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U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action



Prepared for the U.S. Department of Energy
Assistant Secretary for Defense Programs



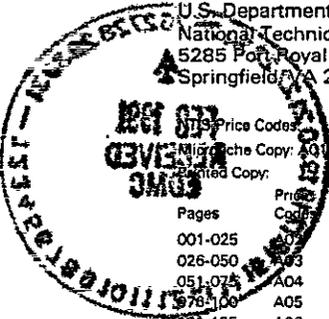
Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action

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ABSTRACT

Westinghouse Hanford Company (Westinghouse Hanford) requested ICF Northwest (ICF) to assist Westinghouse Hanford with determining the following:

- *The need for additional characterization of a uranium groundwater plume associated with the 216-U-1 and 216-U-2 cribs (U1/U2 cribs)*
- *Regulatory requirements for cleaning up the plume beyond the cleanup already completed*
- *The technical feasibility and cost of additional cleanup by pumping and processing groundwater.*

Conclusions resulting from these investigations are summarized below.

- *Additional characterization of the uranium contaminant plume and other nearby contaminant plumes is required before resuming groundwater pumping to cleanse the aquifer below the U1/U2 cribs.*
- *Future groundwater pumping to clean up the aquifer should not be performed without prior agreement with the U.S. Environmental Protection Agency and the State of Washington Department of Ecology. Specifically, negotiations with the regulatory agencies should establish the need for, and appropriateness of, any proposed groundwater pumping.*

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- *The U1/U2 site is documented as a Comprehensive Environmental Response, Compensation, and Liability Act site in the Hanford Site Waste Management Units Report. This calls for effecting remedies according to the Comprehensive Environmental Response, Compensation, and Liability Act process and DOE Order 5480.14, with specific requirements for implementing Comprehensive Environmental Response, Compensation, and Liability Act and Superfund Amendments and Reauthorization Act of 1986. We believe that this is an appropriate approach.*
- *To estimate costs associated with future cleanup, we considered a treatment system with the capacity of removing uranyl carbonate at >99% efficiency. The treatment system uses prefiltration, reverse osmosis, and ion exchange; and will cost approximately \$1.8 million. Operational expenses for the pump-and-treat system are estimated at \$840,000/yr.*

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EXECUTIVE SUMMARY

This report provides the results of work performed by ICF Northwest (ICF) under Task T-1 of Agreement Number SA-432163 with Westinghouse Hanford Company (Westinghouse Hanford). The ICF reviewed plume characterization data, evaluated regulatory requirements, and evaluated additional groundwater flow simulations in order to provide recommendations to Westinghouse Hanford. Conclusions resulting from these investigations are summarized below.

- Additional characterization of the uranium contaminant plume and other nearby contaminant plumes is required before resumption of groundwater pumping to cleanse the aquifer below the U1/U2 cribs.
- Future groundwater cleanup should not be performed without prior agreement with the U.S. Environmental Protection Agency (EPA) and the State of Washington Department of Ecology (WDOE). Specifically, negotiations with the regulatory agencies should establish the need for, and appropriateness of, any proposed activities.
- The contaminant plume below the U1/U2 cribs is moving slowly, so delay of remediation by up to ten years will not significantly increase time and cost of cleanup, if required.
- The U1/U2 site is documented as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site in the Hanford Site Waste Management Units Report (DOE-RL 1987). This calls for remediation to be performed under the CERCLA process and DOE Order 5480.14 (DOE 1985), which provides specific

instructions regarding the implementation of CERCLA/Superfund Amendments and Reauthorization Act of 1986 (SARA) at DOE installations. The ICF believes that this is an appropriate approach.

Background

The U1/U2 cribs are located in the south-central part of the 200 West Area. The cribs were in use from 1951 to 1967 (DOE-RL 1986). In February 1985, it was discovered that uranium concentration in groundwater beneath the U1/U2 cribs had abruptly increased to 72,000 pCi/L. After confirming the accuracy of the monitoring data an investigation was initiated to determine the source of contamination. This investigation indicated that acidic decontamination wastes, which were discharged to the cribs toward the end of their service life, had partially dissolved the sorbed uranium beneath the cribs. The volume of the decontamination waste was not sufficient to transport the dissolved uranium to the groundwater. It remained in the soil column until water from the nearby 216-U-16 crib (U16 crib) provided a groundwater recharge transient that transported the uranium to the aquifer below the U1/U2 cribs.

Cleanup Program

Pumping commenced on June 13, 1985, and continued until November 26, 1985. Eight-million gallons of groundwater were pumped and treated to remove 687 kg of uranium via an ion exchange column. The maximum uranium concentration was reduced from about 72,000 pCi/L to about 17,000 pCi/L. Groundwater samples are presently collected monthly from seven nearby wells to monitor contaminant levels.

Westinghouse Hanford requested ICF to perform the work described in this report to support decisions with respect to resumption of U1/U2 groundwater remedial action. The following summaries provide the conclusions and recommendations that resulted from the work performed by ICF.

Plume Characterization

Additional characterization is needed to ensure that remediation actions, if taken, are cost-effective. Characterization should be performed in collaboration with regulatory agencies to establish effective working relationships. The ICF recommends the following activities be pursued to provide the groundwater contamination data required to make decisions with respect to groundwater pumping for cleanup:

- Additional multi-level sampling devices should be installed to characterize the horizontal and vertical extent of the plume.
- Aquifer tests should be performed to determine hydraulic properties of the U1/U2 site.
- Using the additional characterization data obtained above, three-dimensional flow and transport models should be developed to evaluate the vertical extent of contaminant migration under no-action and pumping scenarios.

- Before resumption of groundwater pumping for cleanup, transport simulations should be performed to evaluate the effect that pumping would have on other groundwater contamination (such as the carbon tetrachloride contamination from the Plutonium Finishing Plant (PFP)).
- Additional contaminants may be introduced into the aquifer below the U1/U2 cribs by discharge of treated groundwater. The treated groundwater contains some residual contamination because the ion column treatment system cannot be 100% efficient, and additional contamination may be transported from the unsaturated portion of the flow system to the water table. This should continue to be considered when planning for remediation.
- The need to characterize the nitrate contamination in the groundwater below the U1/U2 cribs for cleanup should also be considered.

Regulatory Analysis

Remedial actions at the U1/U2 site are most likely to be implemented under the CERCLA rather than the Resource Conservation and Recovery Act (RCRA) for the following reasons.

- The CERCLA provides for the cleanup of hazardous substances released to the environment from inactive waste disposal sites.
- The preliminary Hazard Ranking System (HRS) score is high.

- Uranium and nitrate are nonhazardous under RCRA.
- The acid discharged to the U1/U2 cribs was probably a corrosive material.

The RCRA and CERCLA cleanup requirements are not well defined and are not expected to differ significantly. The RCRA and CERCLA programs are being implemented with the intent of having essentially equal waste cleanup requirements.

The degree of remedial action required at the U1/U2 site may depend on the extent of institutional control that DOE-RL can maintain over the Hanford Site. In the event cleanup of the contaminant plume below the U1/U2 cribs falls under CERCLA regulations, three scenarios are envisioned:

- No institutional control--Remedial action would definitely be invoked, with cleanup potentially as low as 3 to 10 pCi/L at the U1/U2 site. These potential limits are discussed in the EPA advanced notice of proposed rule making (EPA 1986) which suggests a Maximum Control Limit (MCL) based on the chemical toxicity of uranium. A 6.6-pCi/L limit has been established as the drinking water limit in Canada.
- Institutional control maintained with monitoring at groundwater discharge to the Columbia River--Remedial action to be invoked with cleanup to the 30- to 200-pCi/L range at the U1/U2 site. A dilution factor of approximately 10-in. groundwater is assumed at the point of discharge to the Columbia River, based on the Pacific Northwest Laboratory (PNL) modeling reports.

- Institutional control maintained with monitoring in the Columbia River--Remedial action is not likely to be required because of the overwhelming dilution of the Columbia River.

In general, remedial action can be resumed without prior concurrence of the regulators, however, ICF does not recommend it for the contaminant plume below the U1/U2 cribs. Further action has the disadvantages of potentially wasting cleanup dollars (because of inadequate characterization) and interfering with establishment of effective working relationships with the regulators.

Feasibility of Groundwater Remediation

Contaminant transport simulations were performed by PNL to evaluate the effectiveness of single and multi-well pumping systems for the U1/U2 site. Results of these simulations are as follows:

- The single pumping well, 299-W19-9, used for the past cleanup operations cannot clean the groundwater to the 3- to 10-pCi/L range. Much of the contaminant plume has already passed the capture zone of well 299-W19-9.
- A two-well scheme with each well pumping at 100 gal/min for 10 to 15 yr effectively cleans the U1/U2 plume to the 10 pCi/L if the wells are properly located. Approximately five years of pumping are required to reduce the U1/U2 plume to a level so that the residual plume does not exceed 10 pCi/L at the Columbia River.

- Because of the low permeability values associated with the geologic media in the vicinity of the U1/U2 cribs, delaying implementation of remediation up to 10 yr does not significantly impact the mass removal efficiency of a multi-well pump-and-treat system. The optimal location of the wells will depend on the location of the plume at the time the system is implemented; however, the plume dispersion is small enough over 10 yr that pumping efficiency does not decrease significantly.

In order to estimate costs associated with future cleanup, ICF considered a treatment system with the capability of removing uranyl carbonate to a >99% efficiency. The treatment system uses prefiltration, reverse osmosis, and ion exchange technologies and will cost approximately \$1.8 million. Operational expenses for the pump-and-treat system are estimated to be \$840,000/yr.

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GLOSSARY

ACL	Alternate Concentration Limits
ANPRM	Advance Notice of Proposed Rulemaking
ARAR	Applicable or Relevant and Appropriate Requirements
ALARA	As Low As Reasonably Achievable
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFEST	Coupled Fluid, Energy, and Solute Transport
CWA	Clean Water Act
DCG	Derived Concentration Guides
DOE	Department of Energy
DOE-RL	Department of Energy-Richland Operations
DOJ	Department of Justice
EPA	U.S. Environmental Protection Agency
HRS	Hazard Ranking System
INEL	Idaho National Engineering Laboratory
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NCP	National Contingency Plan
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NPL	National Priorities List
NPRM	Notice of Proposed Rulemaking
ORNL	Oak Ridge National Laboratory
PNL	Pacific Northwest Laboratory
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act of 1986
VTT	Variable Thickness Transient
WDOE	State of Washington Department of Ecology
WQC	Water Quality Criteria
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

This letter report provides the results of work performed by ICF Northwest (ICF) under Task T-1 of Agreement Number SA-432163 with Westinghouse Hanford Company (Westinghouse Hanford). The task requested ICF to review plume characterization data, evaluate regulatory requirements, and evaluate additional groundwater flow simulations in order to provide Westinghouse Hanford with recommendations on the continuation of cleanup activities at the U1/U2 site.

1.1 OBJECTIVE

The objective of the study is to evaluate the need to resume groundwater remedial action at the U1/U2 site in the near future, and to make recommendations with respect to remediation options. Our recommendations are based on U.S. Department of Energy (DOE) environmental policy, applicable federal and state requirements, and our assessment of the cost effectiveness of interim remedial action alternatives.

1.2 SCOPE

The ICF was asked to assist Westinghouse Hanford in three areas:

- Evaluate characterization data for the contaminant plume below the U1/U2 cribs to determine if the data are adequate to support decisions associated with resumption of remediation, and to make recommendations for additional characterization data collection, if required.
- Review applicable regulations to assess the regulatory need for additional remediation. Identify areas of regulatory uncertainty, and provide a range of options.
- Assess the technical feasibility of future remediation, design a cleanup methodology, and assess the costs associated with delay in resumption of cleanup.

1.3 APPROACH

The approach taken to perform the requested work involved the assessment of the plume characterization data, a review of relevant state and federal regulatory requirements, an assessment of the technical feasibility of future remediation using groundwater transport modeling, and the development of a conceptual design for a pump-and-treat system. This approach permitted us to identify the uncertainties associated with the existing characterization data and also within the regulatory context.

1.4 SUMMARY

1.4.1 Plume Characterization

The uranium contamination plume below the U1/U2 cribs is not characterized sufficiently to make effective decisions with respect to pumping groundwater for cleanup. Characterization should be performed in collaboration with regulatory agencies to establish effective working relationships.

1.4.2 Regulatory Analysis

Cleanup actions at the U1/U2 site may be implemented under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) rather than the Resource Conservation and Recovery Act (RCRA) for the following reasons: the Hazard Ranking System (HRS) score is high; uranium and nitrate are nonhazardous under RCRA; and the acid discharged to the U1/U2 cribs was probably a corrosive liquid. The RCRA and CERCLA cleanup requirements are not well defined and are not expected to differ significantly.

The degree of remedial action required at the U1/U2 site may depend upon the extent of institutional control that DOE-RL can maintain over the Hanford Site.

1.4.3 Feasibility of Groundwater Cleanup

Contaminant transport simulations were performed by Pacific Northwest Laboratory (PNL) to evaluate the effectiveness of single and multi-well pumping systems for the U1/U2 site. Results of these simulations are as follows.

- The single pumping well, 299-W19-9, used for the past cleanup operations cannot clean the groundwater to levels in the 3- to 10-pCi/L range.
- A two-well scheme with each well pumping at 100 gal/min for 10 to 15 yr effectively cleans the U1/U2 plume to 10 pCi/L if the wells are properly located. Approximately 5 yr of pumping are required to reduce the U1/U2 plume to a level so that the residual plume does not exceed 10 pCi/L at the Columbia River.
- Because of the low permeability values associated with the geologic media in the vicinity of the U1/U2 cribs, delaying implementation of remediation up to 10 yr does not significantly impact the mass removal efficiency of a multi-well pump-and-treat system.

A treatment system with the capability of removing uranyl carbonate to a >99% efficiency was designed that employs prefiltration, reverse osmosis, and ion exchange technologies. Capital costs are estimated to be approximately \$1.8 million with operational expenses approximately \$840,000/yr.

1.5 CONCLUSIONS

Conclusions resulting from these investigations are as follows:

- Additional characterization of the uranium contaminant plume and other nearby contaminant plumes is required before resumption of groundwater pumping to cleanse the aquifer below the U1/U2 cribs.
- Future groundwater pumping to clean up the aquifer should not be performed without prior agreement with the U.S. Environmental Protection Agency (EPA) and the State of Washington Department of Ecology (WDOE). Specifically, negotiations with the regulatory agencies should establish the need for, and appropriateness of, any proposed groundwater pumping activities.
- The contaminant plume below the U1/U2 cribs is moving slowly, so delay of remediation by up to ten years will not significantly increase time and cost of cleanup, if required.
- The U1/U2 site is documented as a CERCLA site in the Hanford Site Waste Management Units Report (DOE-RL 1987). This calls for remediation to be performed under the CERCLA process and DOE Order 5480.14 (DOE 1985), which provides specific instructions regarding the implementation of CERCLA at DOE installations. The ICF believes that this is an appropriate approach.

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2.0 PLUME CHARACTERIZATION

This chapter consists of three sections: (1) a summary of the remedial activities that have been performed to clean up the contaminant plume below the U1/U2 cribs, (2) an evaluation of the previous remediation activities, and (3) recommendations for additional characterization activities. Figure 1 shows the layout of the U1/U2 cribs, crib 216-U-16, and seven monitoring wells referred to in the discussion that follows.

2.1 SUMMARY OF PREVIOUS CLEANUP ACTIVITIES AT THE U1/U2 SITE

The following summary describes the remediation activities involving the contaminant plume below the U1/U2 cribs.

2.1.1 Uranium Discharge

The 216-U-1/2 cribs are located in the south-central part of the 200 West Area. Records indicate that 4,040 kg of uranium were discharged to the cribs between 1957 and 1967 (DOE-RL 1986). The uranium discharged to the cribs between 1957 and 1967 originated from recovery operations of waste streams. The uranium became insoluble as it reached the sediments by reacting with carbonate to form an insoluble carbonate-phosphate compound.

Acid wastes discharged to the cribs some time between 1957 and 1967 reacted with the uranium complexes to form compounds that are both soluble and nonsorbing in the sediments. While the acid had mobilized the uranium, the volume of fluid discharged was inadequate to transport the uranium in significant quantities to the water table. A new crib, 216-U-16, which is located a few hundred yards south of the U1/U2 cribs, was constructed to accept liquid wastes. Liquid discharges into U-16 were sufficient by early 1985 to form a pond above a caliche layer (about 165 ft below surface), move laterally below the U1/U2 cribs and transport the uranium through holes in the caliche layer to the water table. The holes in the caliche layer were hypothesized to either be natural "thin spots" or holes caused by boreholes in the vicinity. In February 1985, it was discovered that uranium concentrations in the groundwater below the cribs had abruptly increased from a background of about 166 to about 72,000 pCi/L.

2.1.2 Cleanup Activities

Based on the conclusions summarized above, three actions were taken to remedy the discharges of uranium to the groundwater: (1) pump groundwater through an ion-exchange column to remove uranium, (2) grout portions of existing wells to prevent vertical groundwater communication, and (3) install new monitoring wells to aid in characterization of the uranium plume and its cleanup.

