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January 18, 2010

Attn: Document Control Desk
Doug Mandeville, Project Manager
Uranium Recovery Licensing Branch
Division of Waste Management
and Environmental Protection,
Office of Federal and State Materials
and Environmental Management Programs,
US Nuclear Regulatory Commission
Two White Flint North, MS T8F5
11545 Rockville Pike
Rockville, MD 20852

RE: ADDITIONAL INFORMATION REQUESTED FOR THE MOORE RANCH IN SITU URANIUM RECOVERY PROJECT LICENSE APPLICATION (TAC JU011), SAFETY EVALUATION REPORT OPEN ISSUES.

Dear Mr. Mandeville:

By letters dated May 26, September 8 and September 17, 2009, the U.S. Nuclear Regulatory Commission (NRC) staff provided questions on open issues identified as part of the development of the Safety Evaluation Report (SER) for the License Application for the Moore Ranch In Situ Uranium Recovery Project. By letters dated December 4 and 10, 2009, Uranium One submitted responses to all but eight of the Open Issues.

By this letter, Uranium One is submitting responses to the remaining open issues (OI's) identified in the referenced SER Open Issues conference call summary report. These remaining open issues include the following:

- From the May conference call, a revised response to hydrology open issue number 17;
- From the July conference call, radiological open issues number 6a and 6f; and
- From the August conference call, radiological open issues number 13, 16, 17, 18, 19 and 20.

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Each response includes a detailed written answer to the SER open issue. If revisions to the Technical Report are necessary as a result of these responses, then the specific section of the Technical Report is presented in a redline strike-out format with the proposed revisions.

In addition, by letter dated March 23, 2009, the NRC staff provided a request for additional information (RAI) to complete review of the license application Environmental Report for the Moore Ranch In Situ Uranium Recovery Project. By this letter, Uranium One is submitting a response to one outstanding RAI related to Section 4.4.2.3.2 concerning the potential impact of surface spills on shallow groundwater.

If you should have any questions on these responses, please contact me by phone at (307) 234-8235 ext. 331 or by email at jon.winter@uranium1.com.

Sincerely,

Jon Winter
Manager, Wyoming Environmental and Regulatory Affairs

Enclosures: Safety Evaluation Report Open Issues responses
Environmental Report RAI response

Hydrology Open Issue No. 17
Restoration of groundwater to the standards in 10 CFR part 40, Appendix A, criterion 5B is not proposed
May 11 2009 Teleconference

Open Issue discussion:

EMC stated that the goal of the groundwater restoration is to return the groundwater quality of the production zone at Moore Ranch to the standard of baseline water quality using Best Practicable Technology (BPT). If this standard cannot be achieved, EMC stated it will achieve pre-mining class of use based on WDEQ standards. NRC regulations require that the groundwater quality be returned to the standards identified in Criterion 5B(5) of 10 CFR Part 40, Appendix A. Those standards are background, the values in the table in Criterion 5C of 10 CFR Part 40, Appendix A, or an alternate concentration limit established by NRC in accordance with Criterion 5B(6). The applicant's goal of restoration to background would meet the standard in Criterion 5B(5)(a), provided the staff approved the proposed background values. The proposal to restore groundwater to its pre-mining class of use is not consistent with the requirements of Criterion 5B(5) and is, therefore, not acceptable to NRC staff.

Answer:

NRC staff has concluded that the standards contained in 10 CFR Part 40, Appendix A currently apply to the restoration of groundwater at ISR facilities. Although we do not agree that 10 CFR Part 40, Appendix A, Criterion 5B(5) applies to ISR facilities, the license application will be revised to reflect this situation.

Proposed Revisions to License Application

The following changes are proposed to the license application in response to this Open Issue. Changes to the original text as submitted to NRC are noted in red-line/strikeout method.

Technical Report section 6.1.1:

6.1.1 Groundwater Restoration Criteria

The purpose of groundwater restoration is to protect groundwater adjacent to the mining zone. Approval of an aquifer exemption by the WDEQ and the EPA is required before mining operations can begin. The aquifer exemption removes the mining zone from protection under the Safe Drinking Water Act (SDWA). Approval is based on existing water quality, the ability to commercially produce minerals, and the lack of use as an underground source of drinking water (USDW). Groundwater restoration prevents any mobilized constituents from affecting aquifers adjacent to the ore zone.

The goal of groundwater restoration will be to return the concentration of a hazardous constituent in the production zone to an NRC-approved background concentration or to the maximum concentration limit (MCL), whichever is higher, or to an alternate standard approved by NRC using Best Practicable Technology. The pre-mining baseline water quality and class of use will be determined by the baseline water quality sampling program which is performed for each wellfield, as compared to the use categories defined by the WDEQ, Water Quality Division (WQD). Baseline, as defined for this project, shall be the mean of the pre-mining baseline data after outlier removals. Restoration shall be demonstrated in accordance with Chapter 11, Section 5(a)(ii) of the WDEQ, Land Quality Division Rules and Regulations and NUREG-1569 Section 6.

Technical Report section 7.2.5.3.1:

7.2.5.3.1 Lixiviant Excursions

Water quality impacts in adjacent aquifers from ISR mining activities are related to the identification, control, and clean-up of excursions. During production, injection of the lixiviant into the wellfield results in a temporary degradation of water quality compared to pre-mining conditions. Movement of this water out of the wellfield results in an excursion. Excursions of contaminated groundwater in a wellfield can result from an improper balance between injection and recovery rates, undetected high permeability strata or geologic faults, improperly abandoned exploration drill holes, discontinuity and unsuitability of the confining units which allow movement of the lixiviant out of the ore zone, poor well integrity, or hydrofracturing of the ore zone or surrounding units. Past experience from other commercial scale in-situ recovery projects in the Powder River Basin has shown that when proper steps are taken in monitoring and operating a wellfield, excursions, if they do occur, can be controlled and recovered and that serious impacts on the groundwater are prevented.

Excursions of lixiviant at ISR facilities have the potential to contaminate adjacent aquifers with radioactive and trace elements that have been mobilized by the mining process. These excursions are typically classified as horizontal or vertical. A horizontal excursion is a lateral movement of mining solutions outside the mining zone of the ore-body aquifer. A vertical excursion is a movement of solutions into overlying or underlying aquifers.

The historical experience at other ISR uranium operations indicates that the selected excursion indicator parameters and UCLs allow detection of horizontal excursions early enough that corrective action can be taken before water quality outside the exempted aquifer boundary is significantly degraded. As noted in NUREG/CR-6733, significant risk from a horizontal excursion would occur only if it persisted for a long period without being detected.

Vertical excursions can be caused by improperly cemented well casings, well casing failures, improperly abandoned exploration wells, or leaky or discontinuous confining layers.

The State of Wyoming and the NRC require restoration of affected groundwater in the mining zone following production activities. The mining aquifer must be exempted by the WDEQ and the EPA from protection under the Safe Drinking Water Act (SDWA) before mining can occur. One of the criteria for exemption is that the water is not currently used as an underground source of drinking water (USDW) and will not be used as a USDW in the future. By restoring the exempted aquifer, EMC ensures that adjacent, non-exempted aquifers will not be affected in the future.

Technical Report section 8.2:

8.2 PROPOSED ACTION

The proposed Moore Ranch Uranium Project contains a licensed area of approximately 7,110 acres. Of this potential licensed area, the surface area to be affected by mining operations will be less than 150 acres for the central plant and facilities including the wellfields. The Moore Ranch Uranium Project is located in Campbell County, Wyoming within Township 42 North, Range 75 West, Sections 26, 27, 33, 34, 35, 36 and Township 41 North, Range 75 West, Sections 1, 2, 3, and 4, and Township 42 North, Range 74 West, Section 31 between the towns of Wright and Edgerton with access to the project site from Wyoming State Highway 387. The proposed action will consist of construction, operation, and ultimately decommissioning of wellfields, an ion exchange facility, wastewater disposal well(s), and a processing and drying facility.

Commercial production of the reserves at the Moore Ranch Project and subsequent groundwater restoration activities are projected to extend over the next ten years. The minimum projected life of the central plant is projected to be 25 years since EMC plans to use the facility to process ion exchange resin from satellite facilities operated by EMC or others. Aquifer restoration and reclamation at Moore Ranch will be accomplished concurrent with operations to the extent feasible plus an additional two years at the end of the project for final decommissioning of the central plant facilities and surface reclamation in these areas. More detailed schedules were provided in Section 1.

The in-situ process consists of an oxidation step and a dissolution step. The oxidants utilized in the facility are hydrogen peroxide and/or gaseous oxygen. A sodium bicarbonate lixiviant is used for the dissolution step. The uranium-bearing solution is recovered from the wellfield and piped to the central plant for extraction. The central plant process utilizes the following steps:

- *Loading of uranium complexes onto an ion exchange resin;*

- *Reconstitution of the solution before reinjection by the addition of sodium bicarbonate and oxygen;*

- *Elution, precipitation, drying, and packaging of yellowcake in the central plant; and*

- *Restoration of groundwater following mining activities.*

The operation of the Moore Ranch Project will result in a number of effluent streams. Airborne effluents are limited to the release of radon-222 gas during the uranium recovery process. Liquid wastes are handled through deep well injection.

Groundwater restoration activities consist of three steps:

- *Groundwater transfer;*

- *Groundwater sweep; and*

- *Groundwater treatment;*

Groundwater restoration will take place concurrently with development and production activities. The goal of groundwater restoration will be to return the concentration of a hazardous constituent in the production zone to an NRC-approved background concentration or to the maximum concentration limit (MCL), whichever is higher, or to an alternate standard approved by NRC using Best Practicable Technology.

Technical Report section 9.4.3:

9.4.3 Groundwater Impacts

It is unlikely that any future irrigation development would occur within the proposed Moore Ranch Project area due to limited water supplies, topography, and climate. Irrigation within the 2.0-mile review area is anticipated to be consistent with the past. Based on population projections, future water use within the 2.0-mile review area would likely be a continuation of present use; therefore, it is anticipated that there would be no significant changes from the existing conditions for public water supply in the area.

Following standard mining practice, any impacted water drawn from the aquifer on site would either be treated before re-injection or disposed through deep well injection. Upon decommissioning, wells would be sealed and remaining groundwater would be restored as discussed in Section 6.

Radiological Open Issue No. 6a
Quantity of radioactive material released to unrestricted areas
July 27 2009 Teleconference

Open Issue discussion:

Regulatory Guide 3.59 addresses methods, models, data, and assumptions acceptable to the NRC staff for estimating airborne emissions of radioactive and toxic materials from uranium milling. The applicant did not provide sufficient information regarding the manner in which it will calculate or measure effluent releases from monitored release points. Additionally, the applicant has not provided sufficient information regarding how it plans to meet the requirement in 10 CFR 40.65 for reporting the quantity of each of the principal radionuclides released to unrestricted areas.

Radiological Open Issue No. 6f
Dryer effluent controls
July 27 2009 Teleconference

Open Issue discussion:

The applicant stated that the ventilation system will exhaust air from within the plant to outside the plant building; however, the applicant has not demonstrated how the gaseous effluents will be monitored.

Answer:

The predominant radionuclide released to unrestricted areas will be airborne releases of radon-222 from non-point sources such as well fields and the CPP. Radon-222 releases in the wellfield will occur from material contained in mud pits during drilling, from sample collection in headerhouses, and from wellhead venting activities. Radon-222 releases from the CPP building will occur through tank ventilation systems during venting and backwashing operations and from the normal building ventilation system, which will exhaust building air at various points in the structure. As such, no discrete monitoring locations are available to make representative measurements of radon-222 concentration or air flow rates to estimate semiannual airborne emissions of radon-222. Because of these factors, the methods used to estimate radon-222 emissions in Section 7.3 of the Technical Report will be used to estimate the actual semiannual emissions from the facility as required in 10 CFR §40.65. The parameters from Table 7.3-1 of the Technical Report, coupled with updated parameters in Table 1 below to account for actual operational information, will be used to calculate the semiannual emission estimates.

Table 1 Operational parameters used to estimate semiannual radon-222 emissions.

Parameter	Projected Value	Unit
Mined Area	Determined based on actual mined area for reporting period	m^2 y^{-1}
Average Lixiviant Flow	Determined based on actual lixiviant flow for the reporting period	L m^{-1}
Average Restoration Flow	Determined based on actual restoration flow for the reporting period	L m^{-1}
Operating days per year	Determined based on actual operating days for the reporting period	days
Number of mud pits generated per year	Determined based on actual number of mud pits generated for the reporting period	Number of mud pits
Storage time in mud pits	Determined based on actual storage time for the reporting period	days
Number of Resin Transfers per day	Determined based on actual number of resin transfers for the reporting period	Number of resin transfers

Parameters listed in Table 7.3-1 of the Technical Report which are not included in Table 1 above and for which site specific parameters have not been measured are listed in Table 2. In these cases, default or typical parameters as described in RG 3.59 will be used.

Table 2 Default based parameters used to estimate radon-222 releases.

Parameter	Value	Unit	Source
Ore radium-226 Concentration	282	pCi g^{-1}	Reg. Guide 3.59
Radon-222 emanating power	0.2	NA	Reg. Guide 3.59

The radium-226 concentration in ore assumes that radium-226 is in secular equilibrium with the average uranium-238 concentration for the Moore Ranch project listed in Table 7.3-1, which is consistent with the assumptions used in Regulatory Guide 3.59.

The radon-222 emanating power for the ore has not been measured. Table 8.1 of "Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" (USDOE, 1993) presents a range of radon-222 emanating power for crushed uranium ore of 0.006 to 0.55 with an arithmetic mean of 0.28. Regulatory Guide 3.59 states to use a radon emanating power of 0.2 when this parameter has not been measured. The use of 0.2 for radon-222 emanating power is consistent with methods described in Regulatory Guide 3.59 and is within the range of typical values for uranium ore.

As concluded in Appendix D of NUREG-1569, particulate releases, which include long-lived radionuclides in the uranium decay series, from rotary vacuum dryers are not expected under normal operating conditions. No other sources of long-lived radionuclide releases to the air from routine site operations have been identified.

Proposed Revisions to License Application

The following changes are proposed to the license application in response to this Open Issue. New Section 4.1.3 will be added to the Technical Report.

4.1.3 Reporting Effluent Releases

10 CFR §40.65 requires licensees to submit a semiannual environmental and effluent report to the NRC. The report must specify the quantity of each of the principal radionuclides released to unrestricted areas in liquid and in gaseous effluents during the previous six months of operation.

