RECORD OF TECHNICAL CHANGE

Technical Change No. 1

Project/Job No. 780810.26020100

Date May 26, 1999

Project/Job Name Project Shoal

The following technical changes (including justification) are requested by:

Paul Gretsky
(Name)

Project Manager
(Title)

Page 13, Second Paragraph. Delete bullet #1, which begins, "**Direct discharge to the ground surface...**". Change subsequent numbering of bullets.

Justification: This change is being made as a result of an NDEP comment. During the drilling and test activities at the PSA, the option of fluid discharge directly to the ground surface is not being considered.

The project time will be (Increased)(Decreased)(Unchanged) by approximately 0 days

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Applicable Project-Specific Document(s):

Fluid Management Plan for the Project Shoal Area Off-Sites Project

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CC:

Approved By: [redacted]

(Off-Sites Project Manager)

for RCW

[redacted]

(Division Director, Environmental Restoration Division)

Client Notified Yes __ No ____ Date ______________________

Contract Change Order Required Yes __ No __________________

Contract Change Order No. __________________________________

LV/5-26-99/FORM_141

INTERNATIONAL
TECHNOLOGY
CORPORATION

RECORD OF TECHNICAL CHANGE

Technical Change No. 2

Project/Job No. 799419.0056.0005

Date 11/22/99

Project/Job Name Project Shoal Area.

The following technical changes (including justification) are requested by:

Bryan Cherry	Site Supervisor
(Name)	(Title)

Section 4.1 of the Fluid Management Plan (FMP) specifies that monitoring for tritium shall be conducted every four (4) hours during the aquifer development and testing phase. Well HC-5 has required more time to develop than predicted. Based on current pumping rates, it is estimated that an additional 28 days will be required before the well is fully developed. Tritium monitoring results to date do not demonstrate an upward trend in tritium activity or give any indication that tritium levels will exceed FMP action levels. This technical change will nullify the requirement to collect and analyze tritium monitoring samples for the remainder of the aquifer testing at the HC-5 well. Therefore, the only action required at HC-5 will be collection and analysis of a representative sump sample in accordance with Section 4.2 of the FMP, prior to discharge to the infiltration basin.

Section 4.1 of the FMP also specifies a weekly tritium monitoring frequency for wells involved in the tracer experiment. Based on a revised wellhead capture zone analysis and initial pumping test results, it is predicted that wells involved in the tracer test will not yield groundwater in excess of FMP parameters. This technical change will nullify the requirement to collect and analyze weekly tritium monitoring samples for the remainder of the tracer test. As with well HC-5, the only action required at the wells involved in the tracer test will be collection and analysis of a representative sump sample in accordance with Section 4.2 of the FMP, prior to discharge to the infiltration basin.

The project time will be (**Increased**)(~~Decreased~~)(~~Unchanged~~) by approximately 28 days

Applicable Project-Specific Document(s):

Fluid Management Plan for the Project Shoal Area, Off-Sites Project (DOE/NV–542, Rev. 0, April 1999)

CC:

Approved By: Monica Sanchez Date 12/1/99
(Off-Sites Project Manager)

Runore Shycoff Date 12/1/99
(Division Director, Environmental Restoration Division)

Client Notified Yes X No ____ Date Nov. 23, 1999

Contract Change Order Required Yes __ No X

Contract Change Order No. ____

Project Shoal Wellhead Capture Zone Analysis
by
Greg Pohll
Desert Research Institute
November 18, 1999

Introduction

An analysis of the potential fluid pathways induced by the current groundwater pumping at the Project Shoal Area (PSA) was performed to determine the risk of radionuclide transport from the PSA test to downgradient pumping wells. The semi-analytic model RESSQC (Blandford and Huyakorn, 1991) was used to determine the time-dependent capture zone for the proposed tracer test and purging of HC-5. The input parameters required by RESSQC are not known with full certainty, so the analysis was performed within a Monte Carlo framework to assess the uncertainty in the predicted capture zones.

Pumping is continuing at the PSA in wells HC-7 and HC-5. HC-7 is being used as the discharge well during the forced gradient tracer test and HC-5 is being pumped to remove remaining drilling fluids. HC-6 is currently being used as the injection well in which tracers are injected for short periods, followed by continuous injection of HC-7 discharge fluid. It is expected the tracer test will continue through the end of February, 2000 and the pumping at HC-5 will continue through the end of December, 1999.

Methodology

The semi-analytic model RESSQC (Blandford and Huyakorn, 1991) was used to determine the time dependent capture zones for HC-5 and HC-7. RESSQC is a two-dimensional model and as such assumes that all injection and pumping will be from similar depths. The well screen in HC-5 is approximately 700 m deeper than both HC-6 and HC-7, so the capture zones calculated will be extremely conservative as true migration paths are would require greater migration distances.

RESSQC also assumes that the aquifer is homogeneous, isotropic, and of constant saturated thickness. The fractured granite aquifer at the PSA is not homogeneous at the regional scale, but it is assumed that at the scale of the tracer test, the flow system can be represented by an equivalent homogeneous and isotropic porous media. The assumption that the pumping induced stress will not induce vertical flow (*i.e.* only two-dimension flow is simulated) is conservative as vertical flow would only serve to reduce the capture zone radius.

Table 1 below shows the injection and discharge rates used in the analysis.

Table 1 Injection and discharge rates used in the capture zone analysis.

Well	Injection Rate (GPM)	Discharge Rate (GPM)
HC-5	—	4
HC-6	0.3	—
HC-7	—	3

The groundwater flow and transport model of the PSA was used to assess the present distribution of radionuclides (Pohll, et al., 1998). This analysis suggests that the current radionuclide plume is restricted to a radius of less than 100 m from the test.

The aquifer parameters (transmissivity, effective porosity, and hydraulic gradient) were assumed to be uncertain parameters. Additional data has been collected near the test wells to refine the parameter distributions. Specifically, the aquifer test in HC-7 indicates transmissivity values near 1 m^2/day and specific yields near 0.01. Specific yield is an aquifer property which is analogous to the effective porosity. The lack of breakthrough during the first two weeks of the tracer test also supports effective porosity values near 0.01. Table 2 shows the uncertain parameters and the associated distributions used in the analysis.

The RESSQC model was used to simulate the injection and pumping stresses during combined pumping of HC-5 and HC-7 for a 120-day period. RESSQC computes the time-dependent capture zone for the pumping wells by tracing the movement of fluid particles through the groundwater flow system. The fluid particles are traced in reverse direction until termination of the pumping. The program tracks multiple fluid particles to delineate the entire capture zone for the time-period of interest.

Table 2 Parameters and associated distributions used in capture zone analysis.

Parameter	Mean	Standard Deviation	Lower Bound	Upper Bound	Distribution
Transmissivity (m^2/day)	1	3	—	—	Log Normal
Effective Porosity	0.01	—	0.005	0.02	Log Uniform
Hydraulic Gradient	0.06	—	0.03	0.1	Uniform

Results and Discussion

Figure 1 shows the 99% confidence level for the simulated capture zone. The 99% confidence level is indicative of the worst case scenario in terms of potential migration of test related solutes toward the pumping wells.

Of the 100 realizations, none showed capture zones that intersected the calculated location of the radionuclide plume associated with the PSA test.

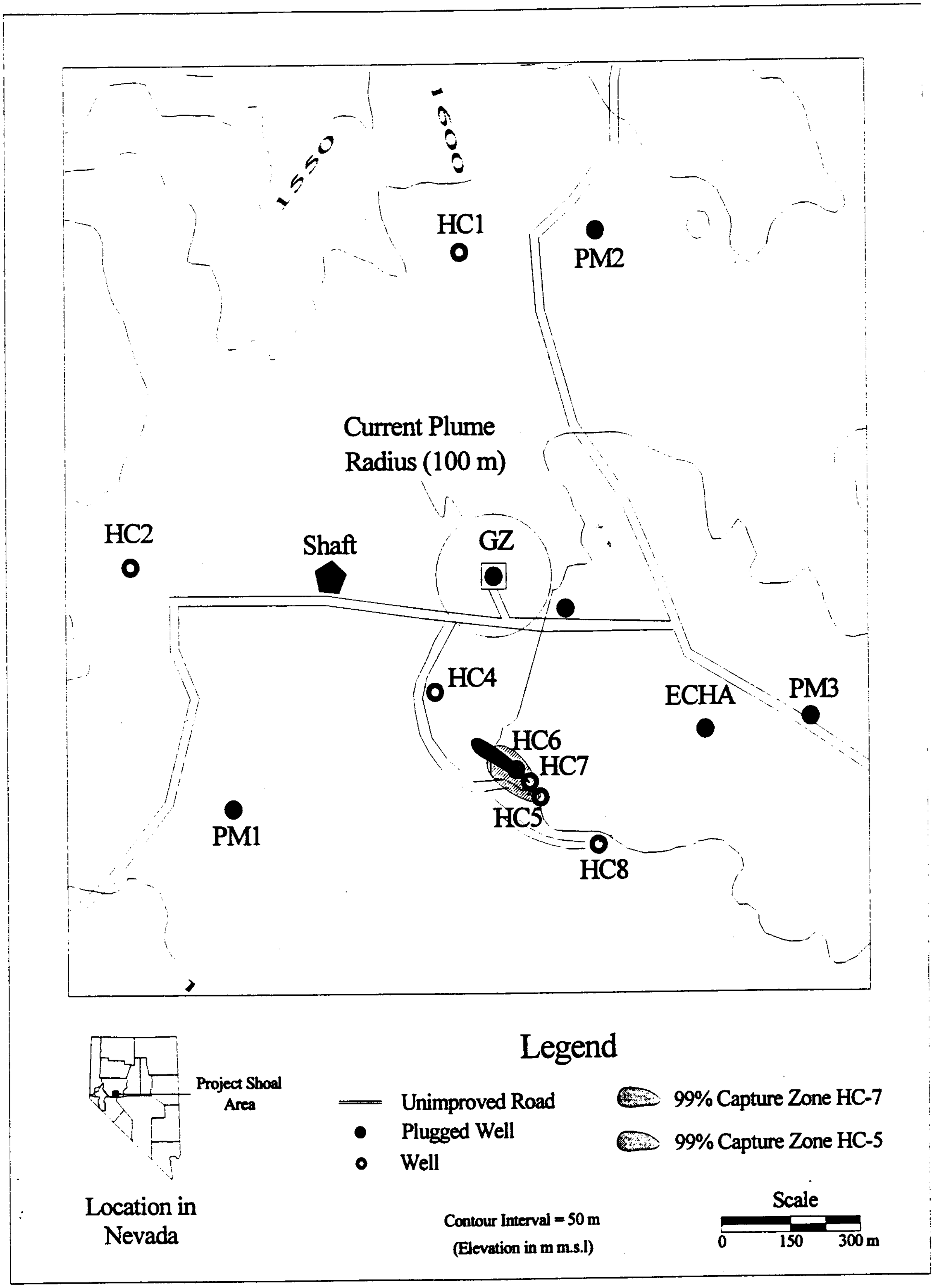


Figure 1 Predicted 99% capture zone confidence levels for HC-5 and HC-7.