Groundwater was pumped through an ion exchange column to remove uranium from June 13, 1985, to November 26, 1985. Eight-million gallons of groundwater were pumped removing 687 kg of uranium. The maximum concentration measured in groundwater sampled from nearby wells was

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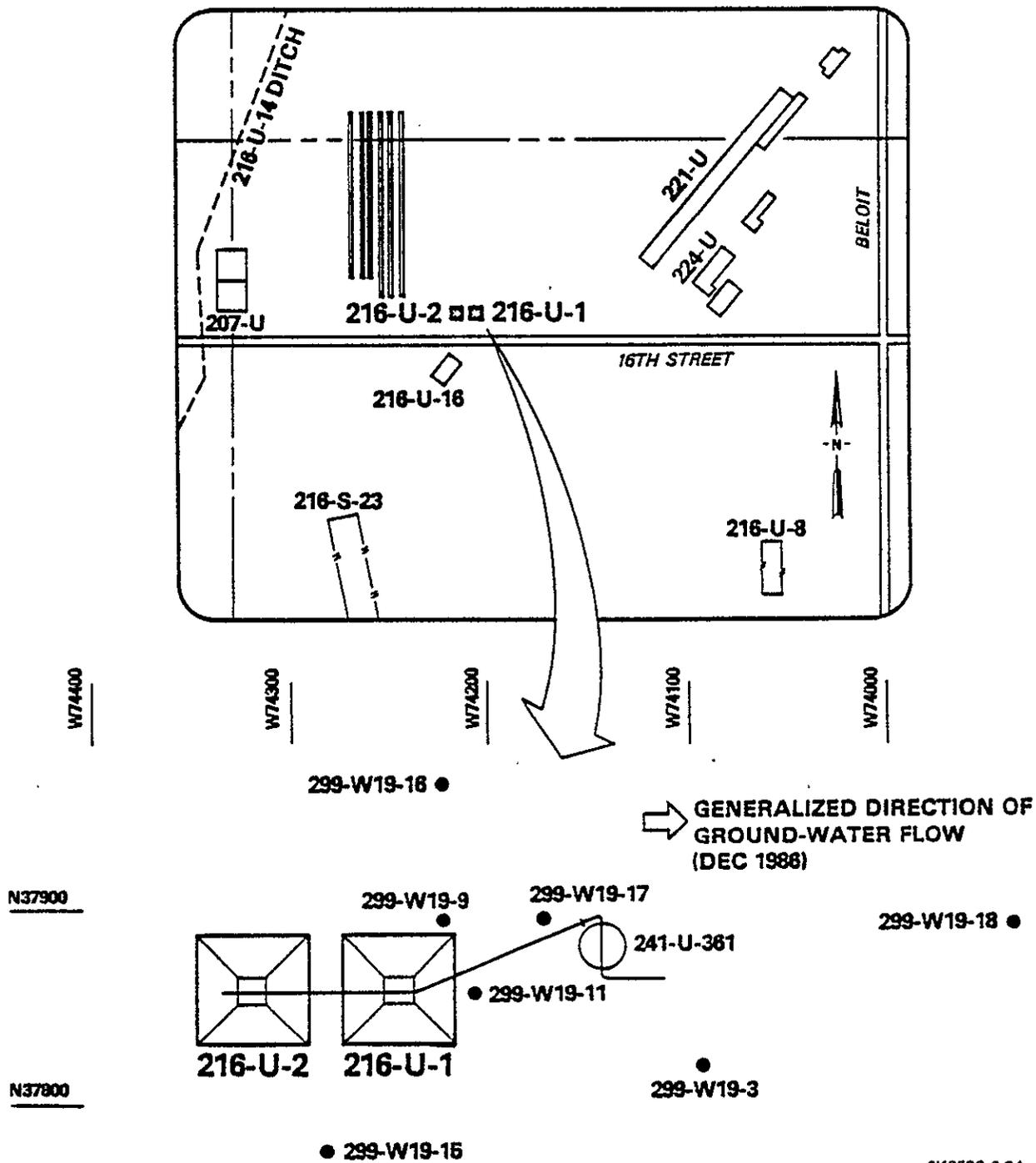


Figure 1. Layout of U1/U2 Cribs and Monitoring Wells.

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reduced from about 72,000 to about 17,000 pCi/L. The ion-exchanger was about 90% efficient in removing uranium. Discharge from the ion-exchange column went to 216-S-25 crib. Ion-exchanger regenerant water was sent to a double-shelled tank.

Three wells were modified to prevent vertical movement of wastes to the groundwater. Well 299-W19-9 had never been grouted. The casing below 254 ft was cut off, and the well casing and bottom sealed with grout. In May 1985, groundwater monitoring well 299-W19-3 was grouted to 200 ft and well 299-W19-11 was regrouted to 210 ft.

Four new groundwater monitoring wells were constructed since May 1985 to better define the boundary of the contamination plume and to better characterize the interior of the plume beneath the U1/U2 cribs in the 200 West Area. Two new wells were recommended by PNL and installed (see Figure 1). Well 299-W19-17 was located about 50 ft to the east of the well 299-W19-9 to sample an area of high contamination. The other well was located about 165 ft east of well 299-W19-3 to determine the probable maximum extent of contamination. This well was designated 299-W19-18. Two other wells were added. Well 299-W19-15 to define the southern extent of the plume, and well 299-W19-16 to define its northern extent.

2.2 EVALUATION OF PREVIOUS REMEDIATION ACTIVITIES

This evaluation covered four areas: (1) the source of the uranium, (2) transport mechanisms, (3) the completed cleanup campaign, and (4) groundwater transport modeling.

2.2.1 Source of the Uranium

The most plausible source of the uranium observed in the groundwater monitoring wells around the U1/U2 cribs is the 4,040 kg of uranium reported to be disposed of in the U1/U2 cribs. Numerous other waste-disposal sites in the 200 West Area are reported to have received uranium in similar or larger quantities. Most of these sites also received large quantities (thousands of kilograms) of nitrate. Table 1 lists the amount of uranium, nitrate and nitric acid disposed at waste sites around the U1/U2 cribs. The largest sources of uranium in the 200 West Area are the burial grounds 218-W-3 and 218-W-4A, with a total reported disposal inventory of about 825,000 kg of ²³⁸U. The 216-U-10 pond is reported to have received 1530 kg of uranium as of 1983.

It is possible that one or more of these other sites might have contributed to the uranium plume near the U1/U2 cribs. Comparing the locations of the uranium waste sites in the 200 West Area, the location of the U1/U2 cribs, and the direction of groundwater flow, ICF would expect U-Pond to be the most likely contributor to the plume other than the U1/U2 cribs (see Figure 2).

There are several other waste sites between the U-Pond and the U1/U2 cribs, but these are reported to have received no or small (less than 80 kg) quantities of uranium. No data were provided giving uranium concentrations in wells in the 200 West Area other than those near the U1/U2 cribs, so ICF assumes that uranium concentrations in other wells are insignificant. Because only the monitoring wells directly around the U1/U2 cribs were reported to show an increase in their uranium content with the activation of crib 216-U-16, the most credible source of the observed uranium would be the U1/U2 cribs.

Table 1. Quantities of Nitrate and Uranium Disposed Near the U1/U2 Site (from DOE-RL 1986).

Waste sites	Nitrate (kg)	Nitric acid (kg)	²³⁸ U (Ci)
216-S-1&2	60,000	100,000	0.76
216-S-03	9	None	0.00013
216-S-04	1	None	None
216-S-05	100	None	0.0911
216-S-06	140	None	0.912
216-S-07	110,000	250,000	0.868
216-S-08	100	None	0.0633
216-S-09	None	30,000 ^a	0.0114
216-S-11	None	None	0.0737
216-S-12	None	None	0.00167
216-S-13	10,000	None	0.0305
216-S-15	1	None	None
216-S-16P	1,600	None	1.06
216-S-17	140	None	0.0456
216-S-20	20,000	None	0.0126
216-S-21	None	None	0.0014
216-S-22	7,000	None	0.00002
216-S-23	None	300	0.00013
216-S-25	10	0	0.0555 ^a
216-U-1&2	1,200,000	None	0.702 ^a
216-U-03	9	None	0.00606
216-U-08	None	208,000	8.04
216-U-10	100,000	0	0.5100 ^a
216-U-13	None	None	0.00012
216-U-15	None	None	0.00076
216-Z-1&2	100,000	None	0.027 ^a
216-Z-03	600,000	None	0.00002

^aWaste Information Data System data base.

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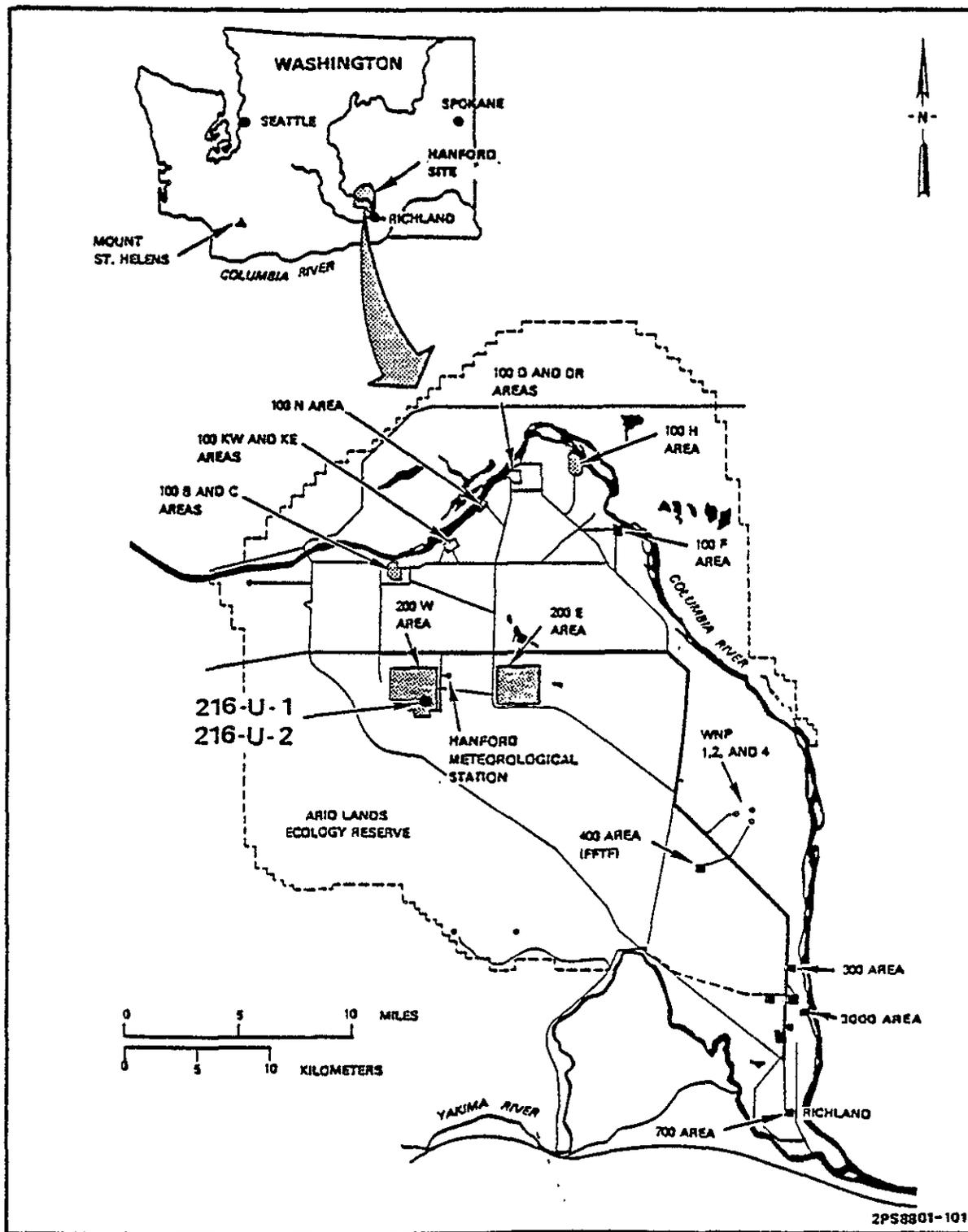


Figure 2. Hanford Site Map.

2.2.2 Uranium Transport Mechanisms

Uranium is generally considered to be poorly sorbed by sandy sediments; estimates of uranium distribution coefficient (K_d) are between zero and one milliliter per gram (Rancon 1973). Thus, uranium moves with the groundwater in sandy sediments. Although uranium was discharged to the U1/U2 cribs beginning in 1957, uranium was not detected in the groundwater until 1985. The reported scenario for the delayed uranium transport entailed: (1) uranium immobilized by formation of insoluble carbonate-phosphate compound, (2) uranium compounds dissolved by nitric acid discharges to U1/U2 cribs, (3) uranium now mobile, but limited migration caused by low volume of water through the caliche layer, and (4) uranium transported by large volumes of discharges from the nearby 216-U-16 crib reaching the groundwater by draining through windows or well perforations in the caliche layer. The reported scenario for the uranium transport or migration was well supported by field and laboratory evidence. The ICF concludes that it was the most probable scenario for the uranium transport.

The addition of nitric acid to the cribs could have had several other detrimental effects besides dissolving the insoluble carbonate-phosphate compound. The nitric acid could have enlarged pervious windows in the caliche layer and decreased the groundwater pH, thus increasing the mobility of uranium.

2.2.3 Completed Cleanup Campaign

Uranium levels from groundwater at well 299-W19-18, located farthest downgradient from the U1/U2 cribs, increased slowly after pumping stopped on November 26, 1985. This increase could be caused by movement of the eastern boundary of the residual uranium plume past this well. If the observed increase was due to plume movement, then a significant amount of contamination remains. More characterization data on the areal extent of the plume and the effectiveness of the pumping action is required to evaluate further options.

2.2.4 Groundwater Transport Modeling

Appendix A reviews groundwater transport modeling by PNL. The PNL used the following common assumptions:

- The Hanford Site model and a smaller subregional model of the U1/U2 site used a two-dimensional numerical implementation of groundwater flow that ensures that the uranium is uniformly distributed with depth over the saturated thickness of the surface aquifer and the well pumps uniformly along the entire depth of the surface aquifer. The lack of three-dimensional uranium plume data precluded modeling of the system at any higher degree of dimensionality.
- Two-dimensional, steady-flow, transient contaminant transport simulations were performed over the subregional (U1/U2 site) domain using the Coupled Fluid Energy and Solute Transport (CFEST) code to evaluate the effectiveness of pumping (or no action) in well 219-W19-99. These CFEST subregional simulations evaluated the effect of pumping and the longitudinal and transverse dispersion on uranium concentrations on a local basis. Initial uranium distributions were prescribed using the January 1986 measured uranium groundwater concentration values.

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- One-dimensional, steady-flow, transient contaminant transport simulations were performed along three-dimensional stream tubes emanating from the subregional model domain and continuing to discharge locations along the Columbia River. The stream tubes were generated using the Hanford Site groundwater flow models under steady or transient conditions. The one-dimensional simulations evaluated the effect of longitudinal dispersion and radioactive decay at discharge points at the Columbia River. Fully two-dimensional transport simulations of the U1/U2 plume to the Columbia River using the Hanford Site groundwater flow models were not performed because the Hanford Site finite-element grid was too coarse to permit effective transport simulations.

The PNL used the Variable Thickness Transient (VTT) groundwater flow model for the Hanford Site under 1984 steady-flow conditions to determine the stream-tube path length and travel time to the Columbia River. (A discharge of 15,000 gal/min to the B Pond was assumed to be from decommissioning of the Gable Mountain Pond.) A travel time of 192 yr was predicted for the 61,300-ft stream tube. The observed distribution of total uranium in January 1986 was input to the CFEST subregional transport model to project uranium concentrations under the no-pumping, 3-, 6-, and 12-mo pumping (well 219-W19-99) alternatives.

The PNL simulations predicted peak total uranium concentrations at the Columbia River discharge of 722, 537, 440, and 324 pCi/L under the no-action pump 3-, 6-, and 12-mo alternatives, respectively. An additional 12 mo of pumping would reduce the contaminant mass of the uranium plume by approximately 55%.

The PNL used the CFEST two-dimensional groundwater flow model for the Hanford Site to establish water table conditions and the stream tubes from the U1/U2 subregional model to the Columbia River for three cases:

- 1987 discharge conditions assumed to be steady state
- 1987 discharge conditions assumed until 1995 when water and stream condensate volumes are reduced by 90%
- Identical to Case 2 except cooling water and stream condensate volumes are reduced 90% in the year 2010.

The latter two cases resulted in transient flow simulations. The stream-tube path lengths and travel times for these three cases are 67,030 ft and 130 yr, 105,720 ft and 150 yr, and 101,660 ft and 150 yr, respectively. Significant differences in travel paths result from the three simulations. The CFEST subregional transport model was used to factor in longitudinal and transverse dispersion on a local (U1/U2 site) transport under the no-action alternative. One-dimensional transport simulations were used to factor in the effect of longitudinal dispersion and radioactive decay on predicted total uranium concentrations at the Columbia River. Peak concentrations at the Columbia River discharge locations were predicted to be 650, 510, and 490 pCi/yr for the three Hanford Site simulations, respectively. The average concentration of uranium remaining after 164 yr (potentially the end of institutional control) is in the 1- to 10-pCi/L range. These simulations assume a rather conservative (small) longitudinal dispersion value of 100 ft for the more than 60,000-ft path length.

The PNL modeling of the U1/U2 site provides an excellent analysis of comparing the no-action and pumping for 30-, 60-, and 120-d alternatives. It is clear the continued pumping significantly reduces the uranium concentration in the vicinity of the U1/U2 site. The analyses has limitations as observed in Appendix A:

- To provide accurate contaminant predictions, the uranium plume must be characterized with depth and the alternatives must be simulated with a fully three-dimensional model of the U1/U2 subregion and the Hanford Site. Furthermore, the uranium geochemistry must be better understood to determine the degree of soil adsorption and contaminant velocity retardation.
- Interferences from neighboring uranium plumes must be explicitly modeled within the region of influence (from the well field) in the subregional simulations.
- Interference from other uranium plumes migrating within the Hanford Site could affect uranium concentrations at discharge locations along the Columbia River.

2.3 RECOMMENDATIONS FOR ADDITIONAL CHARACTERIZATION

Additional characterization data are required to plan for effective cleanup of the contaminant plume. A major uncertainty that must be addressed is the spatial extent of contamination including the areal and vertical distribution of the plume.

2.3.1 Need for Additional Characterization of Plume

All the waste sites in the 200 West Area have a similar history in that uranium waste plus large volumes of nitrate and nitric acid were discharged to cribs. Similar uranium plumes may exist beneath many other waste sites in the 200 West Area. The migration of the uranium plume below U1/U2 cribs was initiated by first dissolving the uranium contained in the immobile carbonate-phosphate compound and then by flooding with wastewater. Similar situations may exist at other locations on the Hanford Site. For example, the uranium concentration in the groundwater monitoring well near the 216-S-25 crib (where the discharge from the U1/U2 campaign was released) had increased from about 10 pCi/L to about 43 pCi/L by late 1986. The 36,000 gal of residual wastewater from the ion exchange column that was discharged to the 216-S-25 crib might have contributed directly to elevated 216-S-25 concentration values or mobilized discharges of sorbed uranium (located beneath the crib) to the groundwater. The increase may be caused by some other source (such as U pond). Further characterization activities are required to determine the sources of groundwater contamination well enough to plan remedial action.

Remedial pumping, if accompanied by waste water discharges in the 200 West Area, could provide a driving force to mobilize the uranium below other waste sites in the 200 West Area. Wastes other than uranium (such as carbon tetrachloride) could also be mobilized. Therefore, it is recommended that the groundwater data base for characterization of the U1/U2 plume be expanded. The information added would allow assessment of the potential for mobilization or migration of other plumes as a result of remedial action pumping.

2.3.2 Recommendations for Further Investigations

The ICF recommends the following activities be pursued:

- Additional multi-level sampling devices should be installed to characterize the horizontal and vertical extent of the plume.
- Aquifer tests should be performed to determine hydraulic properties near the U1/U2 cribs.
- Three-dimensional Hanford Site regional and subregional site flow and transport models should be developed to evaluate the vertical extent of contaminant migration under no-action and pumping scenarios.
- After data are available from the new boreholes that were installed to characterize the contaminant plumes, transport simulations should be performed to evaluate interference effects among contaminant plumes.
- Introduction of contaminants to the aquifer from any proposed corrective action should be considered to ensure the effectiveness of the action.
- The characterization of the U1/U2 cribs should consider the presence of other contaminants (such as nitrates) in anticipation of future remediation requirements.

