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UMTRA
Ground Water Project

Final Site Observational Work Plan for the Green River, Utah, UMTRA Project Site

September 2002

Prepared by the
U.S. Department of Energy
Grand Junction Office

Work Performed Under DOE Contract No DE–AC13–02GJ79491 for the U S. Department of Energy,
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Acronyms and Abbreviations

ACL	alternate concentration limit
bls	below land surface
BLRA	Baseline Risk Assessment
CFR	Code of Federal Regulations
COPC	constituent of potential concern
DOE	U.S. Department of Energy
EA	Environmental Assessment
E-COPC	ecological COPC
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FDA	U.S. Food and Drug Administration
FR	Federal Register
ft	foot (feet)
ft/ft	foot per foot
ft/day	feet per day
GCAP	Ground Water Compliance Action Plan
gpm	gallons per minute
HQ	hazard quotient
IC	institutional control
IRIS	Integrated Risk Information System
LTSP	Long-Term Surveillance Plan
MAP	management action process
MCL	maximum concentration limit
mg	milligram
mg/kg/day	milligram per kilogram per day
mg/L	milligram per liter
mV	millivolt
NEPA	National Environmental Policy Act
NOAEL	no-observed-adverse-effect level
NRC	U.S. Nuclear Regulatory Commission
ORP	oxidation-reduction potential
pCi/L	picocuries per liter
PEIS	Programmatic Environmental Impact Statement
POC	point of compliance
POE	point of exposure
RAP	Remedial Action Plan
RBC	risk-based concentration
RfD	reference dose
ROD	Record of Decision
RRM	residual radioactive material
SOWP	Site Observational Work Plan
TAGR	Technical Approach to Ground Water Restoration
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
USC	United States Code

Executive Summary

The Green River Uranium Mill Tailings Remedial Action Project site is a former uranium-ore processing facility located approximately 1.5 miles southeast of the City of Green River in Grand County, Utah. The site is just south of the ephemeral Browns Wash and approximately 0.5 mile east of the Green River. Uranium ore was processed at the site from March 1958 through January 1961, with the ore concentrate shipped to a uranium mill in Rifle, Colorado, for further processing. Ground water in the uppermost aquifers (Browns Wash alluvium and the middle sandstone unit of the Cretaceous Cedar Mountain Formation) beneath the Green River site has been contaminated by uranium processing activities. Constituents of potential concern (COPC) include arsenic, manganese, nitrate, selenium, sodium, sulfate, and uranium. The abandoned uranium mill tailings and all residual radioactive material were stabilized by the U.S. Department of Energy (DOE) in a disposal cell onsite from November 1988 through September 1989. DOE owns the disposal site and the State of Utah owns the rest of the former uranium processing site.

The conceptual site model for the Green River site presented in this final Site Observational Work Plan (SOWP) is based on existing information and results of additional characterization information collected during 2002. Additional investigation included drilling and monitor well installation in the Browns Wash alluvium and the Cedar Mountain Formation to better understand the hydrogeologic system and the extent and magnitude of site-related ground water contamination. Additional ground water and surface water sampling was undertaken after installation of the new monitor wells Aquifer pumping tests were performed in select monitor wells to estimate hydraulic parameters of the aquifers. Assessment of ecological data and identification of downgradient property owners was also completed. An update of the earlier Baseline Risk Assessment is also included in the final SOWP.

DOE's goal is to implement a cost-effective ground water compliance strategy at the Green River processing site that is protective of human health and the environment and returns contaminated ground water to its maximum beneficial use. Based on evaluation of existing site information, and following the decision framework in the Programmatic Environmental Impact Statement, the proposed compliance strategy is no ground water remediation and application of alternate concentration limits for COPCs that exceed maximum concentration limits or other applicable benchmarks in ground water in the Cedar Mountain Formation and a supplemental standard for COPCs in the Browns Wash alluvium. The compliance strategy will be implemented in conjunction with monitoring to observe the effectiveness of the strategy and institutional controls, if necessary, to provide adequate control of nearby land use and ground water withdrawals. This compliance strategy will also be applicable to Subpart A of 40 CFR 192 for the disposal site. This approach will be protective of human health and the environment.

End of current text

1.0 Introduction

1.1 Purpose and Scope

The Green River Uranium Mill Tailings Remedial Action (UMTRA) Project site is a former uranium-ore processing facility located approximately 1.5 miles southeast of the City of Green River in Grand County, Utah (Plate 1 and Figure 1–1). The site is just south of the ephemeral Browns Wash and approximately 0.5 mile east of the Green River. Uranium ore was processed at the site from March 1958 through January 1961, with the ore concentrate shipped to a uranium mill in Rifle, Colorado, for further processing. Ground water in the uppermost aquifers beneath the Green River site has been contaminated by uranium processing activities, with constituents of potential concern (COPC) identified as arsenic, manganese, nitrate, selenium, sulfate, and uranium. The abandoned uranium mill tailings and all residual radioactive material (RRM) were stabilized by the U.S. Department of Energy (DOE) in a disposal cell on site from November 1988 through September 1989. DOE owns the disposal site and the State of Utah owns the rest of the former uranium processing site.

DOE's goal is to implement a cost-effective ground water compliance strategy at the Green River processing site that is protective of human health and the environment and returns contaminated ground water to its maximum beneficial use. Based on evaluation of existing site information, and following the decision framework in the Programmatic Environmental Impact Statement (PEIS) (DOE 1996), the proposed compliance strategy is no ground water remediation and application of alternate concentration limits (ACL) for COPCs that exceed maximum concentration limits (MCL) or other applicable benchmarks in ground water in the Cedar Mountain Formation and a supplemental standard for constituents in the Browns Wash alluvium. The compliance strategy will be implemented in conjunction with monitoring to observe the effectiveness of the strategy and institutional controls (IC), if necessary, to provide adequate control of nearby land use and ground water withdrawals. This compliance strategy will also be applicable to Subpart A of 40 CFR 192 for the disposal site. This approach will be protective of human health and the environment.

Investigations at the Green River site have been ongoing since the mid-1980s with results reported in numerous documents, including the Remedial Action Plan (RAP) (DOE 1991), Modification No. 2 to the RAP (DOE 1998a), and the Baseline Risk Assessment (BLRA) (DOE 1995). The conceptual site model presented in this final Site Observational Work Plan (SOWP) is based on existing information, as well as results from additional field investigations performed during 2002.

Compliance requirements for meeting the regulatory standards at the Green River site are presented in Section 2.0. Site background information, including physical setting, land and water use, and an overview of the history of the former milling operations and surface remedial activities is reviewed in Section 3.0. Results of the 2002 field investigations are summarized in Section 4.0. Site-specific characterization of the physical system and contaminant configuration are synthesized in the conceptual site model in Section 5.0. An update of the human health and ecological risk assessments are included in Section 6.0. The process for selecting the proposed ground water compliance strategy is presented in Section 7.0.

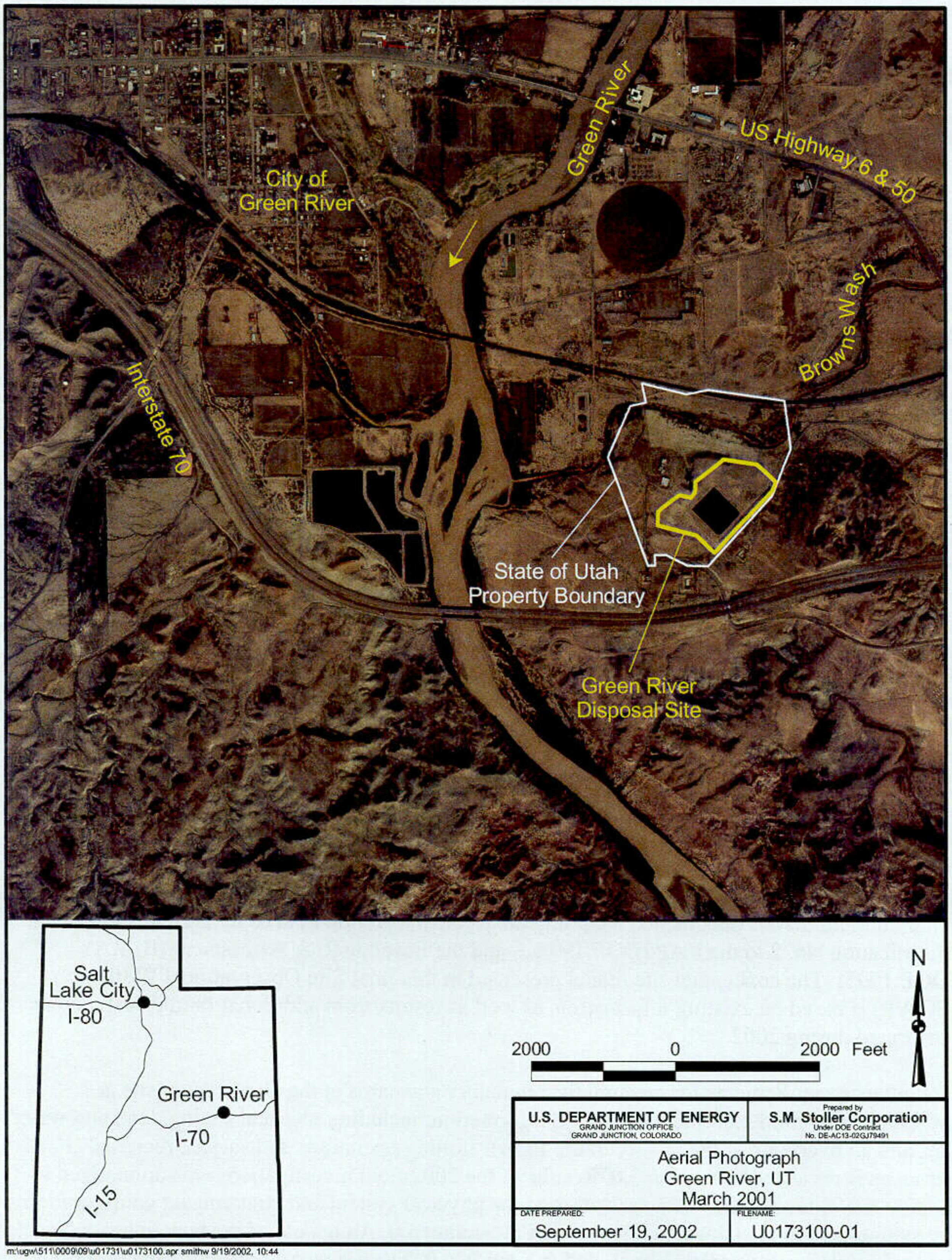

Figure 1–1. Aerial Photograph of the Green River Area—March 2001

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1.2 UMTRA Project Programmatic Documents

Programmatic documents that guide preparation of the SOWP include the *UMTRA Ground Water Management Action Process* (MAP) (DOE 2001b), the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996), and the *Technical Approach to Groundwater Restoration* (TAGR) (DOE 1993b). The MAP states the mission and objectives of the UMTRA Ground Water Project and provides a technical and management approach for conducting the project. The PEIS is the programmatic decision-making framework for conducting the UMTRA Ground Water Project. Stakeholder review and acceptance of the final PEIS is documented and supported by the Record of Decision (ROD) in April 1997. DOE will follow PEIS guidelines to assess the potential programmatic impacts of the Ground Water Project, to determine site-specific ground water compliance strategies, and to prepare site-specific environmental impact analyses more efficiently. Technical guidelines for conducting the ground water program are presented in the TAGR.

1.3 Relationship to Site-Specific Documents

The surface RAP (DOE 1991) contains the initial site characterization information. Modification No. 2 to the RAP (DOE 1998a) documents modifications made to the original RAP based on revision of the proposed ground water protection strategy and the ground water monitoring program for the disposal site. This version of the SOWP summarizes existing information and the current understanding of the site. After a ground water compliance strategy is selected for the site in the final SOWP, a Ground Water Compliance Action Plan (GCAP) will be prepared to document the decision. The GCAP will be the regulatory concurrence document for compliance with Subpart B of 40 CFR Part 192 for the Green River site and will provide details on implementation of the compliance strategy

A BLRA (DOE 1995) was prepared that identified potential public health and environmental risks at the site. Potential risks identified in the BLRA are considered and updated in this SOWP to ensure that the proposed compliance strategy is protective of human health and the environment.

After the proposed compliance strategy is identified in the SOWP and described in the GCAP, a site-specific National Environmental Policy Act (NEPA) document (e.g., an environmental checklist or environmental assessment [EA]) will be prepared to determine the potential effects, if any, of implementing the proposed compliance strategy.

The Long-Term Surveillance Plan (LTSP) (DOE 1998b) for the disposal cell will be modified after U.S. Nuclear Regulatory Commission (NRC) concurrence with the comprehensive site-wide compliance strategy.

End of current text

2.0 Regulatory Framework

A ground water compliance strategy is proposed for the Green River site to achieve compliance with U.S. Environmental Protection Agency (EPA) ground water standards applicable to Title I UMTRA Project sites. This section identifies the requirements of the Uranium Mill Tailings Radiation Control Act (UMTRCA), the EPA ground water protection standards promulgated in 40 CFR Part 192, NEPA, and other regulations that are applicable to the UMTRA Project.

2.1 Federal Regulations

2.1.1 Uranium Mill Tailings Radiation Control Act

The U.S. Congress passed UMTRCA (42 USC §7901 *et seq.*) in 1978 in response to public concerns about the potential health hazards from long-term exposure to uranium mill tailings. UMTRCA authorized DOE to control, stabilize, and dispose of mill tailings and other contaminated materials at former uranium-ore processing sites.

