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Latif Hamdan,
Project Manager
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Mail Stop T7J9
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SUBJECT: GANDT Modeling Code

Dear Latif,

Enclosed is a paper I wrote on the GANDT modeling code. This is the code on which B. Knowlton gave a presentation during the last ground water workshop. I plan on using this code for modeling the UMTRA natural flushing sites.

B. Knowlton will be in D.C. in early October and he will contact you about the details of the code. I would like to give you the code and a documentation/instruction manual. Please let me know if I can set up a meeting with you and others to discuss the use of the code in support of UMTRA ground water.

I'm presenting the enclosed paper at the Mine & Mill Tailings '97 conference at Fort Collins, CO

I look forward to hearing from you (970) 248-7612.

Sincerely,

Don Metzler

Don Metzler,
Project Manager

DRM:emo

cc:
M. Layton, NRC
B. Knowlton, Sandia
GWADM3.6

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Implementing the natural flushing strategy: an approach to meeting the EPA ground water standards at select uranium mill tailings sites

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ABSTRACT: The U.S. Department of Energy (DOE) is targeting many of the Title I Uranium Mill Tailings Remedial Action (UMTRA) former processing sites for "Natural Flushing" as the compliance strategy to meet the Environmental Protection Agency (EPA) ground water standards (CFR 192, Subpart B). Most of the Title I former processing sites retain residual ground water contamination in their uppermost aquifers as a result of former milling activities and past uncontrolled tailings seepage. The general basis for natural flushing candidacy is that their uppermost aquifers are a potential drinking water resource, the affected resource is not currently nor projected to be a source of drinking water to local municipalities, an institutional control can be implemented to prevent inappropriate uses of the contaminated ground water during the flushing period, and the contaminants of concern are predicted to attenuate to EPA Maximum Concentration Limits (MCLs) and/or background within a 100 year time frame. Candidate sites were modeled using analytical and numerical methods to predict the flushing process.

1 INTRODUCTION

As the first step in evaluating the application of natural flushing to the Title I former processing sites, the DOE created a hypothetical model of a uranium mill tailings site to assess the natural flushing strategy in a generic convention (Metzler, 1995). A rudimentary solute transport analytical model was used to predict if the site would flush to the standards within 100 years. The hypothetical model was assigned conceptual conditions and aquifer and water chemistry parameters comparable to the Title I sites that

are targeted for natural flushing. Results of this modeling approach support the assumptions that many of the Title I sites are strong candidates for this strategy.

The next step involved site-specific modeling of the candidate sites. The DOE contracted with Sandia National Laboratory for support in developing a tool for use in simulating contaminant flowpaths and concentrations. The result of the modeling effort predicts if the residual contamination that resulted from former milling activities and tailing seepage would attenuate to Maximum Concentration Limits (MCLs) or background within a 100 year period. The Groundwater Analysis and Network Design Tool (GANDT), formerly known as the Borehole Optimization Support System (BOSS) was selected for this task. This tool is intended for use in evaluating uncertainties in the flow and transport of the contaminants, in designing monitor well networks for determining the nature and extent of contamination, and in performing analyses to evaluate the potential for natural attenuation. Sandia has used this code to perform scoping analyses to evaluate the potential for natural flushing at several Title I UMTRA sites and the results are very promising. The GANDT code is one of the most comprehensive flow and transport simulators available, allowing users the ability to: perform scoping calculations with analytical models (for quick, simple, proof of concept simulations); perform probabilistic Monte Carlo analyses to quantify uncertainties; evaluate the effects of spatial variability with geostatistics; condition simulation results on observed water quality data (essentially a built-in calibration procedure); display real-time results of simulations (including spatial depiction of plumes and plots showing the probability of exceeding specific concentration thresholds).

2 BASIS OF ANALYSIS

The applied logic was to start simple and proceed to more thorough solution predictions if the early analysis supports the assumptions. GANDT was used to simulate the contaminant migration potential with a simple analytical process model to determine the likelihood of compliance during the 100 year performance period. If the candidate site passes the analytical step, then the conceptual model is used to simulate the migration potential with the numerical process model to account for stream-aquifer interactions and other boundary conditions.

