						

1991												1992						
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul		
Calibration Activities	17**, 22	23	17, 26	11, 25		5	3	18		3, 18	26, 27	3, 10, 20	17, 24	8, 11, 12, 23, 24, 25, 26	2, 10, 11, 12, 13, 18	14, 28		
*sample dates **calibration/maintenance dates health and safety sample																		

Figure 9. Schedule for Tunnel Effluent Characterization Project sampling and characterization.

Figure 10. Temperature of U12e tunnel discharge from April 1991 to August 1992.

Figure 11. Temperature of U12n tunnel discharge from April 1991 to August 1992.

Figure 12. Temperature of U12t tunnel discharge from April 1991 to August 1992.

Figure 13. Rate of discharge for the U12e tunnel effluent from April 1991 to August 1992.

Figure 14. Rate of discharge for the U12n tunnel effluent from April 1991 to August 1992.

Figure 15. Rate of discharge for the U12t tunnel effluent from April 1991 to August 1992.

Figure 16. pH of U12c tunnel discharge from April 1991 to August 1992.

Figure 17. pH of U12n tunnel discharge from April 1991 to August 1992.

Figure 18. pH of U12t tunnel discharge from April 1991 to August 1992.

Figure 19. Electrical conductivity of U12e tunnel discharge from April 1991 to August 1992.

Figure 20. Electrical conductivity of U12n tunnel discharge from April 1991 to August 1992.

Figure 21. Electrical conductivity of U12t tunnel discharge from April 1991 to August 1992.

Figure 22. Turbidity of of U12n tunnel discharge from April 1991 to August 1992.

Figure 23. Turbidity of of U12t tunnel discharge from April 1991 to August 1992.

Figure 24. Histogram of accuracy achieved for trace metal and cation analysis of control spikes submitted on July 29, 1991 and February 28, 1992.

Figure 25. Histogram of accuracy achieved for volatile organic analysis of control spikes submitted on July 29, 1991 and February 28, 1992.

Figure 26. Histogram of accuracy achieved for semivolatile organic analysis of control spikes submitted on July 29, 1991 and February 28, 1992.

a 17/06/91
 b 18/06/91
 c 19/06/91
 d 20/06/91
 e 21/06/91
 f 22/06/91
 g 23/06/91
 h 29/06/91
 i 05/07/91
 j 11/07/91
 k 05/08/91
 l 09/09/91
 m 08/10/91
 n 25/11/91
 o 13/01/92
 p 12/05/92

Figure 27. Piper diagram for the 16 samples acquired from U12e tunnel.

a 17/06/91
 b 18/06/91
 c 19/06/91
 d 20/06/91
 e 21/06/91
 f 22/06/91
 g 23/06/91
 h 26/06/91
 i 29/06/91
 j 02/07/91
 k 05/07/91
 l 08/07/91
 m 11/07/91
 n 17/07/91
 o 23/07/91
 p 29/07/91
 q 05/08/91
 r 19/08/91
 s 09/09/91
 t 08/10/91
 u 25/11/91
 v 01/01/92
 w 28/02/92
 x 09/04/92
 y 12/05/92
 z 09/06/92
 A 14/07/92

Figure 28. Piper diagram for the 27 samples acquired from U12n tunnel.

- a 29/06/91
- b 02/07/91
- c 05/07/91
- d 08/07/91
- e 11/07/91
- f 17/07/91
- g 23/07/91
- h 29/07/91
- i 05/08/91
- j 08/10/91
- k 25/11/91
- l 13/01/92
- m 12/05/92
- n 14/07/92

Figure 29. Piper diagram for the non-affected samples acquired from U12n tunnel.

- a 17/06/91
- b 18/06/91
- c 19/06/91
- d 20/06/91
- e 21/06/91
- f 22/06/91
- g 23/06/91
- h 26/06/91
- i 19/08/91
- j 09/01/92
- k 28/02/91
- l 09/04/91
- m 09/06/91

Figure 30. Piper diagram for the affected samples acquired from U12n tunnel.

Figure 31. Time series of pH sample from U12n tunnel.

Figure 32. Piper diagram for the 16 samples acquired from U12t tunnel.

- a 17/06/91
- b 18/06/91
- c 19/06/91
- d 20/06/91
- e 21/06/91
- f 22/06/91
- g 23/06/91
- h 29/06/91
- i 05/07/91
- j 11/07/91
- k 05/08/91
- l 09/09/91
- m 08/10/91
- n 25/11/91

Figure 33. Piper diagram of U12t tunnel during high-flow conditions extending from 4/17/91 to 12/10/91.

- a 13/01/91
- b 12/05/91

Figure 34. Piper diagram of U12t tunnel during low-flow conditions extending from 12/11/91 to 7/28/92.

Figure 35. Iron concentrations in U12e tunnel effluent.

