U.S. Department of Energy, Grand Junction, Colorado

Calculation Cover Sheet

Calc. No. 05-2004-01-06-00 **Discipline:** Hydrologic **Number of Sheets:** 8

Project:
Moab Ground Water

Site:
Moab, Utah

Feature:
Calculation of Ground-Water and Contaminant-Mass Flows at Selected Locations at the Moab Site

Sources of Data:
GJO-LM SEE_Pro Database

Sources of Formulae and References:

Diersch, J. J.G., 2002. FEFLOW (Finite Element Subsurface Flow and Transport Simulation System) 5.0. WASY Institute for Water Resources Planning and Systems Research Ltd., Berlin, Germany.

DOE 2003. *Site Observational Work Plan for the Moab, Utah, Site*, GJO-2003-424-TAC, prepared for the U.S. Department of Energy, Grand Junction, Colorado, December.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.** ______

		M. Kautsky	5/21/04	Dave Peterson		[signature]	5-25-04
Rev. No.	Revision	Calculation by	Date	Checked by	Date	Approved by	Date

1.0 Problem Statement

Ground-water and contaminant-mass flows for selected portions of the U.S. Department of Energy (DOE) Moab, Utah, site (Moab site) are calculated. The flow values represent the amount of ground water or contaminant mass flowing across a plane perpendicular to the ground water flow direction. Table 1 describes the relevant parameters pertaining to the flow calculations. The *Parameter* column signifies whether the ground water or contaminant (ammonia or uranium) is being considered. The *Start* and *End* column headings identify the spatial limits of the plane across which the flow is calculated. The plane forms a line in map view.

2.0 Methods

The Finite Element Subsurface Flow and Transport Simulation System 5.0 (FEFLOW) (Diersch 2002), a three-dimensional (3-D) finite-element simulator, was used to model freshwater domain at the Moab site and is described in the Moab SOWP (DOE 2003, Chapter 7). The base-case model from that project was used in this calculation to obtain estimated ground-water and contaminant-mass flows at selected locations near the Colorado River.

Separate input files were required to obtain simulation results for ammonia and uranium. The fluid-flow portions of these two input files were identical. After the flow-and-transport models had been run for ammonia and uranium, the fluid-flux analyzer in the FEFLOW post-processor was used to obtain the ground-water flow estimates. Table 1 identifies the locations of the line segments across which the fluid flows were calculated. Locations described in Table 1 are referenced to Figures 1 and 2, which show the ammonia and uranium concentration maps respectively, for the shallowest part of the aquifer at the Moab site.

Because there is no mass-flux analyzer tool in FEFLOW, a relatively complicated and approximate procedure was used to obtain the mass flow across the planes. First it was necessary to write output files of coordinates (x, y, and z), concentrations, and Darcy velocities for a series of model nodes whose locus approximates the line segment representing a plane. These output files were then edited using the spreadsheet program Excel. Elemental Darcy velocities (V_x and V_y) were used to compute a resultant Darcy velocity and the Pythagorean Theorem was used to calculate the distances that separate each adjoining node. The internodal distances were multiplied by the model-layer thickness to obtain the cross sectional area perpendicular to flow for each node. The resultant nodal velocities were multiplied by the cross sectional area for each node to obtain the groundwater discharge for each node. Nodal concentrations were then multiplied by the nodal ground-water discharge values to obtain the nodal mass flows for both ammonia and uranium. Then the nodal mass fluxes were summed to obtain the estimated total mass flows.

Ground water discharges were consistently larger using the nodal computation method than those produced by the fluid-flux analyzer. These differences were attributed to two general causes: (1) the sum of computed lengths between nodes used to approximate a plane was larger than the actual plane length because the nodes were not located directly on the plane, and (2) many computed nodal velocities were not orthogonal to the plane and were, consequently, larger than their orthogonal components. To account for the differences, total mass fluxes were scaled downward in proportion to the ratio of ground-water discharge obtained with the fluid-flux analyzer to the equivalent total nodal flow. The footnotes in Table 1 list the ratios that were used to scale the total mass flows.