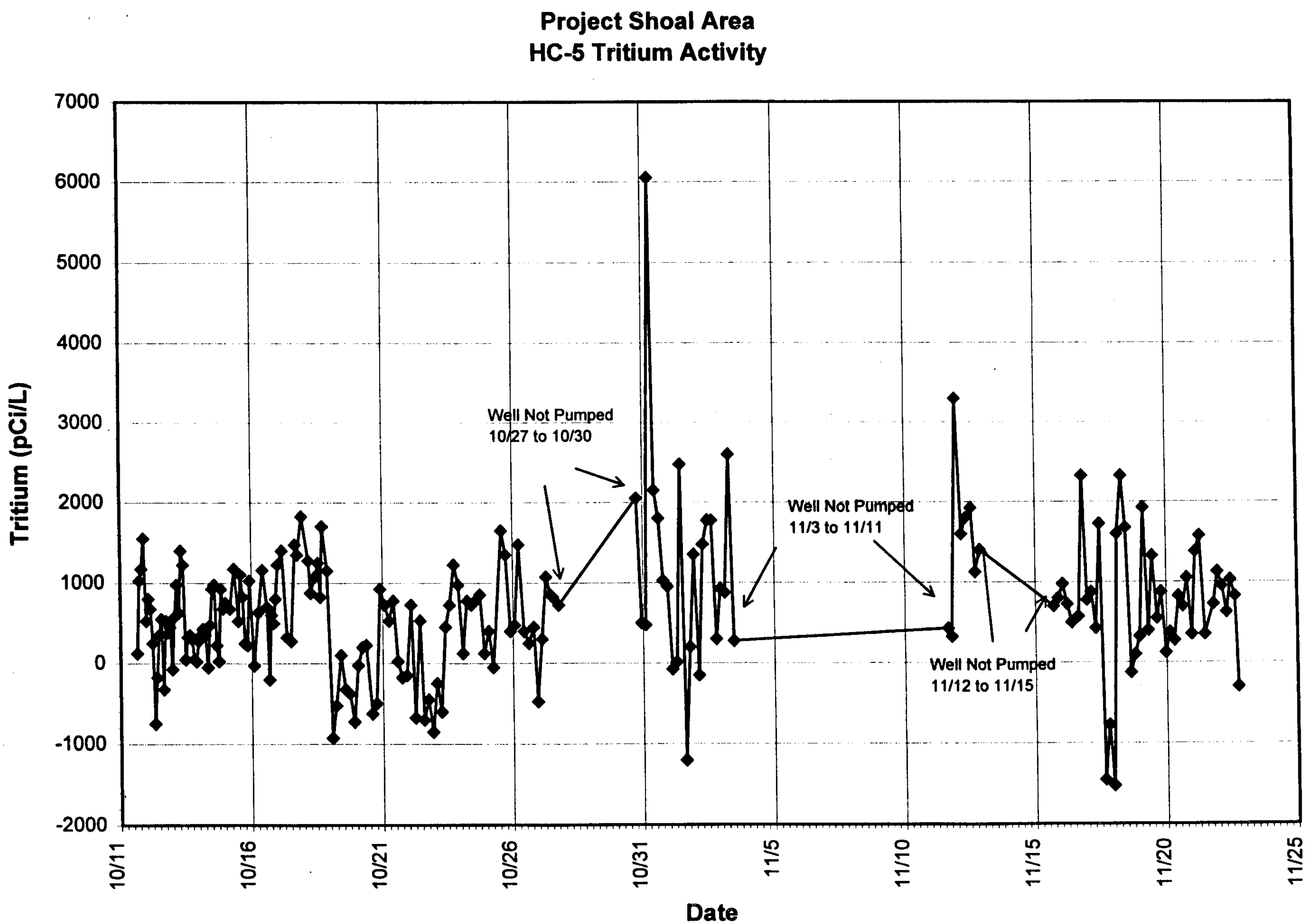
Conclusions

A semi-analytical model, RESSQC, was used to determine the risk of encountering radionuclides in HC-5 and HC-7 associated with the 120 day tracer test and purging of drilling fluids.. The results indicate that there is a very low probability that either well will encounter test related solutes during the testing period.

References

Blandford, T. N., and P. S. Huyakorn, 1991. WHPA 2.0 Code - A Modular Semi-Analytical Model for the Delineation of Wellhead Protection Areas. U.S. EPA Office of Ground-Water Protection, Washington, DC.

Pohll, G., J. Chapman, A. Hassan, C. Papelis, R. Andricevic, and C. Shirley, 1998. Evaluation of Groundwater Flow and Transport at the Shoal Underground Nuclear Test: An Interim Report. Desert Research Institute, Water Resources Center Publication 45162.



Project Shoal Area
HC-5 Tritium Activity
Tritium (pCi/L)
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
Well Not Pumped
10/27 to 10/30
Well Not Pumped
11/3 to 11/11
Well Not Pumped
11/12 to 11/15
10/11
10/16
10/21
10/26
10/31
11/5
11/10
11/15
11/20
11/25
Date

Table 3
HC-5 Tritium Monitoring Data

Date (mm/dd/yy)	Tritium (pCi/L)
10/11/1999 15:15	125
10/11/1999 17:25	1025
10/11/1999 19:25	1175
10/11/1999 21:30	1550
10/11/1999 23:30	525
10/12/1999 1:30	800
10/12/1999 3:30	675
10/12/1999 5:30	250
10/12/1999 7:30	-750
10/12/1999 9:30	-175
10/12/1999 11:30	350
10/12/1999 13:30	550
10/12/1999 15:30	-325
10/12/1999 17:35	525
10/12/1999 19:30	375
10/12/1999 21:30	450
10/12/1999 23:30	-75
10/13/1999 1:30	575
10/13/1999 3:40	975
10/13/1999 5:40	625
10/13/1999 7:40	1400
10/13/1999 9:40	1225
10/13/1999 11:30	50
10/13/1999 13:30	325
10/13/1999 15:30	350
10/13/1999 17:30	300
10/13/1999 19:30	50
10/13/1999 21:30	25
10/13/1999 23:30	275
10/14/1999 1:30	350
10/14/1999 3:30	425
10/14/1999 5:30	350
10/14/1999 8:00	-50
10/14/1999 10:00	475
10/14/1999 12:00	925
10/14/1999 14:00	975
10/14/1999 16:00	225
10/14/1999 18:00	28
10/14/1999 20:00	925
10/14/1999 22:00	675
10/15/1999 0:15	750
10/15/1999 4:05	675
10/15/1999 8:15	1175
10/15/1999 11:55	525
10/15/1999 14:00	1100
10/15/1999 16:00	825
10/15/1999 18:00	250

Table 3
HC-5 Tritium Monitoring Data

Date (mm/dd/yy)	Tritium (pCi/L)
10/15/1999 20:00	225
10/15/1999 22:00	1025
10/16/1999 2:00	-27
10/16/1999 6:10	632
10/16/1999 10:05	1158
10/16/1999 14:00	700
10/16/1999 16:00	-200
10/16/1999 18:00	600
10/16/1999 20:00	500
10/16/1999 22:00	800
10/17/1999 0:00	1225
10/17/1999 4:05	1400
10/17/1999 8:10	325
10/17/1999 11:55	275
10/17/1999 16:00	1475
10/17/1999 18:05	1350
10/17/1999 22:15	1825
10/18/1999 4:04	1275
10/18/1999 6:13	875
10/18/1999 10:16	1075
10/18/1999 13:05	1250
10/18/1999 15:00	825
10/18/1999 17:00	1700
10/18/1999 21:15	1150
10/19/1999 1:24	-925
10/19/1999 5:03	-525
10/19/1999 9:19	100
10/19/1999 13:20	-325
10/19/1999 17:10	-375
10/19/1999 21:28	-725
10/20/1999 1:03	-25
10/20/1999 5:12	200
10/20/1999 8:34	225
10/20/1999 13:44	-625
10/20/1999 17:47	-500
10/20/1999 21:38	925
10/21/1999 1:34	725
10/21/1999 5:30	525
10/21/1999 9:30	775
10/21/1999 13:30	25
10/21/1999 17:31	-175
10/21/1999 21:38	-150
10/22/1999 1:51	725
10/22/1999 5:30	-675
10/22/1999 10:08	528
10/22/1999 13:22	-700
10/22/1999 17:40	-450

Table 3
HC-5 Tritium Monitoring Data

Date (mm/dd/yy)	Tritium (pCi/L)
10/22/1999 21:37	-850
10/23/1999 1:35	-250
10/23/1999 5:30	-600
10/23/1999 9:30	450
10/23/1999 13:37	725
10/23/1999 17:34	1225
10/23/1999 21:34	975
10/24/1999 1:50	125
10/24/1999 5:50	775
10/24/1999 9:38	725
10/24/1999 13:26	775
10/24/1999 17:42	850
10/24/1999 21:23	125
10/25/1999 1:35	400
10/25/1999 5:47	-50
10/25/1999 13:36	1650
10/25/1999 17:30	1350
10/25/1999 21:25	400
10/26/1999 1:24	475
10/26/1999 5:29	1475
10/26/1999 9:55	400
10/26/1999 14:35	250
10/26/1999 18:48	450
10/26/1999 22:31	-475
10/27/1999 2:25	300
10/27/1999 6:23	1075
10/27/1999 10:30	852
10/27/1999 12:30	825
10/27/1999 17:58	725
10/30/1999 18:20	2050
10/30/1999 22:20	500
10/31/1999 2:15	475
10/31/1999 6:20	6050
10/31/1999 10:20	2150
10/31/1999 14:15	1800
10/31/1999 18:25	1025
10/31/1999 22:25	950
11/1/1999 2:25	-75
11/1/1999 6:30	15
11/1/1999 10:35	2475
11/1/1999 14:25	-1200
11/1/1999 18:35	200
11/1/1999 22:25	1350
11/2/1999 2:25	-150
11/2/1999 6:35	1475
11/2/1999 10:35	1775
11/2/1999 14:30	1775

