PERFORMANCE MEASUREMENTS FOR NATURAL FLUSHING (ATTENUATION) OF CONTAMINATED GROUND WATER IN THE UMTRA GROUND WATER PROJECT

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ABSTRACT

Ground-water standards for the 24 Uranium Mill Tailings Remedial Action (UMTRA) Title I sites are published in Title 40 *Code of Federal Regulations* Part 192. These standards allow for natural flushing of sites if water use and ecological considerations are not affected and cleanup will occur within a reasonable time. Criteria in these standards specify that (1) contaminant levels will be below standards within 100 years, (2) effective institutional controls can be verified and maintained for the entire period of time they are in use, and (3) ground water is not a current or potential source of drinking water subject to provisions of the Safe Drinking Water Act during the extended period.

The UMTRA Ground Water Project, which is managed by the U.S. Department of Energy (DOE), is responsible for ground-water remediation at these Title I sites. To determine if natural flushing is an acceptable compliance strategy, project personnel use probabilistic numerical models of ground-water flow and contaminant transport to predict contaminant concentrations at discrete time periods. Probability plots help forecast the expected decrease in contaminant levels during the 100-year period. Interim institutional controls, such as restrictions on land and water use that can be employed in conjunction with alternate water supplies, may be required to ensure protection of human health and the environment. Up-front coordination with local regulatory agencies and frequent communication with the public are essential in providing a clear understanding of the compliance strategy. Performance measures, developed to verify that the site is flushing according to predictions, consist of periodic monitoring of the institutional controls and comparison of current and predicted future contaminant concentrations at specific locations.

BACKGROUND

One of the missions of the U.S. Department of Energy (DOE) is to plan, implement, and complete DOE Environmental Restoration Programs at facilities that were operated by or in support of the former U.S. Atomic Energy Commission. These facilities include the 24 inactive uranium processing sites identified as Title I sites in the Uranium Mill Tailings Radiation Control Act (UMTRCA) (42 *United States Code* [U.S.C.] Section 7901 *et seq.*). These Title I sites operated from the late 1940s through the 1970s. In UMTRCA, Congress acknowledged the potentially harmful health effects associated with uranium mill tailings and directed DOE to stabilize, dispose of, and control the tailings and tailings-contaminated material in a safe and environmentally sound manner. The Uranium Mill Tailings Remedial Action (UMTRA) Surface Project involves cleanup of buildings, tailings, and contaminated soils at these former millsites and any associated vicinity properties. Surface remediation at the processing sites was completed in fiscal year 1998.

The UMTRA Ground Water Project was authorized in an amendment to UMTRCA (42 U.S.C. Section 7922[a]) when Congress directed DOE to perform ground-water remediation at the designated processing sites. Congress also directed DOE to comply with U.S. Environmental Protection Agency (EPA) standards (Title 40 *Code of Federal Regulations* [CFR] Part 192). The final EPA ground-water standards pertinent to the project were published on January 11, 1995 (60 *Federal Register* 2854–2871). The UMTRA Ground Water Project, which addresses any ground-water contamination derived from a milling operation that is present at levels above EPA standards, is funded by the DOE Environmental Restoration Program and is managed by the DOE Grand Junction Office (GJO).

The mission of the UMTRA Ground Water Project is to implement compliance strategies that will ensure protection of human health and the environment from ground water contaminated by past operations at these 24 uranium processing sites. These sites are located in 10 States and on 4 Native American-owned lands. At many of these former millsites, contaminated ground water is migrating beyond boundaries of the sites. DOE has controls in place at some of these sites to minimize any potential effects to human health and the environment that could be a result of this off-site ground-water contamination. Results of baseline risk assessments indicate that no one is being adversely affected by use of the contaminated ground water at this time.

The U.S. Nuclear Regulatory Commission (NRC), the regulatory agency for the UMTRA Ground Water Project, ensures DOE compliance with EPA standards. NRC is also authorized to license or to certify the cleanup and closure of the UMTRA Project sites. DOE works in partnership with NRC and the project stakeholders, including States, Native American tribes/nations, local communities, and land owners, to complete the project in a timely and cost-effective manner consistent with Environmental Restoration Program priorities.