UMTRCA has three titles that apply to uranium-ore processing sites. Title I designates 24 inactive processing sites to undergo remediation. Title I authorizes EPA to promulgate standards and mandates remedial action in accordance with those standards. This Title also directs remedial action to be selected and performed with the concurrence of the NRC in consultation with states and Indian tribes, authorizes DOE to enter into cooperative agreements with the affected states and Indian tribes, and directs NRC to license the disposal sites for long-term care. Title II applies to active uranium mills, and Title III applies to specific uranium mills in New Mexico. The UMTRA Project has responsibility for administering Title I of UMTRCA.

In 1988, Congress passed the Uranium Mill Tailings Remedial Action Amendments Act (42 USC 7922 *et seq.*) authorizing DOE to extend without limitation the time needed to complete ground water remediation at the processing sites.

2.1.2 EPA Ground Water Protection Standards

UMTRCA requires EPA to promulgate standards for protecting public health and the environment from hazardous constituents associated with uranium ore processing and the resulting RRM. On January 5, 1983, EPA published standards in 40 CFR Part 192 for the cleanup and disposal of RRM. The standards for ground water compliance were revised, and a final rule was published on January 11, 1995 (60 FR 2854), and codified in 40 CFR Part 192.

The standards in 40 CFR 192.02(c)(1) require that the Secretary of Energy determine which of the constituents listed in Appendix I to Part 192 are present in or reasonably derived from RRM. Those standards also require the Secretary to determine the areal extent of ground water contamination by listed constituent. COPCs at the Green River processing site are identified in this document.

The standards for cleanup address two ground water contamination scenarios. The first scenario addresses ground water contaminated as a result of RRM associated with disposal cells and is regulated by Subparts A and C of 40 CFR 192. Protection of ground water at the disposal sites is monitored as part of the Long-Term Surveillance and Maintenance Program The second scenario addresses ground water contaminated as a result of RRM in the uppermost aquifer at the former processing site. The UMTRA Ground Water Project addresses this ground water contamination and is regulated by Subparts B and C of 40 CFR Part 192. Although the second scenario is the focus of this document, the first scenario will also be considered when determining the compliance strategy for the Green River site since the disposal cell is located onsite. The ultimate goal will be a comprehensive site-wide compliance strategy to address both Subparts A and B of 40 CFR 192.

Subpart B: Cleanup Standards

The regulations allow the option of complying with four general standards. Three are numerical standards and are set forth in 40 CFR 192.02(c)(3) as follows:

Background level—Concentrations of constituents in the uppermost aquifer in an area that was not affected by ore-processing activities.

Maximum Concentration Limit (MCL)—EPA defined maximum concentrations for certain hazardous constituents in ground water and are specific to the UMTRA Project. The MCLs for inorganic constituents that apply to UMTRA Project sites are given in Table 1 to Subpart A of 40 CFR Part 192.

Alternate Concentration Limit (ACL)—An ACL may be applied to a hazardous constituent if it does not pose a substantial present or future risk to human health or the environment, as long as the limit is not exceeded. An ACL may be applied after considering options to achieve background levels and MCLs.

Subpart B of the EPA standards may also be met through natural flushing within an extended period not to exceed 100 years if (1) the concentration limits are projected to be satisfied at the end of this extended period, (2) ICs are in place which will effectively protect human health and the environment and satisfy beneficial uses of ground water during the extended period, and (3) the ground water is not currently and is not now projected to become a source for a public water system subject to provisions of the Safe Drinking Water Act during the extended period (40 CFR 192.12(c)(2)).

Subpart C: Implementation

Subpart C provides guidance for implementing methods and procedures to reasonably ensure that standards of Subpart B are met. Subpart C requires that the standards are met on a site-specific basis using information gathered during characterization and monitoring. The plan for implementation must be stated in a site-specific GCAP and must contain a continued monitoring program, if necessary.

Supplemental Standards—DOE may, with NRC concurrence, apply a fourth option to contaminated ground water. Supplemental standards may be applied if any one of the following criteria is met as set forth in 40 CFR 192.21:

(a) Remedial actions required to satisfy Subpart A or B would pose a clear and present risk of injury to workers or to members of the public.

(b) Remedial actions to satisfy the cleanup standards for land and ground water would directly produce health and environmental harm that is clearly excessive compared to the health and environmental benefits, now or in the future.

(c) The estimated cost of remedial action is unreasonably high relative to the long-term benefits, and the RRM do not pose a clear present or future hazard.

(d) The cost of a remedial action for cleanup of a building is clearly unreasonably high relative to the benefits.

(e) There is no known remedial action.

(f) The restoration of ground water quality is technically impracticable from an engineering perspective.

(g) The ground water is considered of limited use and meets the criteria of 40 CFR 192.11(e).

(h) Radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant hazard from RRM.

If supplemental standards are applied, DOE shall inform any private owners and occupants of the affected location and solicit their comments (40 CFR 192.22(c)).

2.1.3 Cooperative Agreements

UMTRCA requires that compliance with ground water standards be accomplished with the full participation of the states and Indian tribes on whose lands uranium mill tailings are located. DOE has a cooperative agreement with the State of Utah that covers ground water activities at the Green River site.

2.1.4 National Environmental Policy Act

UMTRCA is a major federal action that is subject to the requirements of NEPA (42 USC 4321 *et seq.*). DOE NEPA regulations are codified in 10 CFR Part 1021, "National Environmental Policy Act Implementing Procedures." Pursuant to NEPA, DOE finalized a PEIS (DOE 1996) for the UMTRA Ground Water Project to analyze potential effects of implementing the alternatives for ground water compliance at the UMTRA Project processing sites. A ROD was published in April 1997 in which DOE's preferred alternative was selected based on the information available at the time. This ROD gave DOE the option of implementing one or a combination of the following compliance strategies:

- No ground water remediation
- Passive remediation—natural flushing
- Active ground water remediation

A Green River site-specific EA (or appropriate documentation) will be prepared to recommend the preferred remediation alternative and to address all environmental issues associated with the selected alternative.

2.1.5 Other Federal Regulations

In addition to UMTRCA, EPA ground water standards, and NEPA requirements, DOE must comply with other federal regulations and executive orders that may be relevant to the UMTRA Project sites.

2.2 DOE Orders

Several environmental, health and safety, and administrative DOE orders apply to the work being conducted under the UMTRA Ground Water Project DOE orders prescribe the manner in which DOE will comply with federal and state laws, regulations, and guidance, and will conduct operations that are not prescribed by law. DOE guidance for complying with federal, state, and tribal environmental regulations is provided in the DOE Order 5400.1 series, which is partially superseded by DOE Order 231.1. DOE Order 5400.5 requires public protection from radiation hazards. DOE guidance for NEPA compliance is provided in DOE Order 451.1, and specific guidance pertaining to EAs is provided in *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993a).

2.3 State Regulations

DOE must comply with state regulations where federal authority has been delegated to the state. These include compliance with Utah permits required for monitor wells (drilling, completing, and decommissioning), water discharge, and waste management.

3.0 Site Description

3.1 Physical Setting

The Green River site is approximately 1.5 miles southeast of the City of Green River, in Grand County, Utah, in Sections 15 and 22, T21S, R16E, Salt Lake Meridian (Plate 1 and Figure 1–1). The site is immediately south of the ephemeral Browns Wash and approximately 0.5 mile east of the Green River, with elevations ranging from 4,075 to 4,140 feet (ft). The site is bounded on the north by the Burlington Northern Santa Fe railroad, U.S. Army property, and private property; on the south by U.S. Army property; and on the east and west by Umetco Minerals property (Figure 3–1). The U.S. Army property is part of the Utah Launch Complex of the White Sands Missile Range. There is additional private property west of the Umetco property on Browns Wash alluvium downgradient from the processing site.

The nearest perennial surface water is the Green River approximately 0.5 mile west of the Green River site. The site region is drained by the Green River, a major tributary to the Colorado River. Surface water samples have been collected from the Green River upstream and downstream (0801 and 0802) from the discharge point of Browns Wash over time and there is no indication of any site-related impact to water quality (Plate 1). The ephemeral Browns Wash is normally dry and flows only during precipitation events in the area. Occasionally there have been pools of stagnant water along Browns Wash that have been sampled in the past (Section 6.2.2 and DOE 1995). In recent years, there has been no water available in Browns Wash during the scheduled sampling events. Earlier reports of seeps into Browns Wash were probably related to pre-remediation time when the tailings were still present on the floodplain, or when the ground water levels were higher during wetter years. Surface water has been sampled in Browns Wash as far upstream as water occurs (0847), which represents backwater from the Green River, and at the confluence of Browns Wash and the Green River (0846) (Plate 1). There is no indication of impact on surface water from site-related contamination. Surface water data are provided in Appendix E.

Aerial photographs were taken of the Green River site and surrounding area in March 2001 (Plate 1 and Figure 1–1). The existing monitor wells, surface water sampling points, and cultural features have been superimposed on the photographic base map of the site (Plate 1).

3.2 Land and Water Use

The City of Green River is a community of approximately 1,000 residents on the border of Emery and Grand Counties, Utah. The economy of the area is mainly dependent on agriculture and tourism. The former uranium-ore processing site is currently owned by the State of Utah, and the disposal cell area is owned by DOE (Plate 1 and Figure 3–1). There is no current use of the former processing site area. Several of the mill buildings were cleaned up and remain on the site. These buildings are currently abandoned and in a state of disrepair. There is also an abandoned water tower on the site just northwest of the disposal cell. Future land use plans for the site area will be discussed with state and local governments and the community.

Ground water is not a current or potential source of drinking water in the area of the Green River site because of the generally poor water quality in the region and the availability of good quality

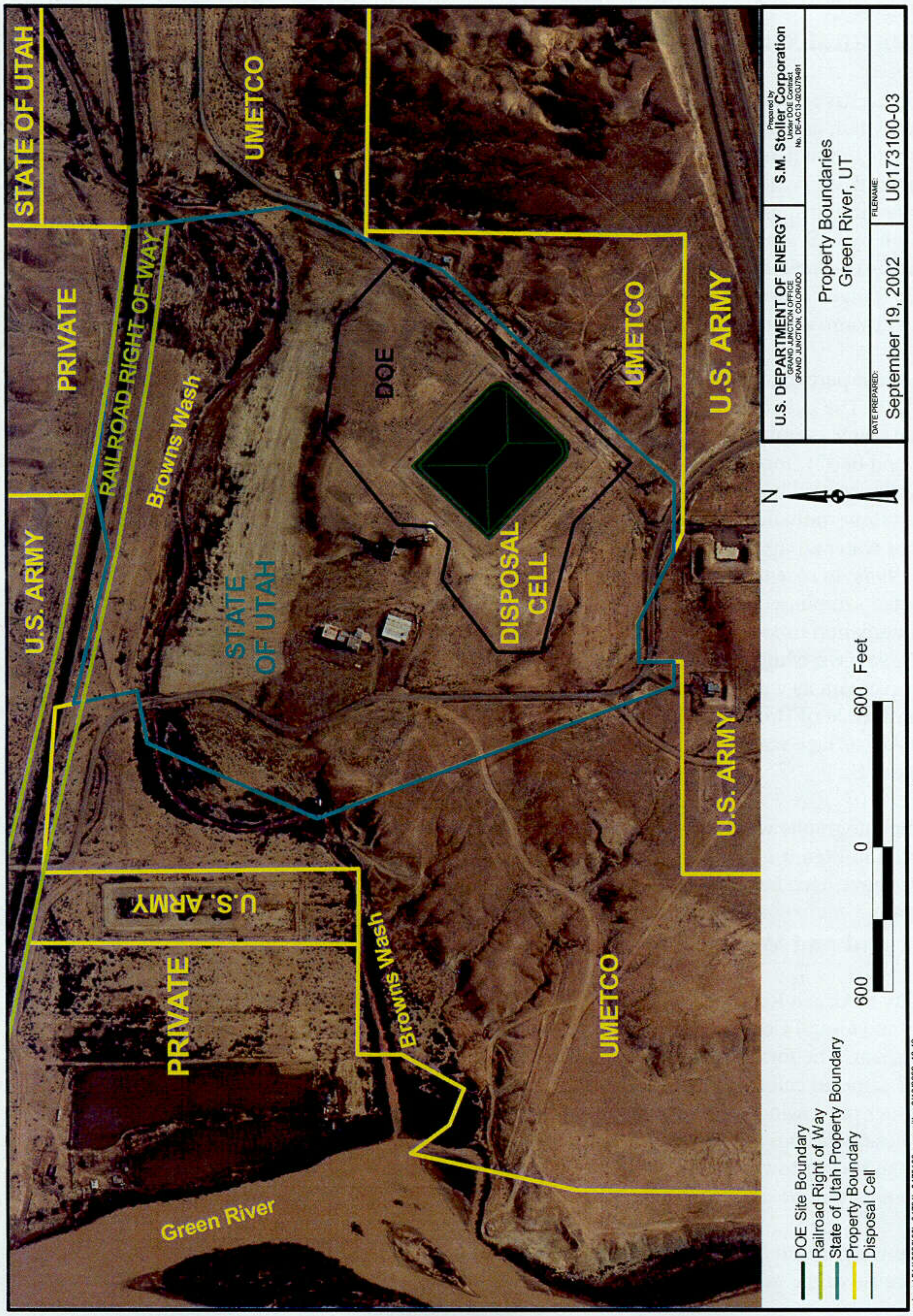

Figure 3–1. Property Ownership Near the Green River Site

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water from the Green River municipal water supply system or the Green River (DOE 1995). The source of water for the municipal supply system is the Green River. The new water intake station and treatment plant are on the east side of the Green River approximately 0.75 mile upstream from the confluence with Browns Wash. Residents of the City of Green River are connected to the municipal water system. One residence west of the site is reportedly not connected to the system, but the owner hauls water for domestic purposes from the city water supply system and stores it in a water tank. The nearest domestic wells in the area are north of U.S. Highway 6 and 50, and south of Interstate Highway 70, and are used for irrigation (DOE 1995). There are no known current uses of surface water or ground water along Browns Wash in the vicinity of the site.