The predominant radionuclide released to unrestricted areas from the Moore Ranch project will be airborne releases of radon-222 from non-point sources such as well fields and the CPP. Radon-222 releases in the wellfield will occur from material contained in mud pits during drilling, from sample collection in headerhouses, and from wellhead venting activities. Radon-222 releases from the CPP building will occur through tank ventilation systems during venting and backwashing operations and from the normal building ventilation system, which will exhaust building air at various points in the structure. As such, no discrete monitoring locations are available to make representative measurements of radon-222 concentration or air flow rates to estimate semiannual airborne emissions of radon-222. Because of these factors, the methods used to estimate radon-222 emissions in Section 7.3 of the Technical Report will be used to estimate the actual semiannual emissions from the facility as required in 10 CFR §40.65. The parameters from Table 7.3-1 of the Technical Report, coupled with updated parameters in Table 4-1 below to account for actual operational information, will be used to calculate the semiannual emission estimates. These updated parameters will be applied to Equations 1 through 6 of Section 7.3.3 to calculate the semiannual releases as required on 10 CFR §40.65.

Table 4-1 Operational parameters used to estimate semiannual radon-222 emissions.

Parameter	*Projected Value*	*Unit*
Mined Area	*Determined based on actual mined area for the reporting period*	$m^2\ y^{-1}$
Average Lixiviant Flow	*Determined based on actual lixiviant flow for the reporting period*	$L\ m^{-1}$
Average Restoration Flow	*Determined based on actual restoration flow for the reporting period*	$L\ m^{-1}$
Operating days per year	*Determined based on actual operating days for the reporting period*	*days*
Number of mud pits generated per year	*Determined based on actual number of mud pits generated for the reporting period*	*NA*
Storage time in mud pits	*Determined based on actual storage time for the reporting period*	*days*
Number of Resin Transfers per day	*Determined based on actual number of resin transfers for the reporting period*	*NA*

Parameters listed in Table 7.3-1 of the Technical Report which are not included in Table 4-1 above and for which site specific parameters have not been measure are listed in Table4- 2. In these cases, default or typical parameters as described in RG 3.59 will be used.

Table 4-2 Default based parameters used to estimate radon-222 releases.

Parameter	**Value**	**Unit**	**Source**
Ore radium-226 Concentration	282	pCi g^{-1}	Reg. Guide 3.59
Radon-222 emanating power	0.2	NA	Reg. Guide 3.59

The radium-226 concentration in ore assumes that radium-226 is in secular equilibrium with the average uranium-238 concentration for the Moore Ranch project listed in Table 7.3-1, which is consistent with the assumptions used in Regulatory Guide 3.59.

The radon-222 emanating power for the ore has not been measured. Table 8.1 of "Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" (USDOE, 1993) presents a range of radon-222 emanating power for crushed uranium ore of 0.006 to 0.55 with an arithmetic mean of 0.28. Regulatory Guide 3.59 states to use a radon emanating power of 0.2 when this parameter has not been measured. The use of 0.2 for radon-222 emanating power is consistent with methods described in Regulatory Guide 3.59 and is within the range of typical values for uranium ore.

As concluded in Appendix D of NUREG-1569, particulate releases, which include long-lived radionuclides in the uranium decay series, from rotary vacuum dryers are not expected under normal operating conditions. No other sources of long-lived radionuclide releases to the air from routine site operations have been identified.

Radiological Open Issue No. 13
Location of boundary air particulate samplers and impacts on proposed operational air particulate and direct radiation sampling locations
August 18, 2009 Teleconference

Open Issue discussion:

The applicant shows the air particulate and radon sampling locations in Figure 5.7-2, however, the applicant does not identify these air particulate and radon sampling locations by sector or distance. The applicant has not provided sufficient information demonstrating that the three site boundary air particulate and radon sampling stations have been placed in locations and sectors that have the highest predicted concentrations of airborne particulate that is consistent with Regulatory Guide 4.14. The staff notes that the location of the air particulate and radon sampling locations may have an impact on the proposed soil sampling locations.

Answer:

Figure 1 below shows the air monitoring locations, the sector with respect to the central processing plant, and the distance from the central processing plant. The predominant wind direction as discussed in Section 2.5.2.4 of the Technical Report is from the southwest to west sectors and is from these sectors 40% of the time.

MRA-1 is approximately 1.5 kilometers from the central processing plant in the east-southeast sector. This location is well positioned to monitoring potential airborne emissions from the site carried by winds from the west.

MRA-2 is approximately 1.3 kilometers from the central processing plant bordering the northeast and east-northeast sector. This location is well positioned to monitor potential airborne emissions from the site carried by winds from the southwest.

MRA-3 is approximately 2.4 kilometers from the central processing plant in the south-southwest sector. This location is well positioned to monitoring potential airborne emissions from the site carried by winds from the north and north-northeast sectors.

MRA-4 is approximately 2.5 kilometers from the central processing plant in the west-southwest sector. This location is well positioned to monitor background conditions since the predominant winds are from the southwest to west sectors.

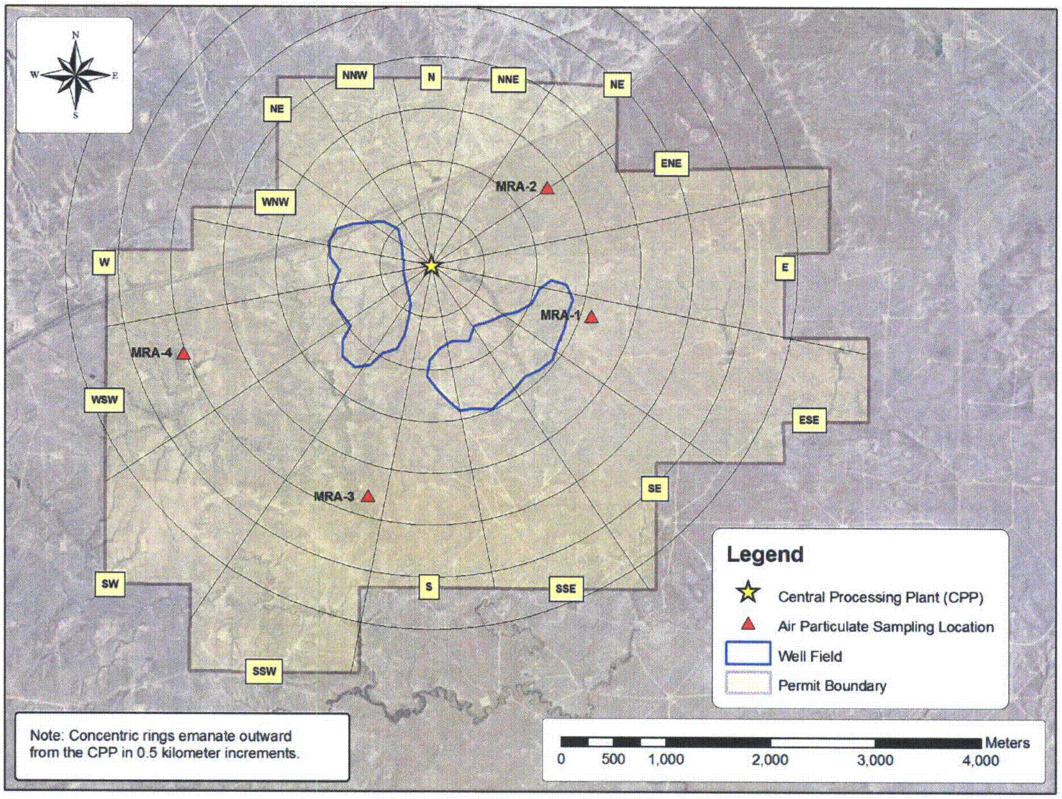

Figure 1. The Location of Air Monitoring Stations for the Moore Ranch Site.

Proposed Revisions to License Application

There are no changes proposed to the license application in response to this Open Issue.

Radiological Open Issue No. 16
Operational sampling for food, fish, and vegetation sampling
August 18, 2009 Teleconference

Open Issue discussion:

The applicant has not provided sufficient justification for not conducting food or fish sampling in the application. The staff notes that the applicant has not provided any calculations to support the position that the vegetation pathway is not a potentially significant exposure pathway and an individual would not exceed 5 percent of the applicable radiation protection standards. The MILDOS analysis does not include a food/vegetation dose pathway analysis for the east sector at a distance of 1.5 km. The staff cannot verify that the assumptions used in the MILDOS analysis are representative of the anticipated conditions at the facility.

Answer:

Table 2.9-19 in Section 2.9.11 provides data from food sampling as reported in the original Conoco baseline study (Conoco 1980). Land use since 1980 within and surrounding the Moore Ranch site has not changed in a manner which would significantly affect these radiological baseline results. Uranium One believes that the data in Table 2.9-19 are representative of current conditions. However, Uranium One will obtain preoperational food samples before operations at Moore Ranch begin as discussed in the response to Radiological Open Issue number 2 from the July teleconference.

Fish sampling has not been conducted because, as Section 2.8.5.5 of the Technical Report (EMC, 2007) describes, the lack of habitat and persistent water sources surrounding the site precludes the presence of fish.

The MILDOS analysis includes a food/vegetation pathway analysis for all receptors. The dose attributable to the vegetation ingestion pathway ranged from 0.01 to 2.3 percent with a mean of 0.18 percent of the estimated total effective dose equivalent (TEDE) for a receptor. The dose attributable to the meat ingestion pathway ranged from 0.003 to 0.5 percent with a mean of 0.04 percent of the estimated TEDE for a receptor.

Table 1 below shows the ground surface concentrations for radon-222 decay products in the east sector at a distance of 1.5 kilometers and 3.4 kilometers as well as doses at each location. It is clear from this data that the vegetation ingestion is not an important pathway for public dose and contributes much less than 5 percent of the applicable radiation protection standard of 100 mrem per year. It should also be noted that 1.5 kilometers in the east sector from the central processing plant is within the proposed license boundary of the site. This area is controlled by Uranium One and no residences will be established here while the site is operational.

Table 1. Ground Surface Concentrations (pCi/m^2) for Radon-222 Decay Products and Total Effective Dose Equivalent (mrem/yr) in the East Sector as Predicted by MILDOS-Area

Distance (km)	Polonium-218	Lead-214	Bismuth-214	Lead-210	TEDE	Fraction of TEDE from Vegetation Pathway
1.5	21	21	21	7.9	2.24	0.0001
3.4*	8.64	8.64	8.64	20	0.89	0.001

* Represents the approximate distance to the permit boundary in the east direction.

Proposed Revisions to License Application

The following changes are proposed to the license application in response to this Open Issue.

1. The following text will be added to section 5.7.7 following the discussion of Deep Disposal Well Monitoring:

   <u>*Fish*</u>

   Operational fish sampling is not planned because, as discussed in Section 2.8.5.5, the lack of habitat and persistent water sources surrounding the Moore Ranch site precludes the presence of fish.

2. Results from preoperational food sampling planned for the spring of 2010 as described in the response to Radiological Open Issue number 2 from the July teleconference will be included in the Technical Report, Section 2.9.11, Food Sampling.

SURFACE SOIL CLEANUP AND VERIFICATION PLAN OPEN ISSUES

Radiological Open Issue No. 17
Gamma levels and cleanup criteria
August 18, 2009 Teleconference

Open Issue discussion:

The applicant plans to use hand-held and GPS-based gamma surveys to guide soil remediation efforts. The applicant will monitor excavations with hand-held detection systems to guide the removal of contaminated material to the point where the applicant can determine that there is a high probability that an area meets the cleanup criteria. The applicant has not defined what gamma level will correspond to the cleanup criteria. Although the applicant identified a correlation between gamma readings and Ra-226 concentrations in soil in Section 2.9.2.2.3 of the Technical Report, the applicant has not demonstrated how the gamma level will correlate to the uranium or other radionuclides that may be present.

Answer:

Gamma count rates used to identify radium-226 in soil cannot be as easily correlated to natural uranium due to its limited gamma signature. As described in Section 6.4.1.3 of the Technical Report (EMC, 2008), the presence of a radium-226 and natural uranium mixture will tend to drive the cleanup of radium-226 to concentrations below the cleanup level, consequently the uranium in soil will also be remediated.

In case where uranium is suspected to be the only radionuclide of concern, other instruments are available, such as a Field Instrument for the Detection of Low Energy Radiation (FIDLER), which are sensitive to the low energy x-rays emitted by natural uranium and could be used to guide soil remediation efforts. Field studies would have to be conducted to correlate the FIDLER response to natural uranium soil concentrations. If needed, the method used to correlate FIDLER (or equivalent) responses to uranium soil concentrations will be described in a detailed Decommissioning Plan for the facility which is required to be submitted to the USNRC for review and approval at least 12 months before planned commencement of final decommissioning.

Final confirmation that remediated soils meet the established cleanup criteria will be performed via soil sampling using the method described in Section 6.4.3.

Radiological Open Issue No. 18
Definition of potentially contaminated areas
August 18, 2009 Teleconference

Open Issue discussion:

The applicant states that cleanup of surface soils will be restricted to a few areas where there are known spills and, potentially, small spills near wellheads. The applicant will conduct final GPS-based gamma surveys in potentially contaminated areas; however, the applicant does not define potentially contaminated areas.

Answer:

Potentially contaminated areas include areas where known spills have occurred and areas where there is potential for small unknown spills and other contamination including areas under and around header houses, wellheads, buried pipelines that contain radioactive material, radioactive materials storage areas, deep disposal well facilities, and liquid storage areas.

Radiological Open Issue No. 19
Gamma action limits and relation to preoperational gamma survey and preoperational environmental monitoring
August 18, 2009 Teleconference

Open Issue discussion:

The applicant states that pre-reclamation surveys will be conducted, as described in Section 6.2.1 of the Technical Report, in areas where known contamination has occurred or the potential for unknown soil contamination exists. The applicant plans to divide areas into 100 m2 grid blocks. Soil samples will be obtained from these grid blocks with gamma count rates exceeding the gamma action limit. The applicant does not define the gamma action limits or explain the relationship between the gamma count rates obtained during the surface soil cleanup verification and the preoperational gamma survey and preoperational environmental monitoring conducted prior to construction. The applicant has not provided assurance that the survey method for verification of soil cleanup is designed to provide 95 percent assurance that the soil units meet the cleanup guidelines.

Answer:

It is premature to assign a gamma count rate action limit for pre-reclamation surveys since the gamma count rate is dependent on the type of instruments being used and the operational settings. To address this issue, the responses of the gamma instruments used in the pre-ISR gamma survey were converted to exposure rate (μR/hr) based on the method described in Section 2.9.2.1.2 of the Technical Report (EMC, 2008). In addition, the relationship between exposure rate estimates from the gamma survey instruments and radium-226 concentrations in soil was evaluated using methods described in Section 2.9.2.1.3. These cross-calibrations allow for the results of future gamma surveys using different instrumentation to be meaningfully compared against the results of the pre-ISR gamma surveys provided the instrumentation response is also calibrated to exposure rate measurements.