Table 3
HC-5 Tritium Monitoring Data

Date (mm/dd/yy)	Tritium (pCi/L)
11/2/1999 18:30	300
11/2/1999 22:25	925
11/3/1999 2:25	875
11/3/1999 6:35	2600
11/3/1999 10:35	275
11/11/1999 15:30	425
11/11/1999 18:57	325
11/11/1999 18:57	325
11/11/1999 22:55	3300
11/12/1999 4:00	1600
11/12/1999 8:04	1800
11/12/1999 12:55	1925
11/12/1999 16:54	1125
11/12/1999 21:02	1400
11/15/1999 16:41	700
11/15/1999 20:53	800
11/16/1999 1:00	975
11/16/1999 5:00	725
11/16/1999 9:00	500
11/16/1999 15:15	575
11/16/1999 19:05	2325
11/16/1999 23:00	775
11/17/1999 3:00	875
11/17/1999 7:00	425
11/17/1999 11:00	1725
11/17/1999 15:00	-1450
11/17/1999 19:00	-775
11/17/1999 23:00	-1525
11/18/1999 3:00	1600
11/18/1999 7:00	2325
11/18/1999 11:00	1675
11/18/1999 15:00	-125
11/18/1999 19:00	100
11/18/1999 23:00	325
11/19/1999 3:00	1925
11/19/1999 7:00	400
11/19/1999 11:00	1325
11/19/1999 15:00	550
11/19/1999 19:00	875
11/19/1999 23:00	125
11/20/1999 3:00	375
11/20/1999 7:00	275
11/20/1999 11:00	825
11/20/1999 15:00	700
11/20/1999 19:00	1050
11/20/1999 23:00	350
11/21/1999 2:58	1375

Table 3
HC-5 Tritium Monitoring Data

Date (mm/dd/yy)	Tritium (pCi/L)
11/21/1999 6:50	1575
11/21/1999 10:58	350
11/21/1999 19:05	725
11/21/1999 23:05	1125
11/22/1999 2:57	950
11/22/1999 7:01	625
11/22/1999 10:55	1025
11/22/1999 14:52	825
11/22/1999 17:30	-300

RECORD OF TECHNICAL CHANGE

Technical Change No. 3

Project/Job No. 79941900560005

Project/Job Name: Project Shoal Area

Date: 2/16/00

The following technical changes (including justification are requested by:

Jenny Chapman	Project Manager
(Name)	(Title)

Technical Changes: The following relates to Section 4.2 of the Fluid Management Plan (FMP), which currently states that the fluid discharged during the tracer test activities must be stored in a lined sump until a representative sump sample is collected and analyzed before discharging to the infiltration basin.

Fluid Discharge Requirements: The remaining pumping at the PSA for the HC-7 tracer test, and other PSA wells as needed, will be directed toward the infiltration basin and weekly tritium samples will be collected from the discharge line. The pumping rate from HC-7 for the tracer test is low, below 3 gallons per minute (currently 2.54 gpm), with a portion re-injected into HC-6 (currently 0.3 gpm). The Desert Research Institute (DRI) laboratory will perform a tritium scan (detection limit = 3000 pCi/L) on the weekly samples. Results will be presented in the PSA weekly report as soon as the analysis is made available from the laboratory. In the event a sample analysis indicates tritium above the 3000 pCi/ L detection limit, a verification sample will be collected and analyzed, within a 48 hour period. If the elevated level is verified, discharge will be directed back to the lined sumps and fluid management will revert to the previous procedure of sump sampling, analysis, and NDEP approval prior to discharge to the infiltration basin.

Justification: Additional process knowledge has been gained during drilling, hydraulic testing, sampling and the tracer test phases that strongly indicates no risk is posed to human health nor the environment from the groundwater discharged from the Shoal wells. This information includes the following:

1. Increasing trends in tritium, gross alpha, beta, and lead samples have **NOT** been observed during previous and ongoing pumping at PSA wells. All analytical results from the wells under this FMP (HC-5, -6, -7, -8) have indicated background concentrations (or at least below detection limit) for the monitored analytes.
2. Hydraulic testing and preliminary results from the tracer test indicate that the effective porosity is much larger than originally expected. Therefore, the rate at which fluid moves is much slower than originally expected.
3. Preliminary tracer test results indicate that solute breakthrough in discharge wells will be diffuse in nature. Therefore, it is expected that any potential (although the probability is very low) radionuclide migration from the nuclear test would cause a very gradual increase in radionuclide concentrations.
4. An analysis was performed to predict the capture zones for flow to local pumping wells. The results provide a 99% capture zone for one year's worth of pumping at two local wells (HC-5 and HC-7). This capture zone does not intersect the nuclear test (see attached capture zone analysis). The analysis is considered conservative in several ways, a principal one of which is the fact that pumping at HC-5 has now been stopped, so that the modeled pumping rate is more than twice as large as what will be incurred for the remainder of the tracer test.
5. Reducing the sampling costs previously required for sump management will allow the tracer experiment to continue beyond the originally planned termination date. This extension will allow for the collection of critical data required to properly characterize the flow and transport parameters at the PSA. These data are critical for further development of a calibrated and verified numerical model of the PSA groundwater system.

This project time will be increase by approximately 120 days.

Applicable Project-Specific Document(s): Fluid Management Plan for the Project Shoal Area, Off-Sites Project (DOE/NV-542, Rev 0, Date April 1999.

Approved by: Peter Sanders for Monica Sanchez Date: 2/24/00

[illegible] Date: 2/24/00

Client Notified: Yes:____ No:_____

Contract Change Order Required: Yes:____ No:_____

Contract Change Order No.______________________________

Project Shoal Area
Tracer Test Capture Zone Analysis
by

Greg Pohll
Desert Research Institute

January 20, 2000

Introduction

An analysis of the potential fluid pathways induced by extended pumping at the Project Shoal Area (PSA) is performed to determine the risk of radionuclide transport from the PSA test to the downgradient pumping wells. The semi-analytic model RESSQC (Blandford and Huyakorn, 1991) is used to determine the time-dependent capture zones. The input parameters required by RESSQC are not known with full certainty, so the analysis is performed within a Monte Carlo framework to assess the uncertainty in the predicted capture zones. All available hydraulic and solute transport data available to date is used to reduce the uncertainty in the analysis.

The purpose of this analysis is to determine any potential risk of extended pumping at PSA wells HC-5 and HC-7. HC-7 is being used as the discharge well during the forced gradient tracer test and HC-5 is being pumped to remove remaining drilling fluids. HC-6 is currently being used as the injection well for the ongoing tracer test.

This analysis is the third in the series capture zone analyzes. The capture zones determined from each set of analyzes change due to the updated information and the associated reduction in uncertainty.

Methodology

The RESSQC model is used to determine the time dependent capture zones for HC-5 and HC-7. RESSQC is a two-dimensional model and as such, assumes that all injection and pumping will be from similar depths. The well screen in HC-5 is approximately 700 m deeper that both HC-6 and HC-7, which indicates that there is a very low probability that HC-5 and HC-7 capture zones will intersect. Hydraulic data collected during the pumping also supports this hypothesis. However, this analysis assumes that both pumping wells are located at the same depth such that predicted capture zones are highly conservative.

RESSQC computes the time-dependent capture zone for the pumping well by tracing the movement of fluid particles through the groundwater flow system. The fluid particles are traced in reverse direction until termination of the pumping. The program tracks multiple fluid particles to delineate the entire capture zone for the time-period of interest.

The assumptions used in developing the semi-analytical solution are:

1. The aquifer is homogeneous, isotropic, and of constant saturated thickness.
2. The flow of groundwater in the aquifer is two-dimensional in a horizontal plane and reaches steady-state after the pumping begins.

The groundwater flow and transport parameters for the proposed wells are not known with full certainty, so data from the PSA were used to identify ranges of expected values. Distributions of the required input parameters are constructed for use in the uncertainty analysis. Three parameters are deemed uncertain. These parameters include the effective porosity, hydraulic conductivity, and the regional hydraulic gradient. A lognormal distribution are assumed for each of the three uncertain parameters, and the mean and standard deviation are provided in Table 1. The distribution for the effective porosity is estimated from the leading edge of the bromide breakthrough data obtained in the ongoing trace test at PSA. The recently collected samples from HC-7 indicate that the bromide concentrations are beginning to increase after approximately 30 days after injection. Although it is too early to completely describe the aquifer parameters, the initial breakthrough time indicates that the effective porosity is approximately 1 percent. This new information allows us to substantially reduce the uncertainty of this capture zone analysis as previous estimates of the porosity ranged many orders of magnitude. The hydraulic conductivity distribution is estimated from the hydraulic tests performed at HC-5, -6, and 7. The hydraulic gradient is estimated from the region water level data. It should also be noted that the fracture zone located between HC-4 and HC-6 appears to causing a local change in flow direction and hydraulic gradient. The ambient water level in HC-6 is higher than HC-4, which indicates localized flow to the west rather than to the southeast as is indicated by other wells in the vicinity. For the purposes of this analysis, it is assumed that this change in local gradient is localized and that the regional gradient is more appropriate for this analysis. This is assumption is also conservative as this fracture zone is most likely restricting flow from ground zero toward HC-5 and HC-7.

Parameter	Mean	Standard Deviation
Hydraulic Conductivity (m/day)	0.02	0.002
Effective Porosity ( )	0.01	0.005
Hydraulic Gradient ( )	0.05	0.02

Table 1 Mean and standard deviations for the uncertain parameters used in the capture zone analysis.

The remaining parameters required to simulate the tracer test are assumed to be deterministic or known with full certainty. These include the injection and pumping rates, aquifer thickness, and the direction of the regional gradient. The injection rate for HC-6 is 1.6 m^3/day and the discharge rates for HC-5 and HC-7 are 21.8 and 16.4 m^3/day, respectively. . The aquifer thickness is assumed to be equal to the thickness of the screened interval (36 m). The direction of the hydraulic gradient is assumed to be parallel to the line connecting HC-6 and HC-8.

The uncertainty in the model predictions is simulated within a Monte Carlo framework. One-thousand realizations are performed to determine uncertainty in the model predictions. For each realization, a single value of effective porosity, hydraulic conductivity, and the hydraulic gradient are chosen from the described distributions. These values are used in the RESSQC model to determine the capture zones for extended pumping of HC-5 and HC-7 through November 2000. It should be mentioned, that it is unlikely that the pumping will continue this long, but the model is simulated for a total of one year for completeness. These capture zones are ranked based to quantify the confidence intervals for the predicted capture zones. The capture zones associated with the 99 percent confidence interval are plotted relative to the PSA test.

Results

Figure 1 shows the 99% confidence levels for the simulated capture zones assuming one year of continuous pumping. The capture zones for HC-5 and HC-7 merge creating essentially one larger zone. The capture zone created in this analysis is larger in the transverse direction due to the relatively larger hydraulic conductivity value as compared to previous analyzes. Although it is unlikely that pumping will continue for a total of one year, the analysis, suggests that it is still highly unlikely that test related solutes will be drawn into either HC-5 or HC-7 within one year.