3.3 Uranium Processing Activities

The uranium mill at the Green River site was constructed in 1957 and operated from March 1958 through January 1961 by Union Carbide Corporation. Later, Union Carbide leased the site to a company under contract with the U.S. Department of Defense, which used the mill buildings for missile testing and assembly. Union Carbide owned the uranium millsite until the state of Utah acquired ownership in 1988. The plant was operated for upgrading uranium ore from the Temple Mountain mining district area approximately 40 road miles southwest of the site. During its 3 years of operation, the mill processed 183,000 tons of ore with an average grade of 0.29 percent uranium oxide (FBDU 1981). The upgraded ore concentrate was shipped by rail to Rifle, Colorado, for further processing. The former Green River plant generated an estimated 137,000 tons of tailings, which covered approximately 9 acres to an average depth of 7 ft.

Feed to the Green River upgrader plant contained 0.29 percent uranium oxide in a sandstone loosely cemented with clay and asphaltic material and with part of the uranium intimately associated with carbonaceous material (Merritt 1971). The carbonaceous material was recovered separately by screening and flotation of the ground feed slurry, and this concentrate was stockpiled for subsequent treatment. The flotation tailings were separated into sand and slime fractions, and the sands were leached at a pH of 0.5 for about 4 hours. The leached slurry was washed in a 6-stage classifier circuit, and the spent sands were discarded. The recovered slimes and pregnant solution were mixed with a portion of the initial slime fraction of the ore in an acid-kill tank, where most of the free acid was neutralized to a final pH between 5 and 6. Final neutralization with ammonia then precipitated uranium and associated metals in the slurry. This mixed product plus the remainder of the primary slimes were dewatered and dried for shipment to the Rifle plant. Uranium recovery at the Green River plant ranged from 90 to 95 percent.

3.4 Surface Remediation

The processing site was remediated from November 1988 through September 1989, and all mill tailings and RRM were stabilized in a partially below-grade disposal cell in the area just southeast of the former mill buildings (Plate 1). Pre-construction conditions at the site in 1982 are shown in Figure 3–2 and compared with current conditions. The disposal cell base is approximately 35 ft below grade, and contaminated materials were emplaced in the cell to approximately 40 ft above grade. The disposal cell covers approximately 6 acres. The area of the former tailings pile and all areas disturbed at the site during the remedial action were backfilled, graded to promote surface drainage, and revegetated.

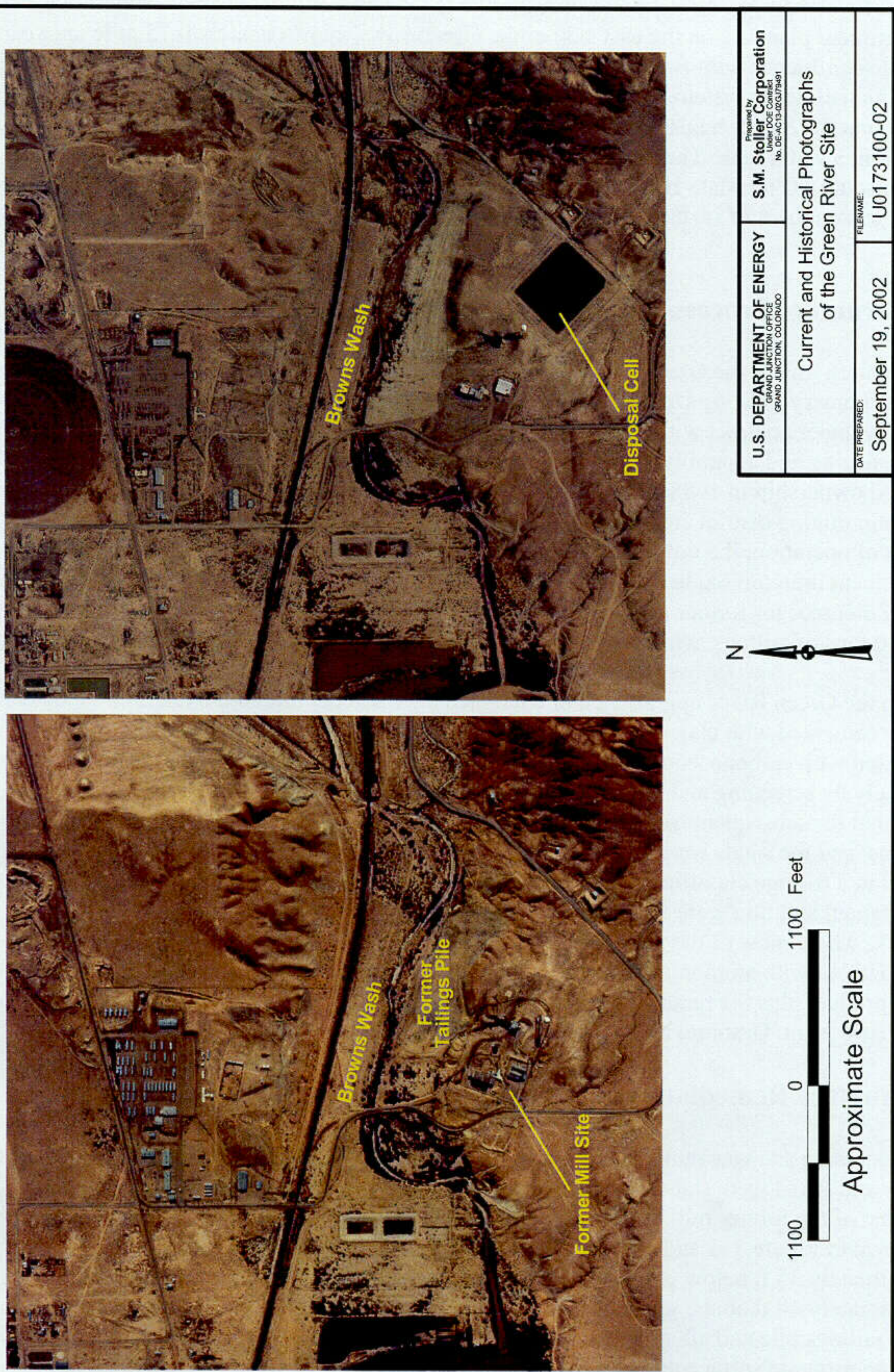

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Figure 3–2. Aerial Photographs of the Green River Site—1982 and 2001

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In order to demonstrate that the disposal cell is performing as designed under Subpart A of 40 CFR 192, ground water is collected from four point of compliance (POC) wells (0171, 0172, 0173, and 0813) downgradient from the disposal cell (DOE 1998a and 1998b). Ground water samples are analyzed for nitrate, sulfate, and uranium and the objective is to meet the proposed concentration limits established in Modification No 2 to the RAP (DOE 1998a). Based on a review of monitoring results in 2001, the recommendation (concurred with by Utah Division of Radiation Control [UT-DRC 2001]) was to continue quarterly monitoring of the POC wells along with collecting ground water levels and precipitation data, until such time as the ground water cleanup (Subpart B of 40 CFR 192) investigation is complete and the comprehensive site wide compliance strategy and monitoring program for both Subparts A and B are revised and approved (DOE 2001a).

End of current text

4.0 Summary of 2002 Field Investigations

The scope of activities performed in the field during 2002, based on Section 7.0 of the draft SOWP, are summarized in this section. Results of the investigations are incorporated into the updated conceptual site model presented in detail in Section 5.0. Monitor well locations are shown on Plate 1 and figures in Section 5.0.

4.1 Monitor Well Installation

Twelve new monitor wells were installed at the Green River site during June 2002, including five in the Cedar Mountain Formation bedrock and seven in the Browns Wash alluvium. Drilling was performed using the Rotasonic method, which provided excellent recovery of lithologic samples. All wells were installed using 4-inch ID PVC casing with factory-slotted PVC screens. This was done to facilitate aquifer pumping tests that were performed in several of the new monitor wells. Of the 14 monitor wells projected in the draft SOWP, two alluvial wells were not completed. Monitor well 0187, drilled just south of Browns Wash northeast of the site, encountered Mancos Shale bedrock at approximately 7 ft, was completely dry, and thus was not completed as a monitor well. Monitor well 0192, northwest of the site and southeast of Browns Wash was not drilled because of lack of reasonable access. Non-completion of these locations will not impact the data collection efforts of this investigation because other monitor wells are located nearby that will provide adequate information for the evaluation of the site. Monitor well lithologic and completion logs for the new wells, along with all existing wells, are provided in Appendix B (on CD-ROM). Geophysical logging of the new monitor wells was considered, but deemed unnecessary because of the excellent sample recovery afforded by the Rotasonic drilling method. Lithologic samples were logged in the field and representative samples from selected bedrock wells were collected and archived.

Monitor well 0181 was installed as an offset to monitor well 0172, from which anomalous results have been observed (DOE 2002). The new well is approximately 20 ft northeast of monitor well 0172 and screened at approximately the same depth as the original well Monitor well 0172 will continue to be monitored as part of the POC monitoring network described in the LTSP (DOE 1998b) until the site-wide compliance strategy is proposed and concurred with by NRC (NRC 2002), and the LTSP is modified accordingly.

4.2 Hydrogeologic Investigation

Additional field reconnaissance, drilling, and monitor well installation were completed during 2002 in the Browns Wash alluvium and the Cedar Mountain Formation to better understand the hydrogeologic system, the ground water flow regime and hydraulic interconnections, and the extent and magnitude of site-related contamination in the aquifers beneath the site

The hydrostratigraphic sequence and definition of uppermost aquifers in the vicinity of the site were also assessed and revised to reflect more recent interpretations. These interpretations were based on lithologic sampling while drilling, field reconnaissance of outcrops in the vicinity of the site, and review of recent literature studies of the area. This allowed for better correlation between surface and subsurface information. The two distinct lithologic subsets in the vicinity of the Green River site are the Browns Wash alluvium and the Cedar Mountain Formation bedrock. The Browns Wash alluvium is not of primary significance because of the limited saturated thickness and lateral extent. The Cedar Mountain Formation in discussions in earlier documents consisted of the unnamed upper member and lower Buckhorn Member. The lower member was fairly distinct and correlateable and contained ground water in a confined aquifer. The unnamed member contained several interfingering sandstone units that may or may not be correlateable over any distance. The previous terminology of "coarse-grained" versus "fine-grained" referred basically to either finding a sandstone unit or not, but completing a well at a relative perceived depth where a sandstone was expected to be. Thus, the hydrostratigraphy will be redefined based on the recent investigations to present a more realistic picture of what is there and relate to the variability of Cretaceous sedimentary conditions and facies.

Fracture/joint measurements were taken in the field at 36 locations around the Green River site. Data are shown in a figure in Section 5.1.

Aquifer pumping tests and slug tests were completed at the Green River site to collect the hydrogeologic data necessary to characterize the Browns Wash alluvial aquifer and the middle sandstone unit of the Cedar Mountain Formation. These data were collected to provide a range of the transmissivity and hydraulic conductivity for both the alluvial and middle sandstone aquifers, and the specific storage for only the middle sandstone aquifer. Tests were performed on well 0191 in the alluvium because it contained an adequate saturated thickness of approximately 2 ft The middle sandstone unit of the Cedar Mountain Formation was tested by pumping newly installed well 0181 and observing water level response in adjacent wells 0171, 0172, 0173, 0174, and 0813. This test was run for 52 hours at a discharge rate of approximately 1 gallon per minute (gpm). All water level responses were measured using pressure transducers and manually with an electronic sounder. Water generated from each test was discharged a minimum of 100 ft from the pumping well and observation wells.

Geophysical methods of investigation were not warranted because of the potential complexity of the subsurface environment, difficulty in significantly defining properties of the bedrock, and the relative insignificance of these data in light of the overall conceptual model of the site and the fact that the proposed compliance strategy is application of ACLs Additional detailed information would not significantly enhance the understanding of the site or further protect human health and the environment.

4.3 Water Quality Sampling

Ground water from all monitor wells at the Green River site was sampled during July 2002, and surface water was sampled from four locations. Analytical results for this sampling round, along with all historic data, are provided in Appendices D and E. Results of ground water and surface water quality data are discussed in Section 5.3 of this document.

4.4 Ecological Survey

Sediment sampling was not conducted at the Green River site for reasons discussed in Section 6.2.

4.5 Property Owners

Property ownership in the vicinity of the Green River site was determined from courthouse records for Grand County In summary, DOE owns the disposal cell; the State of Utah owns the area covered by the former processing site; Umetco Minerals borders the site on the east and west sides; the U.S. Army Missile Range borders portions of the north and south ends of the site; and a parcel of private property borders the northeast part of the site (Figure 3–1). The only residents in the vicinity are on a parcel of land immediately adjacent to the Green River approximately 1,600 ft west of the processing site boundary.