Appendix A contains screen copies produced with the FEFLOW modeling interface at the time of the flow calculations. Ground-water flow results shown in the appendix are calculated in units of cubic meters per day (m^3/day); these results are converted to a more convenient set of units (gallons per minute [gpm]) in Table 1.

The sum of the ground-water discharge values appearing in the first two rows of Table 1 (253 gpm) is a close approximation of the model-generated ground water discharge to the Colorado River from the west side of the river. In the Moab SOWP (DOE 2003, Chapter 7) the water budget indicates that total ground water discharge to the Colorado River is 275 gpm. The discrepancy of 22 gpm between these two estimates is attributed to relatively minor discharge to the river along its east side. Two sources of water contribute to this latter discharge: (1) river losses to ground water in the northern part of the model domain, and (2) areal recharge east of the river.

Table 1. Calculated Water Flows and Contaminant Mass Flows for Selected Regions of the FEFLOW Model Domain

Parameter	Start	End	Value	Unit
Water	Moab Wash	Southern model extent	111	gpm
Water	Moab Wash	Northern model extent	142	gpm
Ammonia	Just north of Moab Wash at the 50 mg/L ammonia contour. See attached figure.	Approximately 2,500-ft downstream from Moab Wash at the 50 mg/L ammonia contour. See attached figure.	407[ǂ]	kg/day
Water	Just north of Moab Wash at the 50 mg/L ammonia contour. See attached figure.	Approximately 2,500-ft downstream from Moab Wash at the 50 mg/L ammonia contour. See attached figure.	149	gpm
Uranium	Moab Wash	Approximately 2,000-ft upstream from Moab Wash at the 0.044 mg/L uranium contour. See attached figure.	2.45[†]	kg/day
Water	Moab Wash	Approximately 2,000-ft upstream from Moab Wash at the 0.044 mg/L uranium contour. See attached figure.	115	gpm
Uranium	Moab Wash	Approximately 2,500-ft downstream from Moab Wash at the 0.044 mg/L uranium contour. See attached figure.	0.75[‡]	kg/day
Water	Moab Wash	Approximately 2,500-ft downstream from Moab Wash at the 0.044 mg/L uranium contour. See attached figure.	97	gpm

mg/L = milligrams per liter; ft = feet, gpm = gallons per minute; kg/day = kilograms per day
ǂ Adjusted downward by a factor of 0.918 to account for the difference in fluid flows obtained using the fluid-flux analyzer and the computed nodal flows.
† Adjusted downward by a factor of 0.735 to account for the difference in fluid flows obtained using the fluid-flux analyzer and the computed nodal flows.
‡ Adjusted downward by a factor of 0.724 to account for the difference in fluid flows obtained using the fluid-flux analyzer and the computed nodal flows.