APPENDIX 3A

Results of U12e Tunnel Effluent Volatile Organic Analyses

The temporal variability of chloromethane in the U12e tunnel effluent is presented in Figure 36. Chloromethane was detected only once in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on June 22, 1991. The detected concentration was $7\mu\text{g/L}$ which was below the detection limit of the method ($10\mu\text{g/L}$). The concentration should be considered a qualitative estimate of the presence of chloromethane rather than a quantitative estimate. In addition, U12e tunnel was closed and very little variability within the discharge should have been seen. The detection of small concentrations of chloromethane in the discharge may be an artifact of the analysis or contamination in the bottles rather than the presence of the chemical in the effluent.

The temporal variability of bromomethane in U12e tunnel effluent is presented in Figure 37. Bromomethane was detected two times in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on June 22 and 23, 1991. The detected concentration was $3\mu\text{g/L}$, on both days, which was below the detection limit of the method. The concentration should be considered a qualitative estimate of the presence of bromomethane rather than a quantitative estimate. VOA field blanks were not taken on the two days during which the chemical was detected in the effluent. The detection of small concentrations of bromomethane in the discharge may be an artifact of the analysis or contamination in the bottles rather than the presence of the chemical in the effluent.

The temporal variability of vinyl chloride in U12e tunnel effluent is presented in Figure 38. Vinyl chloride was detected only once in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on June 22, 1991. The detected concentration was $6\mu\text{g/L}$ which is below the detection limit of the method. The concentration should be considered a qualitative estimate of the presence of vinyl chloride rather than a quantitative estimate. VOA field blanks were not taken on the day during which the chemical was detected in the effluent. The detection of small concentrations of vinyl chloride in the discharge may be an artifact of the analysis or contamination in the bottles rather than the presence of the chemical in the effluent.

The temporal variability of chloroethane in the U12e tunnel effluent is presented in Figure 39. At no time did the sample concentration exceed that of the laboratory or field blank. The one time chloroethane was detected in the effluent was likely due to contamination in the bottle or the analytical procedures and should be classified as a false positive.

The temporal variability of methylene chloride in U12e tunnel effluent is presented in Figure 40. Methylene chloride was detected two times in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on November 25, 1991 and January 13, 1992. The concentrations were 4 and $17\mu\text{g/L}$, respectively. The Nov. 25th concentration was below the detection limit of the method while the Jan. 13th concentration exceeded it. Only the latter analysis was a quantitative estimate of the concentration of methylene chloride in the effluent. VOA field blanks were not taken on the day during which the chemical was detected in the effluent. The

accuracy of the analytical method used to detect this parameter ranged from 85 to 96 percent (Table 13). The accuracy of this analysis and the level of concentration on January 13, 1992 are good indicators that methylene chloride was present during the analysis. However, the EPA does not consider the detection of up to 50 µg/L in samples to be a problem for common laboratory solvents such as methylene chloride (REECO analyst notes for VOA sample Nos. 74970, 14263, and 17115, May 25, 1992).

The temporal variability of acetone in the U12e tunnel effluent is presented in Figure 41. At no time did the sample concentration exceed that of the laboratory or field blank. There does appear to be a problem of acetone contamination within the field blanks used for this project. The source of water for the field blank was reagent grade high pressure liquid chromatography (HPLC) water. The presence of acetone in this water was probably due to contamination of the HPLC grade water by the supplier.

The temporal variability of 1,1-dichloroethene in the U12e tunnel effluent is presented in Figure 42. At no time does the sample concentration exceed that of the laboratory or field blank.

The temporal variability of 1,2-dichloroethene (total) in the U12e tunnel effluent is presented in Figure 43. 1,2-dichloroethene (total) was detected only once in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on June 22, 1991. The concentration was 4 µg/L, which was below the detection limit of the method (5 µg/L). The concentration should be considered a qualitative estimate of the presence of 1,2-dichloroethene (total) rather than a quantitative estimate. In addition, U12e tunnel was closed during the study and very little variability within the discharge should have been seen. The detection of a small isolated concentration of 1,2-dichloroethene (total) in the discharge may be an artifact of the analysis or contamination in the bottles rather than the presence of the chemical in the effluent.

The temporal variability of m,p-xylene in the U12e tunnel effluent is presented in Figure 44. At no time did the sample concentration exceed that of the laboratory or field blank.

Figure 36. Chloromethane concentration in U12c tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 37. Bromomethane concentration in U12c tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 38. Vinyl chloride concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 39. Chloroethane concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 40. Methylene chloride concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 41. Acetone concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 42. 1,1-Dichloroethene concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 43. 1,2-Dichloroethene (total) concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 44. m,p-Xylene concentration in U12e tunnel effluent for the period between April 17, 1991 to July 29, 1992.