End of current text

5.0 Conceptual Site Model

The conceptual site model for the Green River site is based on existing information in the numerous documents referenced in this SOWP, as well as results of the 2002 field investigation. It is presented here to establish the current level of understanding of site conditions relative to the extent and magnitude of site-related contamination of environmental media and pathways to potential receptors. Monitor wells and surface water sampling locations used in this assessment are shown on Plate 1 and Figure 5–1.

5.1 Hydrogeology

5.1.1 Geologic Setting

The Green River site is in the northern part of the Canyonlands section of the Colorado Plateau physiographic province. The Canyonlands section is characterized by large structural upwarps and intervening basins formed mostly in Upper Paleozoic and Mesozoic sandstones and shales. The site lies within the boundaries of the Paradox Basin in the relatively stable interior portion of the Colorado Plateau. The Paradox Basin is characterized by complex systems of northwest-trending normal faults and landslide and slump features. Salt anticlines with collapsed center cores extend to within 12 miles of the site. The collapse features have been active during Quaternary time and may be active today. However, since they result from the very gradual process of salt solution and flowage, they are probably not capable of generating large earthquakes. No intrusive or volcanic rocks crop out within a 40-mile radius of the site.

Bedrock units in the vicinity of the Green River site, from youngest to oldest, include the Tununk Member of the Cretaceous Mancos Shale, the Cretaceous Dakota Sandstone, the Cretaceous Cedar Mountain Formation, and the Brushy Basin Member of the Jurassic Morrison Formation (Figure 5–2 through Figure 5–5). These units consist principally of conglomerate, sandstone, siltstone, mudstone, shale, and limestone. Unconsolidated Quaternary deposits in the area consist of thin, discontinuous covers of alluvial deposits, pediment and terrace gravels, eolian deposits, and colluvium.

The Green River site lies just east of the north-plunging axis of the Green River anticline (Figure 5–2). The bedrock is influenced by some local folding and generally dips in a northeasterly direction, with dips of less than five degrees. No faults with significant displacement are known in the immediate area of the disposal site. Jointing is common in the more resistant units. Fractures and joints in the vicinity of the Green River site were measured in the field at various locations. The pattern is relatively consistent with the predominant direction being N30°W and the secondary trend being N60°W (Figure 5–6). Fractures at the surface locations appear to be relatively tight and probably do not allow significant infiltration of water into the ground. Fracturing was noted in the samples logged during the 2002 drilling and some may have significance in ground water flow patterns. Lithologic logs from earlier holes drilled near the disposal cell indicate some fracturing as well. The potential impact of fractures on ground water flow in the bedrock has been assessed during the aquifer pumping test in well 0181 and is discussed in Section 5.1.2.2 and Appendix F. Fracturing may be more pronounced adjacent to the disposal cell because of construction activities necessary to excavate to approximately 35 ft below grade. This may account for the elevated concentrations of COPCs in the monitor wells adjacent to the disposal cell.

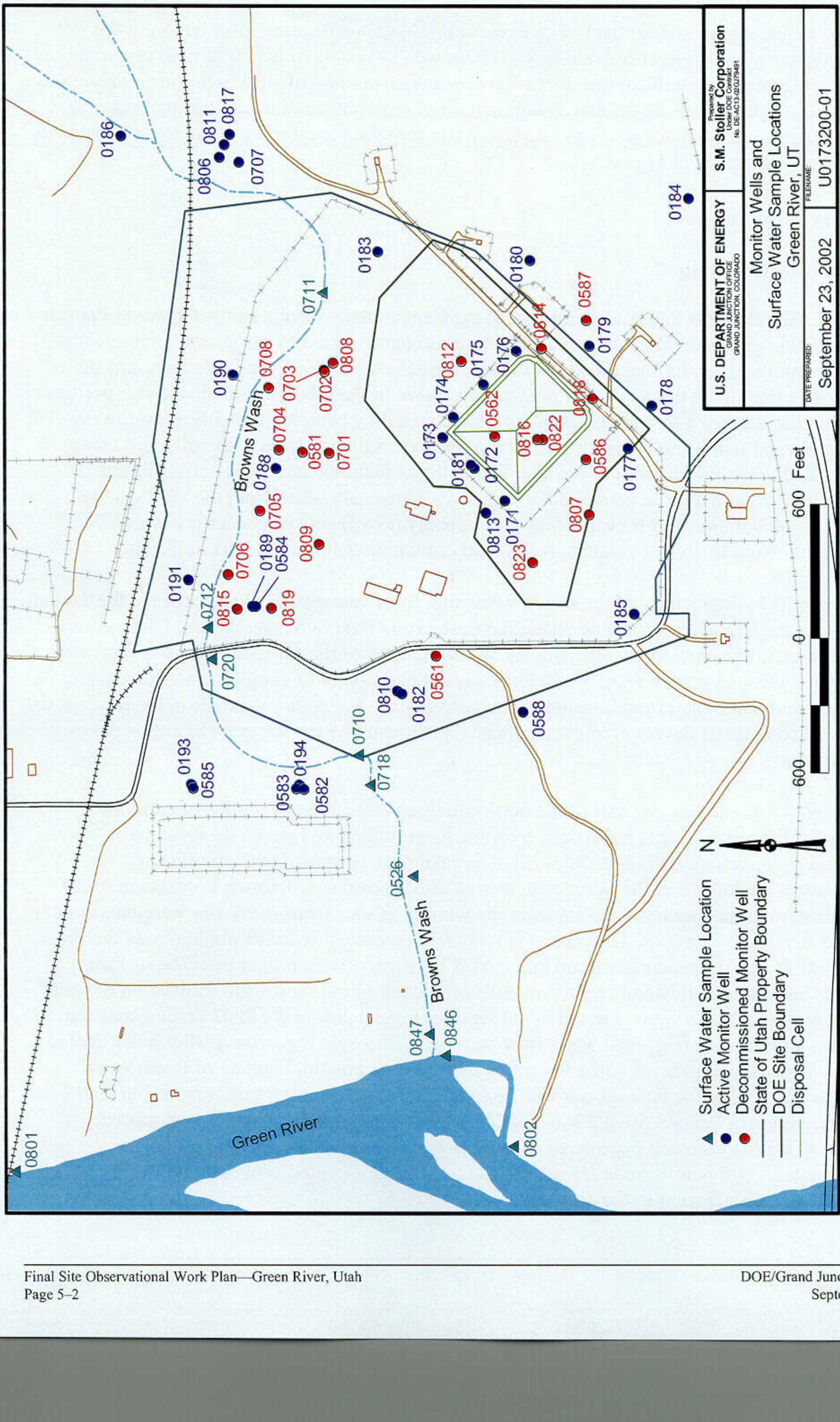


Figure 5–1. Monitor Wells and Surface Water Sample Locations

CO4

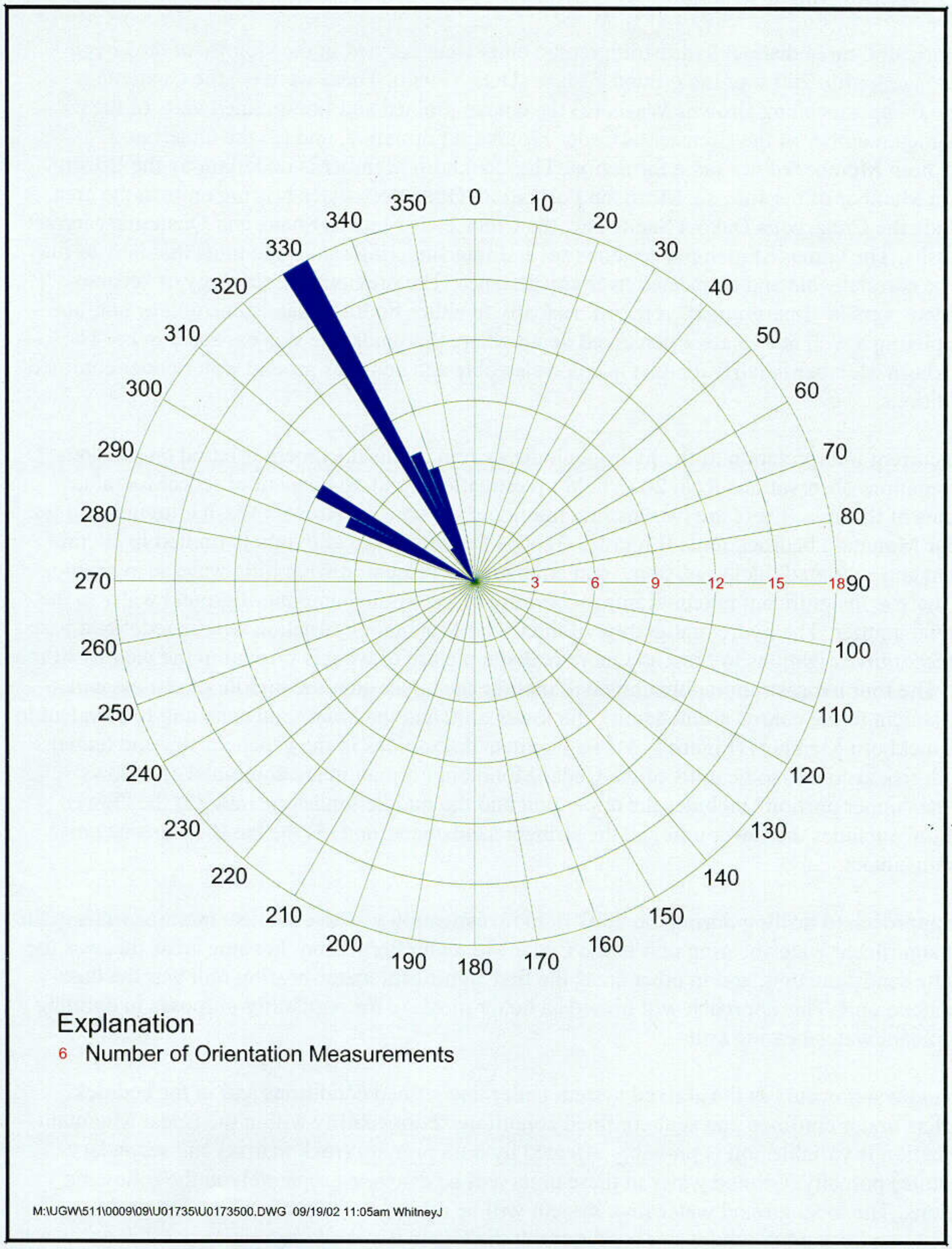


Figure 5–6. Orientation of Fracturing and Joints at the Green River Site

C05

5.1.2 Hydrogeologic System

Historically, three distinct hydrostratigraphic units were defined in the vicinity of the Green River site within 200 ft of the ground surface (DOE 1998a). These were (1) the Quaternary alluvial deposits along Browns Wash, (2) the coarse-grained and fine-grained units of the unnamed member of the Cretaceous Cedar Mountain Formation, and (3) the underlying Buckhorn Member of the same formation. The Buckhorn Member is underlain by the Brushy Basin Member of the Jurassic Morrison Formation. Other non-water-bearing units in the area include the Cretaceous Dakota Sandstone, the Cretaceous Mancos Shale, and Quaternary terrace deposits. The unnamed member contains several interfingering sandstone units that may or may not be correlateable and connected over any distance. The previous terminology of "coarse-grained" versus "fine-grained" referred basically to either finding a sandstone unit or not, but completing a well at a relative perceived depth where the sandstone was expected to be The Buckhorn Member is fairly distinct and correlateable and contains ground water under confined conditions.

The current interpretation of the hydrogeologic system in this document is based on previous information, observations from 2002 field investigations, and assessment of recent literature studies of the area. There are two distinct lithologic subsets, the Browns Wash alluvium and the Cedar Mountain bedrock units (Figure 5–3). The Browns Wash alluvium is limited in lateral extent and saturated thickness. Some contamination is present in what little water is available, but there is insignificant potential impact because of the limited amount of ground water in the alluvial aquifer. The hydrostratigraphy of the Cedar Mountain Formation will be redefined based on recent investigations to present a more realistic picture of what is present in the vicinity of the site. The four hydrostratigraphic units will include the upper unit, the middle sandstone unit (equivalent to the coarse-grained unit), the lower unit, and the basal sandstone unit (equivalent to the Buckhorn Member) (Figure 5–3). To facilitate discussions in the geochemistry and human health risk sections, some units of the Cedar Mountain Formation are combined as follows: (1) the "upper portion" includes the upper unit and the middle sandstone unit, (2) the "lower portion" includes the lower unit and the stringer sandstones, and (3) the basal sandstone unit remains intact

The approach to drilling during the 2002 field investigation was to complete monitor wells in the first significant water-bearing unit in the Cedar Mountain Formation. In some areas this was the middle sandstone unit, and in other areas the first significant water-bearing unit was the basal sandstone unit. This approach will provide a better measure for regulatory purposes in defining a significant water-bearing unit.

Ground water occurs in the alluvial system under unconfined conditions and in the bedrock aquifers under confined and semiconfined conditions. Permeability within the Cedar Mountain Formation is variable and is probably affected by both primary (rock matrix) and secondary (fracture) porosity. Ground water in these units will be discussed separately in the following sections The local ground water flow system will be related to the regional hydrology in an effort to understand ground water conditions at the Green River site in Section 5.1.2.3.