The contaminant of concern chosen for simulating contaminant flowpaths and concentrations was total uranium (U-234 & -238 combined). At most of the Title I former processing sites, under oxidizing conditions, soluble uranium occurs in the form of uranyl carbonates. Common uranium aqueous species are $UO_2\,(CO_3)^0$, $UO_2\,(CO_3)^{2-}$, and $UO_2\,(CO_3)^{4-}$. These species are conservative and generally represent minor partitioning.

2.1 *Conceptual model for a Wyoming Title I site*

Milling activities at the tailings site operated from 1958 to 1963. During 4 years of operation, the mill processed approximately 900,000 tons (800,000 metric tons) of ore. waste solids from the uranium ores were transferred to a tailings pile. The rectangular pile covered 70 acres. Between 1988 and 1990, the uranium mill tailings pile and

contaminated soils were removed from the site. The tailings were relocated to another site for disposal. The excavated areas were backfilled with clean fill, graded to form a crown, and seeded. The area is arid with 8 inches (20 centimeters) of average annual precipitation. The site lies on a nearly level surficial terrace in a major alluvial basin, a few miles upstream of the confluence of two large rivers. A system of irrigation canals exists along the northern and eastern sides of the site. The unlined canals are operational for 5 months per year.

The uppermost aquifer consists of two hydrogeologic systems. An unconfined surficial aquifer, consisting of alluvial sands and gravels of 15 to 20 feet (5 to 6 meters) thick, and a hydraulically connected semiconfined shale system of 40 feet (12 meters) thick, that acts as a leaky confined aquitard. Deeper systems are unaffected by tailing seepage. The water table in the surficial system is approximately 7.5 feet (2.3 meters) below the ground surface. Ground water flow direction is to the east-southeast with a horizontal gradient of 0.0024. Seasonal fluctuations of up to 2 to 3 feet occur in ground water elevations during the year. Ground water in the surficial system discharges predominantly to a gaining river along approximately 1 mile (1.6 kilometer) of its course. Hydraulic conductivity is estimated to be approximately 56 feet (17 meters) per day. The calculated average linear ground water velocity is approximately 160 feet (50 meters) per year. The leaky aquitard does not contain a significant amount of contamination for modeling interpretations.

2.2 *Model overview*

GANDT is used to simulate the flow and transport of a contaminant in a ground water system. GANDT uses external models to implement analytical and numerical solutions to aqueous and vapor phase problems and supports single and unconditional or conditional Monte Carlo simulations. GANDT uses two variants of the Multimed code developed by (Salhotra et al 1990) to simulate the migration of a contaminant from its source to the water table. Contaminant transport in the saturated zone is modeled using subroutines from FTWORK by (Faust et al 1994). The interface between the two groups of code is accomplished by applying the contaminant flux from the unsaturated zone to the appropriate finite difference blocks of the saturated surface layer. The following table lists the six model types supported by GANDT.

GANDT MODEL TYPES	
CONTAMINANT PHASE	SOLUTION PHASE
aqueous chemical	analytical
	numerical
aqueous radioactive	analytical
	numerical
vapor	analytical
	numerical

In modeling the candidate site, the conceptual model of the site was developed and model input parameters and justifications were created. Next, Monte Carlo simulations were run to quantitatively translate site uncertainties into model output uncertainties. A Monte

Carlo simulation is a series of runs in which various parameter values are randomly generated from user-defined distributions. Parameters were defined as uncertain and represent areas where site data may not be consistent for the whole site. Monte Carlo simulations were post-conditioned to observed concentration data. After running Monte Carlo simulations with multiple layers generated, the realization can be visualized. The ultimate purpose of the visualization is to predict the scenario in which the site will naturally flush.

3 MODEL SIMULATION RESULTS

To demonstarte the potential for meeting MCLs using the natural flushing strategy, a Wyoming Title I site was modeled using GANDT. The contaminant of concern, uranium, represents the aqueous chemical contaminant phase. Time zero is when the milling operation started - 1958. Source removal was completed in 1990. Both the analytical and numerical solution phases were simulated. The analytical solution does not account for boundary effects and therefore will not account for surface-water ground water interactions. At the 75 year prediction (after the operation start-up (1958)) the probability distribution for average uranium concentrations is visualized in Figure 1. As depicted in Figure 1, the analytical solution does not accurately account for recharge and discharge phenomena.

Using the numerical solution, which accounts for recharge and stream interactions, the probability distribution for average uranium concentrations at 35 years, 70 years, and 90 years (after the operation start-up (1958)) is visualized in Figures 2, 3, and 4.