APPENDIX 3B

Results of U12n Tunnel Effluent Volatile Organic Analyses

The temporal variability of chloromethane in U12n tunnel effluent is presented in Figure 45. Chloromethane was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 22, 23 and 26, 1991. The detected concentrations were 3, 3, and 8 µg/L, respectively, which were all below the limit of detection.

The temporal variability of bromomethane in U12n tunnel effluent is presented in Figure 46. Bromomethane was detected twice in the effluent in concentrations greater than that of the field and laboratory blanks. This occurred on June 20 and 23, 1991. The concentrations were 3 µg/L on both days, both of which were below the limit of detection for the method.

The temporal variability of vinyl chloride in U12n tunnel effluent is presented in Figure 47. Vinyl chloride was detected four times in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on June 20, 22, 23, and 26, 1991. The concentrations were 6, 5, 3, and 3 µg/L, respectively, all of which were below the detection limit of the method.

The temporal variability of chloroethane in U12n tunnel effluent is presented in Figure 48. Chloroethane was detected one time in the effluent in a concentration greater than that of the field and laboratory blank. This occurred on June 23, 1991. The concentration was 1 µg/L, which was below the limit of detection for the analytical method.

The temporal variability of methylene chloride in U12n tunnel effluent is presented in Figure 49a and 49b. Figure 49b is a close-up view of the variability of methylene chloride over time. Methylene chloride was detected four times in the effluent in concentrations greater than that of the field and laboratory blank. This occurred on June 18 and November 25, 1991 and January 13 and July 14, 1992. The concentrations were 5, 4, 20, and 14 µg/L, respectively. The January 13 and July 14, 1992 concentrations were above the detection limit of the method. The accuracy of the analyses for methylene chloride ranged from 85 to 96 percent (Table 13). The accuracy of the analyses and concentration levels on January 13, 1992 and July 14, 1992 were good indicators that methylene chloride was present during the analysis. However, methylene chloride is a common laboratory solvent and concentrations detected at or below the detection limit within the effluent may actually be due to the analytical method. EPA does not consider the detection of up to 50 µg/L in samples to be a problem for common laboratory solvents such as methylene chloride (REECo analyst's notes for VOA sample No. 74970, 14263, and 17115, May 25, 1992). It is interesting to note that January 13 was the only day in which methylene chloride was detected in the effluent of U12e tunnel above the limit of detection and its associated blanks. This coincidence may be another piece of circumstantial evidence that the detected concentrations of methylene chloride are actually due to laboratory contamination.

The temporal variability of acetone in U12n tunnel effluent is presented in Figure 50. Acetone was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. The chemical was detected on June 20 and 26, 1991 and Jan. 13, 1992. The concentrations

were 2, 26, and 8 µg/L, respectively. Only the June 26, 1991 sample exceeded the detection limit of the method. The laboratory blank for the June 26, 1991 analysis also exceeded the detection limit with a concentration of 11 µg/L. The accuracy of the analyses for acetone ranged from 37 to 100 percent. The accuracy of this analysis and the level of concentration on June 26, 1991 are good indicators that acetone was present during the analysis. Acetone is a common laboratory solvent and its sporadic occurrence and low concentrations during detection may be a result laboratory contamination.

The temporal variability of 1,1-dichloroethene in U12n tunnel effluent is presented in Figure 51. 1,1-dichloroethene was never detected in concentrations greater than that of the field and laboratory blanks.

The temporal variability of 1,2-dichloroethene (total) in U12n tunnel effluent is presented in Figure 52. 1,2-dichloroethene (total) was detected two times in the effluent in concentrations greater than that of the field and laboratory blanks. The chemical was detected on June 22 and July 29, 1991. The concentrations were 4 and 0.5 µg/L, respectively. Neither of these concentrations exceed the detection limit for the method.

The temporal variability of 2-butanone in U12n tunnel effluent is presented in Figure 53. 2-butanone was detected two times in the effluent in concentrations greater than that of the field and laboratory blanks. The chemical was detected on September 9, 1991 and April 9, 1992. The concentrations were 52 and 22 µg/L, respectively. These concentrations were well above the detection limit of the analytical method. The accuracy of the analysis for 2-butanone ranged from 0 to 88.26 percent during the period of this study. This level of accuracy was one of the lower ones for the volatile organic parameters measured during this study and casts some doubt as to the validity of the detected concentrations. 2-butanone is also known as methyl ethyl ketone. The chemical is used as a solvent in the surface coating industry, the manufacture of smokeless powder, and in colorless synthetic resins.

The temporal variability of 1,1,1-trichloroethane in U12n tunnel effluent is presented in Figure 54. 1,1,1-trichloroethane was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. The chemical was detected on June 22, September 9, 1991 and February 28, 1992. The concentrations were 4, 4, and 8 µg/L, respectively. None of the detected concentrations exceeded the detection limit of the method.