5 1.2.1 Browns Wash Alluvium

The west-draining ephemeral Browns Wash is just north of the Green River site (Plate 1). The Browns Wash alluvium consists of a mixture of silt, sand, gravel, and some small cobbles. These alluvial deposits are limited to an area that extends approximately 400 ft on either side of Browns Wash and vary in thickness from 0 to 35 ft. Shallow ground water occurs in the Browns Wash alluvium under unconfined conditions and is limited by the lateral extent of the alluvium. Depth to ground water varies from 8 to 17 ft below land surface (bls). The current (July 2002) saturated thickness of the Browns Wash alluvium is between 0 and 3 ft, with the maximum thickness near Browns Wash. The ground water flow direction is to the southwest (toward the Green River) with a gradient of approximately 0.008 foot per foot (ft/ft) (Figure 5–7). A hydrograph of ground water elevations in the alluvial aquifer versus time is provided in Figure 5–8.

The Browns Wash alluvial system is recharged by infiltration of precipitation and surface water flow from Browns Wash (when flowing). Apparently the alluvial system adjacent to the former tailings pile received recharge during the milling operations and after tailings deposition over the alluvium on the south side of Browns Wash. In the late 1980s and early 1990s several locations along Browns Wash at the downgradient end of the site contained standing water on a regular basis, even in the absence of a recent precipitation event (DOE 1995). However, these surface water locations have been dry since 1996. This further supports the suggestion that the tailings fluids provided a source of recharge to part of the alluvial system in the past. While there was no evidence for a ground water mound beneath the tailings pile (DOE 1995), waste solutions were included with the tailings for disposal (Merritt 1971).

Alluvial ground water discharge is predominantly through evapotranspiration, along with a minor amount of ground water discharge to the Green River. Discharge to the bedrock appears to be minimal because of the low permeability of the underlying competent bedrock and upward hydraulic gradients.

During the 2002 field investigation, at which time the region was experiencing drought conditions, alluvial monitor wells 0186, 0190, 0193, and 0707 were dry, while wells 0188, 0189, and 0194 contained less than 1 ft of water. Based on well development data, wells 0188, 0189, and 0194 have sustainable pumping rates less than 0.035 gpm (or 50 gallons per day). Monitor well 0191 was able to sustain a discharge rate of approximately 1 gpm. It is possible that the weathered Mancos Shale underlying the alluvium contributes some ground water to this well, as the lower 2 ft of screen are in this unit. The sustainable pumping rate associated with this well is almost two orders of magnitude higher compared with the other three wells completed in the alluvium (that contained any water), suggesting that the flow rate for this well is not representative of the entire alluvial aquifer. Although some saturation is present in a few areas, there is generally not enough ground water present in the alluvial system overall to sustain any significant yield to wells, thus the alluvial aquifer system is not considered a viable water resource.

A single-well aquifer pumping test and slug tests were completed in monitor well 0191 just north of Browns Wash (Figure 5–1 and Appendix F). The test was run for 3.5 hours with an average pumping rate of 1.1 gpm. For the slug tests, the well was evacuated at a pumping rate of approximately 5 gpm, which removed all water from the well in 30 seconds. This indicates that even though a rate of 1.1 gpm was sustained over a period of 3.5 hours during the aquifer test, there is not a significant amount of potentially sustainable water in the aquifer. Aquifer pumping test and slug test data using monitor well 0191 indicate that the hydraulic conductivity ranged from 22.4 to 43.4 feet per day (ft/day) (Appendix F). Assuming an effective porosity of 0.15 and a horizontal gradient of 0.008, the seepage velocity for ground water flow in the alluvial aquifer ranged from 1.2 to 2.3 ft/day. Again, this value may be impacted by the ground water contained within the weathered Mancos Shale underlying the alluvium at this location.

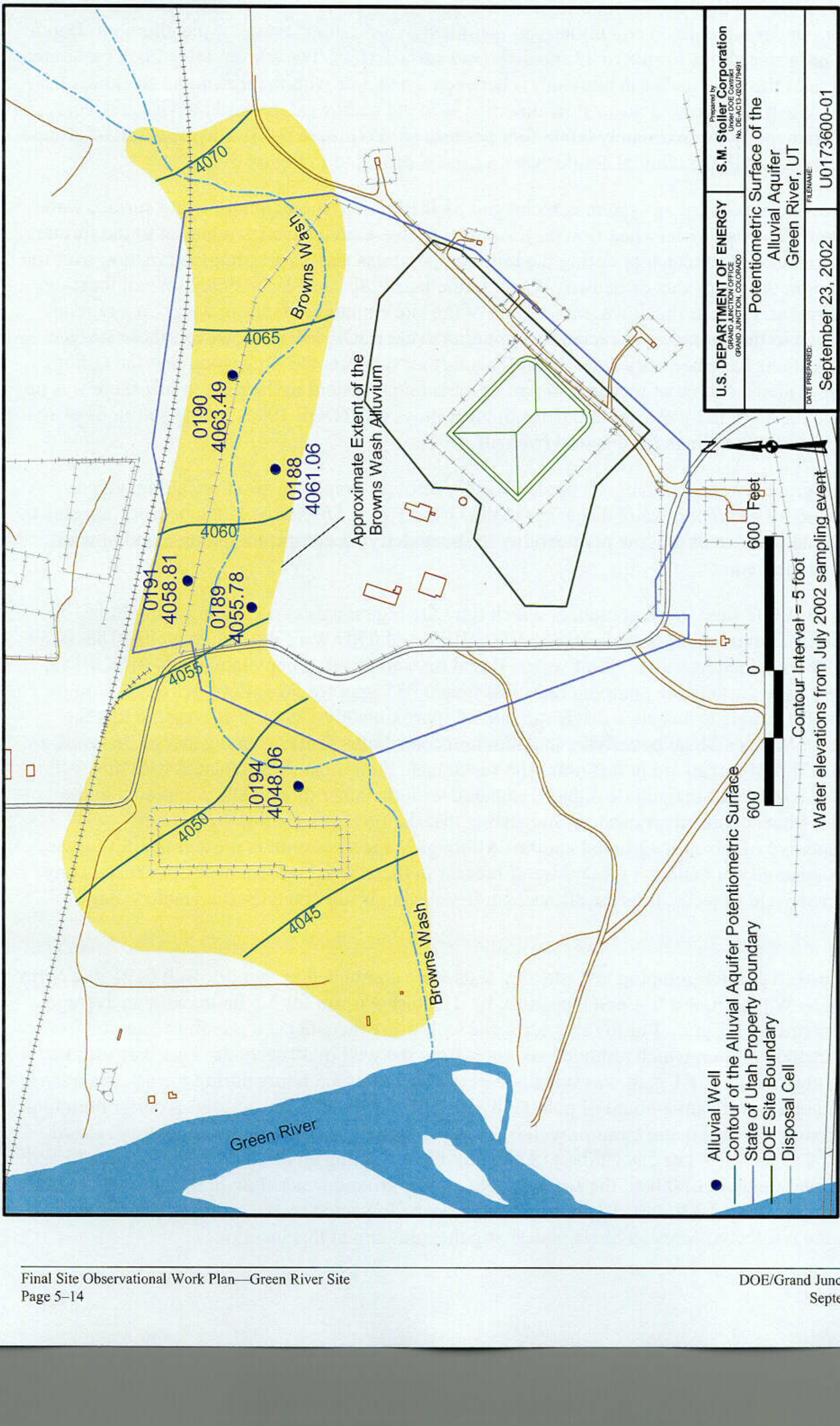


Figure 5–7. Potentiometric Surface of the Alluvial Aquifer at the Green River Site

C06

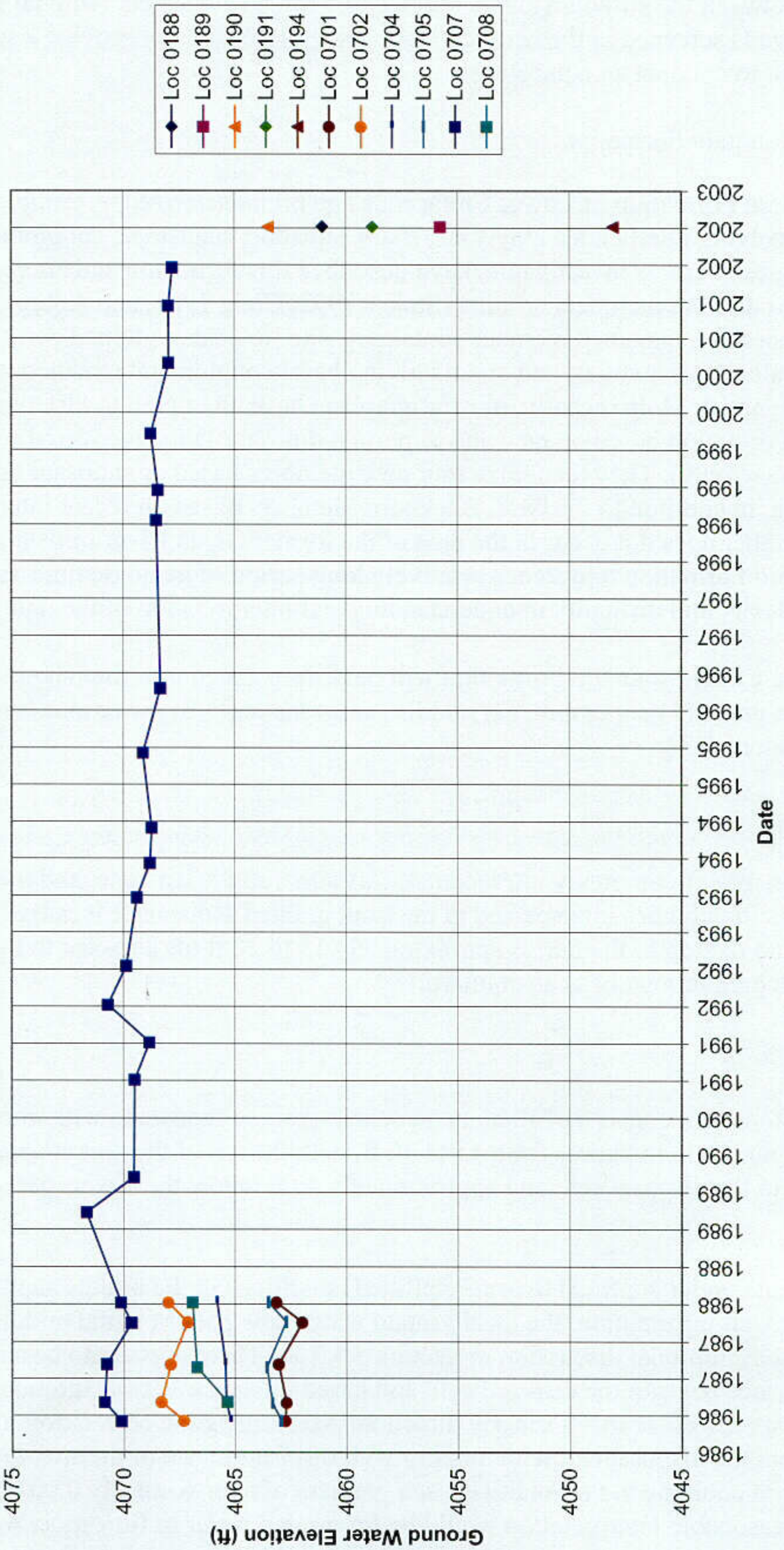


Figure 5–8. Hydrograph of the Browns Wash Alluvium at the Green River Site

C07

As a result of the drought conditions during the 2002 field investigation, the degree of interconnection between the alluvium and bedrock could not be evaluated. Alluvial wells installed next to wells screened in the bedrock were either dry or did not provide a sustainable flow rate sufficient to conduct an aquifer test.

5.1 2.2 Cedar Mountain Formation

The Cedar Mountain Formation of Lower Cretaceous age is characterized by complex lateral facies changes involving interbedded claystone, shale, siltstone, sandstone, conglomerate, and limestone lithologies. Various investigators have described this formation and attempted to differentiate it into discrete members or units (Stokes 1952, Craig 1981, and Aubrey 1998). Generally, an upper thick unnamed member containing fine- to coarse-grained detritus, commonly with calcareous nodules, and an underlying basal conglomerate, named the Buckhorn Member, are recognized. More recently, biostratigraphers have attempted to differentiate the Cedar Mountain Formation based on new and important dinosaur fauna recovered from the area (Kirkland and others 1999). They recognize four new members based on dinosaur assemblages and lithologic data, in addition to the basal Buckhorn Member. Based on recent interpretations, the Buckhorn Member does not occur in the area of the former Green River millsite. The units of the Cedar Mountain Formation represent a relatively long period of geologic time, which may explain the complexity and difficulty in understanding and interpretation of the unit.

For this report, the Cedar Mountain Formation will be differentiated into four significant hydrostratigraphic units: (1) upper unit, (2) middle sandstone unit, (3) lower unit, and (4) basal sandstone unit (Figure 5–3).

Upper Unit

The upper unit consists of complexly interbedded, claystone, shale, siltstone, and minor sandstone with calcitic nodules interspersed in the finer grained sequences. It ranges in thickness from 40 to 70 ft and the top of the unit is approximately 15 to 20 ft bls adjacent to the disposal cell This unit acts predominantly as an aquitard

Middle Sandstone Unit

The middle sandstone unit consists of siltstone to coarse-grained sandstone with minor conglomerates. It ranges in thickness from 15 to 40 ft, with the top of the unit at approximately 80 ft bls adjacent to the disposal cell, and approximately 40 ft below the lowest part of the disposal cell

Ground water occurs under confined to semi-confined conditions in the middle sandstone unit. Based on monitor well information, the local ground water flow pattern in the middle sandstone unit is irregular (see additional discussion in Section 5.1 2.3). There appears to be a relatively flat potentiometric surface beneath the disposal cell, and based on data available, ground water could be flowing to the southwest or in a northerly direction. Assuming good correlation of the middle sandstone unit from the disposal cell with monitor well 0817 northeast of the site, the ground water flow direction could be to the southwest at a gradient of approximately 0.002 (Figure 5–9). Possibly a more reasonable interpretation would be for ground water to flow more to the north, consistent with the regional dip of bedrock formations. Depth to ground water is approximately 60 ft bls, and has fluctuated over a range of approximately 5 ft since 1991 (Figure 5–10).