4 SUMMARY AND CONCLUSIONS

The numerical solution more accurately accounts for hydraulic and chemical processes that affect natural flushing. Simulations at time step 35 years (1993) results in a relatively good fit with observed data. This calibration gives confidence that the conceptual model represents the system and source term fairly accurately. The 70 year time step results in average uranium concentrations still exceeding the EPA ground water MCL (0.044 mg/l). At the 90 year time step, the probability distribution for average uranium concentration is below the MCL. The results of the GANDT numerical simulations support the prediction that this Wyoming Title I site is a strong candidate for natural flushing.

The highly graphical and easy-to-use nature of GANDT makes it useful for regulatory and stakeholder interactions for conveying results of ground water simulations, especially for establishing a technical basis for implementing the natural flushing strategy.

REFERENCES

Faust, C.R. et al. 1994. FTWORKS: Ground water flow and transport in three dimensions, Geotrans

Federal Register. 1995 "60 FR-2854," Ground water standards for remedial actions at inactive uranium processing sites

Metzler, D.R. 1995. Natural flushing strategy: a risk-based approach to meeting ground water cleanup standards. *proceedings of the International Conference and Workshop. Freiberg, Germany*

Salhotra, A.M. et al. 1993. Multimedia exposure assessment model (MULTIMED) for evaluating the land disposal of wastes--model theory