The temporal variability of 4-methyl-2-pentanone in U12n tunnel effluent is presented in Figure 55. 4-methyl-2-pentanone was detected on August 19, 1991 in the effluent in concentrations (1.0 µg/L) greater than that of the field and laboratory blanks. The concentration did not exceed the detection limit of the analytical method.

The temporal variability of tetrachloroethene in U12n tunnel effluent is presented in Figure 56. Tetrachloroethene was detected only once in the effluent in a concentration greater than that of the field and laboratory blanks. The chemical was detected on February 28, 1992 at a concentration of 4 µg/L. The detected concentration did not exceed the detection limit of the analytical method.

The temporal variability of m,p-xylene in U12n tunnel effluent is presented in Figure 57. m,p-xylene was detected two times in the effluent in concentrations greater than that of the field and laboratory blanks. The chemical was detected on June 18 and 21, 1991. The concentrations were 2 and 1 µg/L, respectively. None of the detected concentrations exceeded the detection limit of the method.

Figure 45. Chloromethane concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 46. Bromomethane concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 47. Vinyl chloride concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 48. Chloroethane concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 50. Acetone concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 51. 1,1-Dichloroethene concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 52. 1,2-Dichloroethene (total) concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 53. 2-Butanone concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 54. 1,1,1-Trichloroethane concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 55. 4-Methyl-2-Pentanone concentration in U12n tunnel effluent for the period between April 17, 1991 to July 29, 1992.

APPENDIX 3C

Results of U12t Tunnel Effluent Volatile Organic Analyses

The temporal variability of chloromethane in U12t tunnel effluent is presented in Figure 58. Chloromethane was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 20, 21 and 22, 1991. The detected concentrations were 6, 8, and 3 µg/L, respectively. These concentrations were below the level of detection for the method used during this study.

The temporal variability of bromomethane in U12t tunnel effluent is presented in Figure 59. Chloromethane was detected two times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 21 and 22, 1991. The detected concentrations were 4 and 1 µg/L, respectively. These concentrations were below the level of detection for the method used during this study.

The temporal variability of vinyl chloride in U12t tunnel effluent is presented in Figure 60. Vinyl chloride was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 20, 21 and 22, 1991. The detected concentrations were 6, 7, and 4 µg/L, respectively. These concentrations were below the level of detection for the method used during this study.

The temporal variability of chloroethane in U12t tunnel effluent is presented in Figure 61. Chloroethane was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on June 19, 1991. The detected concentration was 2 µg/L, which was below the level of detection for the method of detection used during this study.

The temporal variability of methylene chloride in U12t tunnel effluent is presented in Figure 62. Methylene chloride was detected four times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 18, 21 and 22, and November 25, 1991. The detected concentrations were 5, 5, 9, and 5 µg/L, respectively. All of the detected concentrations were below the level of detection. A previous sample acquired by REECO (Appendix IV, VOA sample # 97384) detected methylene chloride at a concentration of 3450 µg/L. The level of concentration was inconsistent with samples acquired during this characterization and were likely due to sample contamination.

The temporal variability of acetone in U12t tunnel effluent is presented in Figure 63. Acetone was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on September 9, 1991. The detected concentration was 18 µg/L. This concentration was greater than the detection limit of the method. The field blank for this day was also above the detection limit of the method (15 µg/L). The accuracy of the analyses for acetone ranged from 37 to 100 percent. The accuracy of this analysis, the level of concentration on June 26, 1991, and the elevated levels of the associated field blank suggest that the presence of acetone in the sample may be due to laboratory contamination or laboratory imprecision. Acetone is a common laboratory solvent.

The temporal variability of 1,1-dichloroethene in U12t tunnel effluent is presented in Figure 64. 1,1-dichloroethene was detected one time in the effluent in a concentration greater than that of the field and laboratory blanks. This concentration was detected on July 11, 1991. The detected concentration was 0.5 µg/L, which was below the level of detection for the analytical technique used.

The temporal variability of 1,2-dichloroethene (total) in U12t tunnel effluent is presented in Figure 65. 1,2-dichloroethene (total) was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 21, 22, and 23, 1991. The detected concentrations were 3 µg/L for all three days. These concentrations were below the level of detection for the method used during this study.

The temporal variability of 1,1,1-trichloroethane in U12t tunnel effluent is presented in Figure 66. 1,1,1-trichloroethane was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on September 9, 1991. The detected concentration was 4 µg/L, which was below the level of detection used during this study.

The temporal variability of benzene in U12t tunnel effluent is presented in Figure 67. Benzene was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on August 5, 1991. The detected concentration was 0.2 µg/L, which was below the level of detection used during this study.