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3.0 REGULATORY ANALYSIS

The decision to continue remedial action at the U1/U2 site is subject to uncertainty regarding the regulatory statutes to be invoked (e.g., CERCLA, RCRA, State of Washington Department of Ecology (WDOE), and DOE, as well as the relevant cleanup criteria for the various regulatory statutes. The purpose of this analysis is to reduce these uncertainties through review of applicable regulations, agency policies and precedents, and to identify the most likely regulatory scenarios applicable to U1/U2 remediation.

The primary objectives include:

1. Determine applicable state and federal regulatory statutes.
2. Determine cleanup criteria for the U1/U2 site.
3. Identify uncertainties associated with regulatory statutes and cleanup criteria and provide a range of regulatory scenarios.
4. Provide examples of federal and state remedial action requirements as applied to inactive federal disposal sites.

3.1 POTENTIALLY APPLICABLE REGULATIONS

This section describes the hazardous waste management regulations that would most likely affect U1/U2 remediation.

3.1.1 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

The CERCLA establishes a requirement for remedial action at sites where hazardous substances have been discharged into the environment. The CERCLA explicitly applies to federal facilities and, therefore, to the U1/U2 crib.

The CERCLA requires that remedial action be sufficient to protect human health and the environment. The statute prescribes that remedies comply with all applicable or relevant and appropriate requirements (ARARs) under federal and state law, unless certain conditions for exemptions are met and failure to comply with ARARs is explicitly justified. The statute specifically mentions Maximum Contaminant Level Goals (MCLGs) and Water Quality Criteria (WQC) established under the Clean Water Act (CWA) as potential ARARs. The MCLGs and other potential ARARs can impose stringent standards for cleanup, in excess of levels that could be funded at all sites from CERCLA trust funds. Thus, CERCLA provides several potential exceptions to the basic requirement to comply with ARARs.

The CERCLA specifically provides an exemption to meeting ARARs where doing so would lead to increased risks. This is entirely consistent with As Low As Reasonably Achievable (ALARA) requirements that doses to workers associated with remediation be considered in determining the extent of remediation required for the U1/U2 site.

3.1.2 Resource Conservation and Recovery Act (RCRA)

After extended debate between EPA and DOE, and Department of Justice (DOJ) input, it now appears that the Resource Conservation and Recovery Act (RCRA) corrective action requirements will also apply at federal facilities through negotiated RCRA section 3008(h) consent orders. The DOJ has concluded that EPA cannot unilaterally issue compliance orders to other executive branch agencies under RCRA section 3008(a), but this distinction may have limited practical importance. The consent agreement negotiated recently by EPA and DOE for the Idaho National Engineering Laboratory (INEL) provides EPA with a strong position from which to negotiate specific compliance requirements. A Tri-Party Agreement (TPA) that may lead to a similar consent agreement at Hanford is now being negotiated.

The RCRA will apply to the U1/U2 crib if RCRA hazardous wastes were discharged to the crib in the past. Although uranium and nitrates are not RCRA hazardous wastes, it is possible that other hazardous wastes were discharged. The RCRA section 3004(u) provides that corrective action be required for hazardous constituents in all solid waste management units at a facility seeking a RCRA permit, regardless of when the waste was placed in the unit. The EPA administers this new RCRA provision in Washington State and has not yet issued regulations under the section. It is unclear whether RCRA section 3004(u) units will face the same corrective action requirements as active RCRA units, or whether EPA will use RCRA section 3004(u) to force cleanup of contaminants that are not RCRA hazardous constituents.

It is likely the state will become the lead agency for implementation of RCRA section 3004(u) over the same time frame that might be required to undertake additional remedial action of the contaminant plume below the U1/U2 cribs. Thus, EPA is likely to consult with the State on any decisions regarding remedial action at RCRA section 3004(u) units. In this context, it is worth noting that radionuclides may be classified as a State dangerous waste because of toxicity.

3.1.3 Department of Energy (DOE)

In selecting a remedy for the U1/U2 plume, DOE-RL is bound to comply with applicable DOE Orders limiting total offsite radiation dose from the Hanford Site, requiring that drinking water standards be met offsite, and setting requirements for current discharges and waste management operations. None of these orders, as currently written, would appear to provide an independent requirement for remediation of the U1/U2 plume, but important revisions that may change this situation are pending. The DOE Orders would, of course, require DOE-RL to comply with applicable federal regulatory requirements. Appendix B summarizes DOE Orders and regulations that may be applicable to the U1/U2 remediation.

The DOE requires that all activities at the Hanford Site be conducted to maintain radiation doses as low as reasonably achievable (ALARA). The ALARA procedures compare predicted radiation doses with the costs of dose-reduction measures to determine "reasonable" dose levels.

3.1.4 Washington State Department of Ecology (WDOE)

The possibility exists that the WDOE could attempt to regulate the site per the water pollution requirements of WAC 173-216, which apply to continuing migration of contaminants to groundwater from the U1/U2 crib and underlying soils. Application of this section would require that groundwater under the Hanford Site be subject to state jurisdiction, and that continuing migration of contaminants to groundwater be deemed "discharges."

groundwaters under the Hanford Site be subject to state jurisdiction, and require that continuing migration of contaminants to groundwater be deemed "discharges."

3.1.5 Uncertainties

Significant changes in and clarification of these basic sources of cleanup requirements are likely in the next year or two. Regulations implementing the new remedial action provisions of CERCLA and RCRA are under development, as is an EPA policy to reconcile potential differences in remedial action requirements under these programs. The EPA is developing a policy on environmental regulation of federal facilities in general, and EPA and DOE are negotiating a memorandum of agreement for the Hanford Site that will structure and guide site remediation efforts as a whole. Finally, DOE Order 5480.xx (DOE 1987) (which will set new offsite dose limits) is now being prepared and may set requirements that are so stringent in practice that decisions on remedies of the U1/U2 plume are affected.

3.2 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT VERSUS RESOURCE CONSERVATION AND RECOVERY ACT CLEANUP

The ICF believes that EPA would supervise cleanup at the U1/U2 site under CERCLA rather than RCRA for several reasons:

- The site has a high CERCLA HRS score and is expected to be listed on the National Priorities List (NPL).
- The principal constituents of concern (uranium, nitrate) are not RCRA hazardous constituents.
- RCRA cleanup at inactive units is generally motivated by EPA's desire to use RCRA operating permits as a lever to secure cleanup, as well as a desire to preserve trust funds. These motives are irrelevant at Hanford. (DOE is not recalcitrant, and trust funds cannot be used at Federal facilities.)
- EPA does not expect that the choice of RCRA or CERCLA will actually make as substantial a difference in cleanup levels as might be suggested by statutory language. This assertion is supported by a recent EPA statement in the Federal Register:

"EPA is in the process of developing regulations for corrective action under RCRA and for cleanup of Superfund sites under the National Contingency Plan (NCP). The cleanup goals established in those regulations will be consistent with each other, within the limits of each statute, and it is EPA's expectation that remedies selected and implemented under CERCLA will generally satisfy the RCRA corrective action requirements, and vice versa (52 FR 27645, July 22, 1987)."

Historical precedents at the Fernald (Feed Materials Production Center) site and at ORNL suggest that EPA approaches the "CERCLA versus RCRA cleanup" controversy as previously described. Past disposal activities at Fernald have resulted in a uranium and nitrate plume in groundwater; the plume is now being addressed under CERCLA, but work is still in the early "remedial investigation" stage. Both RCRA and CERCLA were considered as potential bases for

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remedial action at ORNL. When HRS scoring was completed no sites had scored high enough for NPL on the basis of groundwater contamination. Moreover, the units that cause the groundwater contamination of concern had received hazardous wastes as recently as 1984, so RCRA jurisdiction existed outside the possible constraints of RCRA section 3004(u). The State is now leading remediation planning activity under the state RCRA program.

3.3 POTENTIAL CLEANUP CRITERIA

It is not possible to predict cleanup criteria with reliability at this time. These criteria will actually be set in negotiations with cognizant regulators after site investigation, and probably after other elements of an overall regulatory framework are in place [e.g., a Hanford TPA, revised National Contingency Plan (NCP), RCRA section 3004(u) regulations, or precedents at other sites]. Final decision on cleanup standards might not be made until after a uranium maximum contaminant level (MCL) is in place, or after WDOE is authorized to administer RCRA section 3004(u) and other recent additions to the RCRA program.

The following sections address potential cleanup criteria under CERCLA and RCRA auspices. A listing of potential cleanup criteria to be discussed throughout Section 3.3 is included in Table 2.

3.3.1 Cleanup Levels Under Comprehensive Environmental Response, Compensation, and Liability Act

Four major issues must be addressed in establishing cleanup criteria under CERCLA.

- Cleanup under CERCLA must protect human health and the environment. The ICF views DOE orders as bearing on human health protection and discuss the orders in this context.
- The CERCLA remedies are to be consistent with applicable or relevant and appropriate requirements (ARARs). The Clean Water Act specifies maximum contaminant level goals (MCLGs) and water quality criteria (WQC) that must be explicitly considered as potential ARARs.
- Other potential ARARs need be identified.
- Alternatives to and exemptions from meeting ARARs must be considered.

3.3.1.1 Protecting Human Health and the Environment. The CERCLA requires remedies that protect human health and the environment. For radionuclide risk, a likely cleanup criterion will fall somewhere in the range between measures that are currently mandatory at the Hanford Site under DOE Orders, and measures sufficient to achieve environmental goals that have been set by DOE, DOE-RL, and in current site manuals. The DOE Orders 5480.1B, 5480.xx and 5840.2 (DOE 1987 and DOE 1984, respectively) are particularly relevant. The requirements of these orders and internal directives may directly drive remedial actions, if the requirements are more stringent than CERCLA requirements. The ICF discusses DOE and internal requirements as ICF currently understand them in more detail in Appendix B. The discussion here focuses on the central issue of adequate health protection.

Table 2. Potential Cleanup Criteria for the U1/U2 Site.

Uranium concentration Limit ^a (pCi/L)	Where most likely applied	Controlling agency	Notes	Reference section
600 - DCG	At discharge point to Columbia River	DOE-RL	During institutional control, includes new and past activities	Appendix B
200- Background levels	Groundwater beneath U1/U2 site	EPA	Under RCRA if no MCL.	3.3.2
24 - MCL	Outside controlled zone within 100 yr	DOE-RL	Loss of institutional control	3.3.1.3
24 - MCL	Beneath entire site by 2150	DOE-RL	Loss of institutional control, current and future operations,	3.3.1.3
20 - MCL	Beneath U1/U2 site	DOE-RL	Internal radiological exposure guidelines	Appendix B
3.3 - MCL	Drinking water source	EPA	Chemical toxicity	3.3.1.3
400 - WQC or lowest practicable concentration attainable	At discharge point to Columbia River	Washington State	Surface water, radiological exposure	3.3.1.2

^aConcentration as pCi/L of ²³⁸U.
MCL = Maximum contaminant level.
WQC = Water quality criteria.
DCG = Derived concentration guides.

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The DOE system for protection of human health against radiological risks has several parts. Total current offsite doses are limited (EPA also directly limits doses through air pathways under National Emission Standards for Hazardous Air Pollutants (NESHAPs)). Contractors are required to avoid any offsite violations of drinking water standards. Standards are set for specific ongoing activities, including effluent discharges and waste management. A general requirement is that all activities be consistent with ALARA principles, reducing current and future radiation doses to levels that are ALARA. Perhaps most importantly from a CERCLA health protection viewpoint, requirements and goals are set for site conditions at the time of presumed future loss of institutional control.

These orders, requirements, and goals cover a wide range of potential remedial action targets. The point in this range at which human health is adequately protected is difficult to define on a general basis. However, ICF can narrow the range of possibilities for the U1/U2 plume simply because some potential situations do not apply.

The ICF assessment of the situation is that: (1) without further remediation, the U1/U2 plume will not contribute significantly to total offsite radiation exposures; (2) drinking water at current points of use will show no detectable increase in contaminant levels; (3) some additional cleanup would probably be required under ALARA; and (4) goals for site conditions at the time of presumed loss of institutional control cannot be met without cleanup.

Under these circumstances ICF believes some additional remediation of radionuclide contamination would be required to protect health in a CERCLA context. Almost certainly, measures that would be ALARA would be required under CERCLA. The EPA might also argue that cost per unit dose figures used in ALARA calculations are too low for involuntary nonoccupational exposures. Finally, as long as DOE acknowledges the possibility of a future loss of institutional control, EPA is likely to consider scenarios for potential future exposure in judging the adequacy of protection for human health.

Some cleanup of the U1/U2 nitrate plume would also be required for health reasons under scenarios for potential future use of groundwater. It is standard procedure to address all contaminants of concern at a site once the CERCLA process has begun. The EPA recently specified nitrates as part of the remedial investigation for the San Fernando Valley, California, CERCLA site. (This site was listed primarily on the basis of organic solvents contamination; responsible parties have not yet been identified.) Moreover, high nitrate plumes located at the Fernald and ORNL facilities, which are similar to the Hanford Site plume, are currently undergoing interim remediation.

3.3.1.2 Maximum Contaminant Level Goal and Water Quality Criteria (WQC). The CERCLA cleanups are required to meet MCLGs if "relevant and appropriate under the circumstances of the release or threatened release." Some exceptions to this requirement exist.

There is no current MCLG for uranium or nitrates, but a goal of zero has been proposed for uranium. Because this goal has not yet been promulgated, CERCLA MCLG requirements are not triggered. However, the proposed MCLG may be put in place before the remedy at U1/U2 is complete. Meeting a cleanup target of zero for uranium is clearly technically infeasible. If this requirement is applicable, it will be a requirement to do as much cleanup as is feasible from an engineering point of view.

Currently, MCLGs are not viewed by EPA as cleanup targets under CERCLA. It can be argued that MCLGs are by definition goals for drinking water and can be ARARs only with those qualifications. The EPA does not seem eager to impose unrealistic cleanup requirements at CERCLA

sites; and in August 1987 issued interim guidance on ARARs that favors use of MCLs rather than MCLGs. Some members of Congress have objected to this interpretation of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

The EPA may ultimately conclude that MCLGs technically apply, but need not be met at a particular site because of the applicability of one of the exceptions to meeting ARARs that are available under CERCLA. From the point of view of a responsible party, it would clearly be better not to rely on exceptions, as these exceptions have limited scope and introduce procedural and analytic complexities.

The EPA has not promulgated a WQC for uranium; however, Washington State specifies criteria for radionuclides in surface water. This state criteria is expressed as the lowest practicable concentration attainable, but not more than 300 pCi/L for ^{234}U and 400 pCi/L for ^{238}U . See WDOE 1986 (WAC 173-201-35, "Drinking Water Standards" (WAC 1986); and WAC 402-24, "Surface Water Quality Standards," column 2, table II, appendix A (WAC 1987b)). (Units of measure converted to pCi/L.) It is worth noting that background levels of uranium in the Columbia River are about 0.5 pCi/L (PNL 1986).

Under CERCLA, remedial actions shall at least attain WQC where these are relevant and appropriate. In judging whether criteria are appropriate, EPA is to consider the "designated or potential use of surface water or ground water, [and] the purpose for which such criteria were developed" The degree of institutional control maintained by DOE-RL over the Hanford Site will likely determine the potential use of groundwater.

The Washington State radionuclide WQC for surface water is probably not an ARAR for groundwater at the Hanford Site, because access to that groundwater is controlled and marine organisms are not affected. If groundwater discharges to the Columbia River could lead to violations of these criteria, limits on concentration in groundwater would probably be imposed. There is a possibility that WDOE would aggressively pursue the concept of lowest practicable concentration attainable for radionuclides in groundwater discharging to the Columbia River to promote its purposes in setting those criteria. In this case, some exceptions to meeting ARARs discussed later become relevant.

3.3.1.3 Other Potential ARARs. In the absence of regulations, well-established EPA policies, or court decisions, there must be substantial uncertainty about which values in environmental statutes, regulations, policies, and guidance are potential ARARs. The better reading, however, is probably that each word in the phrase "applicable, or relevant and appropriate requirements" has meaning. Thus, potential ARARs must first be "requirements," imposed by statute or through rule-making processes that have been completed. Proposed rules, guidance, and policy statements that lack status as promulgated agency rules cannot be ARARs. Second, ARARs must be applicable, or relevant and appropriate. Applicability is a straightforward legal concept. The MCLs, for example, are "applicable" only to public water supply systems of a certain minimum size.

The greatest uncertainty about ARARs is how to interpret the notion of "relevant and appropriate." For example, MCLs do not set standards for groundwater quality, but are clearly relevant and appropriate where that water is used as a drinking water supply. But what if the groundwater is only moving toward a drinking water supply? Are MCLs "appropriate" where it is unlikely but possible that the groundwater would have been used for drinking in the future (absent contamination)? Current indications are that the EPA views MCLs as potential ARARs for groundwater that may be a source of drinking water in the future.

No MCL for uranium exists in 40 CFR 141 (EPA 1985). However, 10 CFR 20 (NRC 1986) sets radiation protection standards for exposure of the public, and these standards can be used to develop MCL-like limits on concentrations of radionuclides. As discussed more fully in Appendix B, DOE Orders provide for treatment of a 20-pCi/L limit for ^{234}U and a 24-pCi/L limit for ^{238}U as equivalent to MCLs for internal goal setting purposes.

The radiation protection standards in 10 CFR 20 are probably potential ARARs for U1/U2 and other remedial actions at a test point related to the potential for public exposure. However, the more stringently derived concentration guides and similar limits derived for the Hanford Site by DOE and Site operating contractors are not ARARs.

It should be noted for completeness that an Advanced Notice of Proposed Rulemaking (ANPRM) to set MCLs for uranium and several other radionuclides has been issued by the EPA. This advanced notice indicates that uranium is a concern because of chemical toxicity at lower concentrations than create a significant radiological concern. The advance notice also discussed existing and potential numerical standards, including a Canadian limit of 20 $\mu\text{g/L}$ (6.6 pCi/L). Based on the ANPRM as a whole, an actual NPRM for uranium could easily propose a level from one-half to two times 6.6 pCi/L. Uncertainty about the EPA potential direction in this area was increased recently by EPA Science Advisory Board criticism of the criteria document and supporting documents for these and other radiological MCLs. Of course, neither a proposed MCL nor a potential MCL discussed in an ANPRM is an ARAR.