SITES

The uranium millsites governed under 40 CFR 192 are those that sold a substantial amount of the uranium produced before January 1, 1971, to the Federal Government or the site was owned or controlled by any Federal agency as of January 1, 1978. The UMTRA Ground Water Project has targeted compliance strategies for each of these sites: 3 sites were selected for active remedial action, 9 sites for natural flushing, and 12 sites for supplemental standards (no further action). The Riverton, Wyoming, site is targeted for natural flushing based on evaluation of site characterization data and expected future site conditions.

The Riverton site is located 2.3 miles south of the city limits on a nearly level alluvial terrace between the Wind River to the north and the Little Wind River to the south. The mill operated from 1958 to 1963, processing approximately 500,000 tons of ore and producing 1 million cubic yards of tailings that were stored on site. Between 1988 and 1990, buildings on the millsite were demolished and the tailings pile and contaminated soil were removed from the site and surrounding areas.

REGULATIONS

Subpart A of 40 CFR 192 presents standards for the control and long-term disposal of residual radioactive materials from inactive uranium processing sites. Control must be maintained for at least 200 years and up to 1,000 years, must provide reasonable assurance that radon-222 releases will be below specified guidelines, and must provide for protection of ground water at each disposal cell. The UMTRA Ground Water Project establishes performance monitoring programs to verify that the ground water is being protected and to ensure that corrective action will be implemented if contaminant concentration limits exceed the maximum concentration limits (MCLs) listed in 40 CFR 192 or alternate concentration limits (ACLs).

Subpart B of 40 CFR 192 addresses ground-water cleanup and contains standards for cleanup of soil and buildings contaminated with residual radioactive material from inactive uranium processing sites. The standards define radium-226 cleanup criteria, maximum radon levels in buildings, and conditions for ground-water compliance at the processing sites. Three criteria stipulate compliance regulations for ground water:

- Concentrations of constituents in ground water must meet the MCLs listed in Table 1 of 40 CFR 192, Subpart A.
- The site meets requirements for supplemental standards.
- Cleanup of the site can be reasonably accomplished in full or in part through natural flushing, not to exceed 100 years.

Potential carcinogenic risk to human health and the environment must be acceptable (i.e., less than 10^{-4}) to apply supplemental standards or the natural flushing strategy.

COMPLIANCE STRATEGY SELECTION

A Programmatic Environmental Impact Statement (PEIS) document was prepared to evaluate the alternatives for implementing EPA standards. The preferred alternative is to

apply the standards on a site-by-site basis using the acceptable strategies in the regulations: supplemental standards, natural flushing, and active remediation.

To select the preferred alternative for each site, project managers use a compliance-selection flowchart (see Fig. 1) and site-specific information to determine applicable standards and the appropriate compliance strategy. All sites have some historical environmental information that has been collected during the past 15 years. On the basis of these limited data sets, conceptual models are developed and targeted strategies are identified for each site. The historical information is evaluated and, if additional data are needed, a work plan is prepared to address data gaps associated with the primary compliance strategy as well as a secondary strategy if significant uncertainty is associated with the primary strategy. After additional characterization, the flowchart is used to reevaluate the site to verify the appropriateness of the targeted strategy.

NATURAL FLUSHING STRATEGY

Site conditions must meet three criteria for selection of natural flushing as the compliance strategy. The first criterion requires that no unacceptable risk to human health and the environment is associated with ground-water contamination. A baseline risk assessment is prepared to identify current and potential pathways and risks. Future pathways are determined based on intended land and water uses. Industrial controls may be required to ensure that risk is acceptable during the flushing period.

The second criterion requires isolating the source of contamination so it does not present a substantial continued source to ground water or surface water. This criterion can be met in two ways, either by isolating the tailings in a disposal cell on site or by moving the tailings to a different location. In the case of the nine sites in the UMTRA Ground Water Project targeted for the natural flushing compliance strategy, the tailings were transported to off-site disposal cells to expedite resolution of potential compliance issues.

The third criterion requires that contaminant levels in the ground water must be below MCLs or at background levels within the 100-year period. To determine if this compliance strategy can be achieved, computer modeling is performed with analytical and numerical methods (1) to assist in defining data collection needs, (2) to perform uncertainty and sensitivity analyses, and (3) to conduct probabilistic forecasting of the attenuation process as a function of concentrations in relation to time and space.

UMTRA Ground Water Project personnel perform uncertainty analysis with Monte Carlo/Latin Hyper Cube routines. Conditioning algorithms are used to honor water quality data (e.g., built-in calibration), and real-time graphic displays present the probabilistic results.