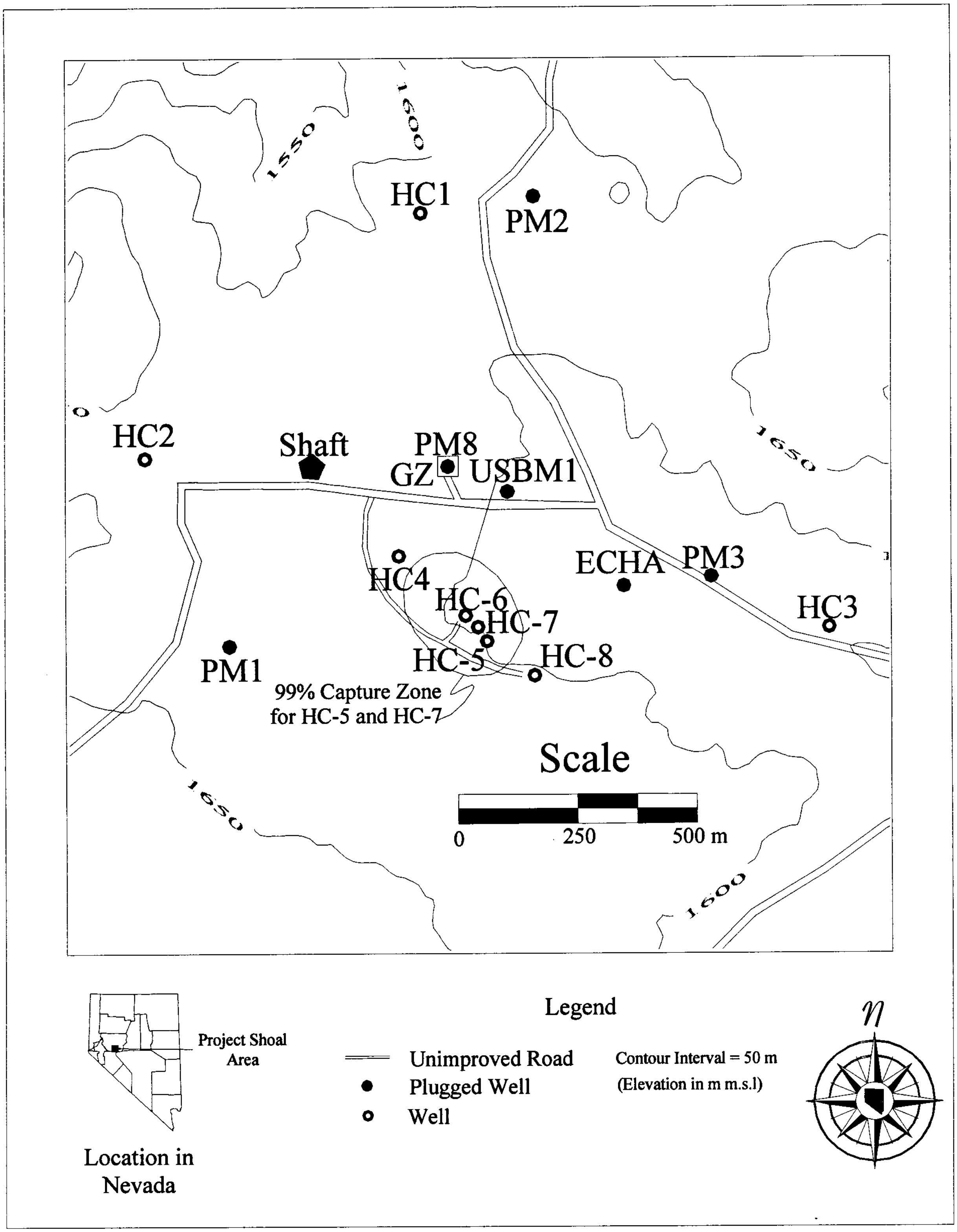
Although not shown, the capture zones for smaller confidence levels plot very close to the 99% level as the uncertainty in the estimates have decreased substantially due to the recently acquired data from hydraulic testing and the tracer test.

Conclusions

A semi-analytical model, RESSQC, is used to determine the risk of encountering radionuclides in the HC-5 and HC-7 due to extended pumping. The analysis indicates that there is a very low probability that radionuclides will be drawn into either HC-5 or HC-7 within the next ten months of pumping (November, 2000).

References

Blandford, T. N., and P. S. Huyakorn, 1991. WHPA / RESSQC 2.0 Code - A Modular Semi-Analytical Model for the Delineation of Wellhead Protection Areas. U.S. EPA Office of Ground-Water Protection, Washington, DC.



1550
1600
HC1
PM2
HC2
Shaft
PM8
GZ
USBM1
HC4
HC-6
HC-7
HC-5
HC-8
ECHA
PM3
HC3
PM1
99% Capture Zone
for HC-5 and HC-7
1650
Scale
0
250
500 m
1600
Project Shoal
Area
Location in
Nevada
Legend
Unimproved Road
Plugged Well
Well
Contour Interval = 50 m
(Elevation in m m.s.l)

Nevada
Environmental
Restoration
Project

DOE/NV--542

Fluid Management Plan for the Project Shoal Area Off-Sites Project

Controlled Copy No.:
Revision No.: 0

April 1999

Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

DOE/NV--542

FLUID MANAGEMENT PLAN FOR THE PROJECT SHOAL AREA OFF-SITES PROJECT

DOE Nevada Operations Office
Las Vegas, Nevada

Controlled Copy No.: ___

Revision No.: 0

April 1999

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FLUID MANAGEMENT PLAN
FOR THE PROJECT SHOAL AREA
OFF-SITES PROJECT

Approved: Signature Approved Date: 4/29/99

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List of Acronyms and Abbreviations

BoFF	Bureau of Federal Facilities
CADD	Corrective Action Decision Document
CAIP	Corrective Action Investigation Plan
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
FFACO	*Federal Facility Agreement and Consent Order*
FMP	Fluid Management Plan
ft	Foot (feet)
gal	Gallon(s)
gpm	Gallon(s) per minute
m	Meter(s)
m^3	Cubic meter(s)
m^3/day	Cubic meter(s) per day
mL	Milliliter(s)
mg/L	Milligram(s) per liter
NDEP	Nevada Division of Environmental Protection
NDWS	*Nevada Drinking Water Standards*
NTS	Nevada Test Site
pCi/L	Picocurie(s) per liter
PSA	Project Shoal Area
RCRA	*Resource Conservation and Recovery Act*
SGZ	Surface Ground Zero
TD	Total depth

1.0 Introduction

The U.S. Department of Energy, Nevada Operations Office (DOE/NV) has initiated the Off-Sites Project to characterize the hazards posed to human health and the environment as a result of underground nuclear testing activities at facilities other than the Nevada Test Site (NTS). The Project Shoal Area (PSA) is one of the Off-Sites Project areas located off the NTS, but within the state of Nevada. The PSA is located approximately 48 kilometers (30 miles) southeast of Fallon, Nevada. Four wells were drilled at the PSA in 1996 as part of the site investigation administered through the *Federal Facility Agreement and Consent Order* (FFACO) (1996). The hydrogeologic data gathered from these wells was used to support the groundwater flow and contaminant transport modeling of the PSA. However, the subsequent evaluation of the groundwater model concluded that further delineation of the subsurface was required to reduce uncertainties in the model. In accordance with the FFACO, an addendum to the Corrective Action Investigation Plan (CAIP) for the proposed PSA subsurface investigation, Corrective Action Unit 447, was developed (DOE/NV, 1999). The addendum proposed the drilling and construction of four additional wells and the conduct of hydrologic testing at the PSA. This Fluid Management Plan (FMP) provides guidance for the management of fluids generated from the well construction and testing activities at the PSA.

2.0 Proposed Investigation

The proposed investigation of the PSA site includes the construction of four wells (HC-5, HC-6, HC-7, and HC-8) at depths ranging from approximately 457.2 meters (m) (1,500 feet [ft]) to 1,219.2 m (4,000 ft) below the ground surface. The placement and construction of these wells will facilitate the collection of subsurface data and allow for the conduct of a tracer experiment involving two of the wells. All data collected during well construction and conduct of the tracer test will support further refinement of the PSA groundwater flow and transport model.

For the purpose of this FMP, the PSA investigation may be divided into three operative phases: well construction, aquifer testing, and the tracer experiment. Each of these phases is described in detail below.

2.1 Well Construction

Well construction activities include unsaturated and saturated zone drilling, and initial well development. Unsaturated zone, or vadose zone, drilling is conducted above the permanent groundwater table. During vadose zone drilling, primarily rock cuttings are produced with a limited amount of drilling fluid.

Saturated zone drilling begins once the water table is reached and continues through the saturated zone to the desired total depth (TD). Groundwater, cuttings, and any necessary drilling fluids are produced during saturated-zone drilling. Once TD is reached, casing and screening will be installed. The borehole will then be developed (i.e., purged) to remove residual cuttings and any drilling fluids which may have invaded the formation during drilling.

A total of approximately 330 cubic meters (m^3) (87,000 gallons [gal]) of fluids were produced during the 1996 well construction effort. It is anticipated that fluids produced during drilling of the four new wells will produce approximately five times the fluid volume encountered during the 1996 drilling effort.

2.2 Aquifer Tests

An aquifer test will be conducted after each well is initially developed. Aquifer testing is expected to last approximately seven days for each well. It is estimated that approximately 450 m^3 (120,000 gal) of fluid will be produced during the aquifer tests.

2.3 Tracer Experiment

The tracer experiment objectives and scope are outlined in the CAIP Addendum (DOE/NV, 1999). The tracer test will involve two wells, HC-6 and HC-8, drilled in this investigation (Figure 2-1). This test will be conducted until adequate tracer breakthrough occurs and thus has the potential to produce the largest volume of fluids (primarily groundwater) during the investigation. The maximum estimated fluid production is 1,970 m^3 (520,000 gal), though much smaller volumes will be produced if breakthrough occurs rapidly.