An MCL does exist for nitrates, and concentrations of nitrates in the U1/U2 plume are above this standard. If Hanford Site groundwater were used for drinking, or if discharge of this plume into the Columbia River could result in violation of the MCL at the point of use, this MCL would clearly be an ARAR. Whether the MCL is an ARAR for groundwater under other circumstances will depend on the EPA approach to the issues of future groundwater use and loss of institutional control.

As discussed above, ICF expects EPA to be concerned with the potential for future use of groundwater. In the past, EPA has frequently viewed MCLs as ARARs for groundwaters that were otherwise suited for and might be used as drinking water. For example, at the ReSolve Site in New England, EPA is asserting that MCLs should be used as ARARs on the basis of potential future use; the responsible parties at this site say instead that the groundwater is not used for drinking, and that they should be held only to RCRA interim status landfill closure standards as ARARs. Similarly, at INEL, EPA is on record as being concerned about concentrations of chromium in groundwater that exceed MCLs, even though that groundwater is not currently used for drinking. At present, the shallow groundwater at the Hanford Site in the vicinity of the U1/U2 site is probably Class IIB (a replaceable potential source of drinking water) or Class III, so it is not clear that EPA would view this MCL as an ARAR based on a potential for direct ingestion of groundwater.

3.3.1.4 Alternatives to Meeting ARARs. Congress recognized that it was not economically feasible to comply with ARARs at all CERCLA sites, and provided several bases for selecting remedies that did not meet those requirements. The most detailed and important of these criteria allows the compliance point for measuring conformance to ARARs to be moved away from the facility boundary if three conditions are met: (1) the points of entry of groundwater into surface water can be accurately determined; (2) no "statistically significant increase" in the contaminant concentrations of the surface water occurs; and (3) human exposure at all points between the source and the point of entry into surface water is precluded. This appears relevant to the U1/U2 site provided that DOE maintains institutional control of the Hanford Site.

Exceptions are also available under other circumstances:

- The ARARs can be set aside when the remedial action is only part of the ultimate site remedy. This exception would apply to U1/U2 remedies if remediation of the entire area were planned, or if another phase of activity were planned at a later time.
- The ARARs can be set aside where compliance would involve greater risk than noncompliance. This exception is likely to be important where worker exposures and population exposures must be balanced in designing remedies.
- The ARARs can be set aside if compliance is technically impracticable from an engineering standpoint. This alternative may limit required remediation for nitrates or uranium, but is unlikely to eliminate requirements for remediation.

Finally, it should be noted again that CERCLA remedies are supposed to be "cost-effective." Cost arguments may play some role in choosing among alternative remedies that are each adequate to protect health and the environment, and are also consistent with ARARs (after any applicable exemptions are considered). Cost arguments on their own are unlikely to displace an ARAR, however, and will not displace minimum health protection requirements.

3.3.2 Cleanup Criteria under Resource Conservation and Recovery Act

There is significant uncertainty regarding cleanup criteria for the U1/U2 plume under RCRA. Corrective action guidelines are not specified under RCRA section 3004(u) and EPA has not issued guidance or reached decisions that could be established as precedents. It appears illogical to require full-scale RCRA cleanups at these units, while closed interim status land disposal units face lesser requirements. The EPA is currently assigning a lower priority for determining whether corrective action is required at RCRA section 3004(u) units than at active units; RCRA section 3004(u) submissions to EPA have been overwhelming and few resources have been available for assessing these submissions.

In general, RCRA corrective actions require the removal of "hazardous constituents" from groundwater until contaminant concentrations are below MCLs or background levels (if no MCL has been established).

As an alternative to this general groundwater protection standard, responsible parties can seek approval for Alternate Concentration Limits (ACLs) based on showing that "hazardous constituents in groundwater are not a substantial present or potential threat to human health or the environment at the ACL levels." The EPA has recently issued a guidance manual for ACL applicants (52 FR 27579). Compliance with ACLs is measured at a compliance point established through negotiation as part of the corrective action plan. Under RCRA, that compliance point may be moved back from the waste management unit boundary where appropriate. This action depends principally on the potential for human exposure between the waste management unit and the compliance point.

The language of RCRA section 3004(u) suggests that corrective actions are required only for RCRA hazardous constituents. Uranium, radionuclides, and nitrates are not currently classified as RCRA hazardous constituents. It is anticipated that this potential loophole may contribute to a decision to invoke CERCLA rather than RCRA for remedial action at this site.

Finally, it should be noted that there may be less flexibility in establishing compliance points beyond the waste management unit boundary under state rules than under RCRA.

3.4 UNILATERAL CLEANUP IMPLICATIONS

Several factors must be considered before undertaking any additional cleanup of the U1/U2 site:

- Required permits
- The NPL listing
- Cleanup costs
- Legal precedents
- Public participation and state consultation opportunities and requirements
- Timing and content of consent agreement.

3.4.1 Permits Required

State, local or federal permits are not required for activities undertaken as part of a State or Federally approved CERCLA cleanup. This CERCLA dispensation can have substantial value where treatment facility or discharge permits might otherwise be required. The value of this dispensation in the context of the U1/U2 plume may be more limited.

The two permits most likely to be required for a voluntary U1/U2 cleanup are a RCRA permit for the water treatment facility and a permit for the discharge from that facility. A RCRA treatment facility permit is needed only if the water being treated contains a hazardous waste. This question typically does not arise in CERCLA cleanups because of the CERCLA permit dispensation. Contaminated groundwater might be considered a hazardous waste under the RCRA "derived from" and "mixture" rules. On the other hand, because neither radionuclides nor nitrates are RCRA hazardous constituents, the water is not a hazardous waste apart from these provisions.

3.4.2 Ultimate Cleanup Costs

Voluntary cleanup can save money only if it is more cost-effective to begin remedial action at once than to wait until a consent agreement has been reached. Voluntary unilateral cleanup can also lead to higher total remediation costs. Remedies selected may go beyond what regulators require or additional remediation may be required later with restart costs that exceed any savings from phasing. Unilateral cleanups may only address hot spots, while regulators later determine a broader area effort is required. Given the high degree of uncertainty about cleanup standards for the U1/U2 plume, all of these potential sources of increased total costs are relevant.

3.4.3 Public Comment and State Participation

The CERCLA provides for public participation during the development of a remedial action plan and state participation in the identification of potential ARARs and remedial actions. A voluntary unilateral cleanup bypasses these important steps which creates a risk of poor community relations and dissatisfaction at the state level. Bypassing this process also makes it virtually impossible for EPA to informally accept that remedial action at the site has been adequate. A public participation and state consultation process is likely to be required when a site undergoes regulatory supervision, regardless of prior cleanup activity.

The CERCLA provides for the cleanup of hazardous substances released to the environment from inactive waste disposal sites.

3.5 CONCLUSIONS AND RECOMMENDATIONS

- Remedial actions at the U1/U2 site are most likely to be implemented under CERCLA rather than RCRA for the following reasons:
 - Its HRS score is high.
 - Uranium and nitrate are not RCRA hazardous constituents.

However, tremendous uncertainties regarding regulatory requirements of EPA exist at the present time. It is remotely possible that RCRA could be used. The ICF does not believe that remedial action will be implemented strictly under Washington State regulations since the state and EPA are closely coordinating their activities at the Hanford Site.

- The degree of remedial action required at the U1/U2 site will depend on the degree of institutional control that DOE-RL can maintain over the Hanford Site. Three scenarios are envisioned:
 - No institutional control -- Remedial action would definitely be invoked with cleanup levels potentially as low as the 3- to 10-pCi/L range at the U1/U2 site. The 3- to 10-pCi/L ARAR value corresponds to a chemical toxicity limit that could be specified in a consent decree between DOE-RL and EPA.
 - Institutional control maintained with monitoring at groundwater discharge to the Columbia River -- Remedial action to be invoked with cleanup levels in the 30- to 100-pCi/L range at the U1/U2 site. A dilution factor of approximately 10 is assumed, based on the PNL modeling reports.
 - Institutional control maintained with monitoring in the Columbia River -- Remedial action is not likely to be required because of the overwhelming dilution of the Columbia River.
- Unilateral (voluntary) cleanup of the U1/U2 site should proceed only if there is an urgent basis to protect human health or to prevent plume growth and excessive future remediation costs. Circumstances associated with the contamination below the

U1/U2 cribs do not require unilateral action. Unilateral cleanup has the following drawbacks:

- It will not prevent EPA from listing on the NPL, selecting ARARs, and developing remedial action measures
- It avoids public and state participation, which could delay the consent decree
- Cleanup criteria are uncertain.

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4.0 FEASIBILITY OF GROUNDWATER REMEDIATION

This chapter evaluates the feasibility of continued groundwater remediation at the U1/U2 site. The ICF considered the following issues:

- Feasibility of a pump-and-treat system, i.e., is it possible to effectively remedy the U1/U2 plume?
- Preliminary design of pump-and-treat system including: the number, locations, and pumping volume of withdrawal wells; treatment system specifications; and capital equipment and operating costs.
- Impacts of delayed remediation (at 1, 3, 5, and 10 yr) in terms of cleanup efficiency and costs.

4.1 FEASIBILITY OF PUMP-AND-TREAT SYSTEM

For this section of the report, a "feasible pump-and-treat system" for the U1/U2 site is defined as a withdrawal well field capable of reducing uranium concentrations of the U1/U2 plume to cleanup levels within 5 to 15 yr. The cleanup levels are not well defined at the present time but are anticipated to be within the 3- to 100-pCi/L range (see Table 3 for details). The ICF has assumed a treatment system operating at >99% efficiency (see Appendix C for a conceptual design of such a treatment system).

Determining feasibility for a particular withdrawal well field involved using a subregional transport model to determine mass removal rates and peak concentrations at the U1/U2 site as a function of time. Uranium concentration predictions from the subregional model may be compared directly to cleanup levels under the hypothesis of no institutional control of the Hanford Site. A one-dimensional contaminant transport model utilizing a stream tube from the U1/U2 site to the Columbia River involves diluting U1/U2 peak concentrations by a factor of 10 to 20 to derive a discharge concentration at the Columbia River. The uranium discharge concentration at the Columbia River may be compared to a CERCLA ARAR assuming that institutional control is maintained at the Hanford Site.

4.1.1 Transport Simulations

The subregional and stream-tube simulations were performed by PNL using the same input parameters and software as reported in the previous U1/U2 site simulations (Appendix A).

The contaminant transport simulations were performed to determine the efficiency of withdrawal well fields for the U1/U2 site. Two particular well fields were considered:

- Single well 299-W19-9 pumping at 35 gal/min
- Two hypothetical wells each pumping at 100 gal/min.

The second well field design involves installation of two new pumping wells located 180 ft apart and 210 ft downgradient from well 299-W19-11. This design represents an improved pumping scheme that reverses the hydraulic gradient so the U1/U2 plume ceases to move towards the Columbia River.

Table 3. Maximal Predicted Uranium Concentration Within U1/U2 Subregion for Two-Well Remediation System with 0-, 1-, 3-, 5-, and 10-yr Delays in Implementation.

Time since pumping started (mo)	No delay	1-yr delay	3-yr delay	5-yr delay	10-yr delay
1	10,707	9,883	8,563	7,606	5,938
2	7,929	7,388	6,480	5,775	4,551
3	6,026	5,641	5,015	4,506	3,588
4	4,710	4,434	3,966	3,592	2,904
5	3,753	3,557	3,220	2,938	2,400
6	3,043	2,902	2,653	2,442	2,029
7	2,516	2,413	2,227	2,064	1,734
8	2,115	2,038	1,897	1,770	1,507
9	1,798	1,739	1,630	1,530	1,319
10	1,542	1,498	1,417	1,340	1,168
15	823	813	790	764	697
20	505	504	499	491	464
25	339	341	343	342	333
30	242	245	250	252	252
40	142	145	150	154	158
50	93	95	99	102	106
60	63	65	68	70	74

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The prescribed hydraulic head boundary conditions for the subregional model were interpolated from a two-dimensional regional model of the unconfined aquifer beneath the Hanford Site. The average hydraulic conductivity in the subregional model is 0.5 ft/d and the effective porosity is assumed to be 0.10. The initial uranium distribution was derived from January 16, 1986 concentration data.

The subregional model was used to simulate conditions of no further pumping, pumping with a single well and no delay, and pumping multiple wells with no delay, and either a 1-, 3-, 5-, or 10-yr delay. Pumping is assumed to begin on October 1, 1987, for the cases with no delay. All of the delay times are assumed to be from October 1, 1987.

4.1.2 Results and Discussion

Figure 3 illustrates the maximal predicted uranium concentration at the U1/U2 site under three remedial alternatives assuming an October 1, 1987, start time:

- No pumping
- Single-well pumping at 35 gal/min
- Two downgradient wells pumping each at 100 gal/min.

The uranium concentration in groundwater discharged to the Columbia River may be calculated using a dilution factor of ten, a conservative value based on the earlier PNL one-dimensional transport simulations. The single-well (299-W19-9) pumping at 35 gal/min cannot clean the U1/U2 plume to a level of 3 to 10 pCi/L measured at the U1/U2 site. Extended pumping of the well leaves a residual plume that migrates to the Columbia River and exceeds the 3- to 10-pCi/L range when measured at the discharge point to the river. A two-well scheme with each well pumping at 100 gal/min for 10 to 15 yr effectively cleans the U1/U2 plume to as low as 63 pCi/L at the U1/U2 site. Approximately five years of pumping are required to reduce the U1/U2 plume to a level so that the residual plume, when measured at the Columbia River, does not exceed the 10-pCi/L range. Thus, effective remediation at the U1/U2 site is feasible, provided additional pumping wells are installed.

Table 3 displays the maximal predicted uranium concentrations at the U1/U2 site under the two withdrawal well alternative, given delays of implementation of 0, 1, 3, 5, and 10 yr. Table 4 displays the maximal predicted uranium concentrations at the U1/U2 site under the single-well alternative, assuming pumping started in October 1987. It is apparent that delaying implementation of the two-withdrawal-well system at the U1/U2 site does not significantly reduce its efficiency. This is due to the minor plume movement over a 10-yr period as predicted by the subregional model (Figure 4). The groundwater pore velocity is approximately 10 ft/yr in the vicinity of the U1/U2 cribs and the 200 West Area. The average pore velocity along a stream tube from the U1/U2 site to the Columbia River is estimated to be one to two orders-of-magnitude higher. Thus, the U1/U2 plume does not pose a migration problem at the present time or the near future.

As previously discussed, the two-dimensional subregional and one-dimensional regional transport simulations are subject to significant uncertainties because of lack of information regarding the: (1) vertical and horizontal extent of contamination; (2) inadequate source identification; (3) two-dimensional modeling hypothesis (i.e., no vertical variation in media properties or contamination) which was used because of the lack of three-dimensional data; and

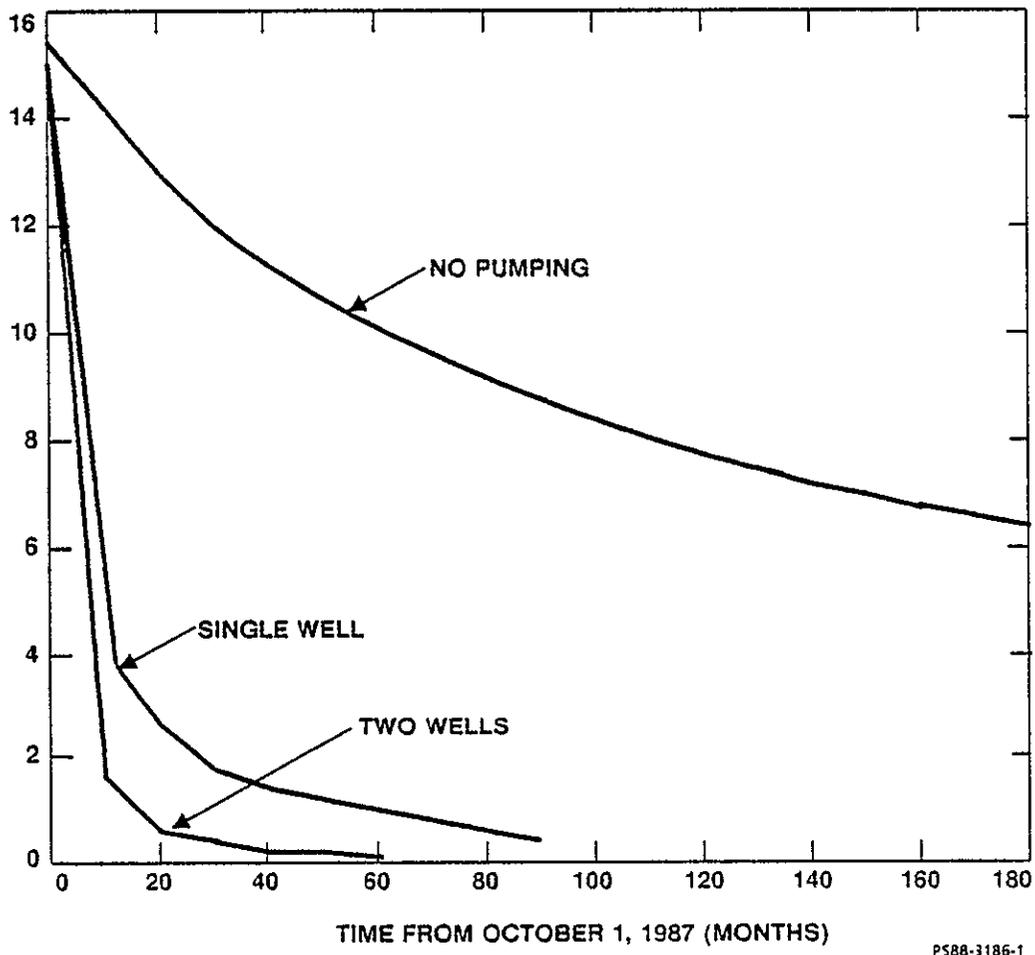


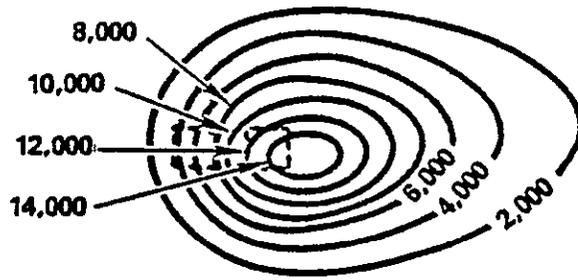
Figure 3. Maximal Predicted Uranium Concentration within Subregion for Three Remediation Alternatives.

Table 4. Maximal Predicted Uranium Concentration Within U1/U2 Subregion for Single Pumping Well Remediation Alternative.