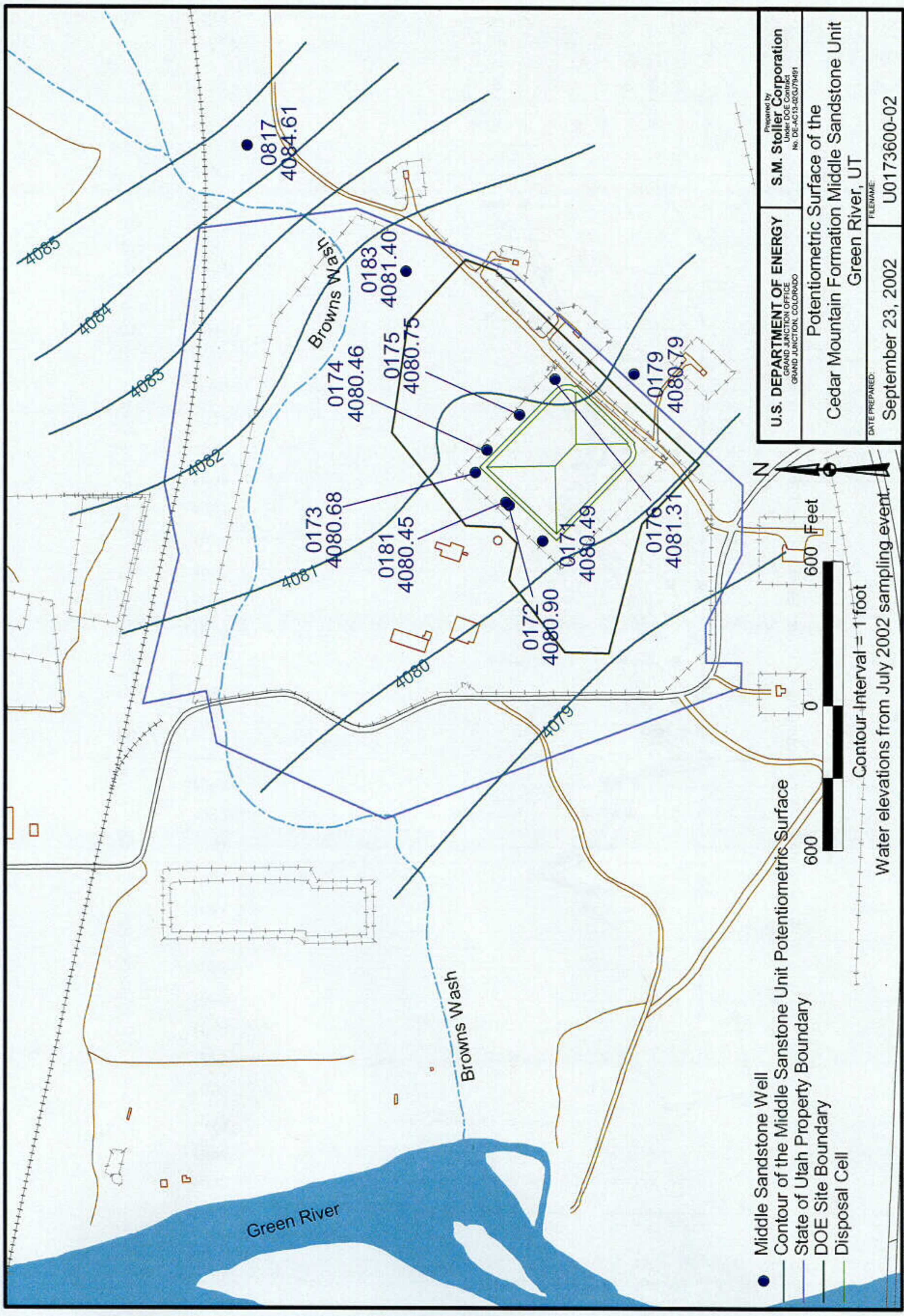


Figure 5–9. Potentiometric Surface of the Cedar Mountain Formation Middle Sandstone Unit at the Green River Site

C08

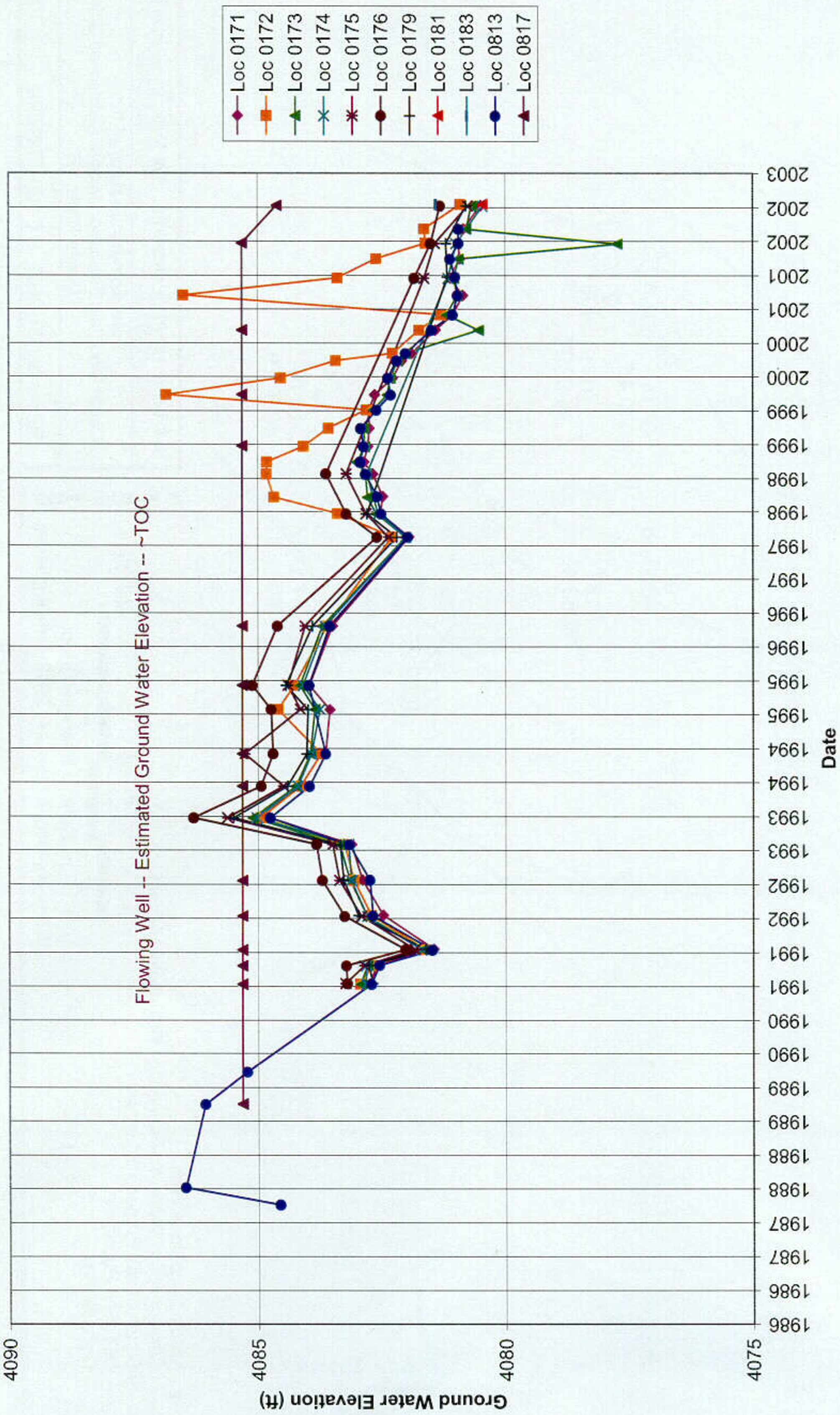


Figure 5–10. Hydrograph of the Cedar Mountain Formation Middle Sandstone Unit at the Green River Site

C09

Recharge is primarily in the form of precipitation where this unit crops out. Ground water migration from the adjacent units above and below the middle sandstone unit is unlikely due to the finer-grained nature of these deposits.

An aquifer test was conducted in newly installed monitor well 0181, just northwest of the disposal cell, and water level response was monitored in wells 0171, 0172, 0173, and 0174 (Figure 5–1 and Appendix F). Water levels in wells 0175 and 0813 were measured to monitor background fluctuations, which were primarily related to changes in barometric pressure. The test was run for 52 hours with an average pumping rate of 1.0 gpm. Drawdowns in all wells except the pumping well and well 0172 were less than 0.5 ft; these data were not analyzed since the barometric fluctuation was approximately 0.2 ft. Field conditions and the plot of drawdown data from well 0172 suggested the response to pumping from well 0181 was caused by dual porosity phenomena (i.e., fracture flow along with matrix flow). As a result, data were analyzed using a calculation method for a fractured, dual porosity medium. This observation was consistent with results from previous tests conducted in the area in 1993. Based on results of this calculation, the estimated hydraulic conductivity of the fractures was larger than that of the matrix. The overall significance of fracture flow in the middle sandstone aquifer in the area relative to that immediately adjacent to the disposal cell has not been determined. Recovery data from the two wells were also used to estimate hydraulic conductivity. Results from all calculation methods applied to this aquifer test indicate the hydraulic conductivity of the middle sandstone unit ranges from 0.09 to 3.1 ft/day.

Lower Unit

The lower unit is similar to the upper unit and consists of interbedded claystone, shale, and siltstone, with numerous calcitic nodules, but also contains several thin sandstone units. These thin sandstones (termed "stringer sandstones") are from 2 to 6 ft thick and are observed in outcrops south of the site. Monitor well 0177 is considered to have been completed in a stringer sandstone. The lateral extent of these minor sandstones is unknown. Overall, the lower unit averages about 70 ft thick (and can be as much as 100 ft thick) based on lithologic logs from wells 0818, 0184, and 0185. It is estimated to be 100 to 120 ft bls adjacent to the disposal cell.

Basal Sandstone Unit

The basal sandstone unit was observed in outcrop south of the site, and was intersected (and screened) in monitor wells 0184, 0185, 0582, 0586, 0587, 0588, and 0818. It consists of two lithologies, a fine- to medium-grained sandstone that is 15 to 20 ft thick, underlain by a prominent basal conglomerate 5 to 20 ft thick that contains cherty clasts up to 2.5 inches in diameter. The top of the upper sandstone in the basal sandstone unit is estimated to be 160 ft bls below the disposal cell. The conductive sandstone and conglomerate of the basal sandstone unit is confined by shales and claystones of the overlying lower unit and by the underlying Brushy Basin Member of the Morrison Formation. Ground water in this unit has not been affected by site-related contaminants because of the hydrogeologic isolation and an upward vertical hydraulic gradient. Ground water generally flows in a northeasterly direction in this unit at a gradient of approximately 0.008 ft/ft (Figure 5–11). A hydrograph of ground water elevations in the middle sandstone unit versus time is provided in Figure 5–12). Ground water in monitor well 0582 is under artesian pressure and flows at the surface. A pressure gauge installed on the well casing indicated an actual ground water level elevation of approximately 95 ft above ground level (~4,075 ft).