Section 2.9.2.2.3 and 2.9.2.2.5 of the Technical Report present two predictive models to estimate radium-226 soil concentrations from exposure rate measurements. One model is a linear model and is best used when predicting radium-226 concentrations when exposure rates are greater than 20 μR/hr. The second model is a power function model and is best used when predicting radium-226 concentrations when exposure rates are less than 20 μR/hr. Section 2.9.3.2.1 of the Technical Report concludes that pre-ISR radium-226 concentrations in soil are unlikely to exceed 2 pCi/g. Based on the radium-226 soil standard contained in 10 CFR 40, Appendix A, Criterion 6-6 and the background radium-226 concentration being below 2 pCi/g, the radium-226 soil cleanup standard for most areas on Moore Ranch site would be about 7 pCi/g. Using the linear model described above, this radium-226 soil concentration would correspond to an exposure rate of approximately 23 μR/hr. Using the power function model described above, this radium-226 soil concentration would correspond to 23.2 μR/hr. Both equations are in agreement that 23 μR/hr correlates to a radium-226 soil concentration equal to the cleanup standard for most areas of approximately 7pCi/g. The gamma count rates corresponding to an exposure rate of 23 μR/hr from instruments used to perform pre-reclamation gamma surveys would be an appropriate and conservative gamma action limit.

There are other physical factors that influence gamma count rates other than radium-226 concentrations in soil and include source geometry and land topography. As such, gamma count rates may not be a reliable tool to provide a 95% assurance that the soil units meet the cleanup guidelines. The gamma action level established above, coupled with pre-ISR gamma survey results contained in the Technical Report will provide sufficient evidence to indicate radium-226 soil concentrations above cleanup guidelines. This evidence will trigger soil removal activities and subsequent post remediation gamma surveys and soil sampling as described in Section 6.4.3 of the Technical Report. The results of the soil sampling will be compared to established soil cleanup goals to demonstrate the effectiveness of the reclamation activities including any confidence level that the soil units meet the cleanup guidelines.

Proposed Revisions to License Application

The following changes are proposed to the license application in response to these Open Issues. Changes to the original text as submitted to NRC are noted in red-line/strikeout method.

6.4.3 Surface Soil Cleanup Verification and Sampling Plan

Cleanup of surface soils will be restricted to potentially contaminated areas. These potentially contaminated areas include areas where known spills have occurred and areas where there is potential for small unknown spills and other contamination including areas under and around header houses, wellheads, buried pipelines that contain radioactive material, radioactive materials storage areas, deep disposal well facilities, and liquid storage areas. Final GPS-based gamma surveys will be conducted in potentially contaminated areas. Areas will be divided into 100 m2 grid blocks. Soil samples will be obtained from grid blocks with gamma count rates exceeding the gamma action level. The samples will be five-point composites and will be analyzed at an offsite laboratory for radium-226 and natural uranium.

Section 2.9.2.2.3 and 2.9.2.2.5 of the Technical Report present two predictive models to estimate radium-226 soil concentrations from exposure rate measurements. One model is a linear model and is best used when predicting radium-226 concentrations when exposure rates are greater than 20 μR/hr. The second model is a power function model and is best used when predicting radium-226 concentrations when exposure rates are less than 20 μR/hr. Section 2.9.3.2.1 of the Technical Report concludes that pre-ISR radium-226 concentrations in soil are unlikely to exceed 2 pCi/g. Based on the radium-226 soil standard contained in 10 CFR 40, Appendix A, Criterion 6-6 and the background radium-226 concentration being below 2 pCi/g, the radium-226 soil cleanup standard for most areas on Moore Ranch site would be about 7 pCi/g. Using the linear model described above, this radium-226 soil concentration would correspond to an exposure rate of approximately 23 μR/hr. Using the power function model described above, this radium-226 soil concentration would correspond to 23.2 μR/hr. Both equations are in agreement that 23 μR/hr correlates to a radium-226 soil concentration equal to the cleanup standard for most areas of approximately 7pCi/g. The gamma count rates corresponding to an exposure rate of 23 μR/hr from instruments used to perform pre-reclamation gamma surveys will be used as an appropriate and conservative gamma action limit.

There are other physical factors that influence gamma count rates other than radium-226 concentrations in soil and include source geometry and land topography. As such, gamma count rates may not be a reliable tool to provide a 95% assurance that the soil units meet the cleanup guidelines. The gamma action level established above, coupled with pre-ISR gamma survey results contained in section 2.9 of the Technical Report will provide sufficient evidence to indicate *radium-226 soil concentrations above cleanup guidelines. This evidence will trigger soil removal activities and subsequent post remediation gamma surveys and soil sampling.*

Gamma count rates used to identify radium-226 in soil cannot be as easily correlated to natural uranium due to its limited gamma signature. As described in Section 6.4.1.3, the presence of a radium-226 and natural uranium mixture will tend to drive the cleanup of radium-226 to concentrations below the cleanup level, consequently the uranium in soil will also be remediated.

In case where uranium is suspected to be the only radionuclide of concern, other instruments are available, such as a Field Instrument for the Detection of Low Energy Radiation (FIDLER), which are sensitive to the low energy x-rays emitted by natural uranium and could be used to guide soil remediation efforts. Field studies would have to be conducted to correlate the FIDLER response to natural uranium soil concentrations. If needed, the method used to correlate FIDLER (or equivalent) responses to uranium soil concentrations will be described in a detailed Decommissioning Plan for the facility which is required to be submitted to the USNRC for review and approval at least 12 months before planned commencement of final decommissioning.

The results of the soil sampling will be compared to established soil cleanup goals for radium-226 and natural uranium to demonstrate the effectiveness of the reclamation activities including any confidence level that the soil units meet the cleanup guidelines.

Radiological Open Issue No. 20
Application of radium benchmark dose on remaining structures
August 18, 2009 Teleconference

Open Issue discussion:

According to 10 CFR 40 Appendix A, Criterion 6(6), it states, "Byproduct material containing concentrations of radionuclides other than radium in soil, and surface activity on remaining structures, must not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of radium contaminated soil to the above standard (benchmark dose), and must be at levels which are as low as is reasonably achievable." In Section 6.3 of the Technical Report, the applicant states that based on the results of the preliminary radiological surveys, gross decontamination techniques will be employed to remove loose contamination before decommissioning activities proceed. The applicant also discusses in Section 6.3 of the Technical Report the release limits for alpha contamination. However, the applicant does not discuss how byproduct material containing concentrations of radionuclides other than radium in soil, and surface activity on remaining structures will not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of the radium contaminated soil to the above standard (benchmark dose) and will be at levels which are as low as is reasonably achievable (ALARA).

Answer:

Soil cleanup criteria have been developed for radium-226 and natural uranium. Other long-lived radionuclides which may be present in byproduct material were not evaluated since they are not expected to be prevalent in the process or waste streams. Should a process or waste stream be identified over the course of the operational life of the Moore Ranch facility where other radionuclides are prevalent and a potential for soil contamination exists, soil cleanup criteria for these radionuclides will be developed using methods similar to those presented in Section 6.4 of the Technical Report (EMC, 2008). These cleanup criteria will be presented in a detailed Decommissioning Plan submitted to the NRC for review and approval. The Decommissioning Plan will be submitted at least 12 months before planned commencement of final decommissioning.

Section 6.4.1 of the Technical Report discusses the methods used to establish the radium-226 benchmark dose associated with the radium-226 soil cleanup criteria in 10 CFR 40 Appendix A, Criterion 6 (6). The radium-226 benchmark total effective dose equivalent (TEDE) for the Moore Ranch project was estimated to be 39.5 mrem per year.

Section 6.4.1.2 of the Technical Report discusses the methods used to established natural uranium soil cleanup criteria for the Moore Ranch project. The natural uranium soil cleanup criteria were based on 1) the radium-226 benchmark dose, 2) the chemical toxicity of natural uranium as discussed in Section 6.4.1.3, and 3) considerations to keep natural uranium soil concentrations to levels that are as low as is reasonable achievable (ALARA). The ALARA goals for soil cleanup are discussed in Section 6.4.1.3 and presented in Table 6.4-2. The dose conversion factor for natural uranium for the Moore Ranch project, as shown in Section 6.4.1.2, is 0.075 mrem/yr per picocurie (pCi) per gram of soil. Given the natural uranium soil cleanup limit in Table 6.4-2 of 225 pCi per gram, the resultant TEDE is approximately 17 mrem per year.

The acceptable TEDE per year from surface activity on remaining structures (22.5 mrem per year) is the radium-226 benchmark dose (39.5 mrem per year) minus the dose resulting from the natural uranium soil cleanup limit (17 mrem per year). RESRAD-Build or a similar software application is required to develop site specific models to assess doses from residual surface activity which may remain on structures. These models are based on assumptions of land use, building use and other important scenario based parameters which are not possible to estimate with any accuracy today. Provided that process related structures will be salvaged and released for some type of end use, EMC will develop appropriate release limits which meet the dose constraints of 10 CFR 40 Appendix A, Criterion 6(6) and the principles of ALARA. The methods used to develop surface activity release criteria for structures will be presented in a detailed Decommissioning Plan required to be submitted to the USNRC for review and approval at least 12 months before planned commencement of final decommissioning.

In Section 6.2.1 of the Technical Report, the following statement is included:

> *"The following sections describe in general terms the planned decommissioning activities and procedures for the Moore Ranch facilities. EMC will, prior to final decommissioning of an area, submit to the NRC a detailed Decommissioning Plan for their review and approval at least 12 months before planned commencement of final decommissioning".*

Section 6.2 discusses plans and schedules for reclaiming disturbed lands. In order to ensure that NRC has a commitment from EMC that the detailed Decommissioning Plan will also address the removal and disposal of structures and equipment and post-reclamation and decommissioning radiological surveys, a similar statement will be added to the beginning of Sections 6.3 and 6.4 of the Technical Report.

Proposed Revisions to License Application

The following changes are proposed to the license application in response to this Open Issue. Changes to the original text as submitted to NRC are noted in red-line/strikeout method.

6.3 PROCEDURES FOR REMOVING AND DISPOSING OF STRUCTURES AND EQUIPMENT

The following sections describe in general terms the planned decommissioning activities and procedures for the Moore Ranch facilities. EMC will, prior to final decommissioning of an area, submit to the NRC a detailed Decommissioning Plan for their review and approval at least 12 months before planned commencement of final decommissioning.

6.3.1 Preliminary Radiological Surveys and Contamination Control

Prior to process plant decommissioning, a preliminary radiological survey will be conducted to characterize the levels of contamination on structures and equipment and to identify any potential hazards. The survey will support the development of procedures for dealing with such hazards prior to commencement of decommissioning activities. In general, the contamination control program used during mining operations (as discussed in Section 5.7) will be appropriate for use during decommissioning of structures.

6.4 METHODOLOGIES FOR CONDUCTING POST-RECLAMATION AND DECOMMISSIONING RADIOLOGICAL SURVEYS

The following sections describe in general terms the planned decommissioning activities and procedures for the Moore Ranch facilities. EMC will, prior to final decommissioning of an area, submit to the NRC a detailed Decommissioning Plan for their review and approval at least 12 months before planned commencement of final decommissioning.

6.4.1 Cleanup Criteria

Surface soils will be cleaned up in accordance with the requirements of 10 CFR Part 40, Appendix A, including a consideration of ALARA goals and the chemical toxicity of uranium. The proposed limits and ALARA goals for cleanup of soils are summarized in Table 6.4-2.

WELLFIELD SPILLS

Question 4.4.2.3.2 Wellfield Spills

RAI Question:

While the ER discusses the measures that will be taken in an effort to minimize the potential for a wellfield spill or other unintended release, analysis of the potential impact of any such release on shallow groundwater quality has not been provided. An analysis of the potential impact of a release at the surface on shallow groundwater should be provided. This analysis should include considerations such as depth to the water table, the permeability of the materials in the unsaturated zone, the potential adsorption of constituents in unsaturated zone materials, and the volume of any potential releases.

Answer:

Potential impacts to shallow groundwater from a wellfield spill were evaluated using a variably saturated flow and transport model. Two scenarios were modeled including a short-duration, high-volume release and a long-duration, low-volume release. Conceptualization of the potentially impacted aquifer is provided below.

The shallowest known occurrence of groundwater within the License Area and the vicinity of the proposed wellfield is within the 80 Sand. Based on water level data from monitor well OMW7B the water table is present at a depth of 30 feet below ground surface (Figure 4.4.2.3.2a). It should be noted that the 80 Sand has a limited lateral extent and is a perched aquifer system. Two other monitor wells installed in the 80 Sand did not encounter sufficient water for either testing or sampling.

Transmissivity for the 80 Sand was estimated from the drawdown response of well OMW7B during sampling activities, as described in the Moore Ranch Supplemental Hydrologic Testing (Petrotek Engineering 2009). The results of the analysis indicate a transmissivity of 13.3 ft^2/d. The saturated thickness of the 80 Sand is 15 feet resulting in a calculated saturated horizontal hydraulic conductivity of 0.89 ft/d. For purposes of this evaluation, it is initially assumed that the 80 Sand extends up to the ground surface and is relatively homogenous and isotropic, such that the saturated horizontal hydraulic conductivity determined from the drawdown analysis is representative of the vertical hydraulic conductivity of entire the column (if it were saturated). Further, the value used in the analysis was rounded to 1 ft/d. Porosity of the 80 Sand is estimated as 35 percent and the specific yield is assumed to be 20 percent. The storativity of the 80 Sand is estimated at 1E-04.

As previously described, two scenarios are examined. The first scenario is that of a long-term, low-volume release. This scenario could result from a slow drip at a piping connection that might go undetected during ISR operations. For this scenario, it is assumed that a 0.1 gpm release occurs near a header house for a period of 18 months, the typically life of a header house during production (not including restoration).

The second scenario is one of a short-term, relatively high-volume release. The license application describes pressure and flow monitoring that would prevent a high volume release from continuing undetected for an extended period of time. Field personnel will also make routine inspections that would identify a significant leak within a few days of initial occurrence. For this scenario, it is assumed that a pipeline leading from an extraction well toward a header house fails, resulting in a release of 10 gallons per minute (gpm) for a period of three days. It is noted that this is an extreme worst-case scenario; the likely response time for a spill of this magnitude would be less than an hour due to the planned monitoring system. Because of the high initial discharge of water, saturated conditions would be quickly established within the soil column. There would also be significant surface expression of the leak (ponding) even if the piping were buried several feet underground which would allow field personnel to identify the leak.

The model used to evaluate infiltration of a wellfield spill under the two previously described scenarios was MODFLOW SURFACT (HydroGeologic 2008). MODFLOW SURFACT is a propriety code based on MODFLOW, the well tested, finite-difference model developed by the U.S. Geological Survey (McDonald and Harbaugh 1988 and 1996). MODFLOW SURFACT is based on the solution of Richardson's equation.