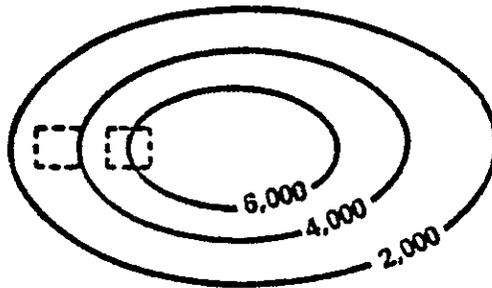
Time from October 1, 1987 (months)	Pumping single well at 35 gal/min
0	15,557
10	3,943
20	2,358
30	1,644
40	1,234
50	967
60	780
70	648
80	546
90	470
100	--
110	--
120	--
130	--
140	--
150	--
160	--
170	--
180	--

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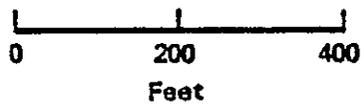
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Concentrations at October 1, 1987



Concentrations After 10 Years of No Action



Contour Interval = 2,000 pCi/L

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Figure 4. U1/U2 Plume Movement Under No-Action Alternative.

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(4) hydraulic conductivity distribution. These uncertainties do not preclude concluding that the plume is moving slowly enough that delay will not cause time or schedule penalties. They do prevent complete design of the cleanup system. For example; stratification of the contaminant would affect the design of the pumping wells, and the presence of higher hydraulic conductivity or lower porosity materials in the vicinity of the U1/U2 site could potentially disperse the uranium plume and significantly reduce the efficiency of any pump-and-treat system. Thus, it is imperative to more fully characterize the contamination site.

4.2 PUMPING METHODOLOGY

Computer simulations were performed to determine contaminant concentration versus pumping time and delay in resumption of cleanup (Table 3 and Figure 3). Costs associated with the single- and double-well field designs and various pumping delays were estimated and are presented in Table 5. These tables provided the basis for judging the most cost- effective remedial action. Secondary waste disposal costs were not included in this evaluation. Cost estimates are grouped into four categories:

- Single well pumping - capital expenses
- Single well pumping - operating expenses
- Two well pumping - capital expenses
- Two well pumping - operating expenses.

Table 5. Cost Estimates.

Costs	One well pumping (\$)	Two wells pumping (\$)
Capital expenses		
Well installation	0	120,000
Treatment system	900,000	1,800,000
Total	900,000	1,920,000
Operational expenses/yr	420,000	840,000

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Capital costs include purchase and installation of major expense equipment. For the cleanup scenario employing the single well pumping design, one-half of the capital cost for the treatment system is assumed.

Capital cost for the two well pumping configuration includes:

- Costs for two well installations were estimated at \$60,000 per well assuming that the completed installations would cost \$200/ft and that each well would be 300 ft deep.

- An enlarged uranium treatment system with a design efficiency of >99% has an estimated cost of \$1,800,000. The treatment system uses prefiltration, reverse osmosis, and ion exchange technologies. Appendix B provides details of the design and cost estimates.

Operating costs were estimated by doubling the operating costs from the single well cleanup campaign of \$35,000/mo provided by Westinghouse Hanford. This factor assumes that inflationary increases since 1985 are reduced by an increase in labor efficiency (i.e., operating two wells does not require twice as much labor expenditure as operating one well). Costs for disposal of ion exchanger regenerant wastes were not evaluated, so the cost of secondary waste disposal was not included in Table 4.

4.3 IMPACT OF DELAY

No significant impact on efficiency of a pump-and-treat system is foreseen if implementation of remediation at the U1/U2 site is delayed up to 10 yr. Delay has no significant impact for the following reasons: (1) a feasible withdrawal well field encompasses installation of two new pumping wells; (2) capital expenses are fixed (assuming inflation is negligible); and (3) the U1/U2 plume is currently located within a low permeability zone. Key uncertainties that could affect this decision are associated with the spatial extent of contamination, media property variations, and large wastewater discharges that could disperse the U1/U2 plume.

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5.0 REFERENCES

- Considine, D. M., ed, 1974, *Chemical and Process Technology Encyclopedia*, McGraw-Hill Book Company, New York, New York.
- DOE, 1984, "Radioactive Waste Management," DOE Order 5480.2, U.S. Department of Energy, Washington, D.C.
- DOE, 1985, "Comprehensive Environmental Response, Compensation, and Liability Act Program," DOE Order 5480.14, U.S. Department of Energy, Washington, D.C.
- DOE, 1986, "Environmental, Safety, and Health Programs for Department of Energy Operation," DOE Order 5480.1B, U.S. Department of Energy, Washington, D.C.
- DOE, 1987, "Radiation Protection of the Public and Environment," DOE Order 5480.xx, U.S. Department of Energy, Washington, D.C.
- DOE-RL, 1986, *Draft - Phase I Installation Assessment of Inactive Waste-Disposal Sites at Hanford*, U.S. Department of Energy-Richland Operations Office, Richland, Washington.
- DOE-RL, 1987, *Hanford Site Waste Management Units Report*, U.S. Department of Energy-Richland Operations Office, Richland, Washington.
- EPA, 1981, *Treatability Manual*, Volume III, Technologies for Control/Removal of Pollutants, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
- EPA, 1985, Title 40, "Protection of Environment," Part 141, "National Interim Primary Drinking Water Regulation," 40 CFR 141, *U.S. Code of Federal Regulations*, U.S. Environmental Protection Agency, Washington, D.C.
- EPA, 1985a, *Drinking Water Criteria Document for Uranium*, Office of Drinking Water, U.S. Environmental Protection Agency, April 1985, Washington, D.C.
- EPA, 1985b, *Handbook: Remedial Action at Waste Disposal Sites*, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
- EPA, 1986, Advanced Notice of Proposed Rule Making, *Water Pollution Control; National Primary Drinking Water Regulations; Radionuclides*, Federal Register, Volume 51, Number 189, p. 34836, U.S. Environmental Protection Agency, Washington, D.C., September.
- EPA, 1987a, "Alternate Concentration Limit Guidance for Hazardous Waste Management Facilities - Notice of Availability of Guidance Manual," *Federal Register*, Vol. 52, p. 27579, U.S. Environmental Protection Agency, Washington, D.C.

- EPA, 1987b, "National Priorities List for Uncontrolled Hazardous Waste Sites: Federal Facility Site Proposed Rule," 40 CFR 300, *Federal Register*, Vol. 52, p. 27645, U.S. Environmental Protection Agency, Washington, D.C.
- GPO, 1976, *Resource Conservation and Recovery Act*, U.S. Government Printing Office, Washington, D.C.
- Gupta, S. K., C. R. Cole, C. T. Kincaid, and A. M. Monti, 1987, *Coupled Fluid, Energy, and Solute Transport (CFEST) Model: Formulation and User's Manual*, BMI/ONWI-660, Office of Nuclear Waste Isolation, Columbus, Ohio.
- Lapedes, D. N., 1978, *Dictionary of Scientific and Technical Terms*, McGraw-Hill Book Company, New York, New York.
- NRC, 1986, Title 10, "Energy," Part 20, "Standards for Protection Against Radiation," 10 CFR 20, *U.S. Code of Federal Regulations*, U.S. Environmental Protection Agency, Washington, D.C.
- Palmer, G. R., I. L. Nichols, and D. C. Seidel, 1979, *Elution of Uranyl Carbonate from a Strong Base Resin with a Mixed Carbonate Eluant in a Fluidized Bed System*, Report of Investigation 8370, Bureau of Mines, Washington, D.C.
- PNL, May 1986, *Environmental Monitoring at Hanford for 1986*, Pacific Northwest Laboratory, PNL-6120, Richland, Washington.
- Ranon, D., 1973, "The Behavior in Underground Environments of Uranium and Thorium Discharged by the Nuclear Industry," in *Environmental Behavior of Radionuclides Released in the Nuclear Industry*, IAEA-SM-172/55, pp. 333-346 (in French), cited in Onishi et al., 1981.
- Ryan, J. P. and R. E. Stimson, 1984, *Technical Data Summary F/H Effluent Treatment Facility*, E.I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.
- Schulz, W. W., C. W. Mallory, R. L. Wallace, and E. J. Wheelwright, 1983, *Ion Exchange and Adsorption in Nuclear Chemical Engineering*, AIChE Annual Meeting, Fall 1983, Washington, D.C.
- Simmons, C. S., C. T. Kincaid, and A. E. Reisenauer, 1986, *A Simplified Model for Radioactive Contaminant Transport: the Transs Code*, PNL-6029, Pacific Northwest Laboratory, Richland, Washington.
- Traut, D. E., I. L. Nichols, and D.C. Seidel, 1974, *Design Requirements for Uranium Ion Exchange from Acidic Solutions in a Fluidized System*, Report of Investigations, 282, Bureau of Mines, Washington, D.C.
- WDOE, 1986, "Drinking Water Standards," *Washington Administrative Code*, WAC 173-201, State of Washington Department of Ecology, Olympia, Washington.
- WDOE, 1987a, "Dangerous Waste Regulations," *Washington Administrative Code*, WAC 173-303, State of Washington Department of Ecology, Olympia, Washington.
- WDOE, 1987b, "Standards for Protection Against Radiation," WAC 402, *Washington Administrative Code*, State of Washington Department of Ecology, Olympia, Washington.

APPENDIX A

**GROUNDWATER FLOW AND CONTAMINANT TRANSPORT
MODELING TO INVESTIGATE REMEDIAL
ACTIONS AT THE 216-U-1,2 CRIBS**

In 1985, elevated concentrations of uranium were observed in wells monitoring the groundwater near the 216-U-1 and U-2 cribs (Figure A-1). Analysis of the contamination demonstrated that the uranium is present in the groundwater as an anionic carbonate complex that is not attenuated by Hanford sediments. The investigation also produced evidence that the uranium had reached the groundwater by flowing down existing well casings and that water flow to the 216-U-16 crib provided the driving force for transport of the uranium. Water flow to the U-16 crib was stopped immediately after the high uranium concentrations were observed in the groundwater. The existing wells monitoring the U-1 and U-2 cribs were grouted to prevent them from continuing to be pathways for further contamination of the groundwater.

In an effort to remediate the uranium contamination, Westinghouse Hanford Company (Westinghouse Hanford) pumped groundwater from well 299-W19-9 and recovered uranium with an anion exchange column. The pumping was initiated in June 1985 and continued for 6 mo. Uranium concentrations in the pumped well and other nearby wells were observed to decrease with time.

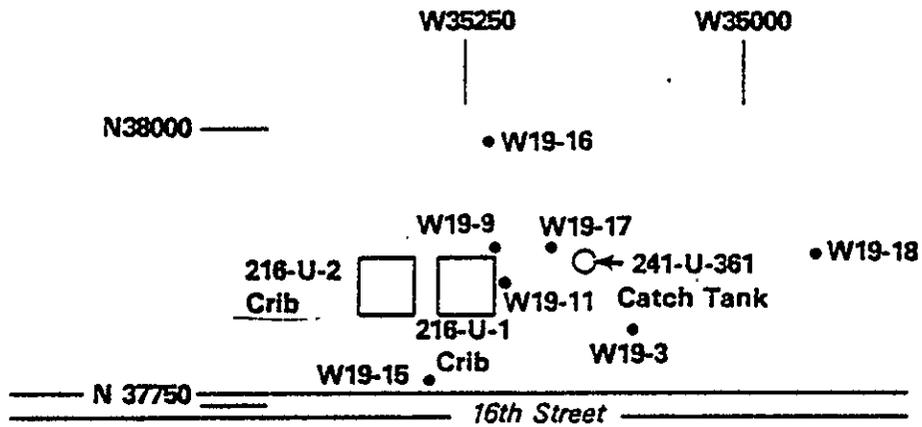
As a part of the Westinghouse Hanford evaluation of alternatives for further remedial action of uranium contamination beneath the U-1 and U-2 cribs, the Pacific Northwest Laboratories (PNL) applied groundwater and contaminant transport models to predict the fate of the uranium in the unconfined aquifer at the Hanford Site.

**A.1 MODELING THE ALTERNATIVES FOR
ADDITIONAL CLEANUP**

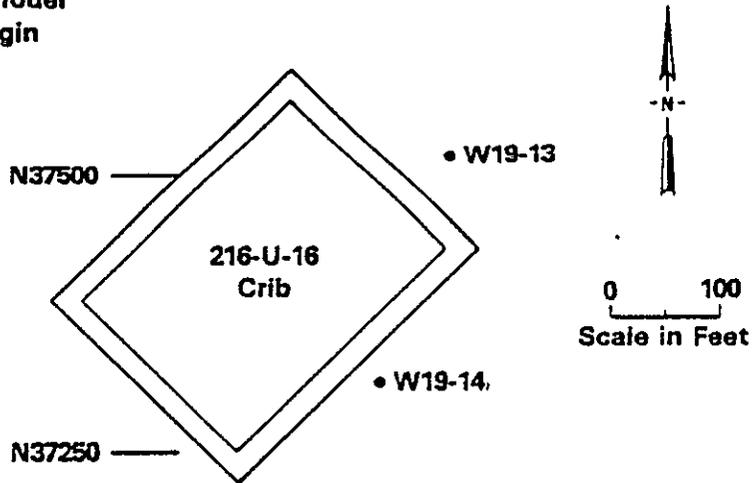
The purposes of modeling the uranium contamination beneath the U-1 and U-2 cribs were to evaluate the mass of uranium in the aquifer, predict short-term transport of the uranium, and predict the long-term fate of the contamination in the unconfined aquifer. The uranium plume occupies a small portion of the 200 West Area beneath the U-1 and U-2 cribs. A single groundwater flow and contaminant transport model was not appropriate for predicting the fate of the uranium contamination. As a result, three different models were applied to predict movement of the uranium.

A two-dimensional groundwater flow model of the unconfined aquifer based on the Coupled Fluid, Energy, and Solute Transport (CFEST) code (Gupta et al. 1987) was applied to establish the water table conditions for the entire Hanford Site and predict streamlines, pathlines, and associated travel times from the U-1 and U-2 cribs. A two-dimensional subregion of the site-wide model (also based on CFEST) was modeled to evaluate groundwater flow, estimate the amount of uranium in the aquifer, and predict uranium transport in the vicinity of the U-1 and U-2 cribs over a period of 15 yr. The movement of uranium from the U-1 and U-2 cribs to the Columbia River was predicted with the TRANSS code (Simmons et al. 1986), which simulates contaminant transport in one dimension along a streamline or pathline. The streamlines, pathlines, and associated travel times considered for uranium transport were predicted with the groundwater flow model of the unconfined aquifer based on CFEST.

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Submodel
 ● Origin



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Figure A-1. Monitoring Wells for the 216-U-1,2 Cribs and Vicinity.

A.2 SUBMODEL OF THE U-1 AND U-2 CRIBS AND VICINITY

The finite-element grid for the submodel in the vicinity of the U-1 and U-2 cribs is based on groundwater flow velocities predicted with the two-dimensional model of the unconfined aquifer at the Hanford Site based on the CFEST code. The grid is regularly spaced at 30 ft and a monthly timestep was used to minimize numerical dispersion. The subregion is 510 ft in the north-south direction and 1620 ft in the east-west direction because the direction of groundwater flow beneath the U-1 and U-2 cribs is toward the east.

The submodel solution for hydraulic head is illustrated in Figure A-2. This solution was obtained by first applying the groundwater flow model of the entire Hanford Site to establish the general water-table conditions near the U-1 and U-2 cribs. The solution from the Hanford Site model was then interpolated at the submodel boundary nodes. These nodes are specified as constant head and provide boundary conditions for the groundwater flow and transport submodel. The distribution of hydraulic head in Figure A-2 was selected to represent average conditions in the aquifer during the 15 yr simulation with the subregion model.

The first step for predicting short-term transport was to input the initial distribution of uranium in the aquifer. The observed distribution of total uranium in the aquifer in January 1986 (Figure A-3) was input to the transport model as an initial condition.

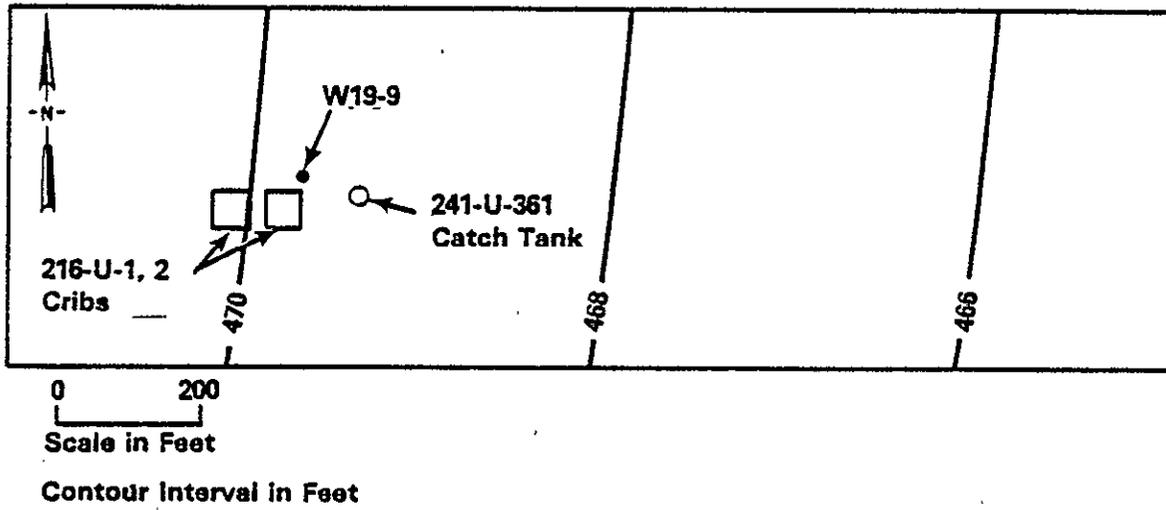
Input of the observed contaminant concentrations allows the model to be used to estimate the amount of uranium in the aquifer. This estimate of uranium mass is preliminary because only limited field measurements are available to confirm the estimate. The predicted distribution of uranium in the aquifer after 15 yr is illustrated in Figure A-4. The mass of uranium in the aquifer at that time is estimated to be 868 kg.

The effects of continuing to pump from well 299-W19-9 for 3, 6, and 12 mo were simulated with the subregion model to predict the amount of uranium remaining in the aquifer and the amount recovered by the different pumping alternatives (Table A-1). In the first row of Table A-1, the 687 kg of uranium recovered from the previous 6 mo of pumping was measured. The 830-kg value is the amount of uranium in the aquifer estimated with the subregion model. The predicted amount for each pumping alternative is the mass of uranium pumped from the ground. The efficiency of the ion exchange column in removing uranium is not reflected in the amounts of uranium in Table A-1. The ion exchange column is assumed to be 100% efficient.