The temporal variability of m,p-xylene in U12t tunnel effluent is presented in Figure 68. m,p-xylene was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 18, 21, and 22, 1991. The detected concentrations were 2, 1, and 3 µg/L, respectively. These concentrations were below the level of detection for the method used during this study.

Figure 58. Chloromethane concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 59. Bromomethane concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 60. Vinyl chloride concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 61. Chloroethane concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 62. Methylene chloride concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 63. Acetone concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 64. 1,1-Dichloroethene concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 65. 1,2-Dichloroethene (total) concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 66. 1,1,1-Trichloroethane concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 67. Benzene concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

Figure 68. m,p-Xylene concentration in U12t tunnel effluent for the period between April 17, 1991 to July 29, 1992.

APPENDIX 4A

Results of U12e Tunnel Effluent Semivolatle Organic Analyses

The temporal variability of N-Nitroso-Di-n-propylamine in the U12e tunnel effluent is presented in Figure 69. At no time did the sample concentration exceed that of the laboratory or field blanks.

The temporal variability of Di-n-butylphthalate in U12e tunnel effluent is presented in Figure 70. Di-n-butylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on July 11, 1991. The detected concentration was 7 µg/L and was less than that of the detection limit for the analytical method.

The temporal variability of butylbenzylphthalate in U12e tunnel effluent is presented in Figure 71. Butylbenzylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on June 22, 1991 and was 0.5 µg/L, which was less than the detection limit for the analytical method used.

The temporal variability of bis (2-Ethylhexyl) phthalate in U12e tunnel effluent is presented in Figure 72. Bis (2-Ethylhexyl) phthalate was detected five times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 18 and 20, August 8, September 9, 1991 and January 13, 1992. The detected concentrations were 12, 11, 5, 6, and 17 µg/L, respectively. The concentrations detected on June 18 and 20, 1991 and January 13, 1992 exceeded the detection limit of the method. The accuracy of the analyses for bis (2-Ethylhexyl) phthalate ranged from 91 to 99 percent. The accuracy of this analysis and the level of concentration on June 18 and 20, 1991 and January 13, 1992 are good indicators that bis (2-Ethylhexyl) phthalate was present during the analysis.

The temporal variability of di-n-octylphthalate in U12e tunnel effluent is presented in Figure 73. Di-n-octylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on June 20, 1991. The detected concentration was 0.8 µg/L, which was less than the detection limit for the analytical method used.

Figure 69. N-Nitroso-Di-n-propylamine concentration in U12e tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 70. Di-n-butylphthalate concentration in U12e tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 71. Butylbenzylphthalate concentration in U12e tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 72. bis (2-Ethylhexyl) phthalate concentration in U12e tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 73. Di-n-octylphthalate concentration in U12e tunnel effluent for the period between April 17, 1991 and July 28, 1992.

APPENDIX 4B

Results of U12n Tunnel Effluent Semivolatile Organic Analyses

The temporal variability of N-Nitroso-Di-n-propylamine in the U12n tunnel effluent is presented in Figure 74. N-Nitroso-Di-n-propylamine was detected two times in the effluent in concentrations greater than the laboratory and field blanks. These concentrations were detected on June 18 and 23, 1991. The detected concentrations were 13 and 16 µg/L, respectively. These concentrations exceeded the detection limit of the method. The accuracy of the analyses for N-Nitroso-Di-n-propylamine was 100 percent. The accuracy of this analysis and the level of concentration on June 18 and 23, 1991 are good indicators that N-Nitroso-Di-n-propylamine was present during the analysis.

The temporal variability of Di-n-butylphthalate in U12n tunnel effluent is presented in Figure 75. Di-n-butylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on June 29, 1991. The detected concentration was 0.5 µg/L, which was less than the detection limit of the method being used.

The temporal variability of butylbenzylphthalate in U12n tunnel effluent is presented in Figure 76. Butylbenzylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on June 21, 1991. The detected concentration was 0.4 µg/L, which was less than the detection limit of the method being used.

The temporal variability of bis (2-Ethylhexyl) phthalate in U12n tunnel effluent is presented in Figure 77. Bis (2-Ethylhexyl) phthalate was detected 11 times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on June 18 and 21, July 5, 8, and 11, August 19, September 9, 1991, January 13, February 28, May 12, and June 9, 1992. The detected concentrations were 24, 60, 10 and 21, 42, 3, 3, 32, 16, 11, and 310 µg/L, respectively. The concentrations detected on June 18 and 21, July 8 and 11, 1991, January 13, February 28, May 12, and June 9, 1992 exceeded the detection limit of the method. The accuracy of the analyses for bis (2-Ethylhexyl) phthalate ranged from 91 to 99 percent. The accuracy of this analysis and the level of concentration on June 18 and 21, July 8 and 11, 1991, January 13, February 28, May 12, and June 9, 1992 are good indicators that bis (2-Ethylhexyl) phthalate was present during the analysis.