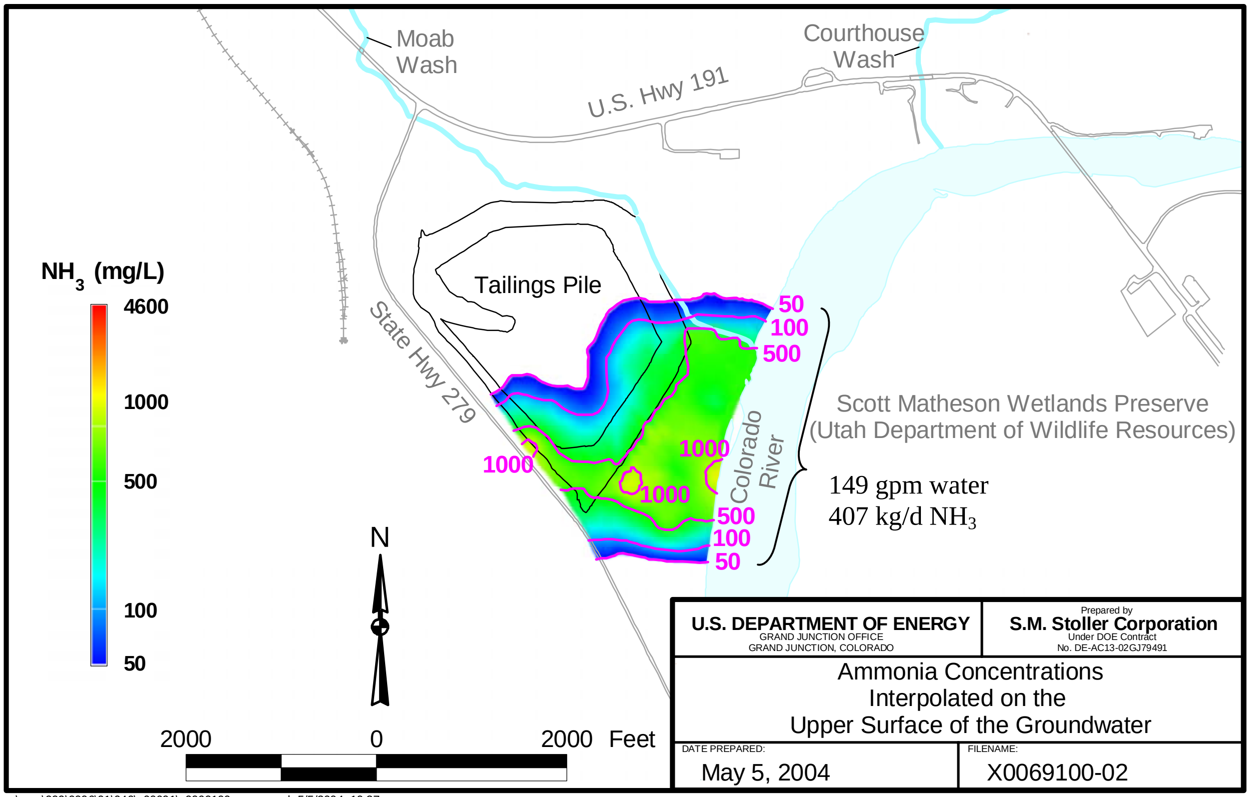

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Figure 1. Ammonia Concentrations in the Shallow Ground Water at the Moab Site