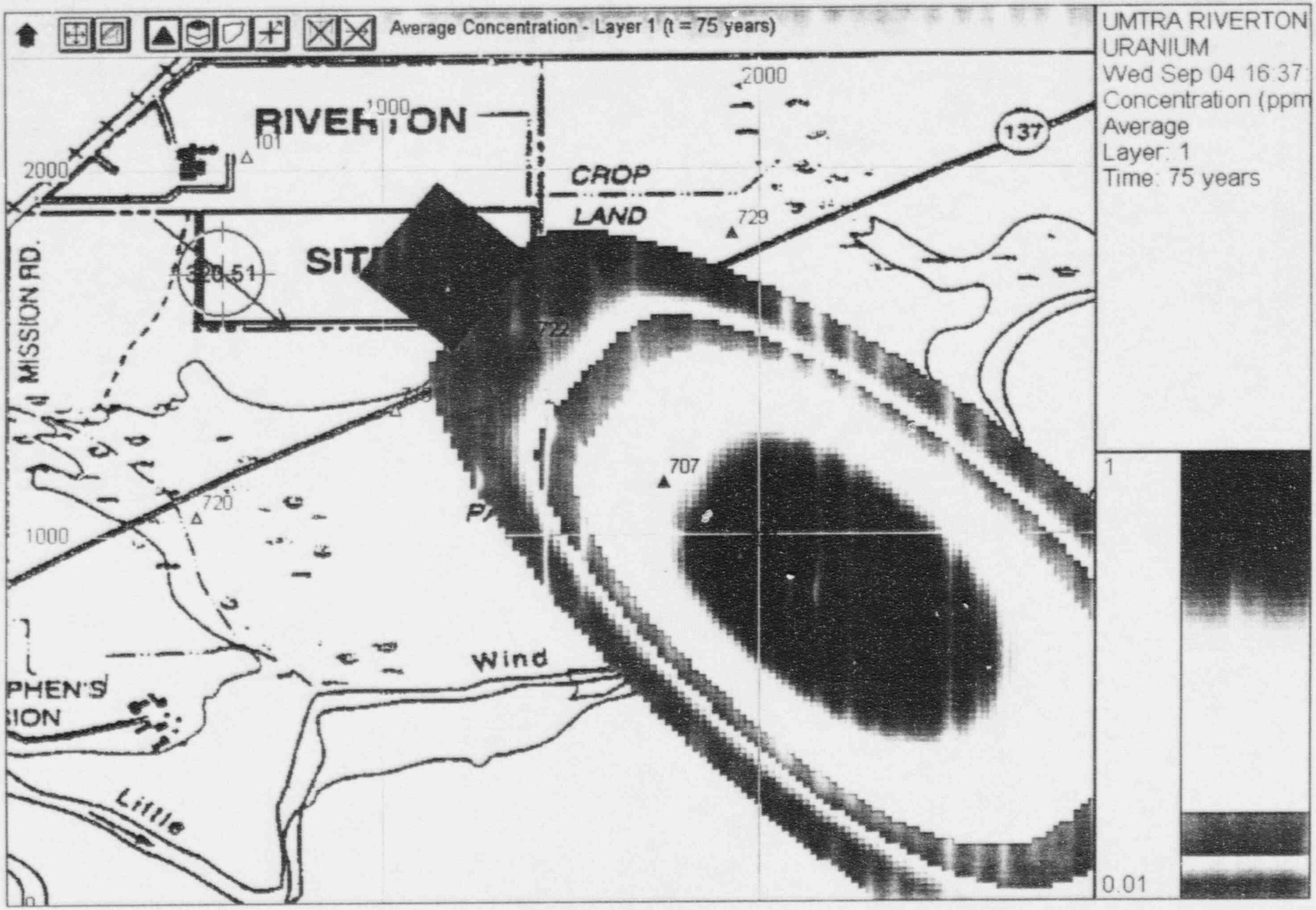

Figure 1. Analytical Results (75 years)