The model was setup with 30 layers. The thickness of each layer was set to 1 foot. The model domain included 21 columns and 21 rows, with each cell having dimensions of 10 ft by 10 ft. The lowermost layer in the model represents the water table. This boundary was modeled using the general head boundary condition of MODFLOW with a head of 0 feet. The sides of the model were simulated as no flow boundaries. The model domain was set large enough so that the "box" would not be filled during the duration of the simulation. The model domain is illustrated in Figure 4.4.2.3.2b

The "leak" was simulated using a well placed in the second layer from the top (to represent a buried pipeline). Injection was applied to the well to simulate the leak. Discharge from the well was assigned a uranium concentration of 50 mg/l (1,417 mg/ft3). This concentration is used in the model to represent the uranium content of a "pregnant" lixiviant. No recharge was simulated other than the "leak" to make it easier to observe the movement of the introduced fluids. Initially the aquifer was simulated as isotropic and homogenous with a horizontal and vertical hydraulic conductivity of 1 ft/d. Solute transport was initially simulated with no sorption or dispersion

The variably saturated flow option of SURFACT was implemented using the van Genuchten parameters for water flow. The alpha and beta exponents used for the model simulations were 0.5 and 2.0, respectively, representative of a fine-grained material. The residual saturation was simulated as 5 percent. A baseline steady state simulation was run to establish initial conditions for subsequent simulations.

For the low volume, long duration simulation, a leakage rate of 0.1 gpm (19.25 ft3/d) was simulated for a period of 540 days (18 months). The simulation was continued for an additional 540 days to assess fluid movement once the "leak" was terminated. Observation points were placed at the location of the well and directly beneath the well in layers 14 and 29. The observation point in layer 29 represents the position just above the water table at the start of the simulation. Results of the simulation indicate that the arrival of the wetting front at the water table occurs in slightly over 30 days but it takes over 200 days for a fully saturated column to develop from the "leak" down to the water table (Figure 4.4.2.3.2c). Once the "leak" is turned off at 540 days, unsaturated conditions are quickly reestablished.

Leakage that exceeds the water quality uranium standard of 0.03 mg/l (0.85 mg/ft3) reaches the water table after approximately one hundred days under this idealized, worst case scenario. Figure 4.4.2.3.2d shows the uranium concentration at observation point 29 throughout the simulation. The total mass of uranium that reaches the water table during the 540 day period of operations is on the order of 4.4 kilograms. At the end of the simulation (1080 days), the total mass of uranium that has reached the water table is 5.5E+06 mg or 5.5 kg.

However as previously noted, this simulation represents a homogeneous and isotropic media, conditions that are highly unlikely to actually be present at the site. A more likely condition would be a system of interfingering lenses of sands, silts and clays with highly variable horizontal and vertical hydraulic conductivities. Additionally, solute transport was simulated without sorption or chemical reaction. Sorption is a significant process impacting fate and transport of uranium. Uranium distribution coefficients are highly variable, ranging over several orders of magnitude and can be a dominant process controlling uranium movement in the subsurface.

An example of how strongly these variable conditions could influence the movement of fluids in the subsurface is shown in the following simulation. The simulation was identical to the previous one with the exception that the vertical hydraulic conductivity for the base media is 0.1 ft/d (providing a horizontal to vertical hydraulic conductivity ratio of 10) and a low hydraulic conductivity zone (0.01 ft/d) was placed across a portion of layer 15 (Figure 4.4.2.3.2e). In this simulation the total mass of uranium reaching groundwater during the simulation (1080 days) is only 0.475 mg (Table 4.4.2.3.2a). It takes over 860 days for water that exceeds the uranium groundwater standard to reach the water table under this simulation (Figure 4.4.2.3.2f). Although the concentration in the soil water at Observation Point 29 is rising at the end of the simulation, the volume of water infiltrating to the water table across the entire model domain has decreased to a negligible rate of 2.5 ft3/d (0.013 gpm) and the mass of uranium entering the groundwater is approximately 0.05 mg/d.

A simulation was run to assess potential impacts of sorption on the migration of a wellfield spill. A distribution coefficient of 0.1 ml/g was applied to the previous simulation of uranium transport under the scenario of a heterogeneous media (with a single layer of lower hydraulic conductivity). A distribution coefficient of 0.1 ml/g is considered to be on the low end of the range for uranium. The amount of uranium reaching the water table under this simulation is negligible (5.9E-10 mg) (Table 4.4.2.3.2a). Figure 4.4.2.3.2g shows the hydraulic head and concentration at Observation Point 29 during this simulation. The uranium groundwater standard is never exceeded at

Observation Point 29 during the simulation. The results of these simulations suggest that the presence of heterogeneity within the 80 Sand (or any overlying sediments) and the likely occurrence of sorption would significantly mitigate impacts to the 80 Sand aquifer from a low-volume, long-duration release.

The high-volume, short-duration scenario was simulated using a discharge rate of 10 gpm (1925 ft^3/d) for a period of 3 days. The simulation was continued for an additional 730 days (2 years) to evaluate continued movement of fluids through the subsurface. For the homogenous, isotropic, no-sorption simulation, saturated conditions were established from the "leak" to the water table within 2 days (Figure 4.4.2.3.2h) but then rapidly dewatered following "shutoff" of the leak. Note that the time scale is logarithmic for this figure because of the rapid occurrence and short duration of saturated conditions. Uranium concentrations that exceed the groundwater standard reached the water table within 3.5 days in the simulation (Figure 4.4.2.3.2h). As in a previous simulation, although the uranium concentration remains elevated in the soil water above the water table, the rate of infiltration decreases rapidly once the leak is stopped and unsaturated conditions are again established. Approximately 4.07E+05 mg (407 g) of uranium are released to the 80 Sand under this homogenous, isotropic, no sorption simulation (Table 4.4.2.3.2a). However, as with the low-volume, long-duration simulation, it is highly unlikely that homogenous and isotropic conditions exist in the subsurface at Moore Ranch. Heterogeneous conditions combined with sorption will significantly attenuate uranium transport of any wellfield spill as illustrated in the following two simulations.

The following two simulations illustrate the impacts of heterogeneity, anisotropy and sorption on uranium transport in the subsurface. One simulation was run in which zones of low hydraulic conductivity were placed across portions of layers 6, 20 and 21 (Figure 4.4.2.3.2i). The horizontal and vertical hydraulic conductivity of those zones was 0.01 ft/d. The horizontal hydraulic conductivity of the base media is 1 ft/d but the vertical hydraulic conductivity was simulated as 0.1. Results of that simulation indicate that saturation is never achieved down to the water table (Figure 4.4.2.3.2j) and the total mass of uranium entering the groundwater is negligible (1.8E-54 mg) (Table 4.4.2.3.2a). In another simulation, a distribution coefficient of 1.0 ml/g within a homogeneous, isotropic media, results in a total mass of uranium entering the groundwater of only 5.1E-14 mg (Table 4.4.2.3.2a). A distribution coefficient of 1.0 ml/g would still be considered on the low end of the range for uranium. For the homogenous, isotropic, sorption simulation, saturated conditions were established from the "leak" to the water table within 2 days (Figure 4.4.2.3.2k) but rapid dewatering occurs following "shutoff" of the leak. Note that the time scale is logarithmic for this figure because of the rapid occurrence and short duration of saturated conditions. Uranium concentration in the soil water directly above the water table never exceeds the groundwater standard for the duration of the simulation (Figure 4.4.2.3.2k). Although the uranium concentration is increasing in the soil water above the water table the levels are still well below the groundwater standard. Also, the rate of infiltration decreases rapidly once the leak is stopped and unsaturated conditions are quickly re-established minimizing the amount of uranium that can be transported through the soil column to the water table.

Although site specific data regarding the shallow subsurface environment at Moore Ranch are limited, it is reasonable to assume that heterogeneous, anisotropic conditions exist. Those types of conditions are prevalent within the Wasatch Formation of the Powder River Basin. In the event that a wellfield spill were to occur at Moore Ranch (i.e., the low-volume, long-duration or the high-volume, short-duration type), natural conditions would mitigate impacts to shallow groundwater. Nevertheless, any releases that are observed will be addressed in a timely manner to further minimize potential impacts to shallow groundwater. In the event of a high-volume, short-duration release, response will include immediate recovery of fluids and impacted soils at the surface and in the shallow subsurface, to the extent possible. It is noted that operational monitoring proposed for the site is anticipated to detect a high-volume leak, if one occurred, immediately. In this regard, the estimate of three days used for the high-volume leak assessment is an extreme worst-case condition.

Proposed Revisions to License Application

The following changes are proposed to the license application in response to this RAI question. Changes to the original text as submitted to NRC are noted in red-line/strikeout method.

4.4.2.3.2 Wellfield Spills

Potential impacts to groundwater and surface water may occur during operations as a result of an uncontrolled release of process liquids due to a wellfield leak. Should an uncontrolled wellfield release occur, there would be a potential for contamination of the shallow aquifer as well as surrounding soil. With a slow leak that remains undiscovered or a short duration, high volume release, a shallow excursion is one potential impact. The potential impact to shallow groundwater from a slow, low volume leak occurring over a period of 18 months and a short duration, relatively high volume release are assessed in Addendum 4-1.

The rupture of an injection or recovery line in a wellfield, or a trunkline between a wellfield and the plant, would result in a release of injection or production solution which would contaminate the ground in the area of the break. Small leaks in wellfield piping typically occur in the injection system due to the higher system pressures. These leaks seldom result in soil contamination.

Occasionally, small leaks at pipe joints and fittings in the headerhouses or at the wellheads may occur. Until remedied, these leaks may drip process solutions onto the underlying soil. These leaks seldom result in soil contamination.

Mitigation measures to prevent wellfield spills are described in Section 5.4.2.3.

Technical Memorandum

To: Uranium One

From: Petrotek Engineering Corporation

Date: 1/11/10

Subject: Assessment of Potential Groundwater Impacts from Wellfield Spills, Moore Ranch ISR Uranium Project, Wyoming

Introduction

Energy Metals Corporation US (EMC) plans to develop and extract uranium from in-situ recovery (ISR) wellfields within the Wasatch Formation at the Moore Ranch Project in Campbell County, Wyoming. Petrotek Engineering Corporation (PEC) has prepared an analysis of the potential impacts of a release from a wellfield spill, or other unintended release, on shallow groundwater quality from the proposed ISR project. This analysis includes consideration of the depth to the water table, the permeability of the materials in the unsaturated zone, the potential adsorption of constituents in unsaturated zone materials, and the volume of potential releases.

Potential impacts to shallow groundwater from a wellfield spill were evaluated using a variably saturated flow and transport model. Two scenarios were modeled including a short-duration, high-volume release and a long-duration, low-volume release. Conceptualization of the potentially impacted aquifer is provided below.

Conceptualization

The shallowest known occurrence of groundwater within the Moore Ranch License Area and the vicinity of the proposed wellfield is within the 80 Sand. Based on water level data from monitor well OMW7B the water table is present within the 80 Sand at a depth of 30 feet below ground surface (Figure A4.1-1). It should be noted that the 80 Sand has a limited lateral extent and is a perched aquifer system. Two other monitor wells installed in the 80 Sand did not encounter sufficient water for either testing or sampling.

Transmissivity for the 80 Sand was estimated from the drawdown response of well OMW7B during sampling activities, as described in the Moore Ranch Supplemental Hydrologic Testing (PEC 2009). The results of the analysis indicate a transmissivity of 13.3 feet^2/day (ft^2/d). The saturated thickness of the 80 Sand is 15 feet (ft), resulting in a calculated saturated horizontal hydraulic conductivity of 0.89 feet/day (ft/d). For purposes of this evaluation, it is initially assumed that the 80 Sand extends up to the ground surface and is relatively homogenous and isotropic, such that the saturated horizontal hydraulic conductivity determined from the drawdown analysis is representative of the vertical hydraulic conductivity of the entire column (if it were saturated). Further, the value used in the analysis was rounded to 1 ft/d. Porosity of the 80 Sand is estimated as 35 percent and the specific yield is assumed to be 20 percent. The storativity of the 80 Sand is estimated at 1E-04.

Wellfield Spill Scenarios

As previously described, two scenarios are examined. The first scenario is that of a long-term, low-volume release. This scenario could result from a slow drip at a piping connection that might go undetected during ISR operations. For this scenario, it is assumed that a 0.1 gpm release occurs near a header house for a period of 18 months, the typical life of a header house during production (not including restoration).

The second scenario is one of a short-term, relatively high-volume release. The license application describes pressure and flow monitoring that would prevent a high volume release from continuing undetected for an extended period of time. Field personnel will also make routine inspections that would identify a significant leak within a few days of initial occurrence. For this scenario, it is assumed that a pipeline leading from an extraction well toward a header house fails, resulting in a release of 10 gallons per minute (gpm) for a period of three days. It is noted that this is a worst-case scenario; the likely response time for a spill of this magnitude would be less than an hour due to the planned monitoring system and response procedures. Because of the high initial discharge of water, saturated conditions would be quickly established within the soil column. There would also be significant surface expression of the leak (ponding) even if the piping were buried several feet underground, which would allow field personnel to identify the leak.

Model Development

The model used to evaluate infiltration of a wellfield spill under the two previously described scenarios was MODFLOW SURFACT, Version 3.0 (HydroGeologic, Inc 2008). MODFLOW SURFACT is a propriety code based on MODFLOW, the well tested, finite-difference model developed by the U.S. Geological Survey (McDonald and Harbaugh 1988 and 1996). MODFLOW SURFACT is a fully integrated flow and transport code. The flow code is based on the solution of Richardson's equation. Contaminant transport modules are integrated into MODFLOW SURFACT to perform numerical solution of the advective-dispersive transport equation in steady state or transient flow fields for single or multiple constituents. Sorption and first order decay can also be simulated.The pre- and post-processor Groundwater Vistas, Version 5.0 (Environmental Simulations, 2008) was used to assist with model setup and analysis of simulation results.

The model was setup with 30 layers. The thickness of each layer was set to 1 foot. The model domain included 21 columns and 21 rows, with each cell having dimensions of 10 ft by 10 ft. The lowermost layer in the model represents the water table. This boundary was modeled using the general head boundary condition of MODFLOW with a head of 0 feet. The sides of the model were simulated as no flow boundaries. The model domain was set large enough so that the "box" would not be filled during the duration of the simulation. The model domain is illustrated in Figure A4.1-2.

The "leak" was simulated using a well placed in the second layer from the top (to represent a buried pipeline). Injection was applied to the well to simulate the leak. Discharge from the well was assigned a uranium concentration of 50 milligrams/liter (mg/l) or 1,417 milligrams/foot^3 (mg/ft^3). This concentration is used in the model to represent the uranium content of a "pregnant" lixiviant. No recharge was simulated other than the "leak" to make it easier to observe the movement of the introduced fluids. Initially the aquifer was simulated as isotropic and homogenous with a horizontal and vertical hydraulic conductivity of 1 ft/d. Solute transport was initially simulated with no sorption or dispersion

The variably saturated flow option of MODFLOW SURFACT was implemented using the van Genuchten parameters for water flow. The alpha and beta exponents used for the model simulations were 0.5 and 2.0, respectively, representative of a fine-grained material. The residual saturation was simulated as 5 percent. A baseline steady state simulation was run to establish initial conditions for subsequent simulations.