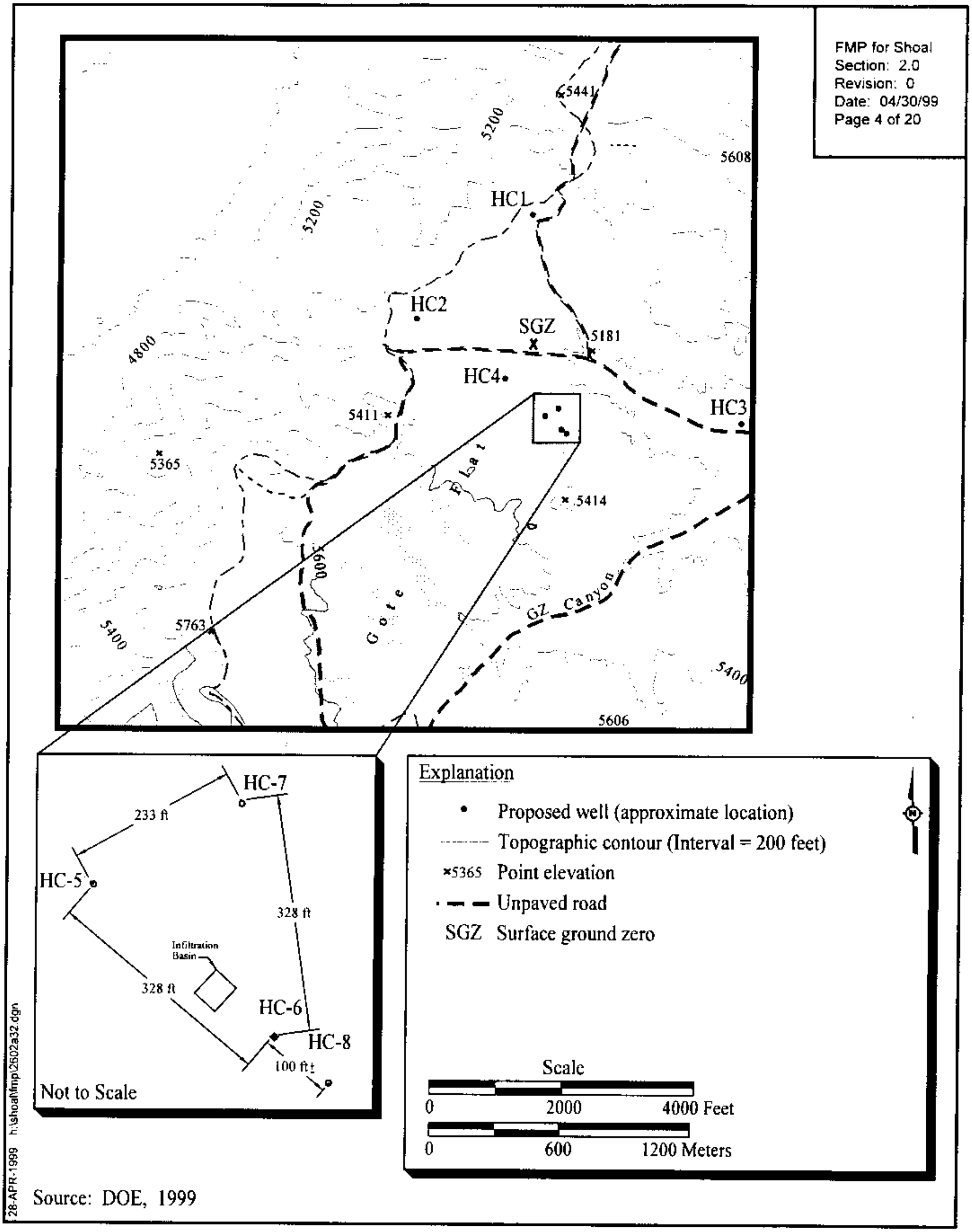

Figure 2-1
Proposed Infiltration Basin Location

3.0 Well Site Operation Strategy

The well-site operation strategy must be determined prior to commencement of the operation. Such a strategy is designed with fluid production and expected contamination in mind. The well-site operation strategy dictates the type of sump(s) required for the operation and the initial on-site monitoring requirements. In order to determine the well-site operation strategy to be employed at the PSA during the proposed investigation activities, an assessment of previous site investigation results and historical data was conducted. It was determined through this assessment, that the four proposed well sites will be constructed based on a "far-field," or uncontaminated, well operation strategy. That is, the site would be constructed and the fluid management strategy proposed under the assumption that radiological and/or chemical contamination would not be encountered at the site. Information used in support of the PSA far-field determination include the following:

- ***Proximity to the Shoal Underground Test and Hydrogeologic Setting of Proposed Wells.*** As detailed in Appendix A, the proposed wells will be drilled well outside the tritium contamination plume predicted by the current transport and flow groundwater modeling effort. This predicted plume extends in a radius of 100 m (328 ft) around surface ground zero (SGZ) of the underground test; the proposed well locations are to be drilled at distances ranging from 426.7 to 579.1 m (1,400 - 1,900 ft) away from SGZ (see Appendix A). In addition, the four wells drilled in 1996 were located within a range of 182.8 to 1,005.9 m (600 - 3,300 ft) from SGZ and did not yield evidence of radioactive or chemical contamination above fluid management parameters (see tritium and lead discussions below).

- ***Potential for Tritium Contamination in Groundwater.*** During the 1996 drilling effort, tritium was monitored on site on an hourly basis while the borehole was being advanced. As indicated in the 1998 *Data Report*, the tritium activities detected during on-site monitoring were all within background activities for the PSA (DOE/NV,1998). All fluids during the 1996 drilling effort were contained in lined sumps during operations. In accordance with the FMP, sump samples were collected and sent to an off-site laboratory for metals and radiochemical analysis. The sump samples showed tritium levels ranging from non-detect to 22 picocuries per liter (pCi/L) (DOE/NV, 1998). The tritium limit for discharge of fluids to the ground surface under the 1996 drilling FMP was 100,000 pCi/L. Because all tritium results were well below the 100,000 pCi/L limit, all fluids from the 1996 drilling effort were discharged from the lined sumps to the ground surface.

- ***Potential for Lead Contamination in Groundwater.*** One of the reasons that lead was chosen as the on-site indicator of chemical contamination in groundwater during drilling operations associated with U.S. Department of Energy (DOE) underground tests, is because lead-laden "racks" were commonly used in the design and construction of such tests. These "racks" provided the necessary infrastructure for proper emplacement of the test device. For the Project Shoal test, however, a different emplacement technique was utilized. A vertical shaft and horizontal drift were mined in the granite subsurface to provide access to the emplacement site (Pohll et. al., 1998). The test design did not result in the use of materials containing large amounts of lead, in contrast to many of the underground tests conducted on the NTS.

During the 1996 drilling effort, lead was monitored on site every eight hours as each borehole was advanced. The lead monitoring results indicated no detectable lead in the drilling fluids and/or groundwater produced. Well sump samples were collected and sent to an off-site laboratory for *Resource Conservation and Recovery Act* (RCRA) metals analyses. Lab analytical results for lead ranged from 0.0013 to 0.0103 milligrams per liter (mg/L) in the sump samples. All RCRA metals, including lead, were detected at concentrations below the fluid management discharge limits for discharge to the ground surface.

In conclusion, such operational and analytical data supports the premise that the probability is remote of encountering radioactive and/or chemical constituents above background levels during the proposed investigation. Operational contingencies have been identified and included in this FMP should radiological and/or chemical contamination be detected.

Table 3-1 outlines the major components of the well operations strategy under this Plan.

3.1 Fluid Containment

Figure 3-1 represents a generic layout for well site operations at the PSA. One lined sump will be constructed for the collection of cuttings and fluids at each well site. A larger excavation intended for use as an infiltration basin will be constructed in a central location to the four proposed well sites (Figure 2-1). This infiltration basin will be used only to discharge fluids which meet the discharge criteria of < 10 x NDWS, as specified in see Section 5.0. Prior to discharge to this infiltration basin, fluid must be sampled as discussed in Section 4.2 of this FMP.

Table 3-1
PSA Well Operation Strategy

	On-Site Monitoring	Action Level	Containment Strategy & Contingency	Off-Site Fluid Analysis	Final Fluid Disposition	Reporting Requirements
Drilling & Well Development	Tritium Monitoring begins at ~200 ft above predicted water level and continues every 100 ft or every 2 hours, whichever is less	Tritium < 200,000 pCi/L	Fluids discharged to lined sump	Required prior to discharge from sump to infiltration basin or ground surface	Dependant on analytical results	On-site tritium results included in Morning Report Sump analytical results in Corrective Action Decision Document (CADD) on FFACO schedule
		Tritium > 200,000 pCi/L	Fluids discharged to lined sump; tritium monitoring increased to hourly			
Aquifer Test	Tritium Monitoring every four hours[a]	Tritium < 200,000 pCi/L	Fluids discharged to lined sump			
		Tritium > 200,000 pCi/L	Fluids discharged to lined sump; tritium monitoring increased to hourly			
Tracer Test	Tritium Sample collected every week (analyzed off-site with one-day turnaround time)	Tritium < 200,000 pCi/L	Fluids discharged to lined sump			Weekly tritium sample results and fluid volume discharged reported once a week
		Tritium > 200,000 pCi/L	Fluids discharged to lined sump; site operations suspended			

[a]Well HC-8 will transition from tritium monitoring every 2 hours (during drilling and development) to tritium monitoring weekly, if tritium results from the other three wells remain below fluid management criteria (i.e., 200,000 pCi/L).

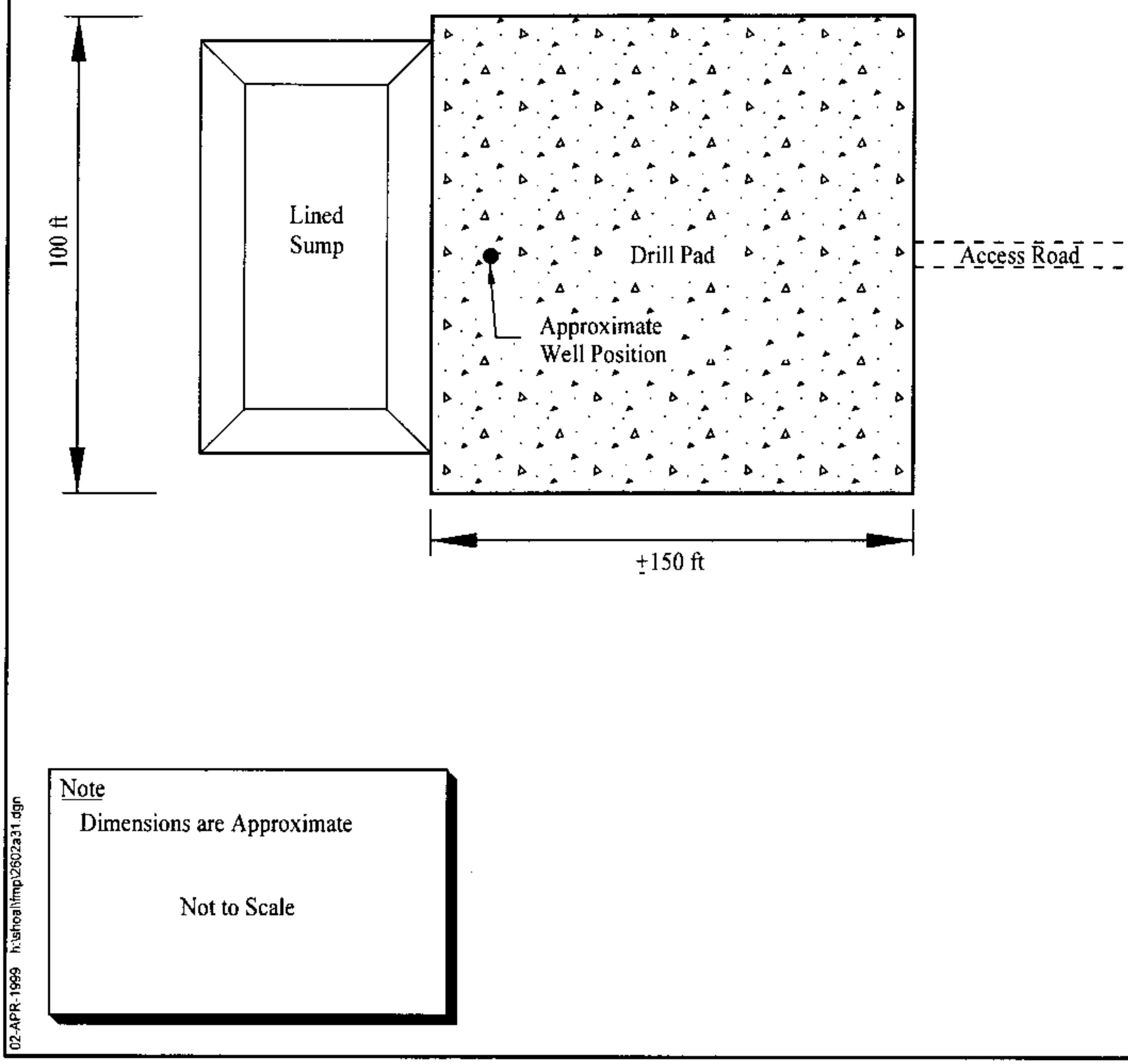

Figure 3-1
Generic Well Site Layout

4.0 Fluid Sampling Program

This FMP provides for the verification of process knowledge through on-site monitoring and off-site laboratory analyses. On-site monitoring provides for the timely detection of contamination indicators during site operations. Off-site laboratory fluid analyses are conducted primarily to confirm process knowledge and ensure that fluid discharge criteria are met.