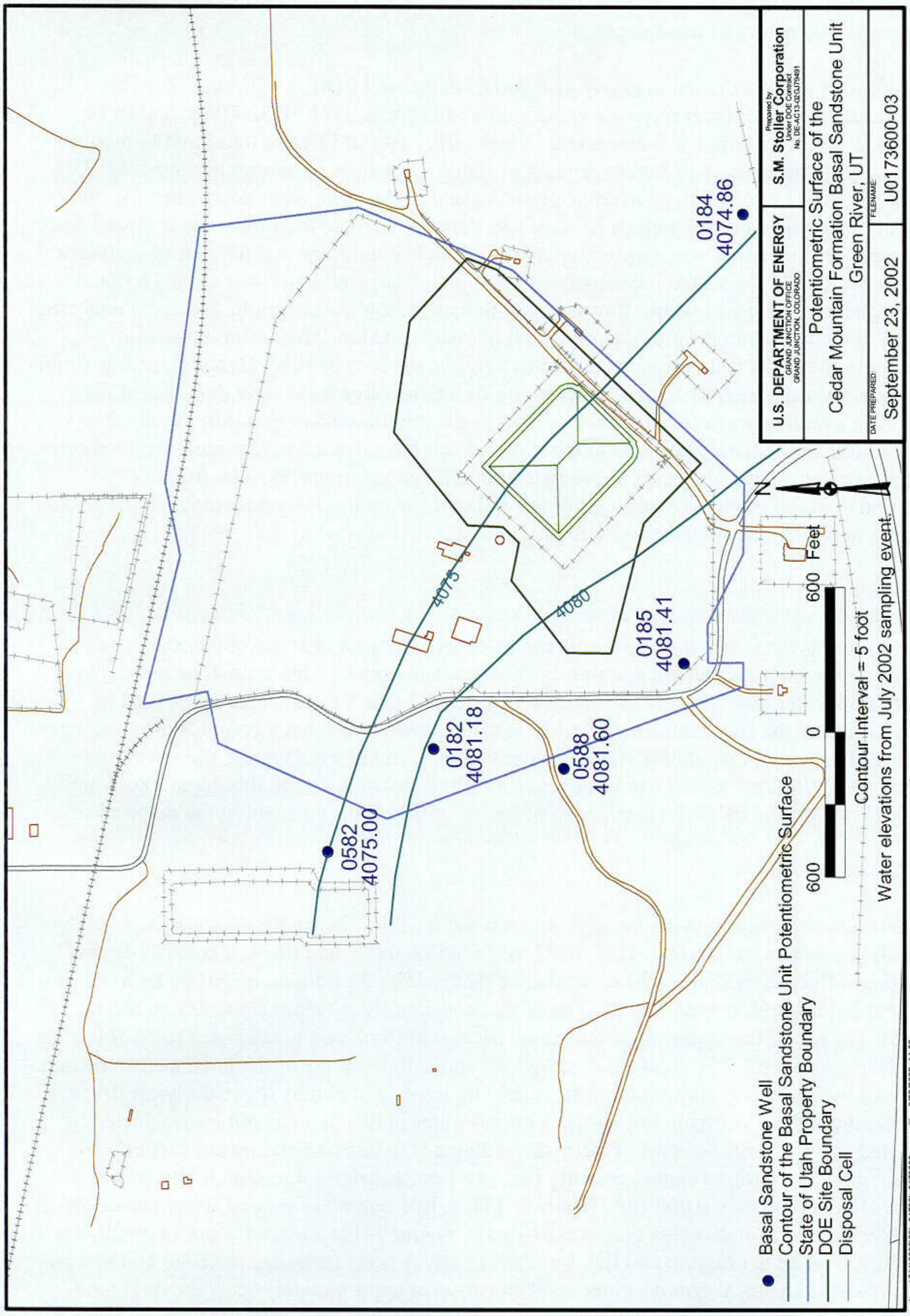


Figure 5–11. Potentiometric Surface of the Cedar Mountain Formation Basal Sandstone Unit at the Green River Site

C10

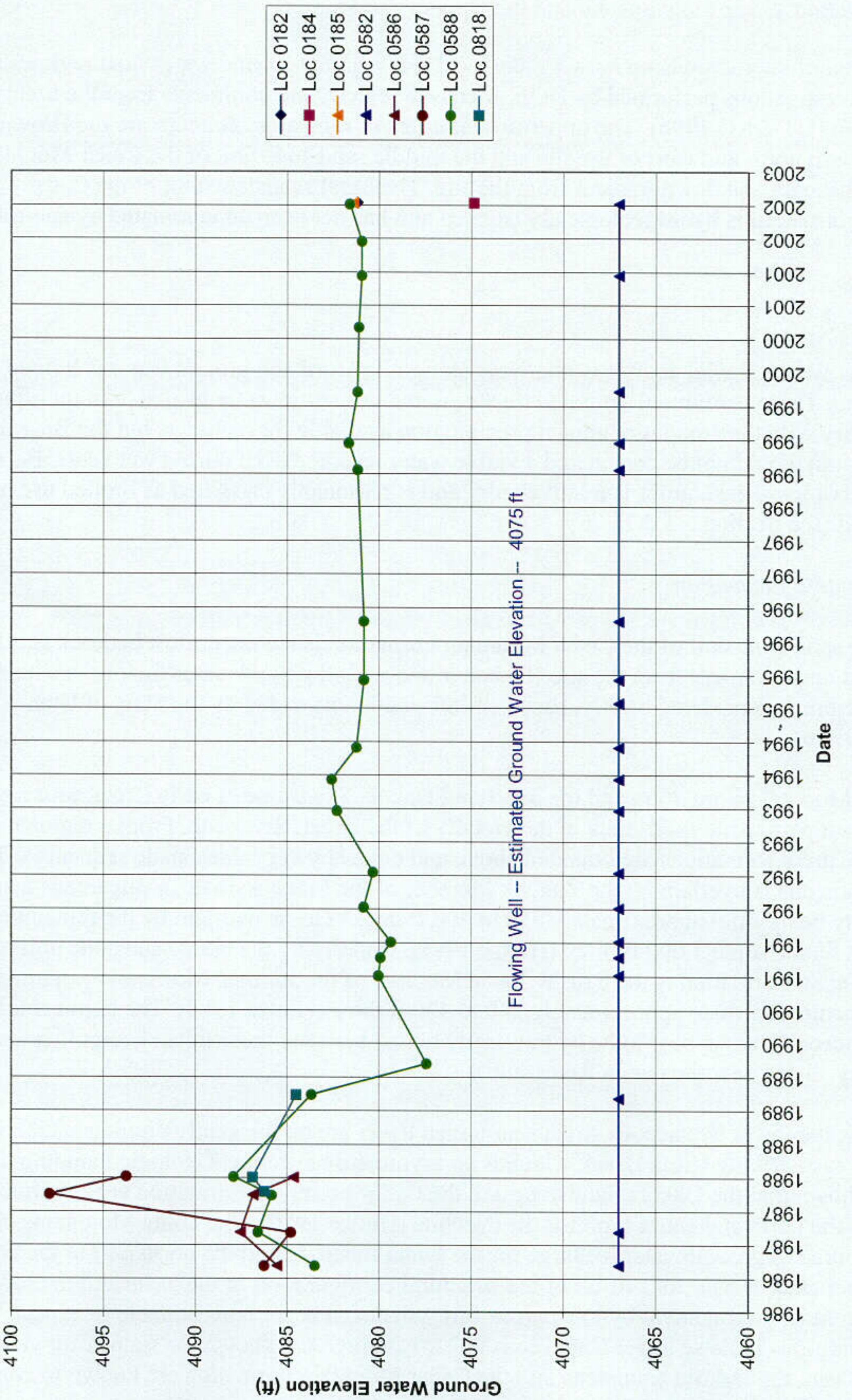


Figure 5–12. Hydrograph of the Cedar Mountain Formation Basal Sandstone Unit at the Green River Site

C11

5.1.2.3 Ground Water Flow System and the Uppermost Aquifers

Interpretation of the relationship between the local and regional ground water flow regimes is based on investigations performed by DOE, literature review, and comments from the State of Utah in 1996 (UT-DRC 1996). The uppermost aquifers of regulatory concern are the Browns Wash alluvium north and west of the site and the middle sandstone unit of the Cedar Mountain Formation beneath and downgradient from the site. The basal sandstone unit of the Cedar Mountain Formation is hydrogeologically isolated and has not been contaminated by site-related activities

Browns Wash Alluvium

The Browns Wash alluvial aquifer is relatively straight forward and ground water is limited in lateral extent. There is minimal saturated thickness and very little water available in the aquifer. This will vary with the amount of annual precipitation available for recharge, but the Browns Wash alluvium would not be considered a viable water resource even during wet years. Based on recent observations, the aquifer is relatively dry and is reasonably classified as limited use based on low yield (see Section 5.1.2.1).

Cedar Mountain Formation

The middle sandstone unit of the Cedar Mountain Formation is the uppermost bedrock aquifer beneath and downgradient from the site To better understand ground water flow in this unit, the regional picture is considered briefly, based on information provided by the State of Utah (UT-DRC 1996).

The Cedar Mountain Formation and the overlying Dakota Sandstone of early Cretaceous age form the most permeable rock strata in the vicinity of the Green River site. From a regional perspective, these formations are bounded above and below by very thick shale sequences. The Dakota Sandstone is overlain by the Tununk Member of the Mancos Shale, a calcareous marine shale (highly bentonitic) approximately 350 to 400 ft thick. This is overlain by the remainder of the Mancos Shale, some 3,000 ft thick (Hintze 1988). Underlying the basal sandstone unit of the Cedar Mountain Formation is the Brushy Basin Member of the Jurassic Morrison Formation, an extremely bentonitic shale approximately 240 to 420 ft thick (Hintze 1988). The permeable lower Cretaceous units appear to be hydraulically bound between these thick, bentonitic, low permeability shales near the Green River site.

Structurally, the lower Cretaceous strata near Green River are on the gently dipping southern limb of the east-striking Uinta Basin, which is an asymmetric syncline. Geologic mapping of this basin has shown that the Dakota Sandstone and the Cedar Mountain Formation are continuous across both the north and south limbs of the syncline (Hintze 1980). The Uinta Mountains, the principal source of ground water recharge for the Uinta Basin, bound the north part of the basin (Schlotthauer et al. 1981). As a result of the structural configuration of the basin and the basal and upper contact confinement by low permeability shales, it is not unreasonable to expect artesian conditions in these lower Cretaceous units. Although not known for significant yield in the Uinta Basin, the Dakota Sandstone and the Cedar Mountain Formation are known to contain ground water (Schlotthauer et al. 1981)

The Green River has downcut southward through the Uinta Basin, forming many deep canyons. The lower Cretaceous formations first crop out along the path of the Green River near Split Mountain, some 100 miles upstream (north) from Green River. The next and only location the Green River cuts into the Dakota Sandstone and the Cedar Mountain Formation over its flow path is in the immediate vicinity of the Green River site. Because the Green River is known to be the regional ground water sink, it is reasonable to expect that ground water confined in the lower Cretaceous formations, likely under artesian conditions, would discharge to the river where its course intercepts subcrops of the Dakota Sandstone and Cedar Mountain Formation.

Based on monitor well information (potentiometric surface maps and hydrographs), the local ground water flow pattern in the middle sandstone unit is irregular. There appears to be a relatively flat potentiometric surface beneath the disposal cell, and based on data available, ground water could be flowing to the southwest or in a northerly direction. Assuming good correlation of the middle sandstone unit from the disposal cell with monitor well 0817 northeast of the site, the ground water flow direction could be to the southwest (Figure 5–9). Possibly a more reasonable interpretation would be for ground water to flow more to the north, consistent with the regional dip of bedrock formations. This anomaly may be explained by the possibility of influence from the regional ground water flow system from the north, with the area beneath the site being near the distal end of the confined artesian flow system Another supporting factor is that even though ground water is under substantial confined pressure in the wells in Cedar Mountain Formation sandstones in the vicinity of the site, where these units crop out in a canyon just over 0.5 mile south of the site, the units are dry (no seeps are present). This substantiates that recharge in these units is not updip to the south, but ground water is possibly associated with the distal end of the regional artesian system to the north. This could account for the variable ground water levels and gradients in the area of the Green River site.

The significance of this interpretation is relevant to the compliance strategy at the site in that ground water may be relatively stagnant beneath the site in the uppermost bedrock aquifer, but that the ultimate discharge zone would be the Green River. At this location, any site-related contamination would be diluted to the point of being protective of human health and the environment. This would also preclude the potential for conventional natural flushing to dilute concentrations over time, as the system would be unpredictably stagnant for the near future. This concept provides credence for the application of the proposed ground water compliance strategy of ACLs for COPCs that is presented in Section 7.2.1. The concept that ground water may be relatively stagnant in the area of the Green River site, and the presence of a disposal cell that may produce minor seepage of site-related contaminants over the long-term disposal situation, supports the need for a compliance strategy that accommodates these conditions. Along with this, human health and the environment will be protected under this proposed strategy because there is no use of ground water from the middle sandstone unit of the Cedar Mountain Formation and no evidence of seepage from this confined unit on the surface. Also, data show that site-related contamination in ground water is not widespread or pervasive, but restricted to the area closely adjacent to the disposal cell.

5.2 Contaminant Source and Release

Uranium was processed at the mill buildings (which still remain at the site), and tailings were deposited on the Browns Wash alluvial plain between bedrock outcrops just north of the millsite and south of Browns Wash (Figure 3–2). Uranium ore concentrate was stored just west and southeast of the millsite prior to processing (DOE 1985).

Constituents related to uranium-ore processing were introduced directly into alluvial sediments and ground water adjacent to Browns Wash, and the contaminant plume migrated downgradient toward the Green River Concentrations of constituents have continued to decrease and migrate downgradient over time, particularly since removal of the source term from the Browns Wash alluvial plain.

Constituents were most likely introduced into ground water in the bedrock aquifers by infiltration through transmissive or fractured units during and after milling operations, during disposal cell construction and cleanup activities, and possibly by transient drainage from the completed disposal cell. The disposal cell was constructed below grade with the base of the cell approximately 35 ft below the surface, which would be within 40 ft above the top of the middle sandstone unit of the Cedar Mountain Formation.

5.3 Geochemistry

5.3.1 Background Ground Water Quality

Background ground water quality is defined as the composition of ground water in lithologically similar areas of the millsite that were not affected by ore-processing activities. This section discusses the monitor wells that have been installed to test for background conditions.

5.3.1.1 Alluvial Aquifer

Monitor well 0707 is upgradient of the millsite in the Browns Wash alluvium, however, because it contains nitrate, uranium, and sulfate, the BLRA did not consider this well to be representative of background (DOE 1995). Historical uranium concentrations in ground water in monitor well 0707 are relatively low, ranging from 0 008 to 0 029 milligrams per liter (mg L) for 25 measurements (Appendix C) Nitrate concentrations in ground water in monitor well 0707 range from 1 to 30 mg/L for 25 measurements, with two exceptions in 1986 and 1987 (prior to construction of the disposal cell) nitrate concentrations were 120 and 140 mg/L, respectively Sulfate concentrations in ground water for the 25 measurements ranged from 4,770 to 6,549 mg/L. Monitor well 0707 was dry during the July 2002 sampling event

The historical uranium concentrations in ground water in monitor well 0707 are relatively low and may not have been influenced by the millsite The two high nitrate values may be analytical error, or nitrate could be derived from local sources such as septic systems, agricultural fertilizers, sewage lagoons, and munitions dumps. Sulfate concentrations in ground water in monitor well 0707 are higher than in the Cedar Mountain Formation wells near the disposal cell suggesting that some or all of the sulfate is derived from other sources Therefore, it is reasonable that monitor well 0707 has not been affected by the milling process and may be representative of background

5.3.1.2 Cedar Mountain Formation

Prior to the field work in 2002, monitor wells that had been considered for background in the Cedar Mountain Formation included wells 0178, 0180, 0806, and 0811 (DOE 1995) Monitor well 0817 is also located in a background area. Monitor wells 0184 and 0185 were completed as background wells in 2002.