Simulations and Results

For the low volume, long duration simulation, a leakage rate of 0.1 gpm [19.25 feet^3/day (ft^3/d)] was simulated for a period of 540 days (18 months). The simulation was continued for an additional 540 days to assess fluid movement once the "leak" was terminated. Observation points were placed at the location of the well and directly beneath the well in layers 14 and 29. The observation point in layer 29 represents the position just above the water table at the start of the simulation. Results of the simulation indicate that the arrival of the wetting front at the water table occurs in slightly over 30 days but it takes over 200 days for a fully saturated column to develop from the "leak" down to the water table (Figure A4.1-3). Once the "leak" is turned off at 540 days, unsaturated conditions are quickly reestablished.

Leakage that exceeds the water quality uranium standard of 0.03 mg/l (0.85 mg/ft^3) reaches the water table after approximately one hundred days under this idealized, worst case scenario. Figure A4.1-4 shows the uranium concentration at observation point 29 throughout the simulation. The total mass of uranium that reaches the water table during the 540 day period of operations is on the order of 4.4 kilograms (kg). At the end of the simulation (1080 days), the total mass of uranium that has reached the water table is 5.5E+06 milligrams (mg) (5.5 kg).

The concentration at observation point 29 reaches the maximum value of approximately 1,417 mg/l and remains there for the duration of the simulation. However, once the leak is turned off, the volume of water moving through the soil column to the water table decreases sharply, resulting in a much lower rate of uranium mass transfer.

As previously noted, this simulation represents a homogeneous and isotropic media, conditions that are highly unlikely to actually be present at the site in the shallow subsurface soils. A more likely condition would be a system of interfingering lenses of sands, silts and clays with highly variable horizontal and vertical hydraulic conductivities. Additionally, solute transport was simulated without sorption or chemical reaction. Sorption is a significant process impacting fate and transport of uranium. Uranium distribution coefficients are highly variable, ranging over several orders of magnitude and can be a dominant process controlling uranium movement in the subsurface.

An example of how strongly these variable conditions could influence the movement of fluids in the subsurface is shown in the following simulation. The simulation was identical to the previous one with the exception that the vertical hydraulic conductivity for the base media is 0.1 ft/d (providing a horizontal to vertical hydraulic conductivity ratio of 10) and a low hydraulic conductivity zone (0.01 ft/d) was placed across a portion of layer 15 (Figure A4.1-5). In this simulation the total mass of uranium reaching groundwater during the simulation (1080 days) is only 0.475 mg (Table A4.1-1). It takes over 860 days for water that exceeds the uranium groundwater standard to reach the water table under this simulation (Figure A4.1-6). Although the concentration in the soil water at Observation Point 29 is rising at the end of the simulation, the volume of water infiltrating to the water table across the entire model domain has decreased to a negligible rate of 2.5 ft^3/d (0.013 gpm) and the mass of uranium entering the groundwater is approximately 0.05 milligrams/day (mg/d).

A simulation was run to assess potential impacts of sorption on the vertical migration of a wellfield spill. A distribution coefficient of 0.1 milliliters/gram (ml/g) was applied to the previous simulation of uranium transport under the scenario of a heterogeneous media (with a single layer of lower hydraulic conductivity). A distribution coefficient of 0.1 ml/g is considered to be on the low end of the range for uranium. The amount of uranium reaching the water table under this simulation is negligible (5.9E-10 mg) (Table A4.1-1). Figure A4.1-7 shows the hydraulic head and concentration at Observation Point 29 during this simulation. The uranium groundwater standard is never exceeded at Observation Point 29 during the simulation. The results of these simulations suggest that the presence of heterogeneity within the 80 Sand (or any overlying sediments) and the likely occurrence of sorption would significantly mitigate impacts to the 80 Sand aquifer from a low-volume, long-duration release.

The high-volume, short-duration scenario was simulated using a discharge rate of 10 gpm (1925 ft^3/d) for a period of 3 days. The simulation was continued for an additional 730 days (2 years) to evaluate continued movement of fluids through the subsurface. For the homogenous, isotropic, no-sorption simulation, saturated conditions were established from the "leak" to the water table within 2 days (Figure A4.1-8) but then rapidly dewatered following "shutoff" of the leak. Note that the time scale is logarithmic for this figure because of the rapid occurrence and short duration of saturated conditions. Uranium concentrations that exceed the groundwater standard reached the water table within 3.5 days in the simulation (Figure A4.1-8). As in a previous simulation, although the uranium concentration remains elevated in the soil water above the water table, the rate of infiltration decreases rapidly once the leak is stopped and unsaturated conditions are again established. Approximately 4.07E+05 mg (407 g) of uranium are released to the 80 Sand under this homogenous, isotropic, no sorption simulation (Table A4.1-1). However, as with the low-volume, long-duration simulation, it is highly unlikely that homogenous and isotropic conditions exist in the subsurface at Moore Ranch. Heterogeneous conditions combined with sorption will significantly attenuate uranium transport of any wellfield spill as illustrated in the following two simulations.

The following two simulations illustrate the impacts of heterogeneity, anisotropy and sorption on uranium transport in the subsurface. One simulation was run in which zones of low hydraulic conductivity were placed across portions of layers 6, 20 and 21 (Figure A4.1-9). The horizontal and vertical hydraulic conductivity of those zones was 0.01 ft/d. The horizontal hydraulic conductivity of the base media is 1 ft/d but the vertical hydraulic conductivity was simulated as 0.1. Results of that simulation indicate that saturation is never achieved down to the water table (Figure A4.1-10) and the total mass of uranium entering the groundwater is negligible (1.8E-54 mg) (Table A4.1-1). In another simulation, a distribution coefficient of 1.0 ml/g within a homogeneous, isotropic media, results in a total mass of uranium entering the groundwater of only 5.1E-14 mg (Table A4.1-1). A distribution coefficient of 1.0 ml/g would still be considered on the low end of the range for uranium. For the homogenous, isotropic, sorption simulation, saturated conditions were established from the "leak" to the water table within 2 days (Figure A4.1-11) but rapid dewatering occurs following "shutoff" of the leak. Note that the time scale is logarithmic for this figure because of the rapid occurrence and short duration of saturated conditions. Uranium concentration in the soil water directly above the water table never exceeds the groundwater standard for the duration of the simulation (Figure A4.1-11). Although the uranium concentration is increasing in the soil water above the water table the levels are still well below the groundwater standard. Also, the rate of infiltration decreases rapidly once the leak is stopped and unsaturated conditions are quickly re-established minimizing the amount of uranium that can be transported through the soil column to the water table.

Summary

Although site-specific data regarding the shallow subsurface environment at Moore Ranch are limited, it is reasonable to assume that heterogeneous, anisotropic conditions exist in the unsaturated zone from the ground surface to the shallow perched aquifer in the 80 Sand. Those types of conditions are prevalent within the Wasatch Formation of the Powder River Basin. In the event that a wellfield spill were to occur at Moore Ranch (i.e., the low-volume, long-duration or the high-volume, short-duration type), natural conditions would mitigate impacts to shallow groundwater. Nevertheless, any releases that are observed will be addressed in a timely manner to further minimize potential impacts to shallow groundwater. In the event of a high-volume, short-duration release, response will include immediate recovery of fluids and impacted soils at the surface and in the shallow subsurface, to the extent possible. It is noted that operational monitoring proposed for the site is anticipated to detect a high-volume leak, if one occurred, immediately. In this regard, the estimate of three days used for the high-volume leak assessment is an extreme worst-case condition.

Table a4.1-1. Mass Balance Output, Wellfield Spill Simulations, Moore Ranch Uranium Project, Wyoming

Simulation		LVLD	LVLDH	LVLDHS	HVSD	HVSDH	HVSDS
Cumulative Volumes (ft3)							
In							
Storage	(ft^3)	1923.7	4302.3	4302.3	6054.7	5032.1	6054.7
Wells	(ft^3)	10395.0	10395.0	10395.0	5775.0	5775.0	5775.0
General Head	(ft^3)	3.06E-06	3.32E-06	3.32E-06	2.95E-06	3.35E-06	2.95E-06
Total In		12318.7	14697.3	14697.3	11829.7	10807.1	11829.7
Out							
Storage	(ft^3)	3130.4	12503.1	12503.1	7284.3	10806.4	7284.3
General Head	(ft^3)	9188.4	2194.9	2194.9	4545.6	0.9	4545.6
Total Out		12318.8	14698.0	14698.0	11829.9	10807.3	11829.9
In - Out	(ft^3)	-0.066	-0.742	-0.742	-0.216	-0.168	-0.215
Discrepancy	%	0.00	-0.01	-0.01	0.00	0.00	0.00
Cumulative Mass							
In							
Storage Loss in Water	(mg)	1.47E+06	2.43E+06	1.72E+06	2.29E+06	2.62E+06	5.88E+05
Storage Loss in Soil	(mg)	0	0	20254	0	0	19228
Wells	(mg)	1.47E+07	1.47E+07	1.47E+07	8.23E+06	8.18E+06	8.48E+06
General Head	(mg)	1.27E-09	1.82E-06	9.50E-08	1.56E-06	1.49E-31	5.80E-14
Total In		1.62E+07	1.72E+07	1.65E+07	1.05E+07	1.08E+07	9.09E+06
Out							
Storage Gain in Water	(mg)	1.07E+07	1.72E+07	1.01E+07	1.01E+07	1.08E+07	1.49E+06
Storage Gain in Soil	(mg)	0	0	6.42E+06	0	0	7.60E+06
General Head	(mg)	5.51E+06	0.47405	5.88E-10	4.07E+05	1.82E-54	5.10E-14
Total Out		1.62E+07	1.72E+07	1.65E+07	1.05E+07	1.08E+07	9.09E+06
In - Out	(mg)	-3.54E-08	3.73E-08	4.72E-06	-3.17E-08	-2.61E-08	4.66E-05
Discrepancy	%	-2.18E-15	2.17E-13	2.87E-11	-3.01E-13	-2.41E-13	5.12E-10

LVLD - Low Volume, Long Duration Simulation
LVLDH - Low Volume, Long Duration Simulation with Heterogeneity
LVLDHS - Low Volume, Long Duration Simulation with Heterogeneity and Sorption
HVSD - High Volume, Short Duration Simulation
HVSD - High Volume, Short Duration Simulation with Heterogeneity
HVSDS - High Volume, Short Duration Simulation with Sorption