The effectiveness of pumping can be evaluated by comparing the rates of uranium recovery with time predicted by the model. The rate of uranium recovery listed in Table A-1 is calculated by dividing the amount of uranium removed from the aquifer by the time of pumping. For example, 71 kg/mo represents 213 kg of uranium recovered over 3 mo of pumping. The rates in Table A-1 decrease as the length of pumping increases. Therefore, the rate of uranium removal for the pumping system will decrease with time.

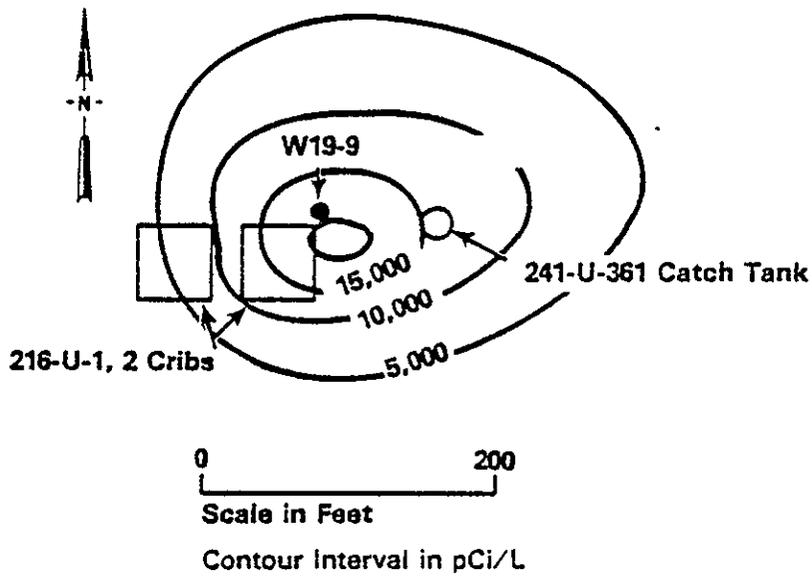
A.3 GROUNDWATER FLOW MODELING

Groundwater flow for the entire Hanford Site was simulated for three cases of future effluent disposal. In the first case (Case 1), the current discharges were assumed to remain constant and steady-state conditions were simulated. In Case 2, the discharges are assumed to remain at the current rate until the year 1995 when cooling water and steam condensate volumes are reduced by



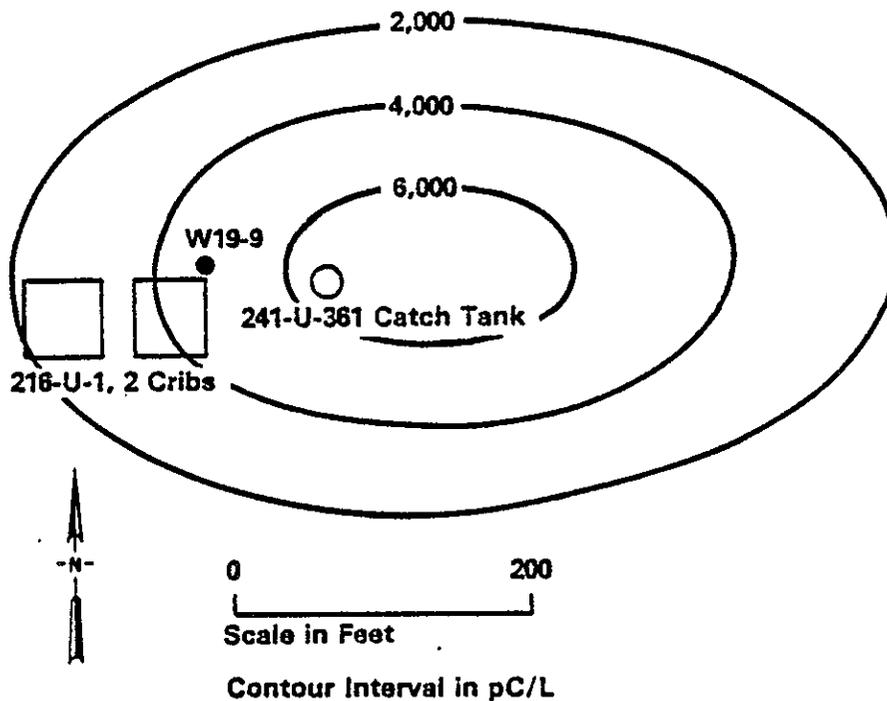
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Figure A-2. Distribution of Hydraulic Head for the Subregion Model.



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Figure A-3. Measured Distribution of Uranium in the Unconfined Aquifer Near the U-1 and U-2 Cribs.



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Figure A-4. Distribution of Uranium in the Unconfined Aquifer Near the U-1 and U-2 Cribs Predicted After 15 Years.

Table A-1. Predicted Amounts of Uranium Recovered and Remaining in the Aquifer for Different Pumping Alternatives.

	Uranium remaining (kg)	Uranium recovered (kg)	Recovery rate (kg/mo)
Previous 6 months pumping	830	687	114
No further pumping	830	0	0
3 months additional pumping	617	213	71
6 months additional pumping	505	325	54
12 months additional pumping	372	458	38

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90%. The simulation for Case 2 was continued until steady-state conditions were reached for the reduced discharge conditions. Case 3 was identical to Case 2, except the cooling water and steam condensate volumes are assumed to be reduced by 90% in the year 2010. Transient groundwater flow conditions were simulated in both Cases 2 and 3.

In the transient simulations, a specific storage of 0.006 was assumed for the aquifer around the 200 West Area and 0.01 was assumed for the remainder of the unconfined aquifer.

These specific storage values provided the best match between observed and predicted water-level decline when U Pond was decommissioned in 1985.

Both the steady-state and transient solutions are based on the transmissivity distribution obtained from an initial inverse calibration of the two-dimensional groundwater flow model for the unconfined aquifer based on the CFEST code. The distribution of hydraulic head resulting from steady-state solution for current conditions (Case 1) is illustrated in Figure A-5. The distributions of hydraulic head at years 1995 and 2105 for transient simulation of the reduced discharges (Case 2) are illustrated in Figures A-6 and A-7, respectively.

The distributions of hydraulic head near B Pond in Figures A-5 and A-6 are not the same because different conditions were simulated for each case. The hydraulic heads near B Pond in Figure A-5 are from steady-state simulation of the current rate of discharge. The hydraulic heads in Figure A-6 reflect transient simulation from an observed water table condition.

The distributions of hydraulic head for Case 3 are similar to those for Case 2. The distribution of hydraulic head for the reduced discharges (Cases 2 and 3) once steady-state conditions are reached is shown in Figure A-8.

A.4 TRANSS PREDICTIONS

Uranium transport was not modeled in two dimensions for the entire path to the Columbia River. The grid spacing required to describe transport of the uranium plume to the river with a two-dimensional model based on CFEST makes the problem impractical to solve. In addition, the uncertainties in the future flow paths and contaminant transport parameters such as dispersion coefficients along the entire path length make two-dimensional representation of uranium transport to the river unrealistic.

The lengths and travel times for streamlines and pathlines from the U-1,2 cribs to the river were determined with the CFEST code. The streamlines for liquid discharges remaining at current conditions (Case 1) are illustrated in Figure A-5. Pathlines for the liquid discharges reduced in the year 1995 and 2010 are illustrated in Figures A-9 and A-10, respectively. The lengths and travel times for these streamlines and pathlines are averages of several different paths from the U-1 and U-2 cribs. The different paths were simulated to account for potential variations of water-table conditions in the unconfined aquifer. The average path lengths and travel times predicted with CFEST for the different liquid discharge conditions are summarized in Table A-2.

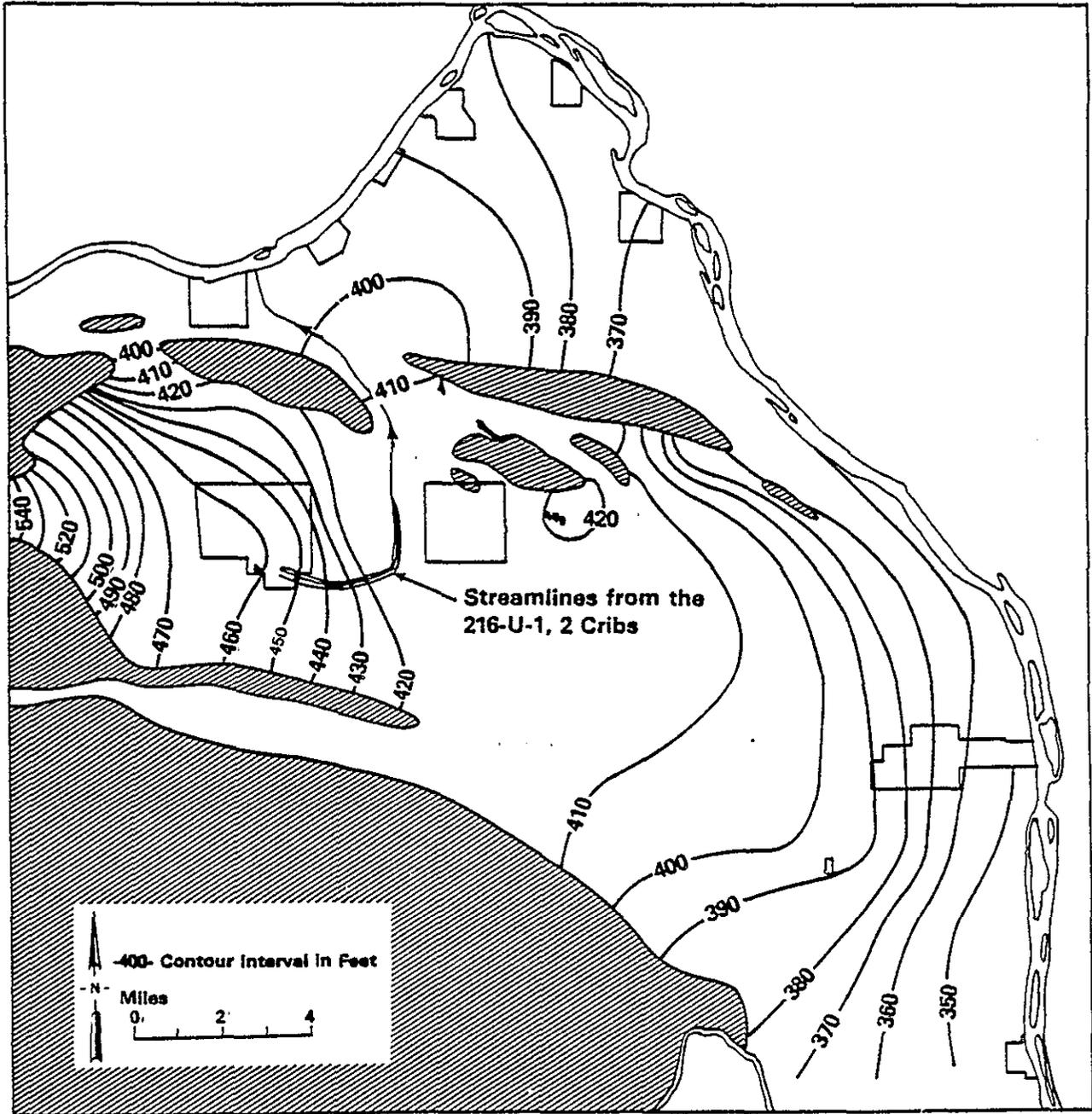
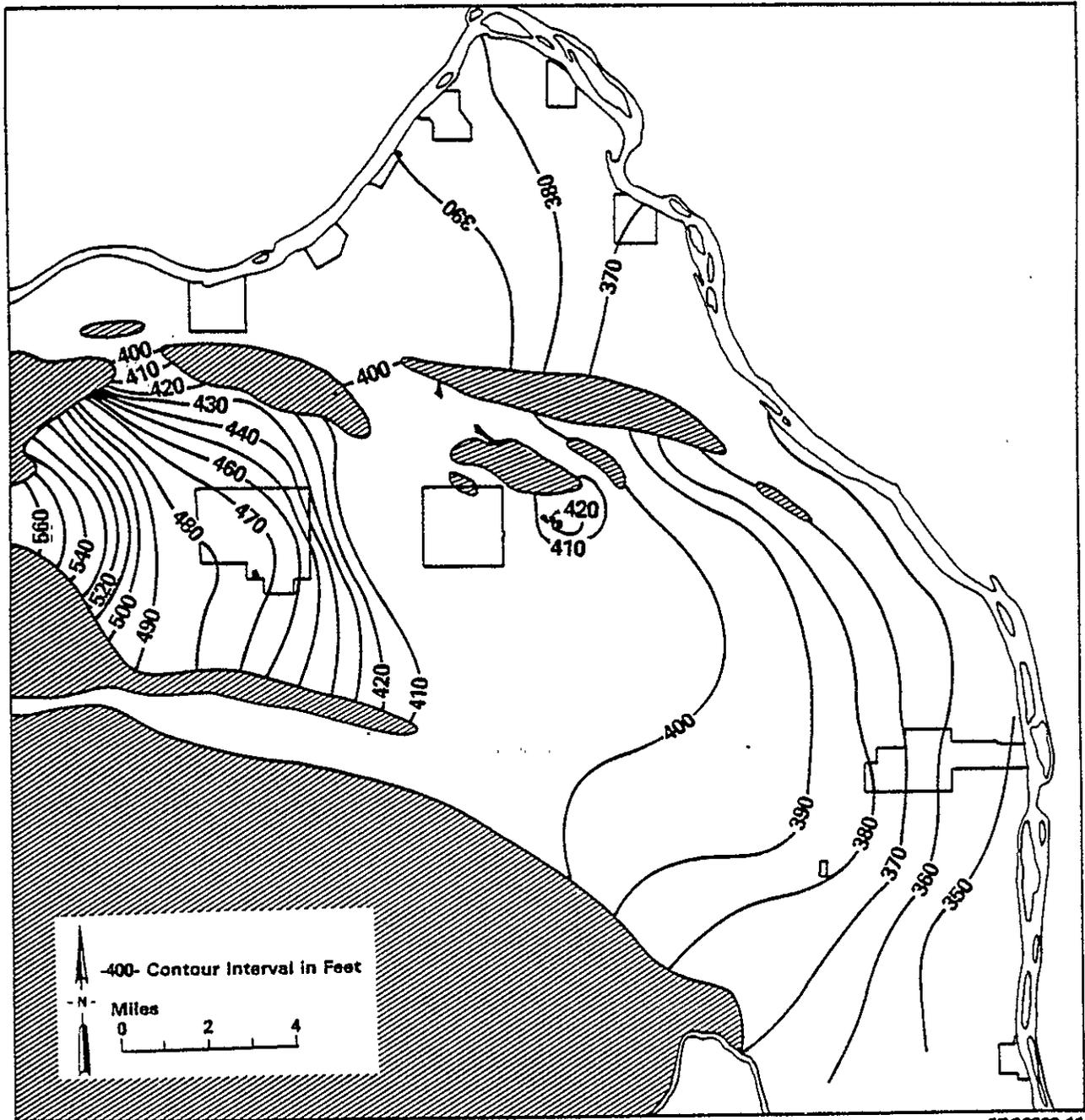


Figure A-5. Steady-State Distribution of Hydraulic Head for Current Discharge Conditions. (Case 1)

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Figure A-6. Distribution of Hydraulic Head at 1995 for Case 2.

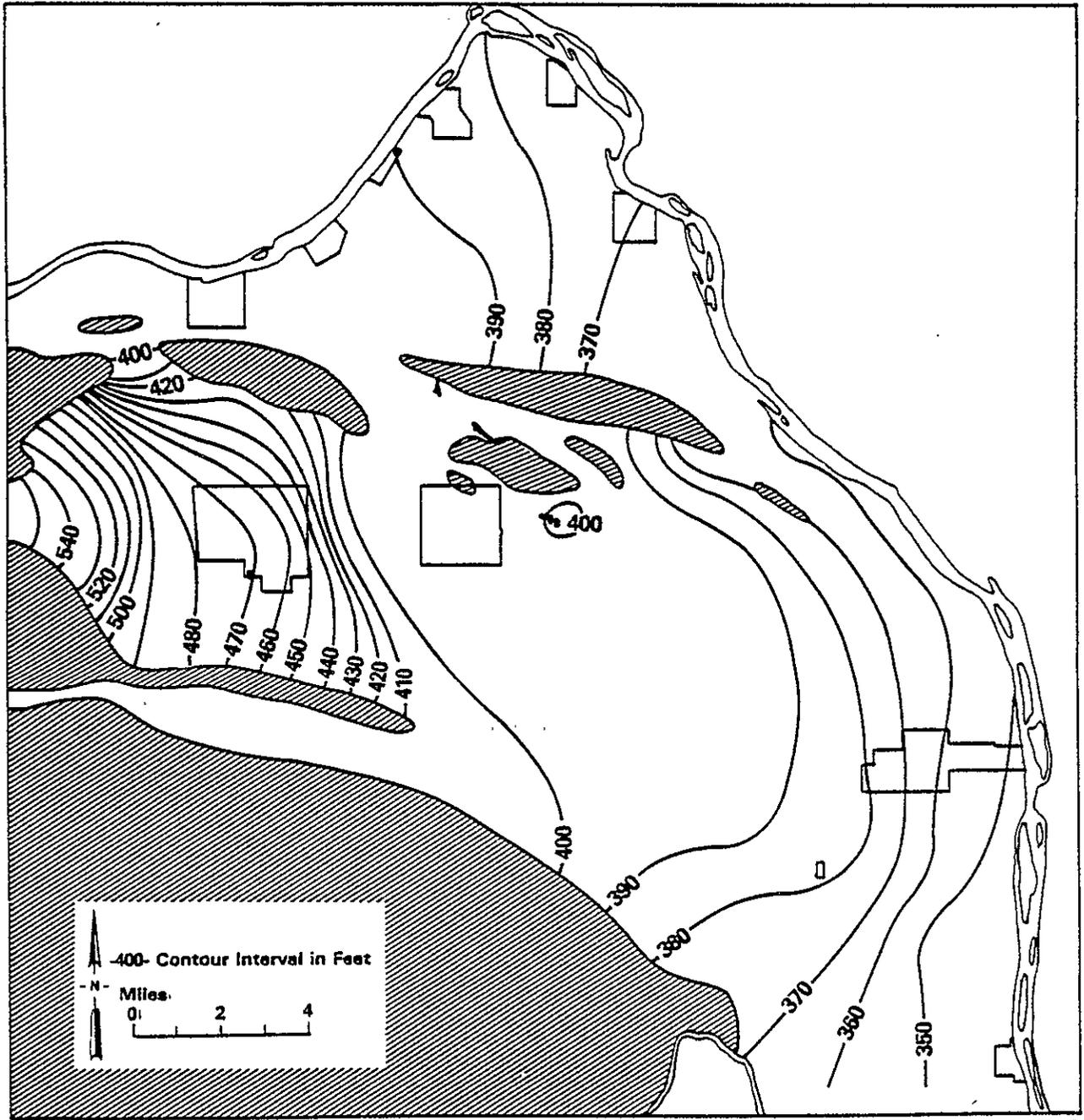


Figure A-7. Distribution of Hydraulic Head at 2105 for Case 2.