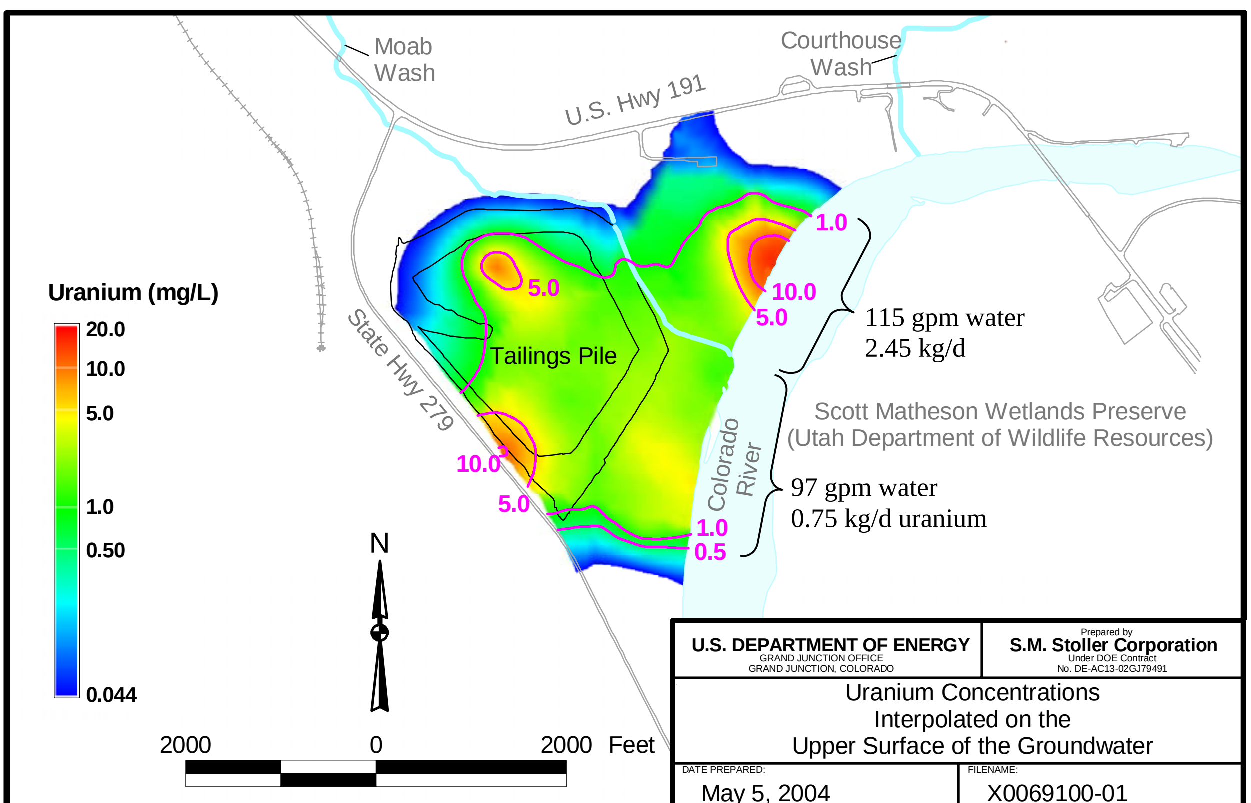

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Figure 2. Uranium Concentrations in Shallow Ground Water at the Moab Site

Appendix A

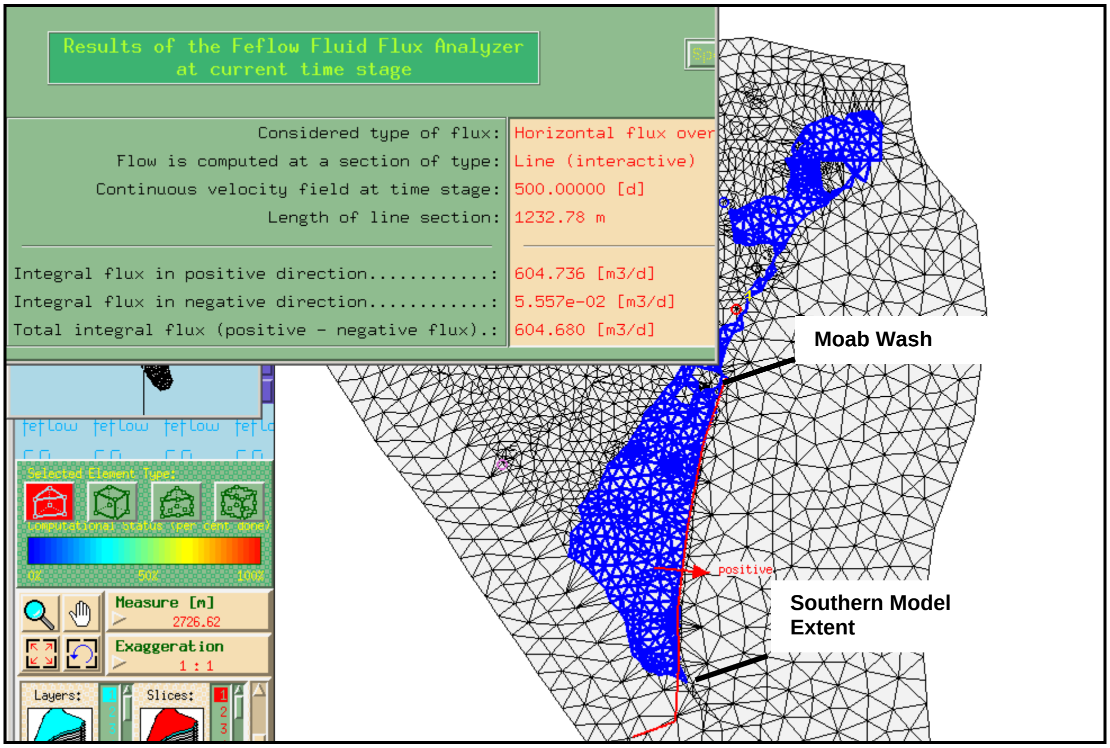

Figure A1. FEFLOW-Calculated Ground Water Flow Between the Mouth of Moab Wash and the Southern Model Extent