FIGURES

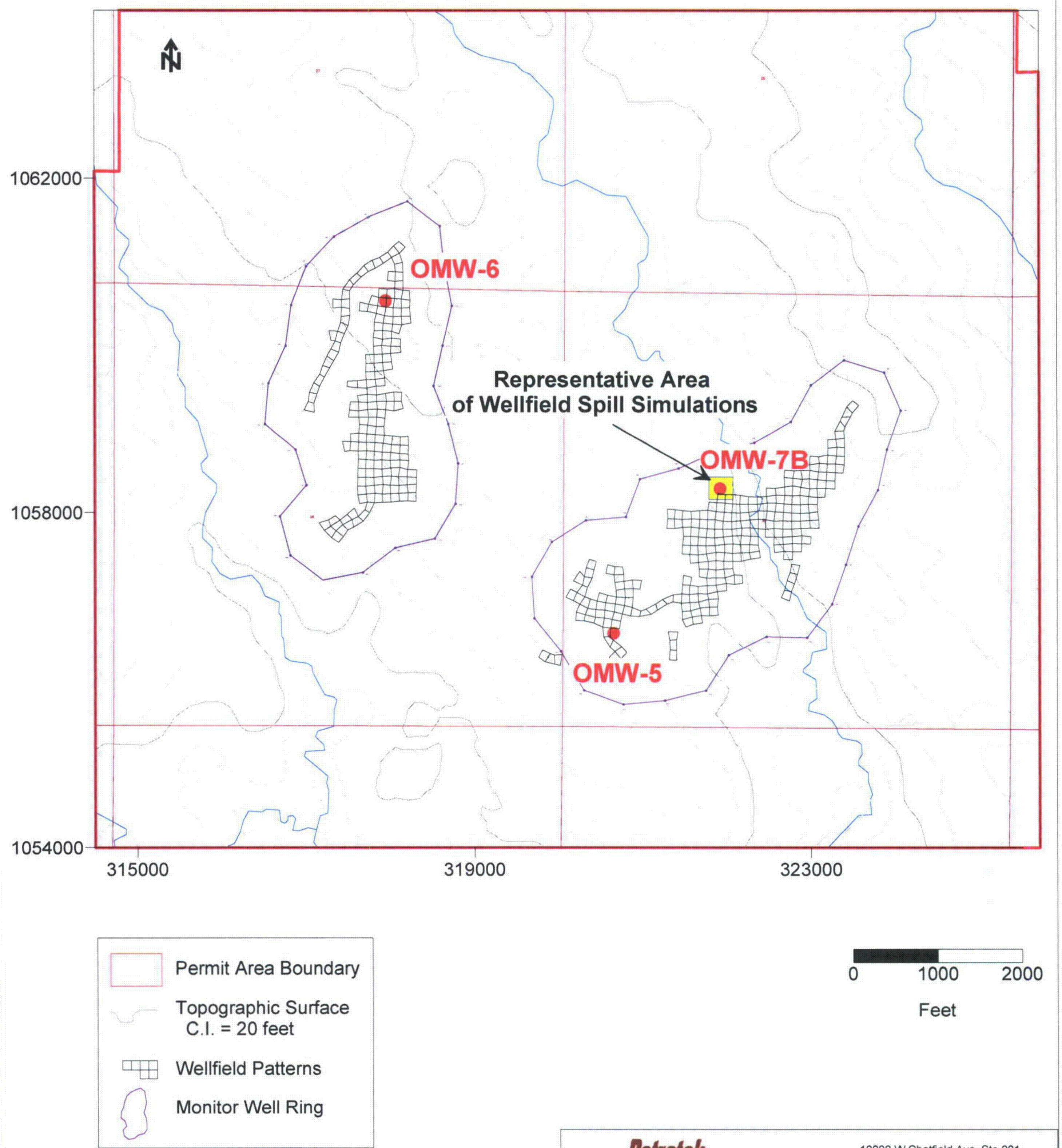

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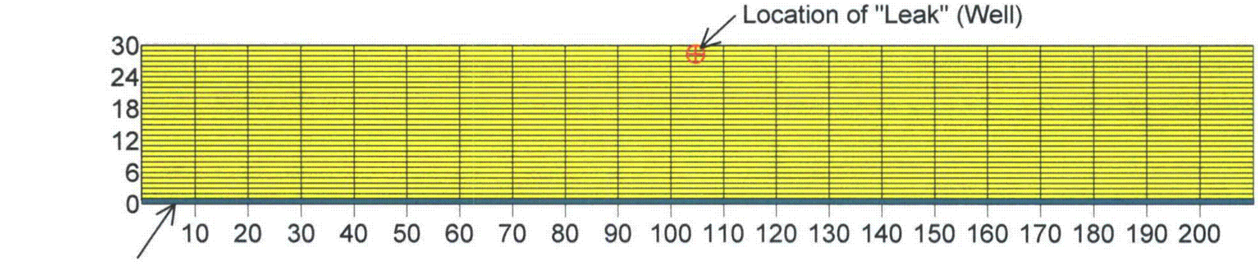
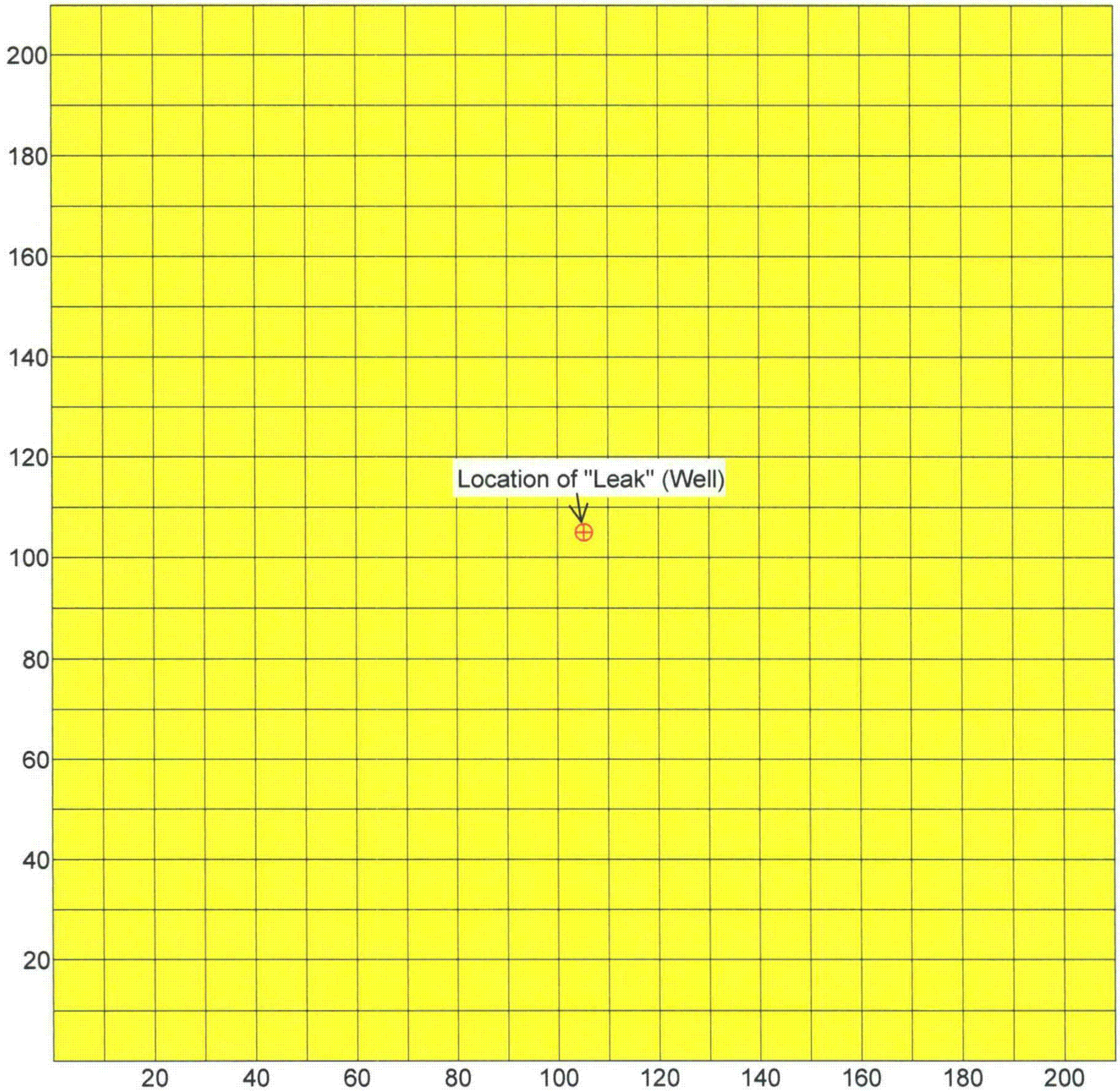
Figure A4.1-1. Location Map, 80 Sand Monitor Wells and Representative Area of Wellfield Spill Simulations Moore Ranch Permit Area, Wyoming

By: EPL | Checked: HD | File ID:figA411.srf | Date: 12/28/09

Cross-Sectional View Through Model Row 11 (center)



Horizontal and Vertical Scale - 1 inch = 35 feet



Plan View - Model Layer 2

Model Dimensions and Parameters

30 Layers, 21 Rows, 21 Columns

Hydraulic conductivity = 1 ft/d
Kh/Kh = 1
Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

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Figure A4.1-2. Model Domain, Wellfield Spill Simulation Moore Ranch Uranium Project, Wyoming

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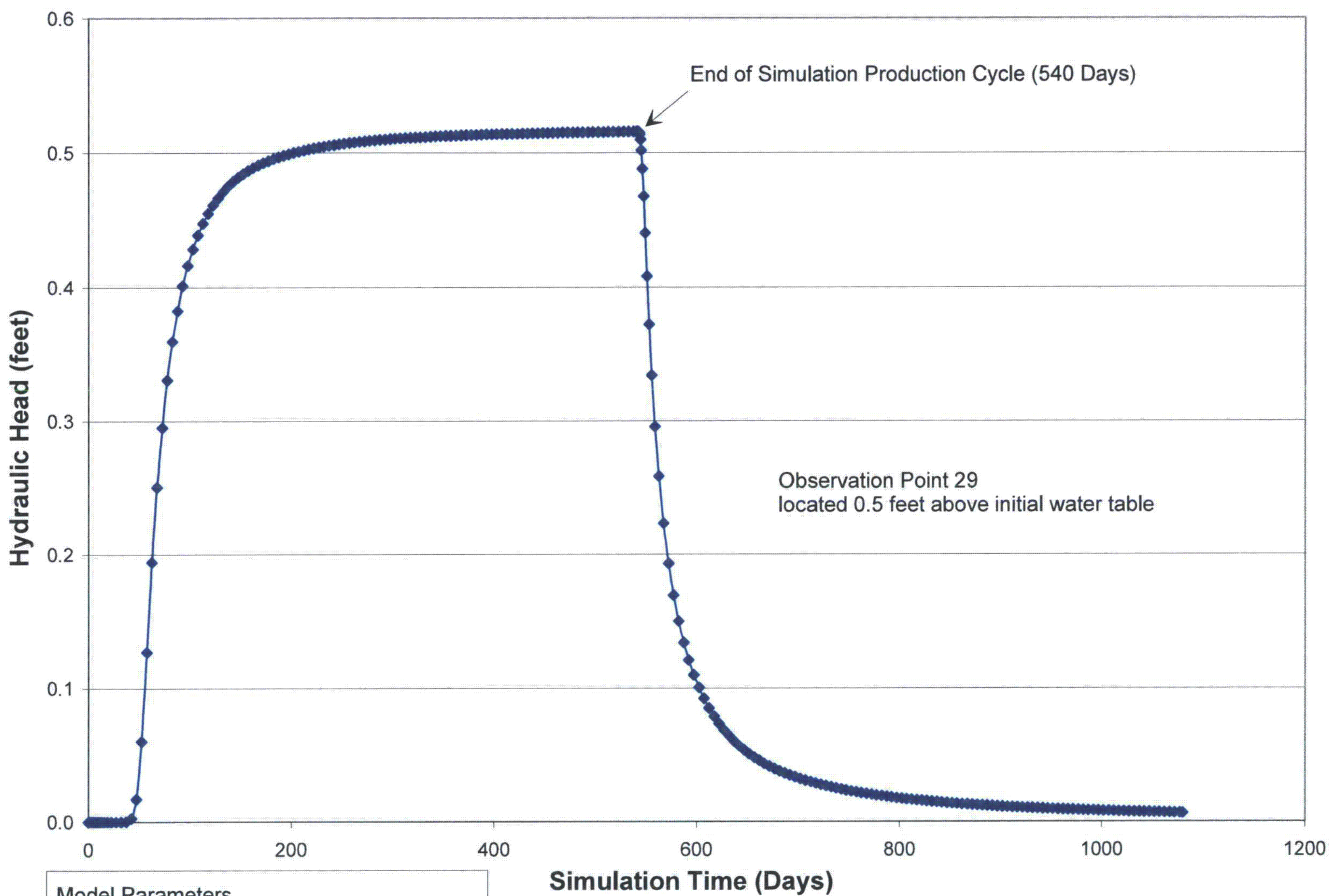

Model Parameters

Hydraulic conductivity = 1 ft/d
Kh/Kh = 1

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

Simulated Leakage = 0.1 gpm for 540 days

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Figure A4.1-3. Hydraulic Head at Observation Point 29
Low-Volume, Long-Duration Simulation
Moore Ranch Uranium Project, Wyoming

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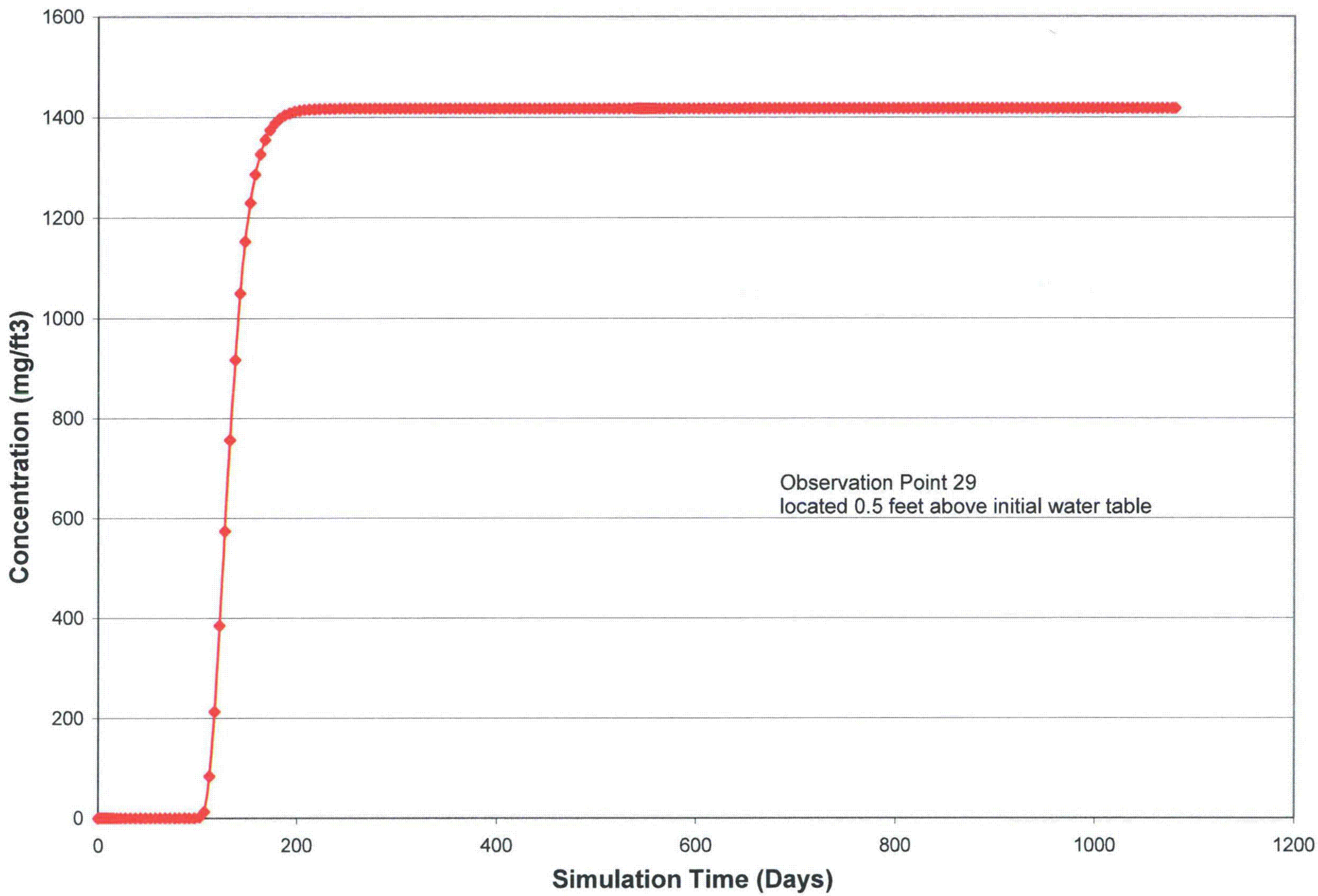

Model Parameters

Hydraulic conductivity = 1 ft/d
Kh/Kh = 1

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

Simulated Leakage = 0.1 gpm for 540 days

Concentration at Leak = 1,417 mg/ft3

No Sorption or Dispersion is Simulated

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Figure A4.1-4. Uranium Concentration at Observation Point 29
Low-Volume, Long-Duration Simulation
Moore Ranch Uranium Project, Wyoming