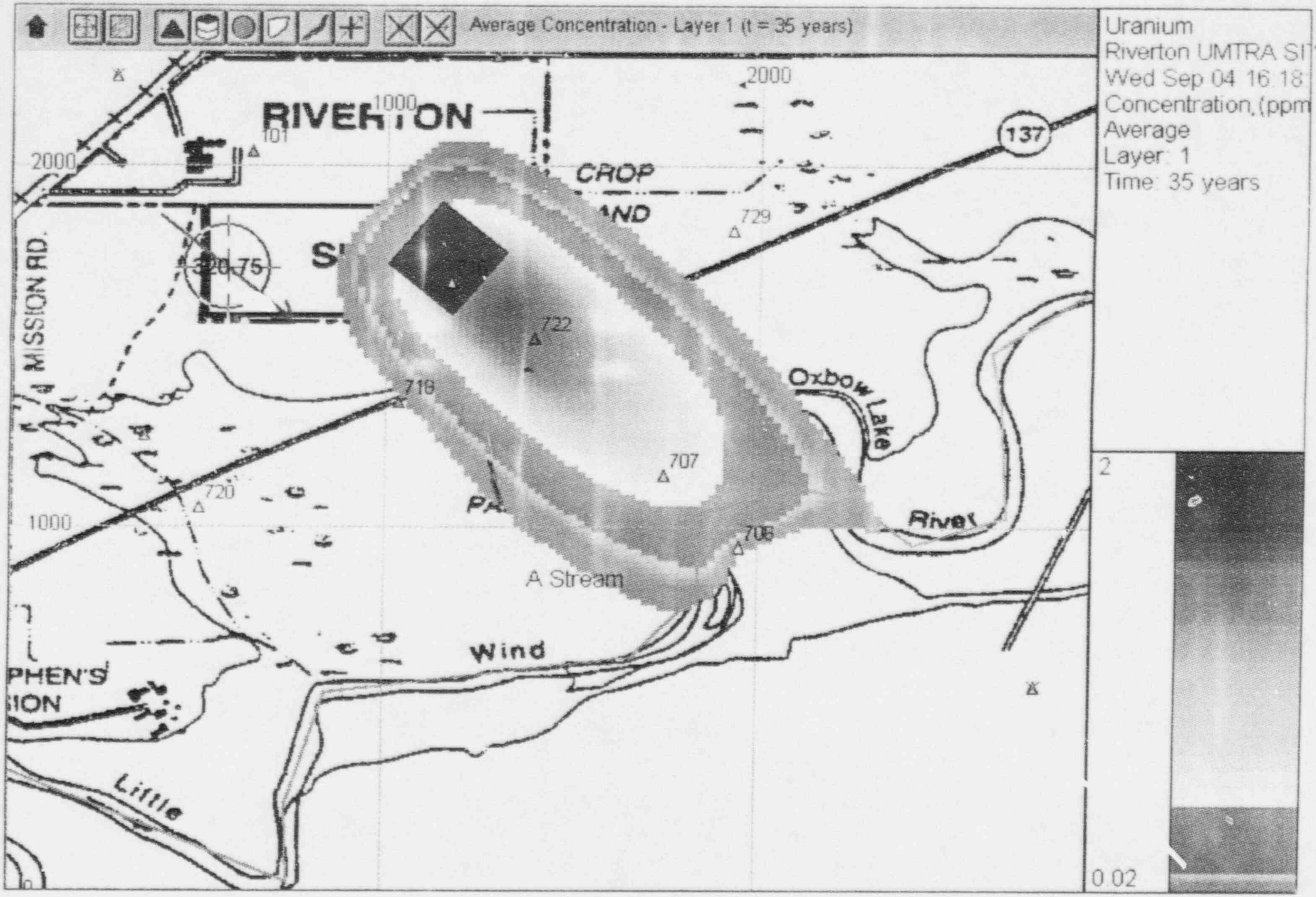

Figure 2. Numerical Results (35 years)

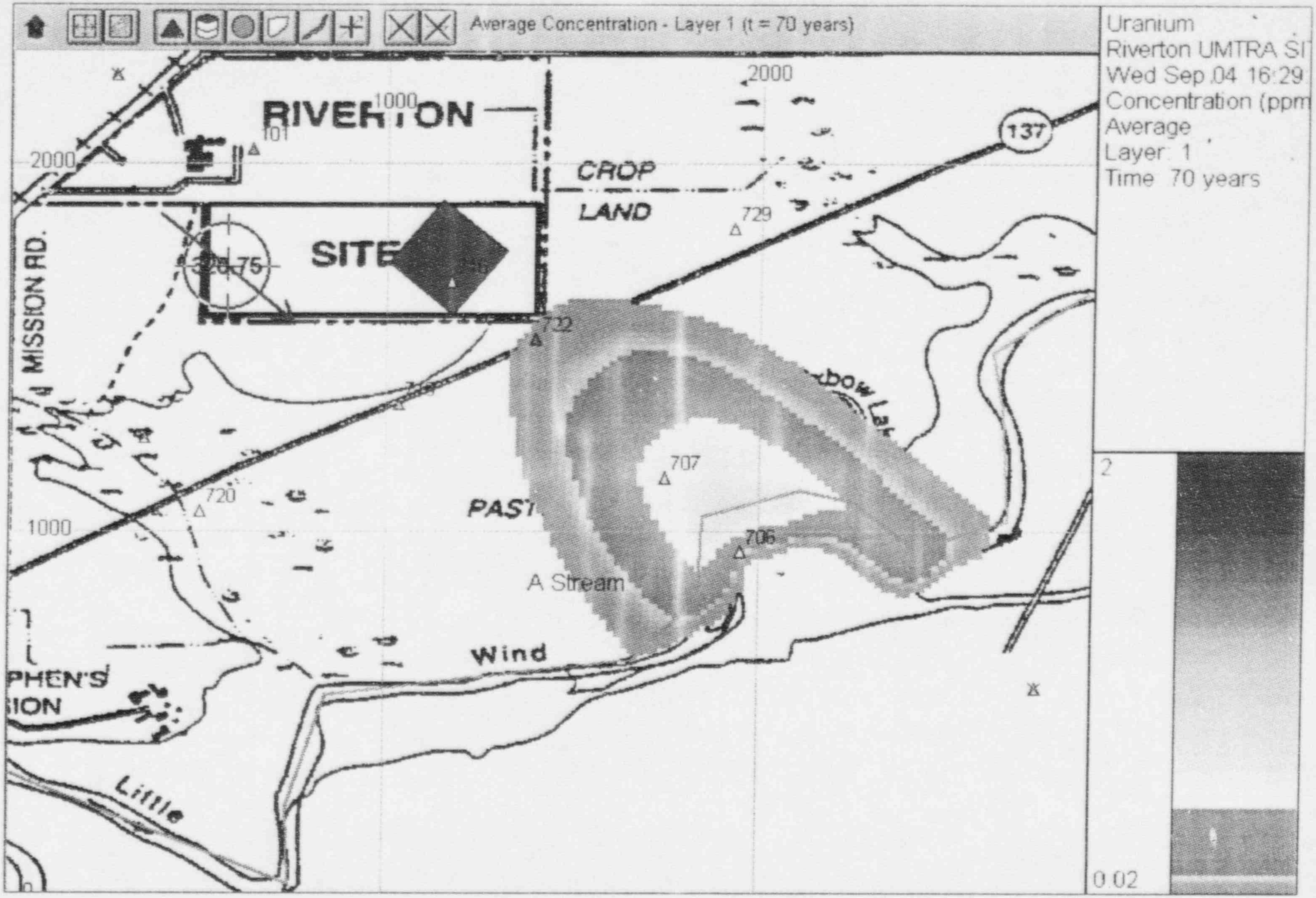

Figure 3. Numerical Results (70 years)