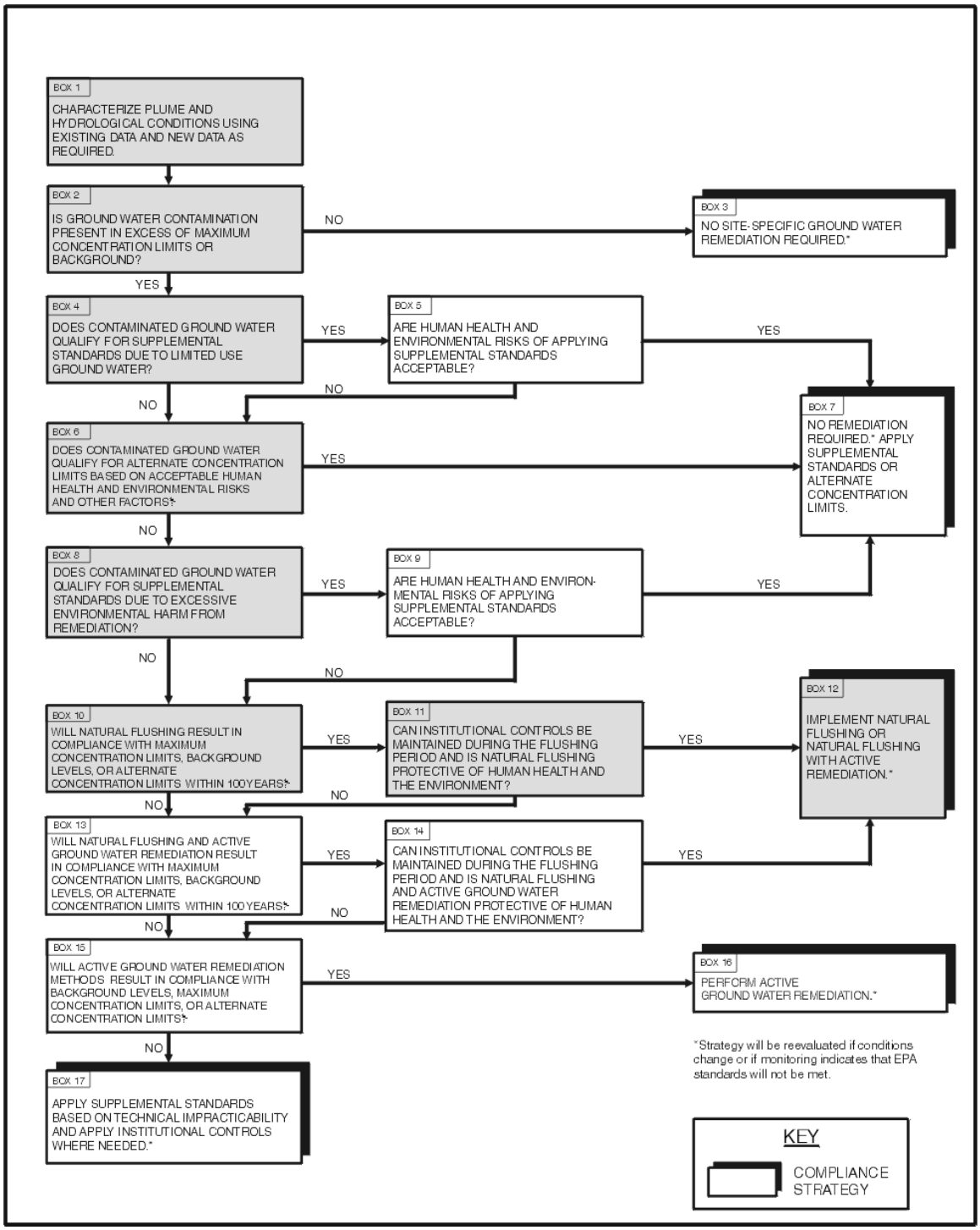

Fig. 1. Proposed Action

INSTITUTIONAL CONTROLS

Institutional controls are measures that effectively protect public health and the environment. They typically depend on some administrative control to ensure that protection is effective. The UMTRA Ground Water Project recommends institutional controls to reduce exposure to health risks or to reduce health risks (1) by preventing intrusion into contaminated ground water or (2) by restricting access to or use of contaminated ground water for unacceptable purposes. As a last resort, institutional controls could limit human access to the land above the contaminated ground water. EPA standards allow the use of institutional controls in place of remediation at sites where remediation can occur through natural flushing of the aquifer within 100 years only if their effectiveness can be verified and maintained.