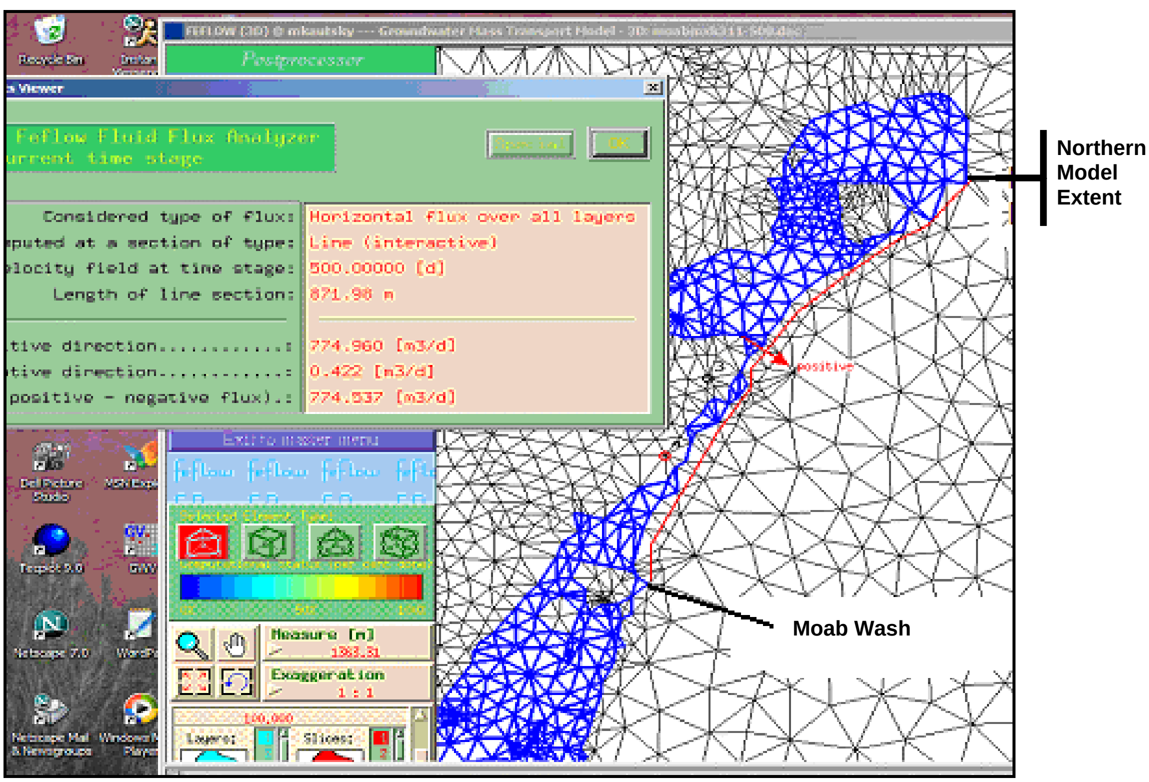

Figure A2. FEFLOW-Calculated Ground Water Flow between the Mouth of Moab Wash and the Northern Model Extent