4.1 On-Site Tritium Monitoring

Based on its physical and chemical properties, tritium has been chosen as the indicator for radioactive contamination. The primary purpose for tritium monitoring under this FMP is to show the relatively "real-time" concentration of tritium in the groundwater being brought to the surface at a given point in time. This monitoring information is used to determine if the site becomes radiologically "contaminated" and triggers subsequent fluid management and health and safety requirements. On-site monitoring results are not used to determine if fluids meet discharge criteria.

Fluids generated during drilling will be analyzed for tritium while the drill hole is being advanced. On-site monitoring of tritium will begin at approximately 61 m (200 ft) above the predicted groundwater level at each well. Samples will be collected and analyzed at every 30 m (100 ft) drilled or every 2 hours, whichever is sooner. In the event that on-site monitoring at any of the four wells during drilling or development reveals tritium concentrations that exceed 200,000 pCi/L (see Section 5.0), tritium monitoring shall increase to hourly and the DOE/NV will be notified immediately. During periods when the hole is not being advanced, during circulation or while attempting to establish circulation, monitoring is not required. Tritium samples for on-site monitoring shall be collected from the discharge line. Additional samples for monitoring purposes may be collected from the discharge line or from the lined sump at DOE/NV's discretion.

During the aquifer tests, tritium will be monitored on site every four hours. In the event that tritium monitoring results from wells HC-5, HC-6, and HC-7 do not indicate an upward trend of tritium concentrations or yield tritium concentrations above 200,000 pCi/L, Well HC-8 will transition directly to the monitoring frequency of the tracer experiment (i.e., weekly monitoring) during its aquifer test. Well HC-8 is the furthest from SGZ of all the investigation well locations and will be the well from which the majority of water will be pumped during the tracer experiment. It is anticipated that if tritium does not exceed fluid management criteria during the aquifer tests on the three prior wells, tritium will not be detected in Well HC-8. In the event that on-site monitoring at any of the four wells during the aquifer tests reveals tritium concentrations that exceed 200,000 pCi/L (see Section 5.0), tritium monitoring shall increase to hourly and the DOE/NV will be notified immediately.

During the tracer experiment, tritium samples will be collected and analyzed for monitoring purposes once a week. The PSA will not be continuously staffed during the tracer experiment. Rather, the site will be visited on a weekly basis, or as needed, to ensure that operations are proceeding as planned. During these visits, or at least weekly, a sample of fluid from the discharge line will be obtained and analyzed at an off-site laboratory for tritium only. This sample will have an anticipated one-day turnaround time with regard to the receipt of results from the time the sample is collected on site.

These reduced requirements for on-site monitoring during the aquifer and tracer tests are predicated on the well sites maintaining "far-field," or uncontaminated, conditions. In the event that on-site monitoring at any of the four wells during the tracer experiment reveals tritium concentrations that exceed 200,000 pCi/L (see Section 5.0), fluid-producing operations shall be suspended. If operations are suspended, DOE/NV shall be notified immediately and DOE/NV will determine any further course of action. Resumption of fluid-producing operations will proceed only upon direction of the DOE/NV.

Tritium monitoring results will be reported to DOE/NV and Nevada Division of Environmental Protection (NDEP) according to the schedule outlined in Section 7.0 of this document.

4.2 Laboratory Analytical Samples

Under this FMP, prior to discharge of any fluid to the unlined infiltration basin, a sample from the lined sump shall be collected and analyzed by an off-site laboratory. The primary purpose of these samples is to characterize the fluids for discharge/disposal. That is, the off-site laboratory sample results should be compared to the fluid management decision criteria limits, as outlined in Section 5.0, to determine if fluids may be discharged. Each sump sample must be analyzed for dissolved lead, gross alpha, gross beta, and tritium, in accordance with Table 4-1.

Table 4-1
Analytical Laboratory Requirements for Fluid Management Samples

Parameter	Analytical Method	Container Type	Preservative	Maximum Holding Time	Reporting Detection Limit	Nevada Drinking Water Standards
Dissolved Lead	SW-846 6010B[a]	(1) 1-L[b] polyethylene or amber glass	Lab filtration and preservation, Cool to 4°C	180 Days	0.003 mg/L[c]	0.015 mg/L
Gross Alpha Gross Beta	L-E10.612.PL[d] or equivalent	(1) 1-L polyethylene	Lab filtration and preservation	180 Days	<15 pCi/L[e] <15 pCi/L	15 pCi/L 50 pCi/L
Tritium	L-E10.614.PL[d] or equivalent	(1) 500-mL[f] polyethylene or amber glass	Lab filtration	180 Days	3,000 pCi/L	20,000 pCi/L

[a]U.S. Environmental Protection (EPA) *Test Methods for Evaluating Solid Waste*, 3rd Edition, SW-846 (EPA, 1996)
[b]Liter
[c]Milligram(s) per liter
[d]Bechtel Analytical Services *Laboratory Procedure Manual* (I), February 1999, Bechtel Nevada
[e]Picocurie(s) per liter
[f]Milliliter

It is anticipated that aquifer testing will proceed directly after completion of a well (i.e., after TD is reached at each well) and the tracer test will begin shortly after completion of the last aquifer test. The lined sump at each well site will be constructed to contain the volume of all fluids resulting from drilling, aquifer testing, and the tracer test (HC-6 and HC-8 only). However, if an active sump at any location is nearing capacity at any stage in the investigation, fluids from this sump may be routed to other empty lined sumps on site. Prior to discharge to the infiltration basin from any sump, however, a sample shall be collected from the sump as stated in the preceeding paragraph. Sump samples may be collected for off-site analysis throughout the investigation at DOE/NV's discretion.

Upon site demobilization at the end of the investigation, at least one representative sump sample must be collected or appropriate analytical data available, for each sump which contains fluid at the PSA site.

5.0 Fluid Management Strategy

The fluid management decision criteria limits set in Table 5-1, are based on dissolved constituents and indicate the thresholds at which fluid management decisions are made. All samples taken under this FMP will be filtered at the receiving laboratory for dissolved analyses. These analytical results will then be compared to Table 5-1 to determine if fluids may be discharged to the infiltration basin.

Table 5-1
Fluid Management Decision Criteria Limits

FMP Parameters	NDWS[a]		5 X NDWS Limit[b]		10X NDWS Limit[c]	
Lead	0.015	mg/L	0.075	mg/L	0.150	mg/L
Gross Alpha	15	pCi/L	75	pCi/L	150	pCi/L
Gross Beta	50	pCi/L	250	pCi/L	500	pCi/L
Tritium	20,000	pCi/L	100,000	pCi/L	200,000	pCi/L

[a] *Nevada Drinking Water Standards*; assumes background value for each parameter is zero
[b] Limit for ground surface discharge
[c] Limit for infiltration area discharge

Fluids generated while the borehole is being advanced will be routed to a lined sump. As sump capacity is reached, or as needed, sump fluids will be sampled and analyzed as outlined in Section 4.2. If the fluid quality criteria of < 10 x NDWS (Table 5-1) are met, sump contents may be discharged to the centrally-located infiltration basin. The final disposition of fluids contained in the lined sumps will depend on operational requirements and fluid quality. The options for disposal of such fluids may include:

(1) ***Direct discharge to the ground surface.*** Fluids documented to be < 5 x NDWS for all parameters may be discharged to the ground surface. Caution shall be taken to ensure that erosion is controlled and fluids do not flow into natural washes or intermittent stream basins.

(2) ***Discharge to an infiltration basin.*** Fluids documented to be < 10 x NDWS for all parameters may be discharged to a constructed infiltration basin.

(3) ***Evaporation within the lined sump.*** Fluids documented to contain lead at concentrations < 5 mg/L and radiological parameters > 10 x NDWS, will be allowed to evaporate in lined sumps. Any associated solids (cuttings) will be transported to

an appropriate disposal facility, upon characterization. If the level of radioactive constituents is great enough that air quality or employee health and safety limits could be exceeded, operations will be suspended and the waste managed as low-level radioactive waste in accordance with applicable DOE Orders and state and federal regulations.

(4) ***Transportation to the NTS or a treatment, storage, or disposal facility.*** Fluids documented to contain lead at concentrations > 5 mg/L would result in the suspension of operations and would be managed as hazardous (or mixed) waste in accordance with State of Nevada hazardous waste regulations and DOE Orders. The NDEP will be immediately notified if fluids are documented to be hazardous or mixed waste. The fluids will be pumped from the lined sumps and transported to an appropriate storage area on the NTS. Alternatively, hazardous waste may be transported directly to a permitted commercial treatment, storage, or disposal facility.

Figure 5-1 illustrates the general decision-flow process for the management of fluids under this FMP.