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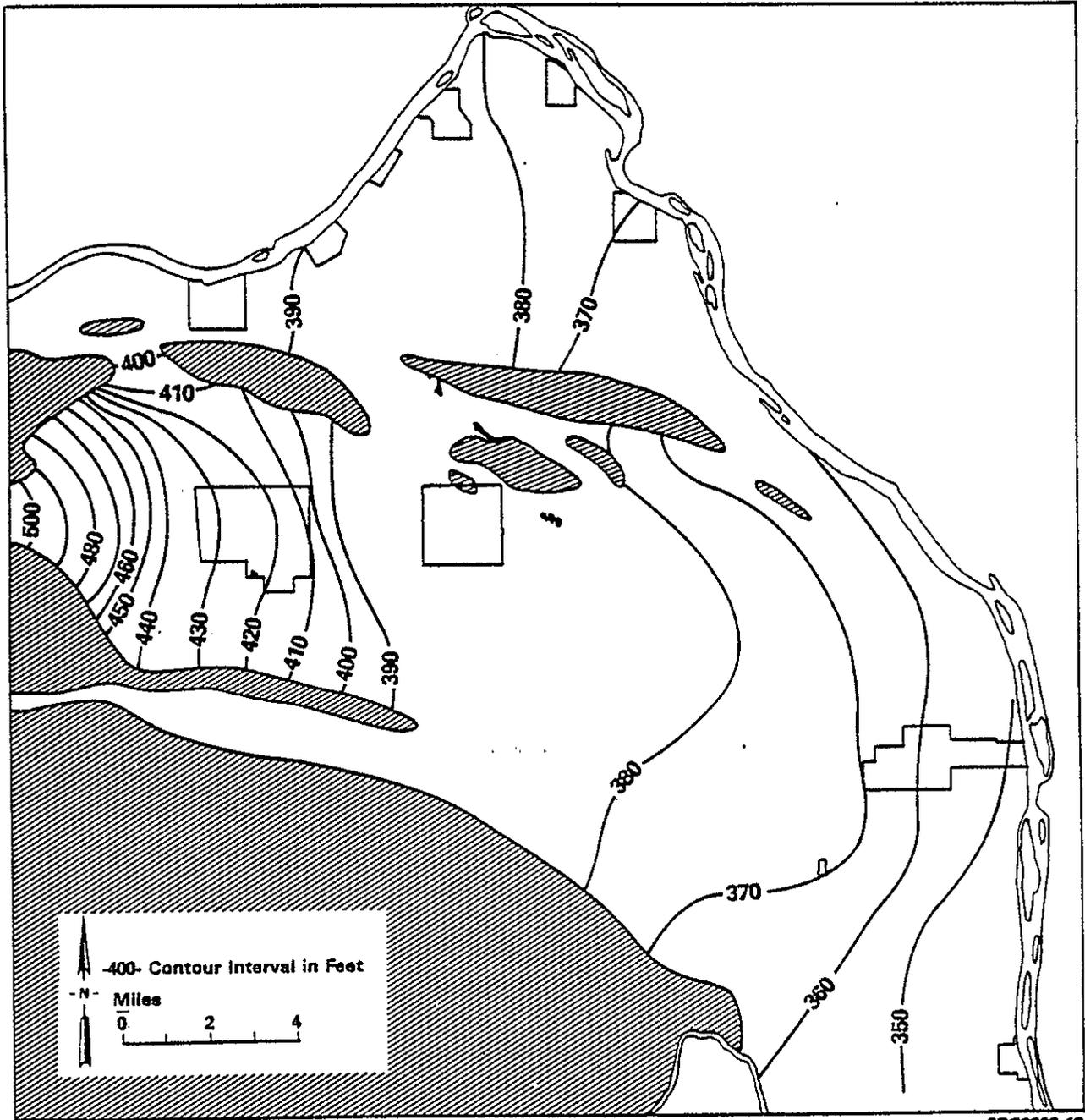
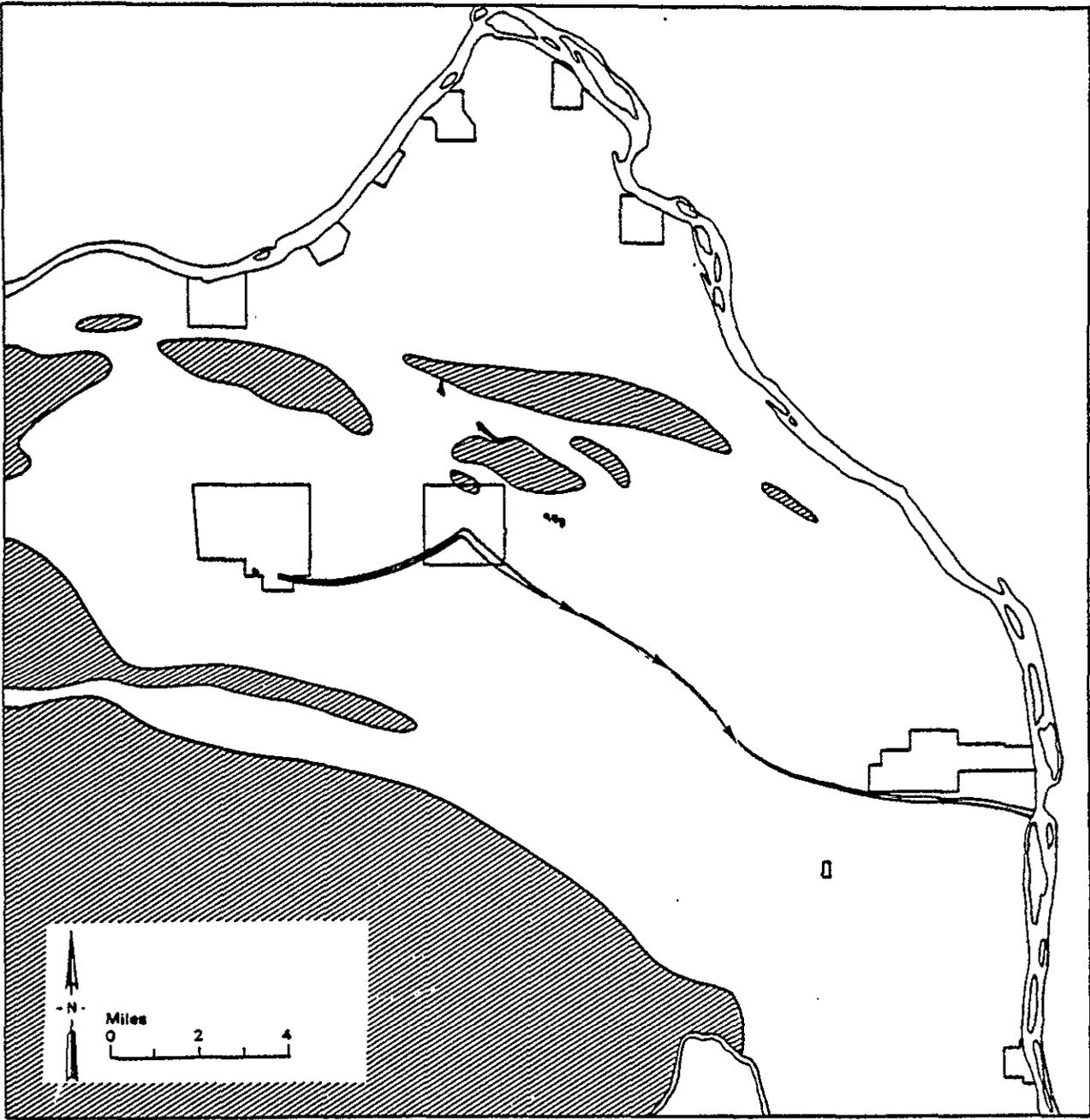


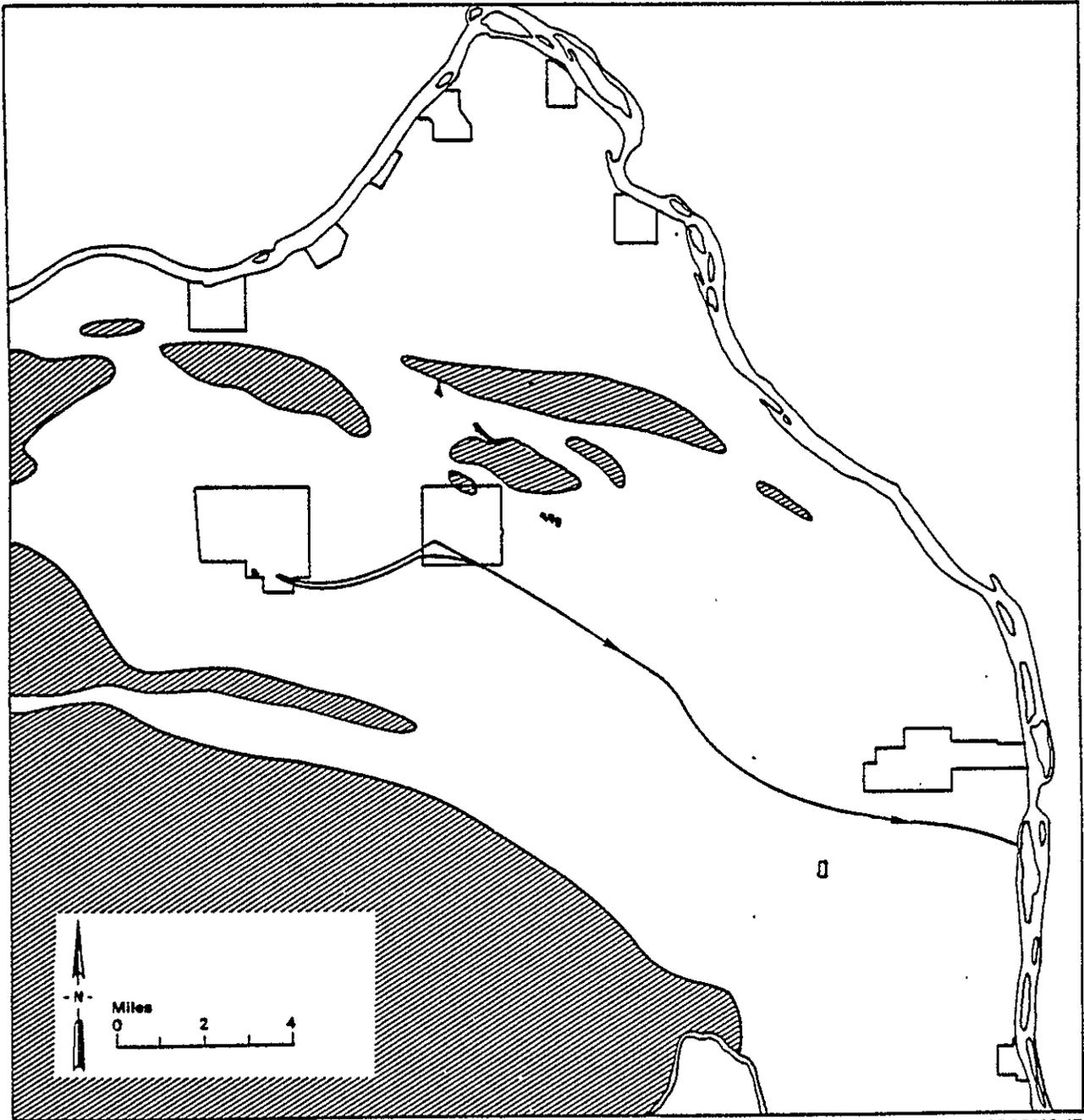
Figure A-8. Steady-State Distribution of Hydraulic Head for Reduced Discharge Conditions. (Case 2 and 3)



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Figure A-9. Pathlines Predicted for Cooling Water and Steam Condensate Volume Reduced in Year 1995. (Case 2)

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2PS8902-15

Figure A-10. Pathlines Predicted for Cooling Water and Steam Condensate Volumes Reduced in Year 2010 (Case 3)

Table A-2. Average Path Lengths and Travel Times from the U-1 and U-2 Cribs to the Columbia River for the Different Cases Considered.

Case	Path length (ft)	Travel time (yr)
1	62,030	130
2	105,720	150
3	101,660	150

PST88-3186-A2

Predictions of uranium transport to the river were made with the TRANSS code by considering the inventory and half life of each isotope, dimensions of a streamtube for estimating concentration, and contaminant transport parameters. The distribution of total uranium in the aquifer predicted with the sub-region model (Figure A-4) was integrated with the CFEST code into a mass and converted to total activity in curies (Ci) for input to the TRANSS code. The activities of ²³⁴U, ²³⁵U, and ²³⁸U were estimated with the fractional activity of each isotope. The inventory and half life for each uranium isotope are listed in Table A-3.

Table A-3. Inventory and Half Life of Uranium Isotopes in the U-1 and U-2 Analysis.

Isotope	Inventory (Ci)	Half life (yr)
²³⁴ U	0.290	2.47 x 10 ⁵
²³⁵ U	0.012	7.1 x 10 ⁸
²³⁸ U	0.287	4.51 x 10 ⁹

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A 700-ft wide by 50-ft deep streamtube was used to predict the concentrations. The 700-ft streamtube width was determined by simulating different pathlines from near the U-1 and U-2 cribs. The spread of the different pathlines was used to estimate the width of the streamtube for uranium transport. The 50-ft depth was determined from concentration data collected to monitor the uranium in the groundwater beneath the U-1 and U-2 cribs. The monitoring data indicates that the contamination may extend into the aquifer as far as 80 ft, but most of the contamination is located within the upper 50 ft. Further characterization is needed to determine the vertical distribution of uranium beneath the U-1 and U-2 cribs. Based on field measurements and previous modeling efforts, the effective porosity was assumed to be 0.10 and the longitudinal dispersivity was assumed to be 100 ft for the transport predictions with TRANSS. The resulting peak concentrations at the Columbia River predicted for each case are summarized in Table A-4.

Table A-4. Predicted Peak Concentrations of Uranium at the Columbia River.

Case	Predicted peak concentration (pCi/L)			
	234U	235U	238U	Total U
1	320	10	320	650
2	250	10	250	510
3	240	10	240	490

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For each of the discharge conditions simulated, the peak uranium concentration is predicted to have reached the Columbia River before the loss of institutional control for the Hanford Site, assumed to be 164 yr. However, some uranium is expected to remain in the aquifer when institutional control is lost. Predictions of uranium transport with TRANSS demonstrate that the average concentration of uranium remaining in the aquifer at the end of institutional control for Cases 1 and 3 will be less than 1 pCi/L. For Case 2, the average concentration of uranium remaining in the aquifer will be 10 pCi/L over 40 yr, beginning at the loss of institutional control.

A.5 SUMMARY AND RECOMMENDATIONS

Assistance with evaluation of the need for further groundwater pumping and uranium removal at the U-1 and U-2 cribs consisted of: (1) modeling two-dimensional groundwater flow and uranium transport in the vicinity of the cribs, and (2) projecting the impacts of the contamination on groundwater quality in the future. The predicted concentrations can be compared with the appropriate concentration guidelines to determine the need for further remedial actions. Predictions of groundwater flow and uranium transport in the vicinity of the U-1 and U-2 cribs were made with a reasonable degree of confidence. This confidence exists because the modeling was done from observed initial conditions and the predicted uranium concentrations compare reasonably well with the measured concentrations. Uranium transport from the U-1 and U-2 cribs to the Columbia River was predicted with the TRANSS code in one dimension along a streamline or pathline. The long-term predictions of uranium transport to the Columbia River along streamlines and pathlines were made with less confidence than predictions of transport near the U-1 and U-2 cribs. Confidence is lower in the long-term predictions because the flow paths are uncertain and the predictions cannot be compared with observations. Discharging at the current rate for an additional 15 yr before reducing the cooling water and steam condensate volumes by 90% has minimal impact on the path length and travel time from the U-1 and U-2 cribs to the river. The effect of other parameters on the predicted flow paths, such as the effective porosity and the distributions of transmissivity and storage coefficient, was not investigated.

Before additional modeling is done to evaluate the alternatives for remedial action and determine the appropriate location(s) of pumping well(s), the uranium plume needs further characterization. This characterization should focus on better definition of the horizontal and vertical distribution of uranium in the aquifer, determination of the aquifer properties near the U-1,2 cribs, and further definition of the geochemistry of uranium in Hanford Site groundwater.

A.6 REFERENCES

Gupta, S. K., C. R. Cole, C. T. Kincaid, and A. M. Monti, 1987, *Coupled Fluid, Energy, and Solute Transport (CFEST) Model: Formulation and User's Manual*, BMI/ONWI-660, Office of Nuclear Waste Isolation, Columbus, Ohio.

Simmons, C. S., C. T. Kincaid, and A. E. Reisenauer, 1986, *A Simplified Model for Radioactive Contaminant Transport: the TRANSS Code*, PNL-6029, Pacific Northwest Laboratory, Richland, Washington.

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APPENDIX B

APPLICABLE U.S. DEPARTMENT OF ENERGY ORDERS AND POLICIES

Three levels of control of radiation risks have been implemented in the DOE/Hanford Site system. First, an overall offsite dose limit has been set. This limit has been apportioned across Hanford Site operations and operationalized in the form of Derived Concentration Guides (DCGs). Second, contractors are required to meet drinking water standards offsite. Third, goals have been set for groundwater quality at the time of presumed loss of institutional control.

B.1 OVERALL HANFORD DOSE LIMITS AND DERIVED CONCENTRATION GUIDES

Under DOE Order 5480.xx (DOE 1987), soon to be issued, the whole body radiation dose to a maximally exposed offsite individual cannot exceed 100 mrem for all Hanford Site operations. At present, a limit of 500 mrem applies at the site boundary, but the lower 100-mrem limit is easily met, and is currently used for planning purposes. The DOE Order 5480.xx may apply the 100-mrem limit at unit boundaries rather than the site boundary; compliance with this limit likely requires remedial action.

The DOE has developed derived concentration guides that can be used to assess compliance with radiation requirements where it is not feasible to evaluate the exposure of individuals in uncontrolled areas directly. The DOE Orders 5480.1B (DOE 1986) and 5480.xx (DOE 1987) require that effluent releases be within certain concentration guides at the point where they pass beyond the site boundary. To meet these guidelines, groundwater concentrations at the geographic limits of the controlled areas must be within the specified concentration limits set in these orders.