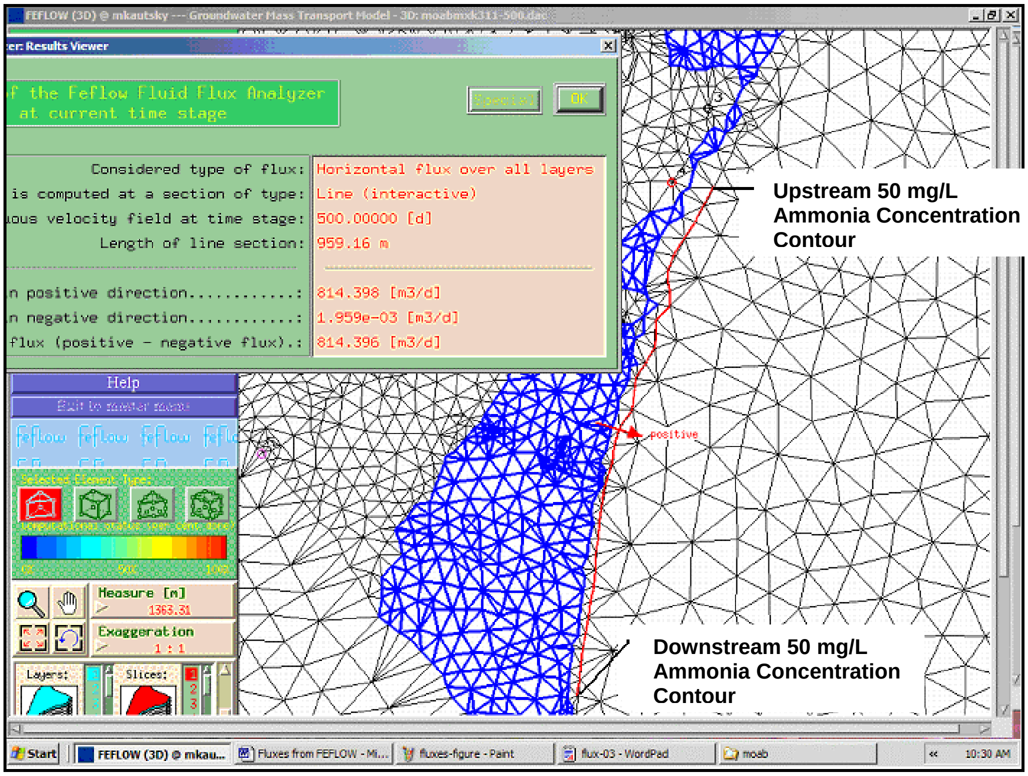

Figure A3. FEFLOW-Calculated Ground Water Flow to the Colorado River Within the Area Bracketed by the 50 mg/L Ammonia Contours