EPA standards require that institutional controls

- Have a high degree of permanence.
- Can protect public health and the environment.
- Can satisfy beneficial uses of ground water.
- Are enforceable by administrative or judicial branches of a government unit.
- Can be effectively maintained and verified.

An example of acceptable institutional controls cited in the EPA standards is a deed restriction that can be enforced by a unit of government (either administratively or through judicial processes). Another example of an institutional control measure is Federal or State ownership of land containing contaminated ground water. EPA recognizes that a combination of controls may be needed to adequately protect public health and safety. Protective safeguards, such as signs, health advisories, or other measures that require voluntary cooperation of private parties, can be used to complement enforceable institutional controls but cannot be considered as primary protective measures. Use of an alternate water supply in conjunction with institutional controls that would prevent human contact with contaminated ground water is a viable institutional control.

The key to identifying, implementing, and enforcing institutional controls is participation by tribal, State, and local governments. While DOE is responsible for compliance with EPA standards at UMTRA Project sites, its authority to implement and enforce institutional controls may be limited, particularly if tailings are disposed of in off-site disposal cells and the disposal site is privately owned or is owned or controlled by other public agencies. Similarly, ground-water contamination from uranium processing activities may have moved beyond the processing site to areas that are not within DOE jurisdiction.

The need for and duration of institutional controls depends on the compliance strategy selected for a site, the type and level of risk, and existing site conditions. As risks decrease over time, so should the restrictiveness of institutional controls. But contaminated plume movement might require applying the restrictions to an extended area for a longer time period. DOE will verify the effectiveness of institutional controls to

ensure extended protection of public health and the environment and beneficial uses of the water.

Institutional controls, if any, are selected in cooperation with the participating private and public landowners, Indian tribes, States, and local governments. DOE and NRC concur with the selection and implementation of site-specific institutional controls. At the Riverton site, a viable and enforceable institutional control is in place through a Memorandum of Agreement among the Indian Health Service, the Northern Arapaho Tribe, and the Northern Arapaho Utility Organization. These organizations govern this institutional control because the contaminated ground water resides beneath tribal lands. An alternate water supply provides potable water to existing and future residents and helps establish a moratorium on domestic wells in the affected area.

PERFORMANCE MONITORING

Upon completion of ground-water modeling, long-term monitoring of the ground water and surface water is performed to compare the actual rates of decline in contaminant concentrations with the model results. Differences between the modeled and actual concentrations are compared with the acceptable ranges established by NRC.

We selected the UMTRA Title I site at Riverton to illustrate the analytical techniques employed to determine if the compliance strategy of natural flushing is meeting EPA regulations. Fig. 2 depicts results of laboratory analyses of uranium concentrations in ground-water samples collected in 1997 at the Riverton site. Fig. 3 shows predicted concentrations of uranium in ground water samples in 75 years. In this example, the source has been removed and the centroid of the contaminant plume is migrating toward the river. Fig. 4 presents the probability that uranium concentrations will exceed MCLs (0.044 part per million [ppm]) in 75 years.

Nineteen locations have been identified at the Riverton site for continued ground-water monitoring. Locations and monitoring frequency are chosen on the basis of the rate of change expected at each location. At some locations, concentration levels may remain fairly constant initially, then decline more rapidly. If future concentrations indicate that the model is not valid, additional modeling or a corrective action may be performed to verify that the site will naturally flush within the 100-year period.

Sites will be monitored more frequently early in the monitoring phase to verify model predictions. At many sites, quarterly sampling is proposed initially to verify seasonal fluctuations in water levels and concentrations. Once verification monitoring has been completed, monitoring frequency will be reduced to a more cost-effective level. At the Riverton site, ground-water monitoring will be performed annually for the first 5 years, then once every 5 years thereafter.