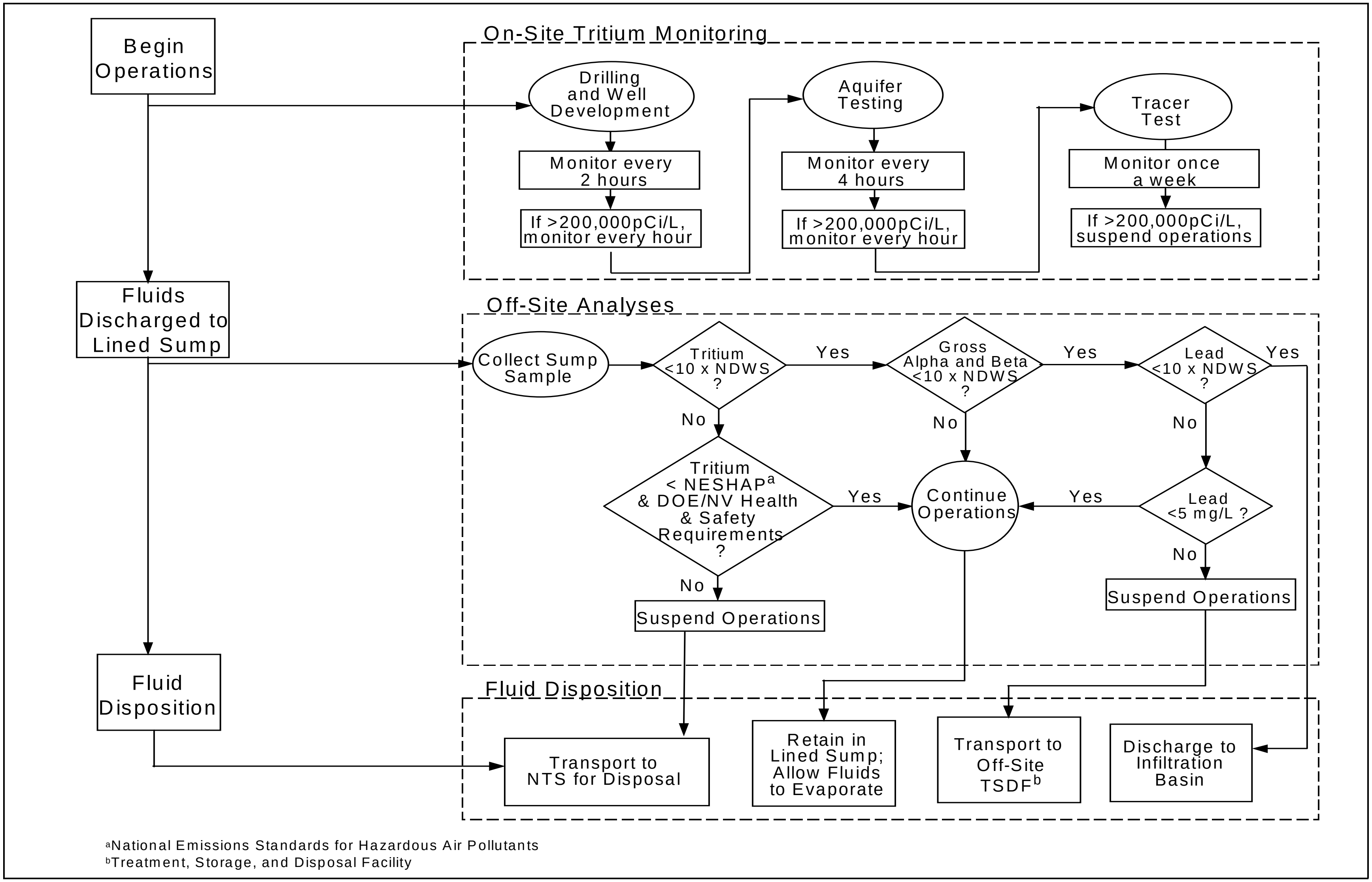

Figure 5-1
Decision Diagram for Fluid Management

6.0 Fluid Management for Routine Monitoring

Monitoring activities are defined as those routine, scheduled, periodic activities associated with collection of groundwater monitoring samples. Groundwater monitoring samples may be collected from the PSA well locations on a periodic basis. Fluid generated from the activities associated with groundwater sampling (such as from purging the well) will be contained in a lined sump unless process knowledge is sufficient to allow for direct routing to an infiltration basin or the ground surface. If fluids are routed to the sump, after the groundwater sampling event has ceased (i.e., no more fluid will be generated by that sampling event), a composite sump sample will be collected and analyzed for the parameters listed in Table 4-1. Analytical results shall be reported to the NDEP in accordance with Section 7.0 of this FMP.

7.0 Reporting Criteria

The reporting criteria proposed for meeting the requirements of this FMP consist of the following:

1. **Release Reporting**
Spills, leaks, and releases shall be reported in accordance with State of Nevada regulations. All fluids in excess of ten times the NDWS limits, as provided in Section 4.0 of this plan, that are conveyed to the infiltration area or beyond the confines of the constructed fluid management devices, in excess of 1 m^3 (264.2 gal), shall be reported to the NDEP by telephone (702-486-2866) prior to the end of the next business day following verification of the incident. Oral notification shall be followed by a written report which includes elements described in spill reporting regulations within ten calendar days.

2. **Hazardous or Mixed Waste Generation**
The NDEP will be notified immediately if laboratory results indicate that mixed or hazardous waste has been generated within any of the lined sumps. Nonemergency actions that constitute deviations to this FMP will be reported to the NDEP prior to implementation of the action. Emergency actions which are taken that constitute deviations to this FMP will be reported orally to NDEP within 24 hours of implementation of the action and a written report will be provided to NDEP within 10 working days of the action.

3. **Well-Site Activity Reporting (Morning Reports)**
The synopsis of well-site activities occurring within a 24-hour period (i.e., the morning report) shall be faxed to the NDEP each day during well drilling and completion activities. In addition, on-site tritium monitoring results will be transmitted to the DOE/NV and NDEP on a daily basis, via the morning report during drilling operations and the aquifer tests. Tritium results from the tracer experiment will be transmitted to the DOE/NV and NDEP on a weekly basis.

4. **Well Completion Report**
The well completion report may be sent to the NDEP as part of the CADD, in accordance with milestones established in the FFACO. The fluid management analytical results from both on-site monitoring and off-site laboratory work, will also be incorporated into the CADD.

5. **Routine Monitoring Report**
A report will be sent to the NDEP within nine months of collection of sump samples collected during routine well monitoring activities (see Section 6.0). The report will contain the date of sampling and a synopsis of laboratory analytical data.

6. **Discharge Concurrence**
   The NDEP will be notified in writing, prior to the discharge of fluids from a lined sump to the infiltration area. All relevant analytical data shall be included with such notification. The NDEP must concur in writing, with the proposed discharge of fluids within ten-calendar days of receipt of the notification letter.

All correspondence to the NDEP Regulator shall be addressed to:

Bureau Chief
Nevada Division of Environmental Protection
Bureau of Federal Facilities
333 West Nye Lane
Carson, City, NV 89706-0866

with copies forwarded to the Las Vegas Office Bureau of Federal Facilities (BoFF) Supervisor:

BoFF Supervisor
Bureau of Federal Facilities
555 East Washington Avenue, Suite 4300
Las Vegas, NV 89101-1049

All field and laboratory data generated in support of PSA well construction activities will be archived and made available for inspection by the NDEP Regulator. Copies of interim fluid status reports will be maintained at the well site for on-site field inspection. The following data will be generated and retained on file. This data may be made available to the NDEP for inspection upon request:

- Legible copies of daily drilling progress reports and records of daily well-site activities
- Volumetric measurements of fluids generated during each stage of well construction
- Records of make-up water delivery and usage during each stage of well construction
- On-site effluent monitoring data
- Laboratory analytical data with supplemental quality assurance/quality control and chain of custody records
- Records of process materials (cement, grout, casing, screens, packing, drilling fluids) and drilling additive usage, and equipment decontamination

- Records of geological, geotechnical, and hydrological evaluations
- Photographs illustrating site operations, methods, procedures, and progress (as required).

8.0 References

AEC, see U.S. Atomic Energy Commission.

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Appendix A

Tracer Test Capture Zone Analysis

(Well Head Protection)

A.1.0 Introduction

An analysis of the potential fluid pathways induced by the proposed tracer test at the PSA was performed to determine the risk of radionuclide transport from the PSA test to the downgradient pumping well. The semi-analytic model RESSQC (Blandford and Huyakorn, 1991) was used to determine the time-dependent capture zone for the proposed tracer test. The input parameters required by RESSQC are not known with full certainty, so the analysis was performed within a Monte Carlo framework to assess the uncertainty in the predicted capture zones.

Methodology

The proposed tracer test will consist of continuous injection at HC-6 at approximately 0.27 cubic meters per day (m^3/day) (0.3 gallons per minute [gpm]) while pumping 2.7 m^3/day (3 gpm) at HC-8. These wells will be installed approximately 15 m (49 ft) into the water table. The entire test should be completed within 120 days. The distance from the PSA test to the pumping well is 580 meters (m) (1,902 ft). The groundwater flow and transport model of the PSA was used to assess the present distribution of radionuclides (Pohll et al., 1998). This analysis suggests that the current radionuclide plume is restricted to a radius of less than 100 m (328 ft) from the test. This analysis included an analysis of the uncertainty due to the spatial distribution of fractures and the uncertainty in mean parameters such as effective porosity. Figure A.1-1 shows the location of the proposed injection (HC-6), pumping (HC-8) and deep monitoring (HC-5) wells that are located directly downgradient of the PSA test.

The RESSQC model was used to simulate the injection and pumping stresses during the 120-day tracer test and the associated capture zone for pumping well HC-8. The RESSQC model computes the time-dependent capture zone for the pumping well by tracing the movement of fluid particles through the groundwater flow system. The fluid particles are traced in reverse direction until termination of the pumping. The program tracks multiple fluid particles to delineate the entire capture zone for the time-period of interest.

The assumptions used in developing the semianalytical solution are:

1. The aquifer is homogeneous, isotropic, and of constant saturated thickness.

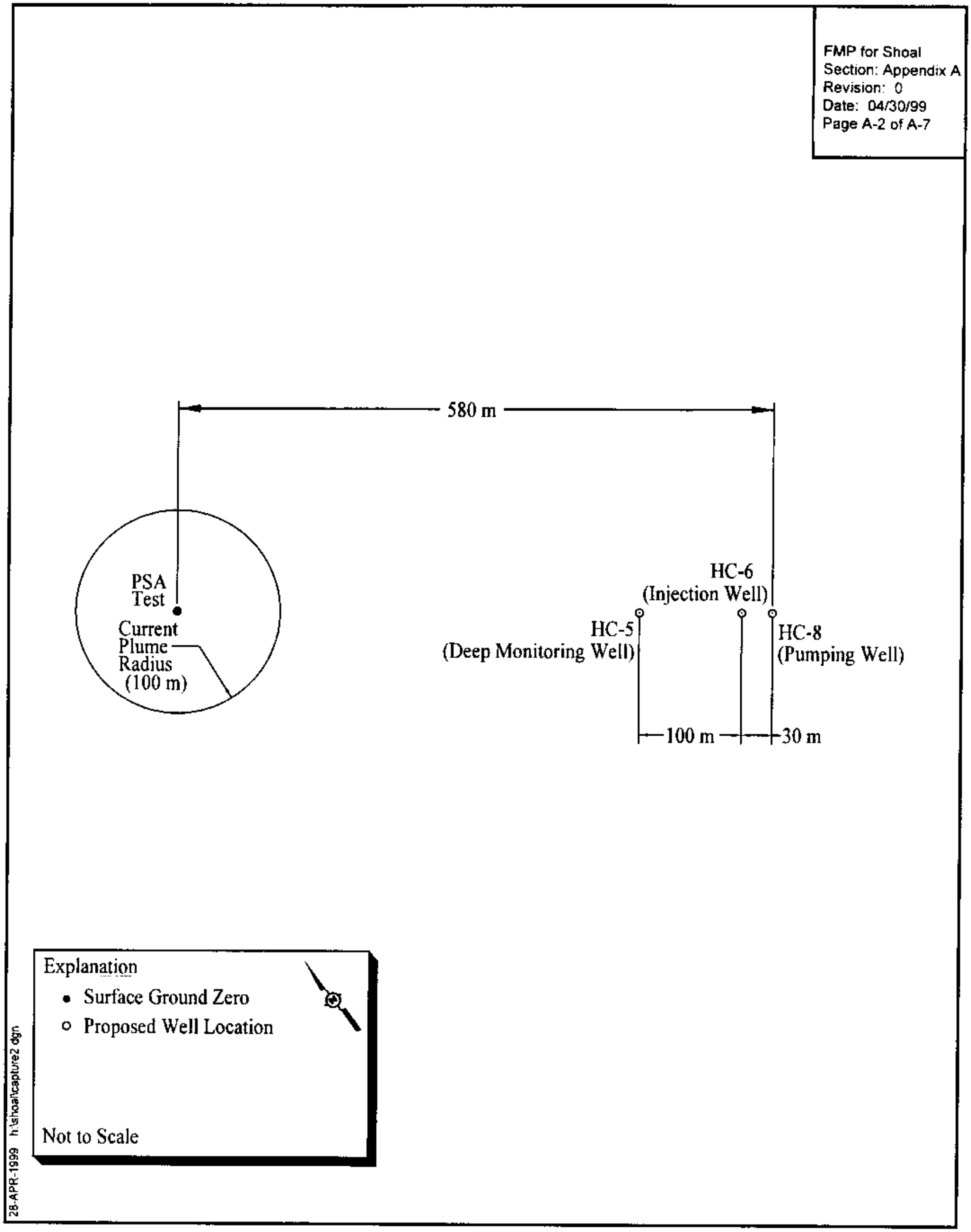

Figure A.1-1
Location of Proposed Tracer Test Wells Relative to the PSA Test

2. The flow of ground water in the aquifer is two-dimensional in a horizontal plane and reaches steady-state after the pumping begins.

The fractured granite aquifer at the PSA is not homogeneous at the regional scale, but it is assumed that at the scale of the tracer test, the flow system can be represented by an equivalent homogeneous and isotropic porous media. The assumption that the pumping induced stress will not induce vertical flow (i.e., only two-dimension flow is simulated) is conservative as vertical flow would only serve to reduce the capture zone radius.

The groundwater flow and transport parameters for the proposed wells are not known, so data from the PSA were used to identify ranges of expected values. Distributions of the required input parameters were constructed for use in an uncertainty analysis. Three parameters were deemed uncertain and included in the uncertainty analysis. These parameters include the effective porosity, transmissivity, and the regional hydraulic gradient. The distribution of effective porosity was assumed to be uniform in $\log_{10}$ space, similar to the methodology used in the data decision analysis (Pohll, et al., 1999). The transmissivity distribution was derived from hydraulic conductivity measurements obtained from stressed thermal flow measurements. The transmissivity was assumed to be equal to the hydraulic conductivity multiplied by the screened interval thickness of 15 m (49 ft). The uncertainty in the nearby HC-3 well led to uncertainty in the hydraulic gradient. The distribution of the hydraulic gradient was assumed to be uniform and bounded by the gradient as calculated from HC-2 to HC-4 and HC-1 to HC-3.

Table A.1-1 shows the distributions, mean, and standard deviations for the three uncertain parameters.

Table A.1-1
Distributions of Uncertain Parameters Used in the RESSQC Simulations

Parameter	Mean	Log_{10} Standard Deviation	Range		Distribution
			Low	High	
Transmissivity (m^2/day)	0.08	0.85	---	---	LogNormal
Effective Porosity (m^3/m^3)	0.002	---	0.0005	0.01	Uniform - Log_{10}
Regional Gradient (m/m)	0.07	---	0.03	0.1	Uniform

The remaining parameters required to simulate the tracer test were assumed to be deterministic or known with full certainty. These include the injection and pumping rates, aquifer thickness, and the direction of the regional gradient. The injection and pumping rates used in the simulations are 0.27 m^3/day (0.3 gpm) and 2.7 m^3/day (3 gpm), respectively. These rates are the proposed maximum rates as increased pumping would most likely cause drawdowns greater than the available saturated thickness (15 m [49 ft]) of the proposed wells. The aquifer thickness is assumed to be equal to the thickness of the proposed well screened interval of 15 m [49 ft]. The direction of the hydraulic gradient is assumed to be parallel to the line connecting HC-6 and HC-8.

The uncertainty in the model predictions was simulated within a Monte Carlo framework. One-thousand realizations were performed to determine uncertainty in the model predictions. For each realization a single value of effective porosity, transmissivity, and hydraulic gradient was chosen from the described distribution. These values were used in the RESSQC model to determine the capture zone for the proposed pumping well after 120 days of pumping. These capture zones were ranked based on the distance from the outer edge of the capture zone to the PSA test. These ranked capture zones were used to quantify the 50 and 95 percent confidence intervals of expected risk of encountering radionuclides during the tracer experiment in the pumping well. The capture zones associated with each confidence interval were plotted to determine the spatial distribution of the capture zone relative to the PSA test.

Results and Discussion

Figure A.1-2 shows the 50 and 95 percent confidence levels for the simulated capture zones. The capture zone associated with the 50 percent confidence level is associated with median values of the transmissivity, effective porosity, and hydraulic gradient. The 95 percent confidence interval capture zone is associated with small values of effective porosity, and large values of transmissivity and the regional gradient. It should be noted that no correlation amongst input parameters was specified which provides a conservative estimate of the risk associated with the tracer test. It could be expected that a larger value of effective porosity would be encountered if the transmissivity were truly larger than the expected value. If this were the case, then the outer edge of the capture zone would be further away from the PSA test. Of the 1,000 realizations, 1.4 percent showed capture zones that intersected the calculated location of the radionuclide plume associated with the PSA test. This suggests that there is a 1.4 percent probability that radionuclides will be encountered in the pumping well during the tracer test. In these cases, the

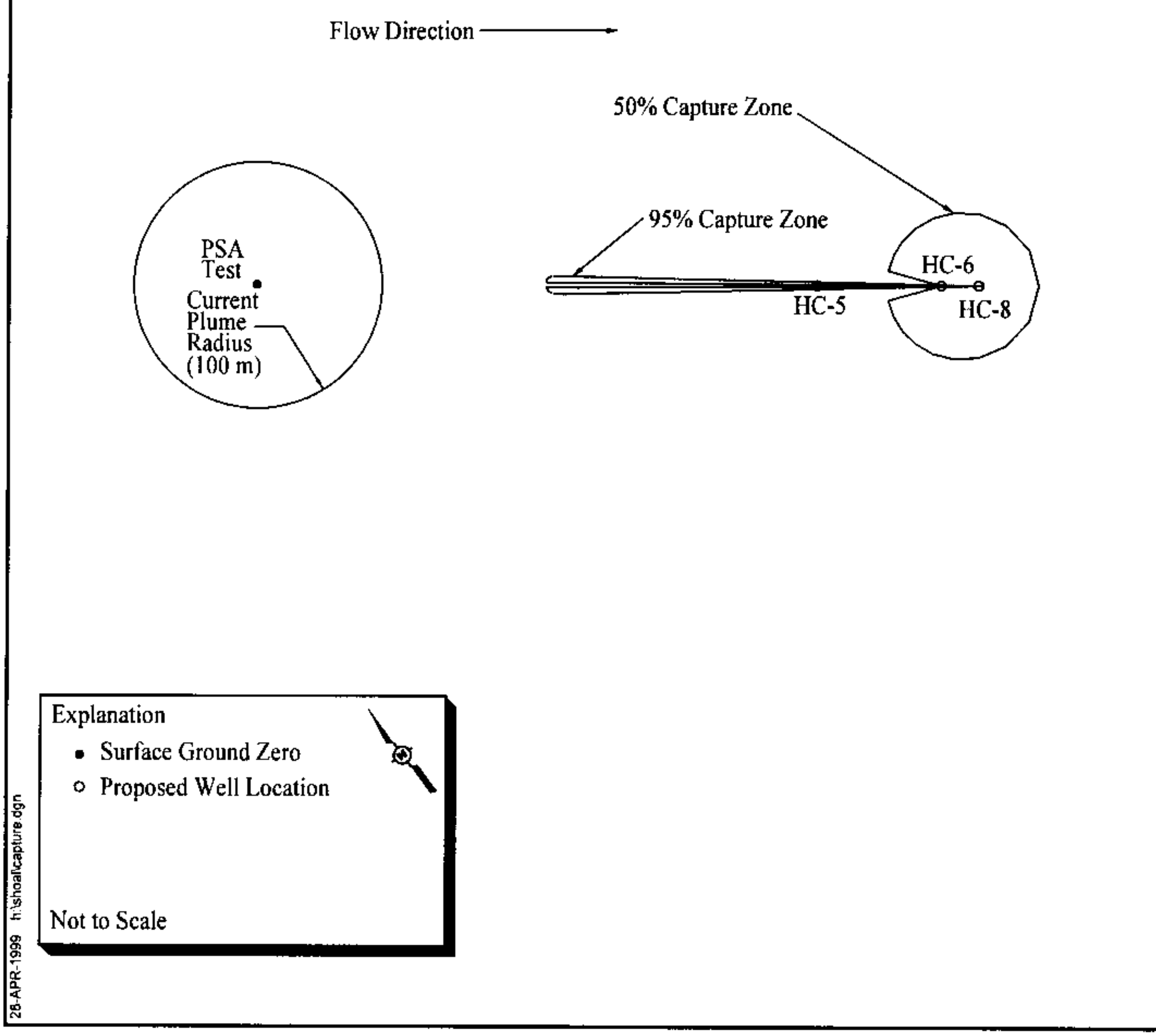

Figure A.1-2
The Capture Zones Associated with the 50 and 95 Percent Confidence Levels After 120 Days of Pumping

capture zone intersected the outer edge of the current plume radius, which suggests that contamination would occur during the final days of the tracer experiment.

Conclusions

A semianalytical model, RESSQC, was used to determine the risk of encountering radionuclides in the pumping well associated with the 120-day tracer test. The results indicated that there is a 98.6 percent probability that no contamination will be encountered. Likewise, there is a 1.4 percent probability that contamination will be encountered during the final days of the tracer experiment. The potential concentrations cannot be determined from this analysis because the RESSQC model only simulates particle movement, not concentrations.

A.2.0 References

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