Under both DOE Orders 5480.1B and 5480.xx, the uncontrolled area limit for soluble ^{238}U is 600 pCi/L. This limit applies to groundwater that is contaminated from past activities, not simply to new discharges. Currently, since all groundwater potentially affected by the U1/U2 crib is controlled, these limits apparently apply only where groundwater discharges to the Columbia River. (It should be noted that DOE Order 5480.1B allows the option of making dose calculations for users; calculated doses for users might be within levels allowable under DOE Order 5480.1B even if DCGs were exceeded in groundwater at the river.)

B.2 MEET DRINKING WATER STANDARDS OFFSITE

The DOE Orders require that drinking water standards be met offsite at the point of water use. Because of the high rate of dilution in the Columbia River this requirement poses no difficulty with respect to actual drinking water standards (MCLs) or for the internal proxies the Hanford Site has developed in the past to supplement MCLs.

B.3 GOALS RELATED TO LOSS OF INSTITUTIONAL CONTROL

The overall offsite dose limit establishes an ambitious goal for groundwater quality at the time of presumed loss of institutional control. This goal is discussed in two places. In the introduction, the document sets a goal of having all groundwater outside the future controlled zone meeting "MCLs" within 100 yr or less. This term is not qualified and the definitions section of the document states that MCLs shall be 1/25th of the DCGs where no standard is stated in 40 CFR 141. For ^{234}U this would be 20 pCi/L and for ^{238}U 24 pCi/L.

In section L, a similar goal is stated. However, in this case the goal is to meet Federal drinking water radioactivity standards (Maximum contaminant levels in 40 CFR 141) beneath the entire site by 2150. This goal is qualified, however, as follows: "these standards only apply to current and future operations in order to prevent additional degradation of the groundwater."

B.4 REFERENCES

- EPA, 1984, Title 40, "Protection of Environment," Section 141, "National Interim Drinking Water Regulations," 40 CFR 141, *U.S. Code of Federal Regulations*, U.S. Environmental Protection Agency, Washington, D.C.
- DOE, 1986, "Environmental, Safety and Health Programs for Department of Energy Operations," DOE Order 5480.1B, U.S. Department of Energy, Washington, D.C.
- DOE, 1987, "Radiation Protection of the Public and Environment," DOE Order 5480.xx, U.S. Department of Energy, Washington, D.C.

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APPENDIX C

U1/U2 TREATMENT SYSTEM: DESIGN AND COST ESTIMATE

The purpose of this investigation is to develop an initial cost estimate for the removal of uranyl carbonate anion, $UO_2(CO_3)_3^{4-}$, from groundwater. The uranyl carbonate anion has an activity of 17,000 pCi/L and is equivalent to a concentration of approximately 50 ppm. This concentration is based on the conversion factor of 3×10^{-7} Curies/g of ^{238}U . The groundwater also contains a concentration in excess of 1,000 ppm of nitrates.

At the site two wells are proposed, each with a capacity of 100 gal/min. The maximum level of control desired is 3 pCi/L (99.98% removal) with a minimum level of 100 pCi/L (99.4% removal). This level is in line with reported values of 10 to 40 pCi/L for drinking water criteria EPA 1985a). The lack of information on the groundwater quality precludes the solicitation of vendor bids. Instead, an initial cost estimate is prepared from the literature.

C.1 DEVELOPMENT OF THE COST ESTIMATE

This section describes the development of the cost estimate from the literature. A simplified flow diagram of the system evaluated is also presented.

C.2 SELECTION OF APPROPRIATE TECHNOLOGY

Uranium in ores is only mildly soluble in water; however, it rapidly dissolves in both acidic and alkaline solutions forming various anion complexes. The most typical means of extraction of uranium from ore is acid leaching (Considine 1974). After the acid and ore form a slurry, the process steps involve solid-liquid separation, filtration, countercurrent washing, and finally, the uranium recovery on an ion exchange resin (Palmer, Nichols, and Seidel 1979). Ion exchange has been used to recover uranium from acidic leach solutions since the early 1950s (Traut, Nichols, and Seidel 1974). Today in the nuclear power industry, ion exchange technology is used in every part of the fuel cycle from mine to recovery of useful transmutation products (Schultz et al. 1983). Ion exchange technologies achieve removal levels in excess of 99% with plant effluent levels of 900 to 1,000 pCi/L in the ore mining and dressing industry (EPA 1981). As a result, ion exchange is an appropriate technology for the removal of uranyl carbonate from groundwater.

C.3 UNIT PROCESSES

Ion exchange technology removes undesirable anions and cations from water by contacting the water with a resin that exchanges the ions with a set of substitute ions. Uranyl carbonate is an anion and collects on positively charged sites (anion resins). Ion exchange technology involves four operating steps: in-service, backwash, regeneration, and rinse. The ion exchange system operates until the undesirable ions are detected in the effluent and establish the breakthrough point. When this occurs, the unit is backwashed, which expands and resettles the bed. Following this occurrence, the unit is regenerated to convert the resin to its original form and finally washed before being placed

in service. Countercurrent continuous systems maintain high effluent quality, offer continuous service, require less chemicals, and offer the most concentrated regeneration waste when compared with other technologies (EPA 1981). However, this is the most expensive technology.

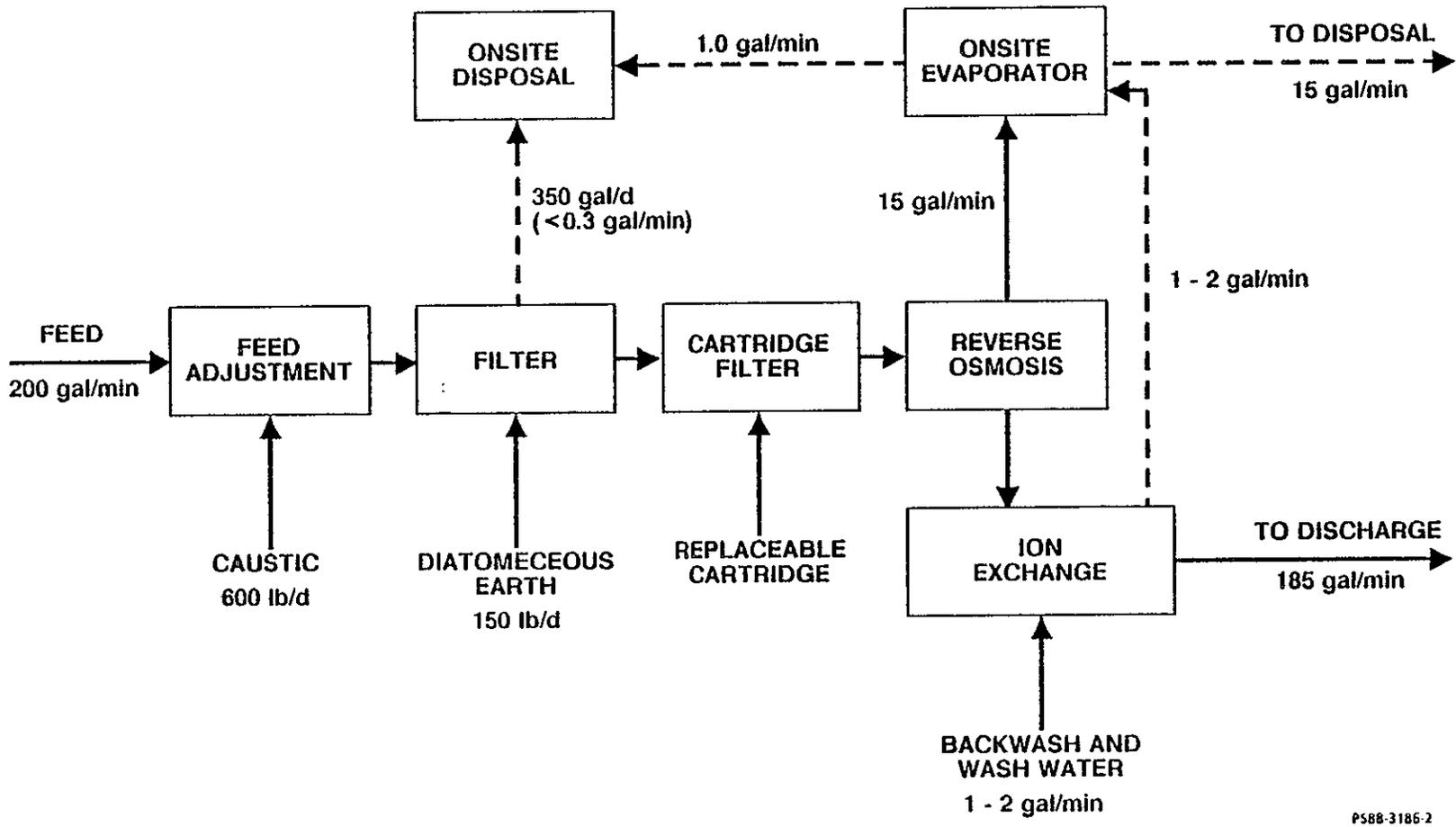
Concurrent and countercurrent fixed bed units are less expensive but are more labor intensive. The countercurrent fixed bed unit achieves high effluent quality, while the effluent quality of the concurrent fixed bed unit fluctuates with resin bed exhaustion. Insufficient information is available to select an operating mode at this time. Since water quality data are not available, the system loads cannot be calculated. Because of the high concentration of nitrate and other anions, some form of removal is required to reduce regeneration and resin usage in the ion exchange unit. As a result, for a worst case design, a reverse osmosis unit will be used prior to the ion exchange unit. The reverse osmosis system may or may not be required depending on the quality of the contaminated groundwater. However, with a required removal efficiency in excess of >99% for uranyl carbonate, the reverse osmosis unit (or other appropriate technologies including hyperfiltration or a second ion exchange unit) is most likely a necessity.

Osmosis is defined as the transport of a solvent (in this case water) through a semipermeable membrane separating two solutions of different solute concentration from the solution that is diluted in solute to the solution that is concentrated in solute (Lapedes 1978). In reverse osmosis, sufficient pressure (19 to 86 kPa) is applied to the concentrated solution to overcome the osmotic pressure and force the net flow of water through the membrane toward the dilute phase. This unit operation concentrates the solute (impurities) in a circulating system on one side of the membrane while relatively pure water is transported through the membrane (EPA 1985b).

Each of these systems requires pretreatment to remove suspended solids, adjust pH, and remove iron and silica. Pretreatment is a typical step in water treatment and reduces suspended solids and dissolved levels to allow the reverse osmosis and ion exchange units to operate most effectively. The extent of pretreatment is determined by the quality of the groundwater. As previously determined, the ion exchange technology is most effective at removal of uranyl carbonate. However, pretreatment and reverse osmosis are used to assure highly efficient operation of the ion exchange unit. As a result, the proposed system will include pretreatment, reverse osmosis (as an option which depends on the water quality of the groundwater), followed by ion exchange in a three-bed system. Supporting systems include evaporation and concentration for final disposal of waste streams.

C.4 SYSTEM CONFIGURATION

The system configuration chosen includes pretreatment, reverse osmosis, and ion exchange. The extent of pretreatment, including chemical addition, settling, and filtration, depends on the groundwater quality. The configuration selected has been extensively investigated by E.I. du Pont de Nemours and Company (Ryan and Stimson 1984) for a proposed effluent treatment facility at the Savannah River Laboratory (Figure C-1). The Savannah River flows are proportioned upward to estimate flows for the 200-gal/min system proposed for the Hanford Site. It should be noted that these flows are representative and could vary significantly based on groundwater quality. At Savannah River, the average nitrate concentration is approximately 1,000 ppm. Also, the ^{238}U isotope concentration in a five-year storage tank is 3.27×10^{-8} Ci/gal. This is equivalent to 0.865×10^{-8} Ci/L which compares favorably to the Hanford Site value of 1.7×10^{-8} Ci/L calculated from 17,000 pCi/L.



C-3

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Figure C-1. Conceptual Level Schematic Representation of Groundwater Treatment System to Remove Uranium.

There is insufficient information to make a distinction between the insoluble or soluble forms. However, efficiency of removal at mine sites exceeded 99% for both forms for plant effluent streams of approximately 1×10^{-9} Ci/L (1,000 pCi/L) (EPA 1981).

The flow diagram as configured includes feed adjustment (pH, grit screen, etc.), and filtration to remove suspended solids including soluble iron. The reverse osmosis unit operation removes approximately 95% of the salts and contaminants which pass the filtration step. The ion exchange unit is a single mixed bed or a multiple bed unit. Typical multiple bed units include a strong acid exchanger (for other radioactive elements), weak base exchanger (for uranyl carbonate), and a mixed bed ion exchanger for final polishing. Again, the choice depends on water quality and the level of removal required. The multiple bed has a higher collection efficiency and requires less regeneration.

At Savannah River, it is estimated that the mixed bed of the multi-bed configuration requires only bimonthly regeneration. The strong acid and/or weak base beds are regenerated in place assuming dual units. When the mixed bed portion is regenerated, the treatment facility is taken off line and the reverse osmosis unit membrane cleaned and other maintenance is completed at the same time. However, at the Hanford Site it appears that dual units are not justified, since it is not critical to keep the unit available 100% of the time. The final determination will be based on water quality and the need for human interaction with the system. The waste from the reverse osmosis and ion exchange units is collected in tanks and sent to the evaporator for concentration and final disposal along with filter wastes. Alternatively, the spent resin in the ion exchange beds could be disposed without regeneration.

C.5 SUMMARY

The conceptual-level system offers a conservative design based on limited information on groundwater quality. To have an effluent concentration of uranyl carbonate below 100 pCi/L, removal efficiency >99%. The conceptual-level system will likely meet the proposed drinking water criteria. It will also reduce the overall pollutant loading in the groundwater, and it improves the operations of the system from an ALARA standpoint.

C.6 COST ESTIMATE

A conceptual-level cost estimate for the groundwater control system is developed. This estimate includes the equipment outline in Figure C-1 (Case 1). A second estimate was prepared with the assumption that the reverse osmosis unit is not required (Case 2). In this case, a second ion exchange unit is used for pretreatment. In both cases, it is assumed that the secondary waste streams from the reverse osmosis and ion exchange units go to onsite evaporators for ultimate disposal. All costs are obtained from EPA's remediation handbook EPA 1985b) adjusted to mid-1987 dollars.

The information used to develop the capital cost estimate is presented in Table C-1. For Case 1, the complete system with reverse osmosis costs approximately \$1,160,000, while Case 2 without the reverse osmosis unit costs approximately \$775,000. A range of costs was established based on -30% and +50% factors. The -30% assumes good groundwater quality not requiring extensive pretreatment, while the +50% is for poor groundwater quality and includes provisions for shielding and special materials of construction. As a result, the cost range for Case 1 is from \$810,000 to \$1,740,000, while that of Case 2 ranges from \$540,000 to \$1,160,000. As previously indicated, Case 1 has the best chance at achieving the high removal efficiencies required.

Table C-1. Conceptual Level Capital Cost Estimate for 200 gal/min Water Treatment Facility.

Item	Case 1	Case 2	Included equipment
Neutralization, Precipitation, and Filtration	\$275,000	\$275,000	Chemical feed, pumps, basins, storage basin, building, and all piping
Reverse Osmosis Unit	\$415,000	-0-	Housings, tanks, piping, membranes, flow meters, cartridge filters, chemical feed equipment, and cleanup equipment
Ion Exchange	\$170,000	\$300,000	Includes duplicate strong acid and weak base exchange columns and a single mixed bed column. Includes contact vessels, linings, resin, housings, and piping
Miscellaneous	\$300,000	\$200,000	Slabs, storage tanks, motor control shed, miscellaneous piping, etc.
Total	\$1,160,000	\$775,000	

NOTE: More columns may be required to achieve greater than 99% removal of uranyl carbonate. However, this decision will be based on pilot plant testing.

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Installation cost is not included in the above estimate. Although most of the equipment is skid mounted, installation costs will be rather high because of the need for shielding and other safety concerns. Installation costs are estimated at 20 to 25% of the capital cost. As previously indicated, these costs do not include the cost of the evaporator or handling between the wells, the treatment facility, and final disposal. These costs also do not include site grading, excavation, roads, fencing, permits, or utility hookups. Operating costs not including evaporation, ultimate disposal, resins, or chemicals could range from \$100,000 to \$200,000 annually. These costs include energy, maintenance parts, and labor.

C.7 REQUIREMENTS FOR CONCEPTUAL/PRELIMINARY DESIGN

Before a conceptual/preliminary capital and operating cost estimate is prepared, the following information is required:

- A detailed groundwater analysis as a function of time including both soluble and nonsoluble materials for various pumping rates
- Space and site constraints including onsite evaporator capacity
- Determination of the length of the project so as to assist in the selection of appropriate equipment and materials of construction
- Determination of ALARA requirements for special shielding and handling equipment (The waste streams from the reverse osmosis and ion exchange units concentrate the ^{238}U by 20 times.)
- Determination of the control level of the effluent, since control levels above >99% become increasingly more difficult to achieve
- Establishment of piping and utility requirements between the wells, the treatment system, ultimate water discharge, and waste disposal areas.

Once this information is available, a more refined cost estimate could be developed. However, for a conceptual/preliminary design and cost estimate, the processes should be piloted. This would involve piloting the reverse osmosis and ion exchange system (Case 1) as well as the ion exchange system alone (Case 2), both of which include pretreatment. Variations would involve ultrafiltration or hyperfiltration instead of the reverse osmosis system. Also, the need for further ion exchange beyond that in Case 1 and Case 2 would be identified. The need for pretreatment would be evaluated. Following this piloting, bid specifications can be prepared and final engineering can proceed.

C.8 REFERENCES

- Considine, D. M., ed, 1974, *Chemical and Process Technology Encyclopedia*, McGraw-Hill Book Company, New York, New York.
- EPA, 1981, "Technologies for Control/Removal of Pollutants," *Treatability Manual*, Volume III, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

- EPA, 1985a, *Drinking Water Criteria Document for Uranium*, Office of Drinking Water, U.S. Environmental Protection Agency, Washington, D.C.
- EPA, 1985b, *Handbook: Remedial Action at Waste Disposal Sites*, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
- Lapedes, D. N., 1978, *Dictionary of Scientific and Technical Terms*, McGraw-Hill Book Company, New York, New York.
- Palmer, G. R., I. L. Nichols, and D. C. Seidel, 1979, *Elution of Uranyl Carbonate from a Strong Base Resin with a Mixed Carbonate Eluant in a Fluidized Bed System*, Report of Investigation 8370, Bureau of Mines, Washington, D.C.
- Ryan, J. P. and R. E. Stimson, 1984, *Technical Data Summary F/H Effluent Treatment Facility*, E.I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.
- Schultz, W. W., et al., 1983, *Ion Exchange and Adsorption in Nuclear Chemical Engineering*, AIChE Annual Meeting, Washington, D.C.

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