CONCLUSION

Three criteria must be met before the natural flushing strategy can be implemented at an UMTRA Title I site. First, no unacceptable risk to human health and the environment

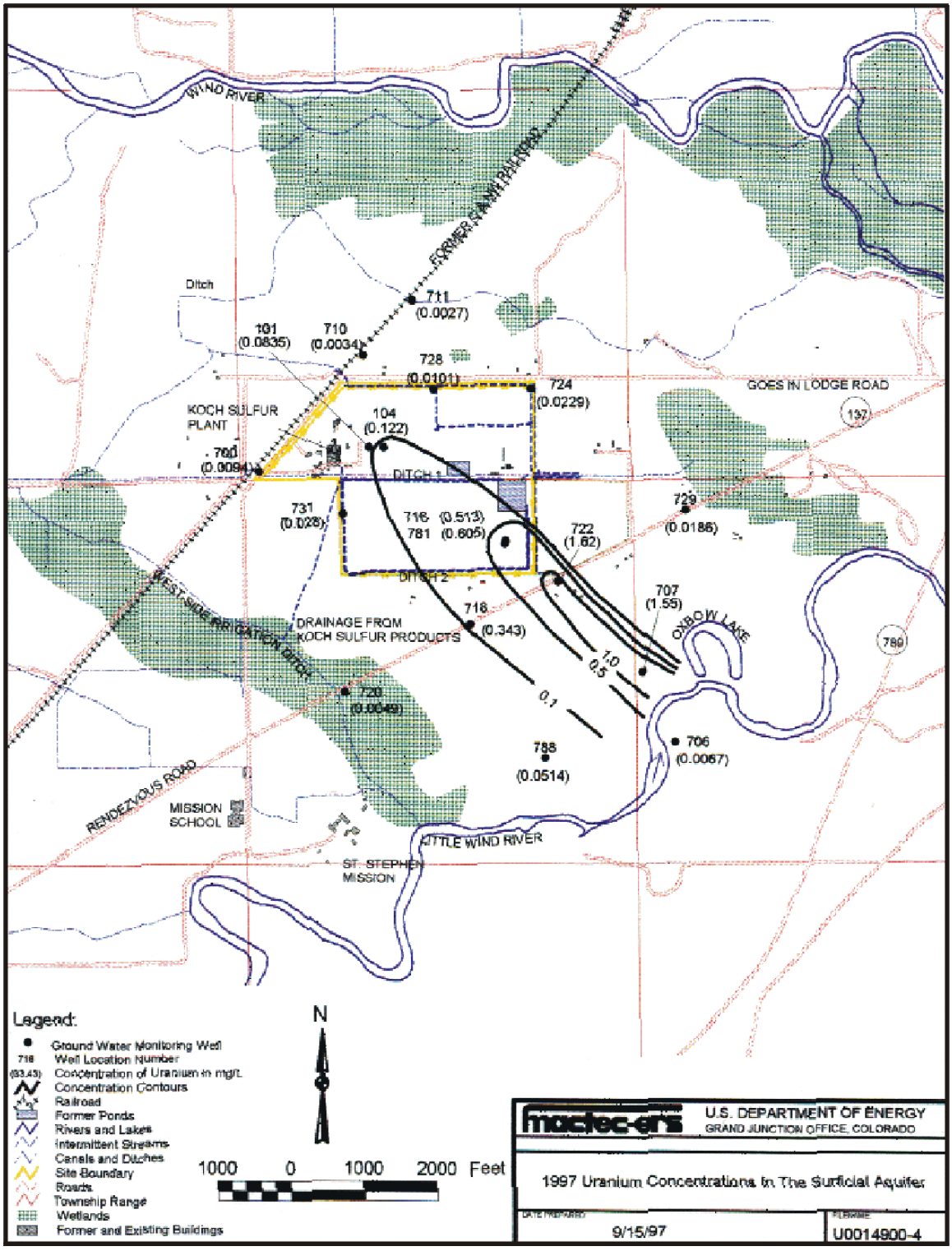

Fig. 2. 1997 Uranium Concentrations in the Surficial Aquifer at the Riverton Site