The temporal variability of di-n-octylphthalate in U12n tunnel effluent is presented in Figure 78. Di-n-octylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on June 20, 1991. The detected concentration was 0.2 µg/L, which was less than the detection limit of the method being used.

Figure 74. N-Nitroso-Di-n-propylamine concentration in U12n tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 75. Di-n-butylphthalate concentration in U12n tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 76. Di-n-butylphthalate concentration in U12n tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 77. bis (2-Ethylhexyl) phthalate concentration in U12n tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 78. Di-n-octylphthalate concentration in U12n tunnel effluent for the period between April 17, 1991 and July 28, 1991.

APPENDIX 4C

Results of U12t Tunnel Effluent Semivolatile Organic Analyses

The temporal variability of N-Nitroso-Di-n-propylamine in the U12t tunnel effluent is presented in Figure 79. At no time did the sample concentration exceed that of the laboratory or field blanks.

The temporal variability of Di-n-butylphthalate in U12t tunnel effluent is presented in Figure 80. Di-n-butylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on August 5, 1991. The detected concentration was 1 µg/L, which was less than the detection limit of the method.

The temporal variability of butylbenzylphthalate in U12n tunnel effluent is presented in Figure 81. Butylbenzylphthalate was detected one time in the effluent in concentrations greater than that of the field and laboratory blanks. This concentration was detected on August 5, 1991. The detected concentration was 0.6 µg/L, which was less than the detection limit of the analytical method.

The temporal variability of bis (2-Ethylhexyl) phthalate in U12t tunnel effluent is presented in Figure 82. Bis (2-Ethylhexyl) phthalate was detected three times in the effluent in concentrations greater than that of the field and laboratory blanks. These concentrations were detected on July 11, August 5, and October 8, 1991. The detected concentrations were 7, 53, and 3 µg/L, respectively. The concentrations detected on August 5, 1991 exceeded the detection limit of the method. The accuracy of the analyses for bis (2-Ethylhexyl) phthalate ranged from 91 to 99 percent. The accuracy of this analysis and the level of concentration on August 5, 1991 are good indicators that bis (2-Ethylhexyl) phthalate was present during the analysis.

Figure 79. N-Nitroso-DI-n-propylamine concentration in U12t tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 80. DI-n-butylphthalate concentration in U12t tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 81. Butylbenzylphthalate concentration in U12t tunnel effluent for the period between April 17, 1991 and July 28, 1992.

Figure 82. bis (2-Ethylhexyl) phthalate concentration in U12t tunnel effluent for the period between April 17, 1991 and July 28, 1992.

APPENDIX 4D

Unknown SVOA Graphs for U12c Tunnel

Figure 83. Temporal variability of unknown SVOA parameter (return time of 5.19–5.27) in U12e tunnel effluent.

Figure 84. Temporal variability of unknown SVOA parameter (return time of 5.89–6.07) in U12e tunnel effluent.

Figure 85. Temporal variability of unknown SVOA parameter (return time of 6.51–6.88) in U12e tunnel effluent.

Figure 86. Temporal variability of unknown SVOA parameter (return time of 7.61–7.67) in U12e tunnel effluent.

Figure 87. Temporal variability of unknown SVOA parameter (return time of 7.83–8.14) in U12e tunnel effluent.

Figure 88. Temporal variability of unknown SVOA parameter (return time of 8.20–8.45) in U12e tunnel effluent.

Figure 89. Temporal variability of unknown SVOA parameter (return time of 8.64–8.78) in U12e tunnel effluent.

Figure 90. Temporal variability of unknown SVOA parameter (return time of 9.45–9.69) in U12e tunnel effluent.

Figure 91. Temporal variability of unknown SVOA parameter (return time of 10.44–10.66) in U12e tunnel effluent.

Figure 92. Temporal variability of unknown SVOA parameter (return time of of 12.07) in U12e tunnel effluent.

Figure 93. Temporal variability of unknown SVOA parameter (return time of 13.19-13.22) in U12e tunnel effluent.

Figure 94. Temporal variability of unknown SVOA parameter (return time of 38.68-39.90) in U12e tunnel effluent.

Figure 95. Temporal variability of unknown SVOA parameter (return time of 40.32–41.66) in U12e tunnel effluent.

APPENDIX 4E

Unknown SVOA Graphs for U12n Tunnel

Figure 96. Temporal variability of unknown SVOA parameter (return time of 5.89-6.07) in U12n tunnel effluent.

Figure 97. Temporal variability of unknown SVOA parameter (return time of 6.51-6.88) in U12n tunnel effluent.