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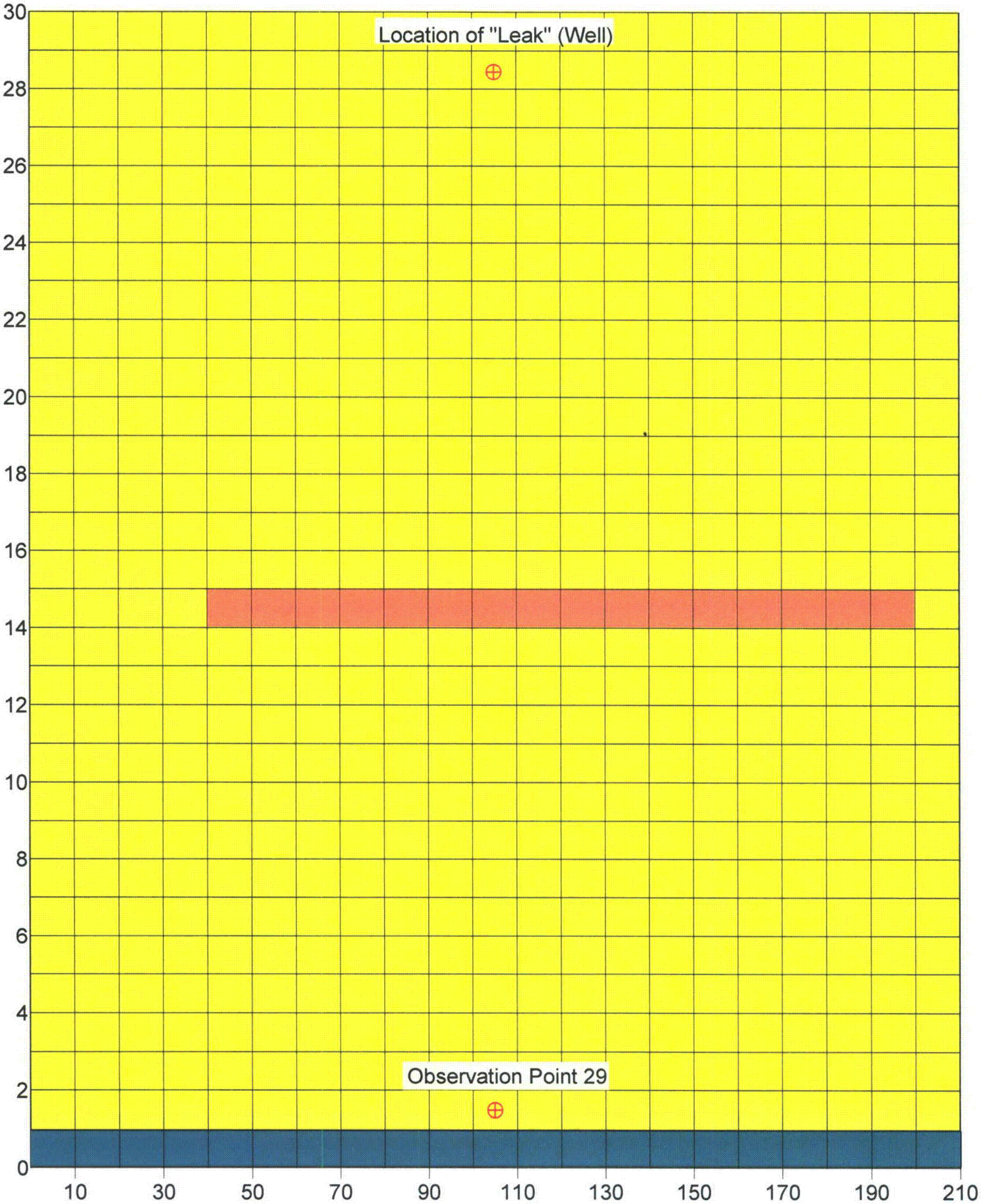

Cross-Sectional View Through Model Row 11 (center)

General Head Boundary

Hydraulic Conductivity (K) Distribution
Horizontal K= 1 ft/d, Vertical K= 0.1 ft/d

Horizontal K= 0.1 ft/d, Vertical K= 0.01 ft/d

Horizontal Scale - 1 inch = 35 feet
Vertical Scale - 1 inch = 4 feet

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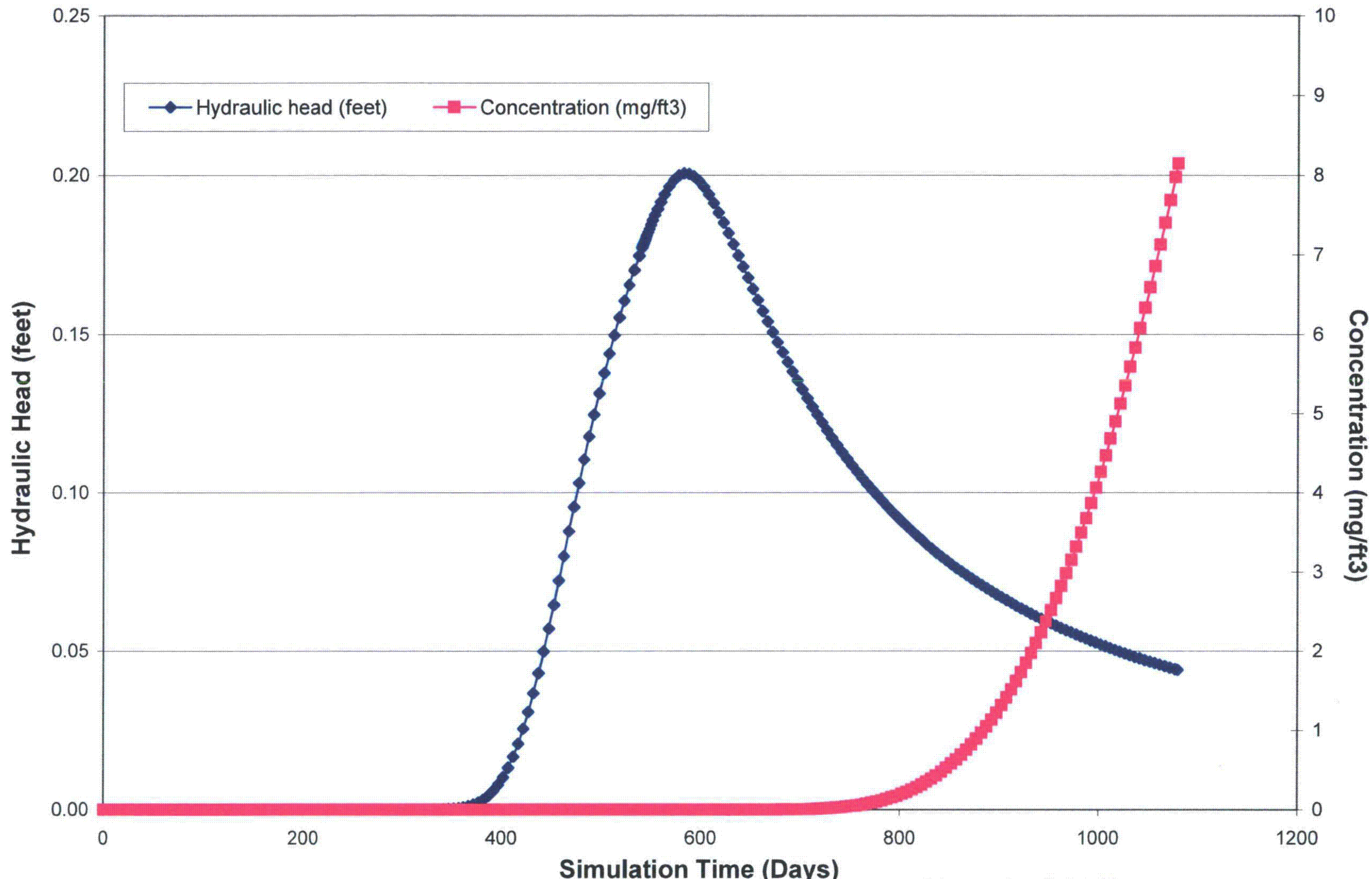
Figure A4.1-5. Wellfield Spill Simulation
Low-Volume, Long-Duration with Heterogeneity
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:figA415.srf Date:12/28/09



Observation Point 29
located 0.5 feet above initial water table

Model Parameters

All layers have hydraulic conductivity = 1 ft/d, Kh/Kv = 10
except portion of Layer 15 has hydraulic conductivity = 0.1 ft/d, Kh/Kv = 10

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

Concentration at Leak = 1,417 mg/ft3

No Sorption or Dispersion is Simulated

Simulated Leakage = 0.1 gpm for 540 days

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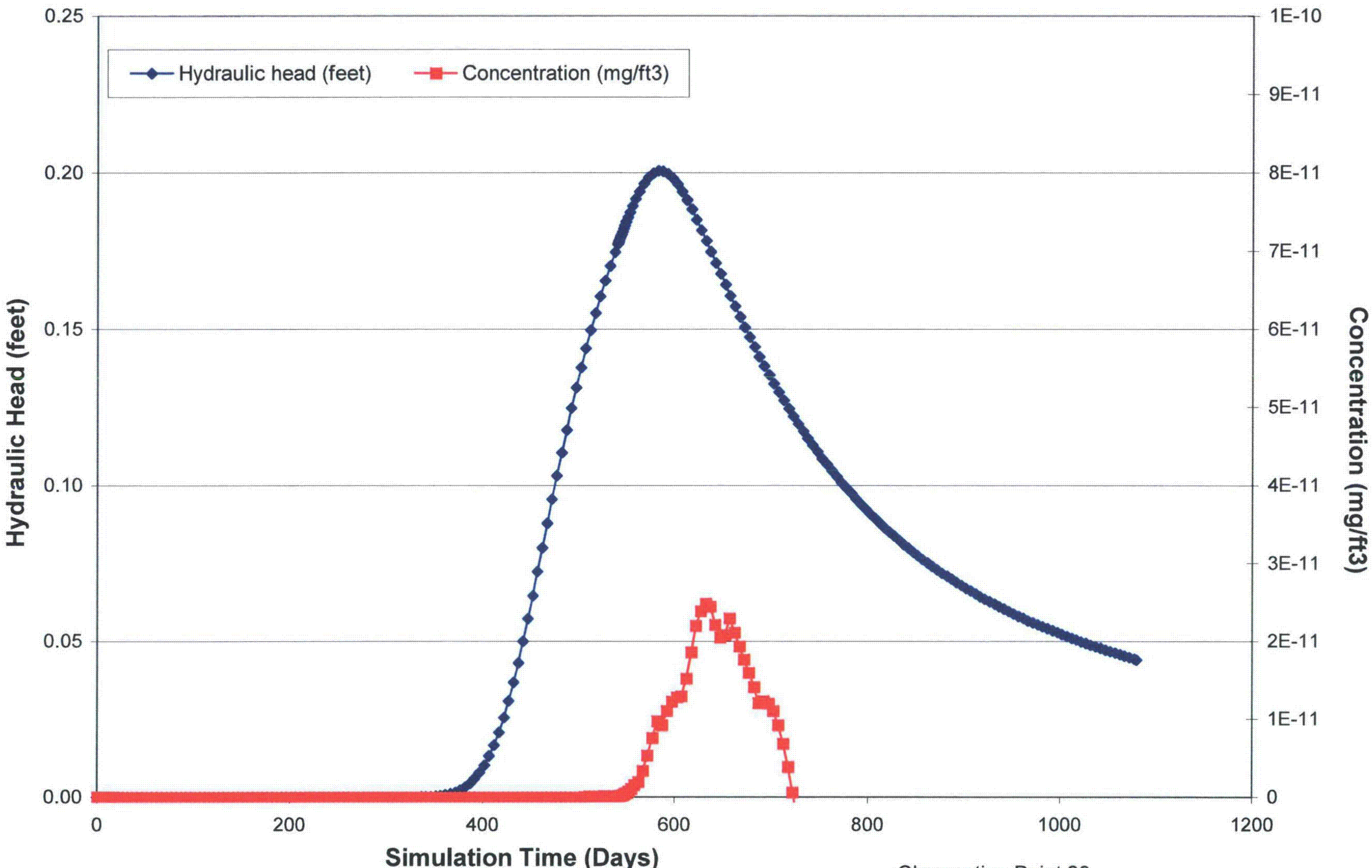
Figure A4.1-6. Concentration and Head at Observation Point 29
Low-Volume, Long-Duration Simulation with Heterogeneity
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:figA416srf Date:12/28/09



Observation Point 29
located 0.5 feet above initial water table

Model Parameters

All layers have hydraulic conductivity = 1 ft/d, Kh/Kv = 10
except portion of Layer 15 has hydraulic conductivity = 0.1 ft/d, Kh/Kv = 10

Concentration at Leak = 1,417 mg/ft3

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

No Dispersion is Simulated

Sorption Coefficient = 0.1 ml/g

Simulated Leakage = 0.1 gpm for 540 days

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Figure A4.1-7. Concentration and Head at Observation Point 29
Low-Volume, Long-Duration Simulation with Heterogeneity and Sorption
Moore Ranch Uranium Project, Wyoming

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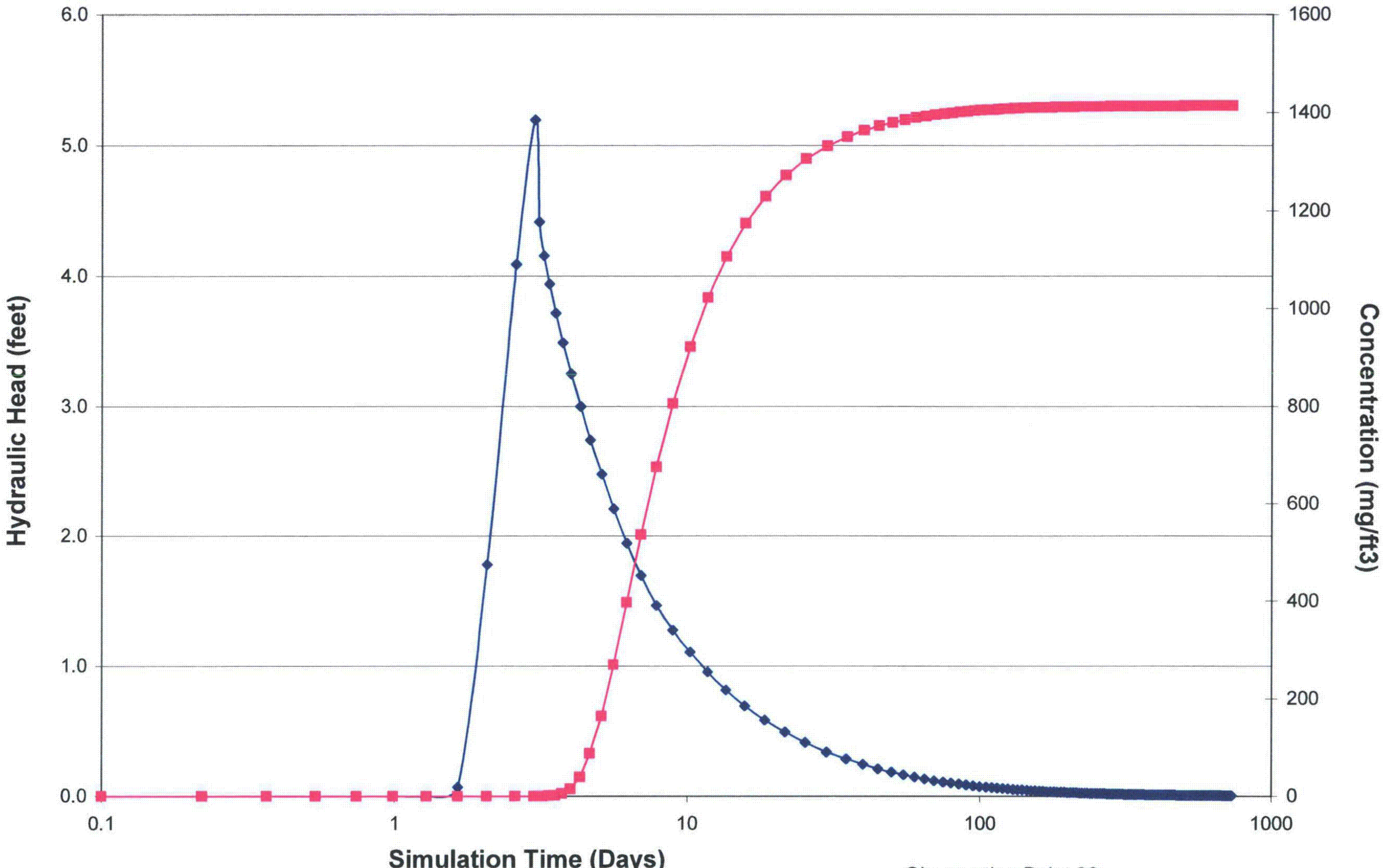