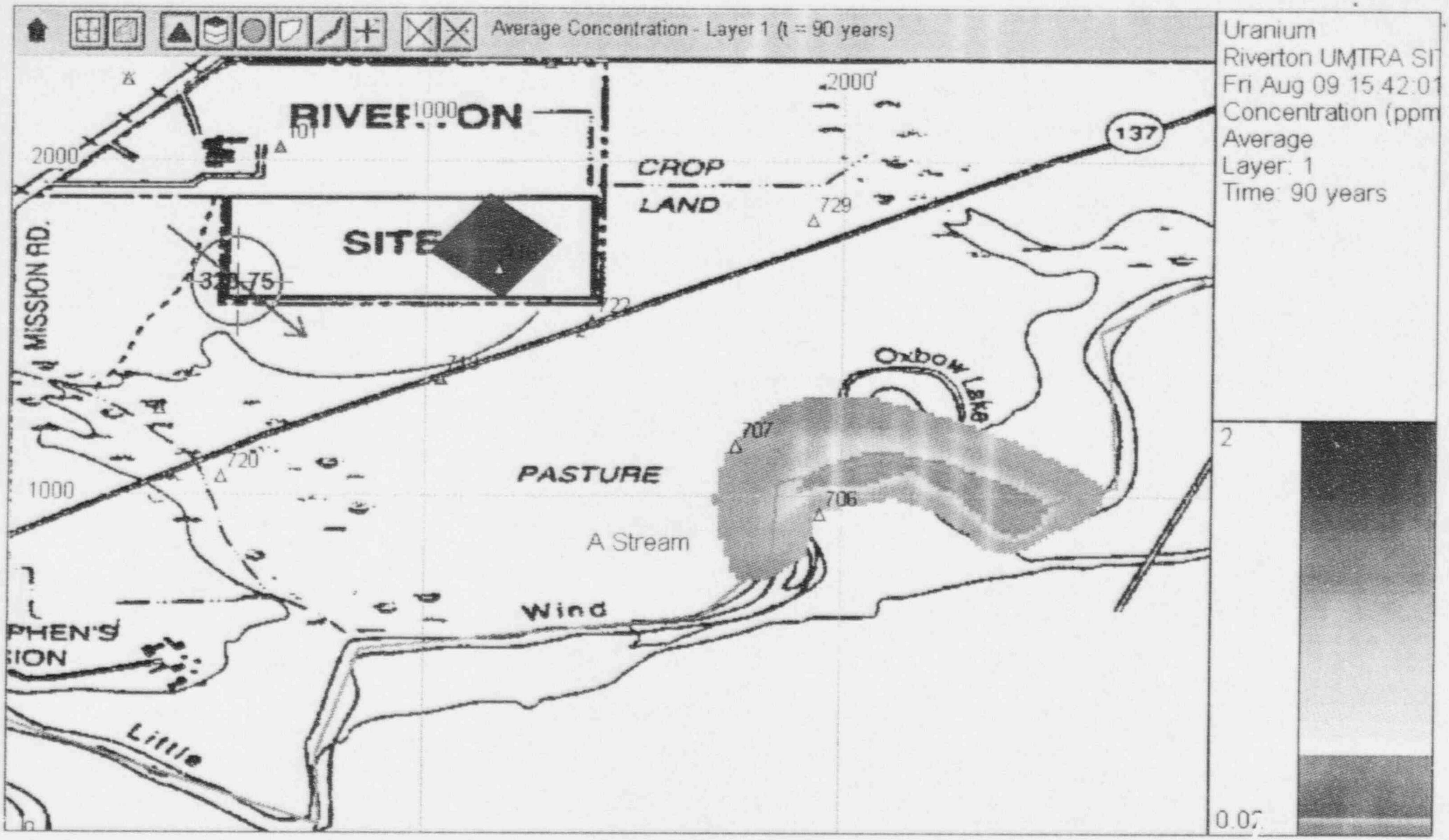

Figure 4. Numerical Results (90 years)