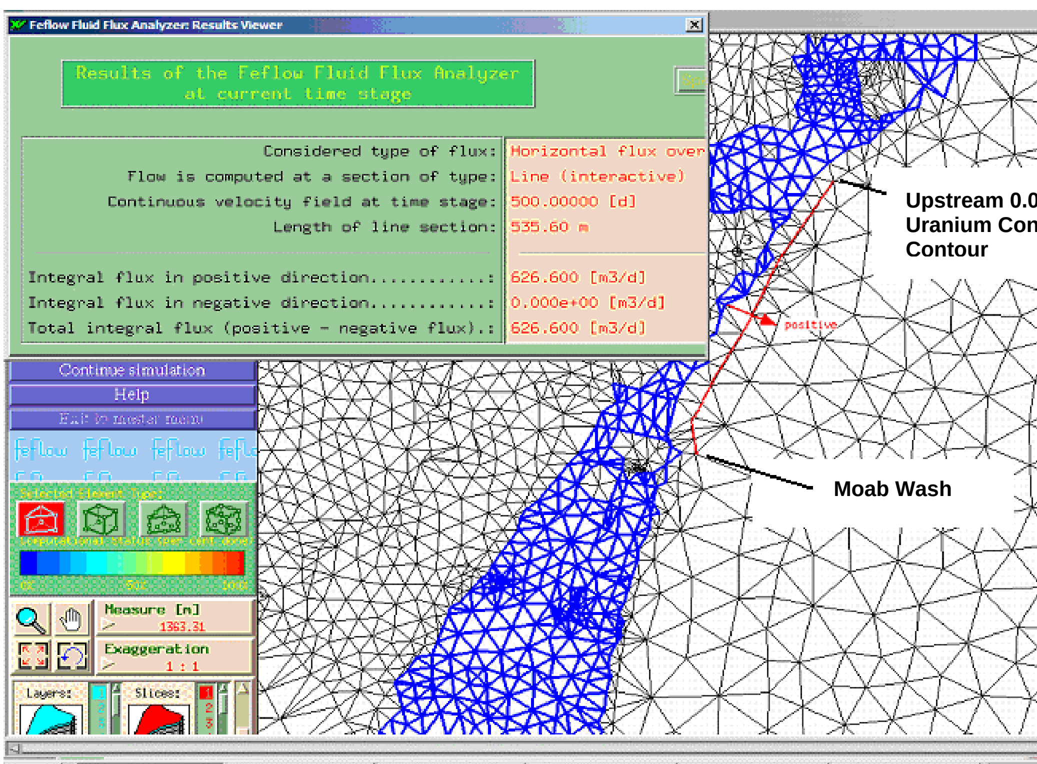

Figure A4 FEFLOW-Calculated Ground Water Flow Between Moab Wash and the Upstream 0.044 mg/L Uranium-Concentration Contour

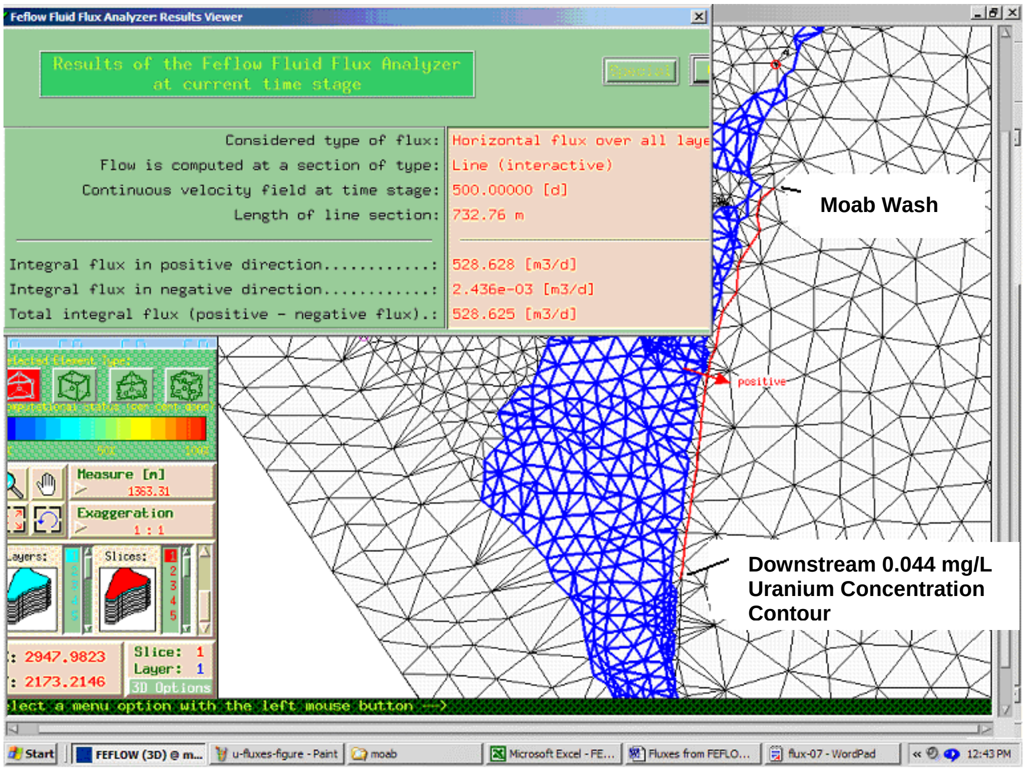

Figure A5. FEFLOW-Calculated Ground Water Flow Between Moab Wash and the Downstream 0.044 mg/L Uranium Concentration Contour