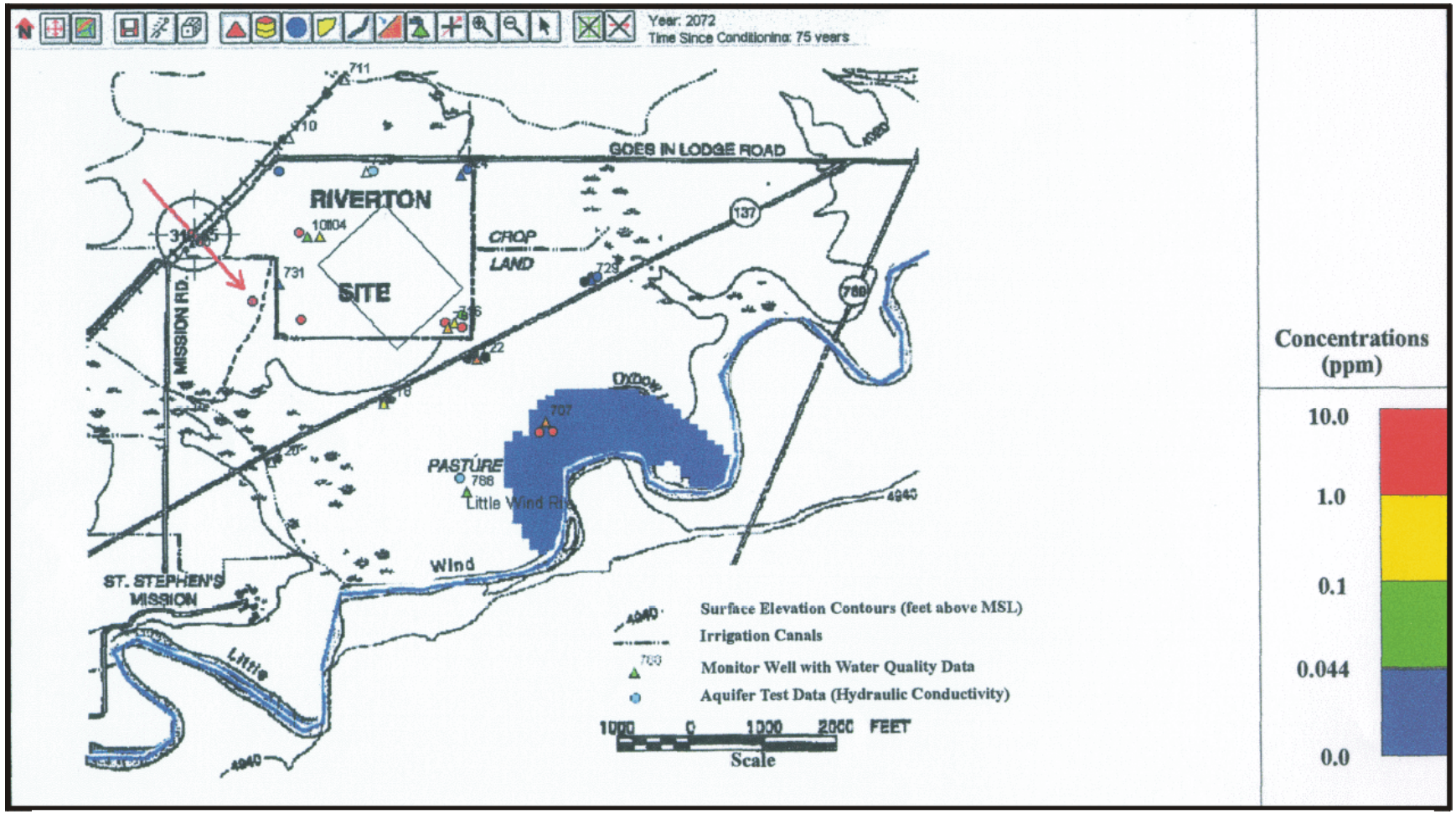

Fig. 3. Mean Concentration Distribution of Uranium From Uncertainty Analysis, 75 Years After Conditioning Time — 2072