Observation Point 29
located 0.5 feet above initial water table

Model Parameters

All layers have hydraulic conductivity = 1 ft/d, Kh/Kv = 1

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

Simulated Leakage = 10 gpm for 3 days

Concentration at Leak = 1,417 mg/ft3

No Dispersion or Sorption is Simulated

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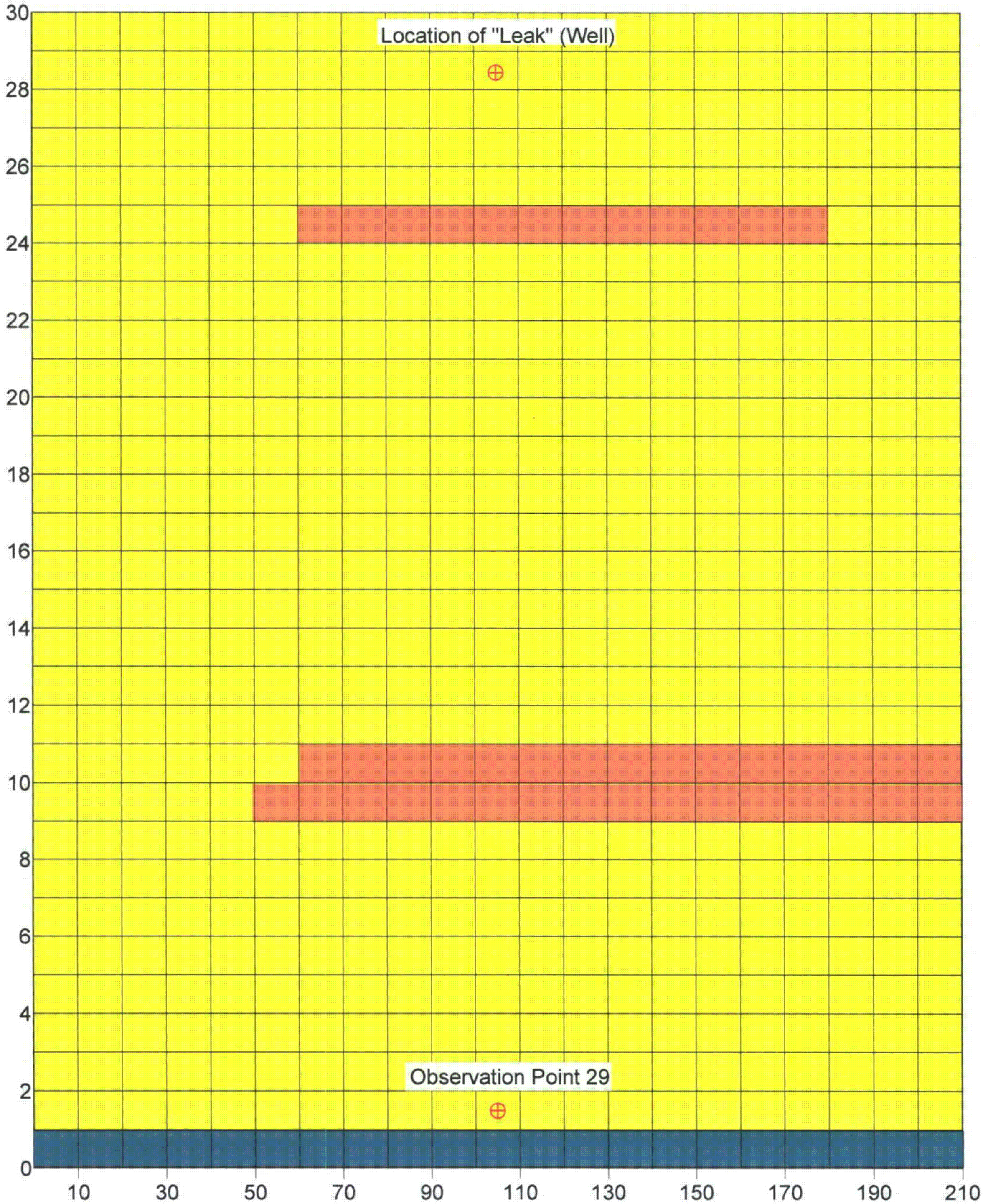
Figure A4.1-8. Concentration and Head at Observation Point 29
High-Volume, Short-Duration Simulation
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:figA418.srf Date:12/28/09



Cross-Sectional View Through Model Column 11 (center)

General Head Boundary

Hydraulic Conductivity (K) Distribution

Horizontal K= 1 ft/d, Vertical K= 0.1 ft/d

Horizontal K= 0.01 ft/d, Vertical K= 0.01 ft/d

Horizontal Scale - 1 inch = 35 feet
Vertical Scale - 1 inch = 4 feet

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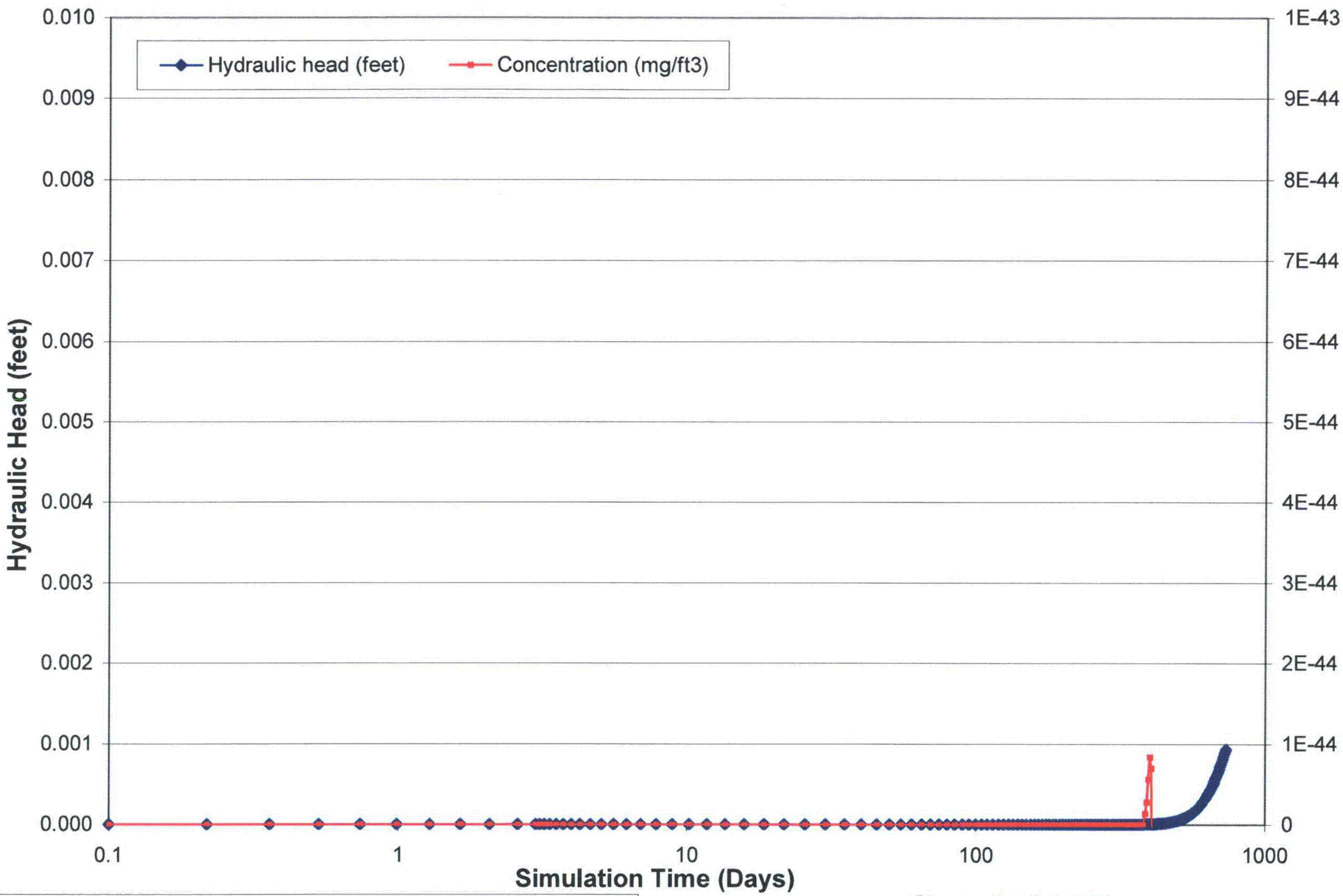
Figure A4.1-9 Wellfield Spill Simulation
High-Volume, Short-Duration with Heterogeneity
Moore Ranch Uranium Project, Wyoming

By: EPL | Checked: HD | File ID:figA419.srf | Date:12/28/09



Observation Point 29
located 0.5 feet above initial water table

Model Parameters

All layers have hydraulic conductivity = 1 ft/d, Kh/Kv = 10
except portions of Layers 6, 20 and 21 have
hydraulic conductivity = 0.01 ft/d, Kh/Kv = 1

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

Concentration at Leak = 1,417 mg/ft3

No Dispersion or Sorption is Simulated

Simulated Leakage = 10 gpm for 3 days

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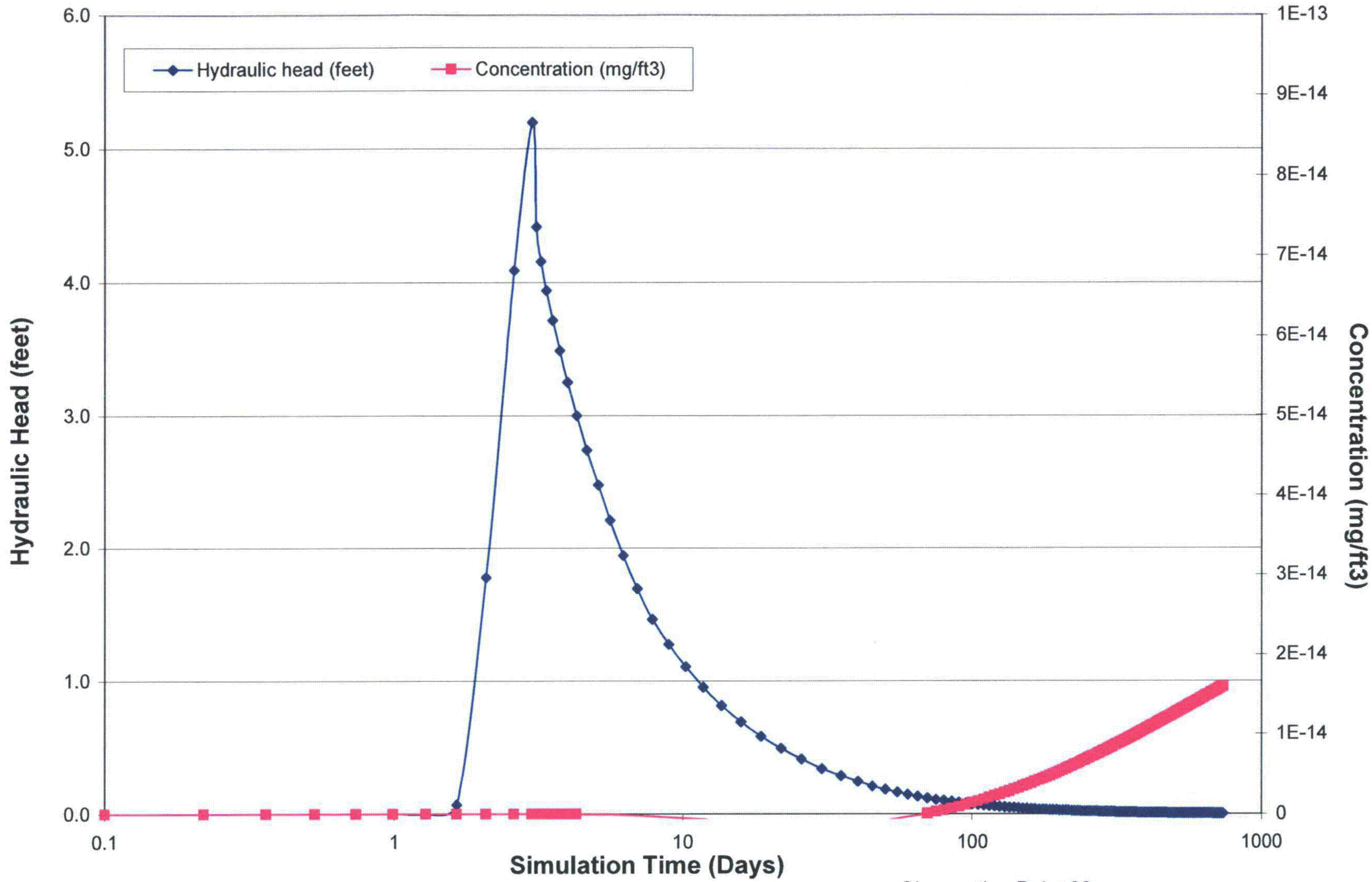
Figure A4.1-10. Concentration and Head at Observation Point 29 High-Volume, Short Duration Simulation with Heterogeneity Moore Ranch Uranium Project, Wyoming

By: EPL | Checked: HD | File ID:figA4110.srf | Date:12/28/09



Observation Point 29
located 0.5 feet above initial water table

Model Parameters

All layers have hydraulic conductivity = 1 ft/d, Kh/Kv = 1

Storativity = 1 E-04
Specific Yield = 0.20
Porosity = 0.35

Simulated Leakage = 10 gpm for 3 days

Concentration at Leak = 1,417 mg/ft3

No Dispersion is Simulated

Kd = 1.0 ml/g

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Figure A4.1-11. Concentration and Head at Observation Point 29
High-Volume, Short Duration Simulation with Sorption
Moore Ranch Uranium Project, Wyoming

By: EPL | Checked: HD | File ID:figA4111.srf | Date:12/28/09