Figure 100. Temporal variability of unknown SVOA parameter (return time of 8.64-8.78) in U12n tunnel effluent.

Figure 101. Temporal variability of unknown SVOA parameter (return time of 9.14-9.18) in U12n tunnel effluent.

Figure 102. Temporal variability of unknown SVOA parameter (return time of 9.45-9.69) in U12n tunnel effluent.

Figure 103. Temporal variability of unknown SVOA parameter (return time of 10.44-10.66) in U12n tunnel effluent.

Figure 104. Temporal variability of unknown SVOA parameter (return time of 10.97-11.07) in U12n tunnel effluent.

Figure 105. Temporal variability of unknown SVOA parameter (return time of 15.29-15.69) in U12n tunnel effluent.

Figure 106. Temporal variability of unknown SVOA parameter (return time of 31.10-31.26) in U12n tunnel effluent.

Figure 107. Temporal variability of unknown SVOA parameter (return time of 33.97) in U12n tunnel effluent.

Figure 108. Temporal variability of unknown SVOA parameter (return time of 35.09–35.92) in U12n tunnel effluent.

Figure 109. Temporal variability of unknown SVOA parameter (return time of 36.51–36.70) in U12n tunnel effluent.

Figure 110. Temporal variability of unknown SVOA parameter (return time of 37.24–37.92) in U12n tunnel effluent.

Figure 111. Temporal variability of unknown SVOA parameter (return time of 38.68–39.90) in U12n tunnel effluent.

Figure 112. Temporal variability of unknown SVOA parameter (return time of 40.32–41.66) in U12n tunnel effluent.

Figure 113. Temporal variability of unknown SVOA parameter (return time of 46.27–47.22) in U12n tunnel effluent.

APPENDIX 4F

Unknown SVOA Graphs for U12t Tunnel

Figure 114. Temporal variability of unknown SVOA parameter (return time of 5.19–5.27) in U12t tunnel effluent.

Figure 115. Temporal variability of unknown SVOA parameter (return time of 6.51–6.88) in U12t tunnel effluent.

Figure 116. Temporal variability of unknown SVOA parameter (return time of 7.83–8.14) in U12t tunnel effluent.

Figure 117. Temporal variability of unknown SVOA parameter (return time of 8.20–8.45) in U12t tunnel effluent.

Figure 118. Temporal variability of unknown SVOA parameter (return time of 8.64–8.78) in U12t tunnel effluent.

Figure 119. Temporal variability of unknown SVOA parameter (return time of 10.44–10.66) in U12t tunnel effluent.

Figure 120. Temporal variability of unknown SVOA parameter (return time of 10.97-11.07) in U12t tunnel effluent.

Figure 121. Temporal variability of unknown SVOA parameter (return time of 14.02) in U12t tunnel effluent.

Figure 122. Temporal variability of unknown SVOA parameter (return time of 15.29–15.69) in U12t tunnel effluent.

Figure 123. Temporal variability of unknown SVOA parameter (return time of 44.71–45.57) in U12t tunnel effluent.

APPENDIX 5A

U12e Tunnel Radionuclide Results

Figure 124. Tritium concentration in U12e tunnel effluent from June 17, 1991 to May 12, 1992.

Figure 125. Gamma radiation levels in U12e tunnel effluent from June 17, 1991 to May 12, 1992.

Figure 126. Gross alpha radiation levels in U12c tunnel effluent from June 17, 1991 to May 12, 1992.

Figure 127. Gross beta radiation levels in U12c tunnel effluent from June 17, 1991 to May 12, 1992.

APPENDIX 5B

U12n Tunnel Radionuclide Results

Figure 128. Tritium concentrations in U12n tunnel effluent from June 17, 1991 to July 28, 1992.

Figure 129. Gamma radiation levels in U12n tunnel effluent from June 17, 1991 to July 28, 1992.

Figure 130. Gross alpha radiation levels in U12n tunnel effluent from June 17, 1991 to July 28, 1992.

Figure 131. Gross beta radiation levels in U12n tunnel effluent from June 17, 1991 to June 28, 1992.

APPENDIX 5C

U12t Tunnel Radionuclide Results

Figure 132. Tritium concentration in U12t tunnel effluent from June 17, 1991 to May 12, 1992.

Figure 133. Gamma radiation levels in U12t tunnel effluent from June 17, 1991 to May 12, 1992.

Figure 134. Gross alpha radiation levels in U12t tunnel effluent from June 17, 1991 to May 12, 1992.

Figure 135. Gross beta radiation levels in U12t tunnel effluent from June 17, 1991 to May 12, 1992.