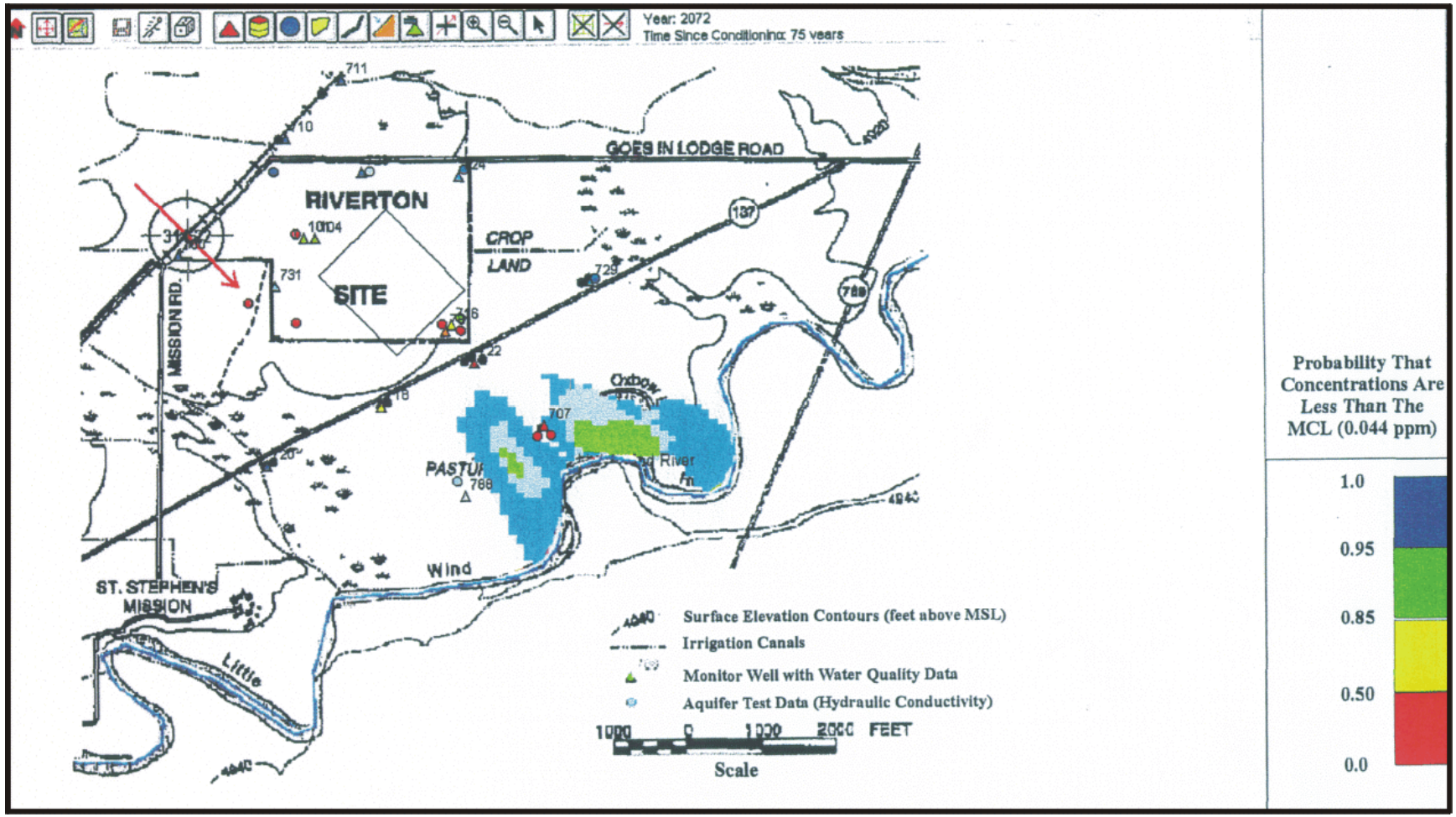

Fig. 4. Probability That Uranium Concentrations Are Less Than the MCL (0.044 part per million) in 75 Years

associated with ground-water contamination can be present at the site. Second, the source of contamination must be isolated and must not present a substantial continued source to the ground water or surface water. Third, the contaminant levels must be below MCLs or at background levels within a 100-year period. If these three criteria can be met, then natural flushing can be selected for compliance with the EPA standards.

During the natural flushing period, performance monitoring is required to verify that the site is flushing according to computer-modeled predictions. At the Riverton site, the plan is to conduct annual ground-water sampling to assess contaminant concentrations at 19 locations during the first 5 years. Analytes are chosen on the basis of the baseline risk assessment and the list of constituents in the EPA standards. Sampling frequency will be determined based on the predicted rate of change. At some locations, concentrations may not change for the first several years as the plume migrates through the downgradient area.

Monitoring results will be compared to predicted values within a probable range of concentrations at each location. If results indicate natural flushing is not working, site conditions will be reevaluated to determine an acceptable compliance strategy.

Performance monitoring is a vital part of any compliance strategy, especially natural flushing because of the length of time required to meet the standards. The frequency and type of monitoring should be based on potential risks, the rate of change in predicted contaminant concentrations, and the institutional controls that are in place.

By careful planning and communication with stakeholders, natural flushing coupled with performance monitoring is a viable, cost-effective strategy to meet the EPA standards at UMTRA Ground Water Project sites.

ACKNOWLEDGMENTS

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