APPENDIX 6

Results of Previous Metals, Radionuclide, VOA and SVOA Analyses

<u>Sample #</u>	<u>Sample Origin</u>
97390	Yucca Decontamination Pond
97384	T Tunnel Effluent
97386	T Tunnel Pond
97387	T Tunnel Pond
97383	E Tunnel Effluent
97385	N Tunnel Effluent
97388	N Tunnel Pond
97389	N Tunnel Pond
3450	Higher of Data

APPENDIX 7

Results of Previous Radionuclide Analyses

Mean Results of REECo's¹ Routine Monitoring of Radioactivity in the Area 12 Tunnel Ponds

Tunnel and Parameter	Mean μCi/ml	Standard Deviation μCi/ml	Minimum μCi/ml	Maximum μCi/ml
U12c Tunnel Ponds				
U12c1 Beta	0.0000115	0.0000205	0.0000002	0.000058
U12c1 Gamma ²	127.8	18.7	102	157
U12c1 Tritium	0.015	0.026	0.003	0.080
U12c2 Beta	.0000172	0.0000379	0.0000002	0.000085
U12c2 Tritium	0.011	0.010	0.005	0.025
U12c3 Beta	0.0000168	0.0000284	0.0000002	0.000069
U12c3 Tritium	0.0095	0.007	0.0025	0.0200
U12c4 Beta	0.0000099	0.0000186	0.0000002	0.00006
U12c4 Tritium	0.026	0.035	0.003	0.100
U12n Tunnel Ponds				
U12n1 Beta	0.0000006	0.0000016	0.00000001	0.0000067
U12n1 Gamma ²	146.6	22.5	112	195
U12n1 Tritium	0.002	0.003	0.00005	0.011
U12n2 Beta	0.0000004	0.0000011	0.00000004	0.0000043
U12n2 Tritium	0.00089	0.00089	0.00011	0.00290
U12n3 Beta	0.00000034	0.00000108	0.00000002	0.0000044
U12n3 Tritium	0.00078	0.00087	0.0005	0.0029
U12t Tunnel Ponds				
U12t1 Beta	0.0001	0.00031	0.000000015	0.00110
U12t1 Tritium	0.064	0.104	0.00003	0.300
U12t2 Beta	0.00014	0.00046	0.000000016	0.0018
U12t2 Gamma ²	438.6	135.4	150	694
U12t2 Tritium	0.064	0.101	0.00006	0.330
U12t Tunnel Upper Ponds				
U12tu Beta	0.0009	0.00026	0.00000001	0.0010
U12tu Tritium	0.014	0.023	0.0002	0.070

¹Results summarized from REECo's routine radiological monitoring reports, 1965-1990

²mrem/yr

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U.S. Department of Energy

Gylan Allen
Test Operations Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

Doug Duncan
Hydrology Program Manager
Office of Environmental Restoration & Waste
Management
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

Don Elle, Director
Environment Protection Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

Joseph N. Flore, Acting Asst. Mgr.
Office of Environmental Restoration & Waste
Management
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
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Joseph H. Kitchen
Technology and Program Management Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
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Environmental Restoration Division
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Test Operations Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

Steve Mellington, Director
Environmental Restoration Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

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Las Vegas, NV 89193-8518

Richard Pearl
Environmental Protection Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

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David Bedsun
Defense Nuclear Agency
U.S. Department of Defense
P.O. Box 98539
Las Vegas, NV 89193-8539

Lawrence Livermore National Laboratory

Greg Nimz
Lawrence Livermore National Laboratory
P.O. Box 808, MS L233
Livermore, CA 94550

Los Alamos National Laboratory

Joe Thompson
Los Alamos National Laboratory
INC-11, MS J514
P.O. Box 1663
Los Alamos, NM 87545

U.S. Geological Survey

Virginia Glanzman
U.S. Geological Survey
Box 2506, MS 913
Denver Federal Center
Denver, CO 80225

Randy Lacznlak
U.S. Geological Survey
Water Resources Division
6770 S. Paradise Rd.
Las Vegas, NV 89119

Paul Orkild
U.S. Geological Survey
Box 2506, MS 913
Denver Federal Center
Denver, CO 80225

Doug Trudeau
U.S. Geological Survey
Water Resources Division
6770 S. Paradise Rd.
Las Vegas, NV 89119

Desert Research Institute

Roger Jacobson
Desert Research Institute
Water Resources Center
P.O. Box 19040
Las Vegas, NV 89132-0040

Marjory Jones
Desert Research Institute
Water Resources Center
P.O. Box 60220
Reno, NV 89506-0220

Paul Seaber
Desert Research Institute
Water Resources Center
P.O. Box 19040
Las Vegas, NV 89132-0040

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Chief, Document Research Section
Health Protection Dept.
Reynolds Electrical & Engineering Co.
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2501 Wyandotte
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Geotrans
c/o IT
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Suite 112
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**Joe Yeasted
International Technology Corp.
Southern Nevada Science Center
P.O. Box 19040
Las Vegas, NV 89132-0040**

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