Monitor well 0178 is screened in the lower unit and 0180 in the middle sandstone unit of the Cedar Mountain Formation; these wells are east and southeast of the disposal cell (Plate 1) The proximity of monitor wells 0178 and 0180 to the processing site and the high levels of site-related contaminants in nearby monitor well 0179 suggest that these wells may not be representative of background water quality.

Monitor wells 0806, 0811, and 0817 are cross gradient northeast of the disposal cell near Browns Wash and should reflect background conditions for the Cedar Mountain Formation (Plate 1). Wells 0806 and 0811 are screened in the upper unit and well 0817 is screened in the middle sandstone unit. Monitor wells 0184 and 0185 are located southeast and southwest of the disposal cell, respectively, and are screened in the basal sandstone unit of the Cedar Mountain Formation. Ground water quality is similar among these five wells, and contaminant concentrations are low (Table 5–1).

Table 5–1. Background Ground Water Characteristics for the Cedar Mountain Formation

Parameter	Monitor Well 0806 Upper Unit	Monitor Well 0811 Upper Unit	Monitor Well 0817 Middle Sandstone Unit	Monitor Well 0184 Basal Sandstone Unit	Monitor Well 0185 Basal Sandstone Unit
pH	7 97	8 26	8 44	8 15	8 51
Alkalinity (mg/L $CaCO_3$)	947	1024	691	430	588
Eh (mV)	+216	+367	+276	+98	-271
Conductivity (µS/cm)	3,493	2,859	2,330	2,355	2,655
Nitrate (mg/L)	0 732	0 557	0 033	0 02	<0 02
Selenium (mg/L)	<0.0001	<0 0001	<0 0001	0.0003	0 0001
Sulfate (mg/L)	644	354	119	570	585
Uranium (mg/L)	<0 0001	<0.0001	<0 0001	0 0001	<0 0001

(July 2002 Sampling)
mV = millivolts
µS/cm = microsiemans per centimeter

5.3.2 Ground Water Chemistry

5.3.2.1 Eh and pH

The Eh of ground water is important to understanding potential mechanisms that could remove contaminants from solution. Concentrations of several constituents in ground water (nitrate, selenium, sulfate, and uranium) can change due to oxidation/reduction processes. For example, nitrate can be reduced to form nitrite, nitrogen gas, or ammonium; selenium can form ferrous selenides; sulfate can be reduced to sulfide; and uranium can be reduced to uranous minerals. These processes decrease the concentrations in ground water.

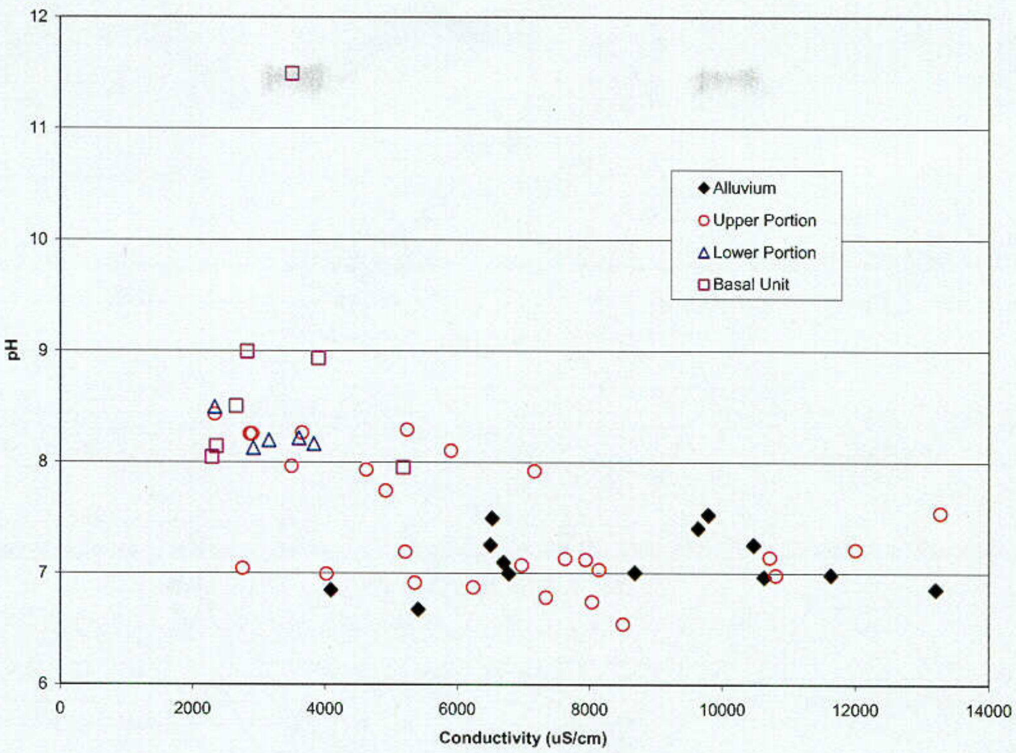
Sporadic measurements of Eh (Eh was calculated from oxidation/reduction potentials [ORP] using ORP measurements of a Zobell solution) were made prior to the 2002 sampling. Both the 2002 measurements and the earlier measurements indicate large fluctuations in Eh, however, some of the variability is probably due to measurement error. ORP is difficult to determine accurately because it often takes a long time for the reading to stabilize, and the measurement is influenced by atmospheric oxygen artificially incorporated during the analysis. The average Eh value for 5 alluvial wells sampled in 2002 is +365 millivolts (mV). The average Eh value for the upper portion of the Cedar Mountain Formation (upper unit and middle sandstone unit) in 2002 is +270 mV; and is +51 mV for the combined lower portion (lower unit and stringer sandstone) and basal sandstone unit. These values suggest relatively oxidized conditions in the alluvium decreasing through the Cedar Mountain Formation and relatively reduced conditions in the basal sandstone unit Decreasing Eh values with depth likely results from the contact of infiltrating water with carbon sources (coal and other organics). At some depth, conditions might be suitable for contaminant precipitation as reduced minerals.

Values of pH are an indication of the tendency of the ground water to react with sediments and can sometimes be used to help determine the source of the water Values of pH in the lower unit, stringer sandstone, and basal sandstone unit of the Cedar Mountain Formation are generally higher than in other units (Figure 5–13) Values of conductivity are lower in the lower portion of the Cedar Mountain Formation indicating that the ground water is fresh relative to the upper units Values of pH in the upper unit and middle sandstone unit of the Cedar Mountain Formation are similar to those in the alluvium (Figure 5–13). These relationships suggest that the upper and middle sandstone units are hydraulically separated from the lower unit, stringer sandstone, and basal sandstone unit.

5.3.2 2 Major Ions

The major ion chemistry of ground water can be used to depict associations with other aquifers, and to describe the origin and chemical evolution of the ground water. Piper trilinear diagrams have been used extensively for this purpose (Piper 1944). Piper diagrams were constructed using the most recent complete sampling events for four portions of the stratigraphic section (alluvium, upper portion of the Cedar Mountain Formation, lower portion of the Cedar Mountain Formation, and the basal sandstone unit of the Cedar Mountain Formation) of interest at the Green River site (Figure 5–14 through Figure 5–17). For this discussion, the upper portion of the Cedar Mountain Formation includes well completions in the Mancos Shale, Dakota Sandstone, upper unit of the Cedar Mountain Formation, and middle sandstone unit of the Cedar Mountain Formation The lower portion of the Cedar Mountain Formation includes the lower unit and the stringer sandstone These designations are used because some of the well screens cross formation boundaries

The alluvial ground water is relatively high in total dissolved solids (TDS) and its chemistry is dominated by sodium and sulfate (Figure 5–14). The upper portion of the Cedar Mountain Formation is also high in TDS and the dominant ions in most samples are sodium and sulfate (Figure 5–15). The cation distribution for the upper portion of the Cedar Mountain Formation displays a linear trend, suggesting mixing between sodium-dominated and calcium/magnesium-dominated waters. The similar geochemical signatures of ground water in the alluvium and some ground water in the upper portion of the Cedar Mountain Formation indicate that these units may be interconnected



Upper portion includes the Mancos Shale, Dakota Sandstone, and upper and middle sandstone units of the Cedar Mountain Formation. Lower portion includes the lower unit and stringer sandstone of the Cedar Mountain Formation.

Figure 5–13. Values of pH versus Conductivity for Four Geologic Units

Ground water in the lower portion and basal sandstone unit of the Cedar Mountain Formation (Figure 5–16 and Figure 5–17) are similar to each other, but have distinctly different signatures from ground water in the alluvium and upper portion of the Cedar Mountain Formation. The ground water in these units is low in TDS. The cations are dominated by sodium and the anions vary. The unique geochemical signatures suggest that the lower portion and basal sandstone unit are interconnected, but hydraulically separated from the upper units.

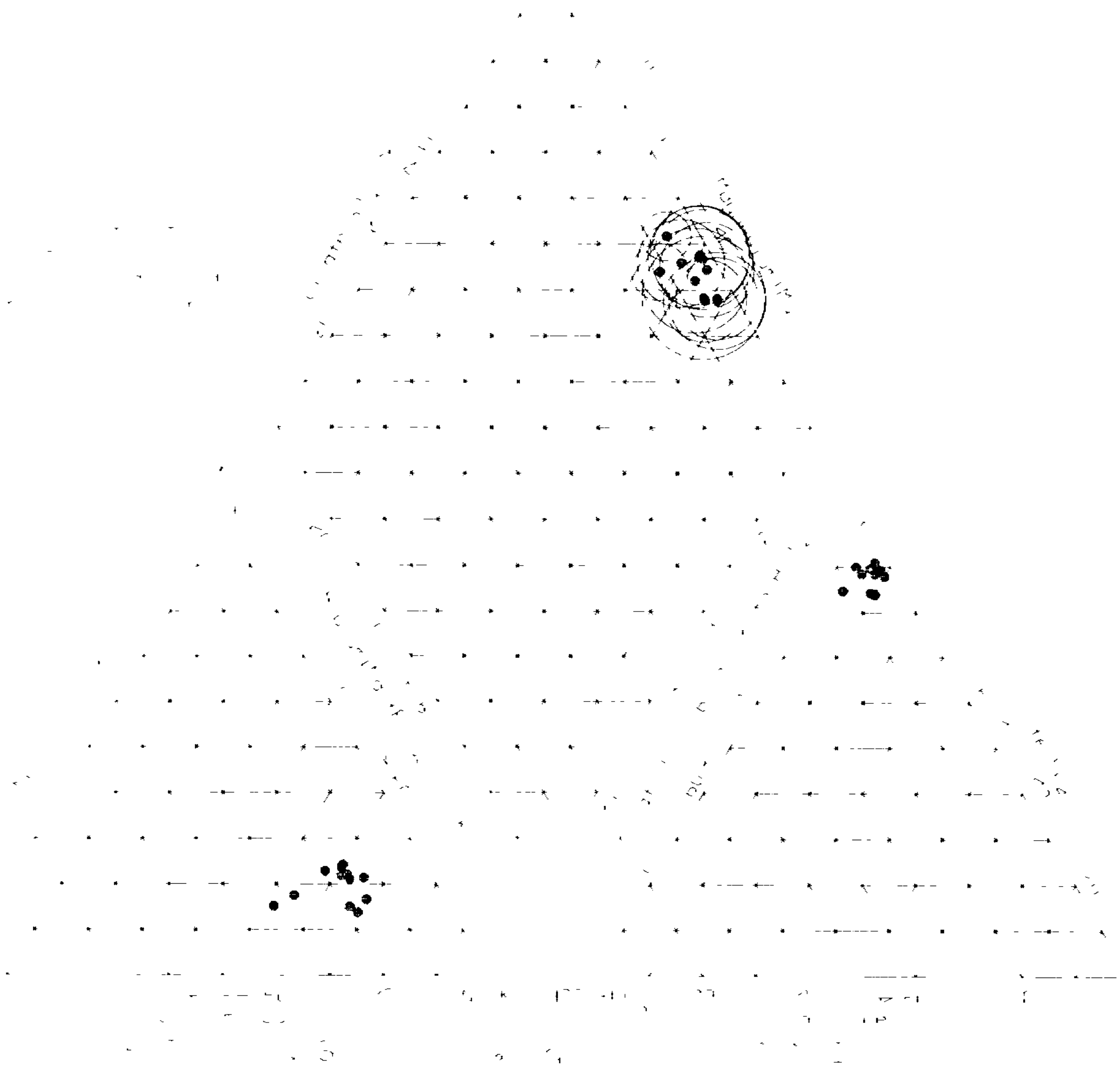
5.3.3 Spatial Distribution of Ground Water Contamination

Analytical results from the most complete sampling event (July 2002) are used to characterize the ground water chemistry in the alluvium. Concentration maps are presented for four of the COPCs – nitrate, selenium, sulfate, and uranium.

5.3.3.1 Alluvial Aquifer

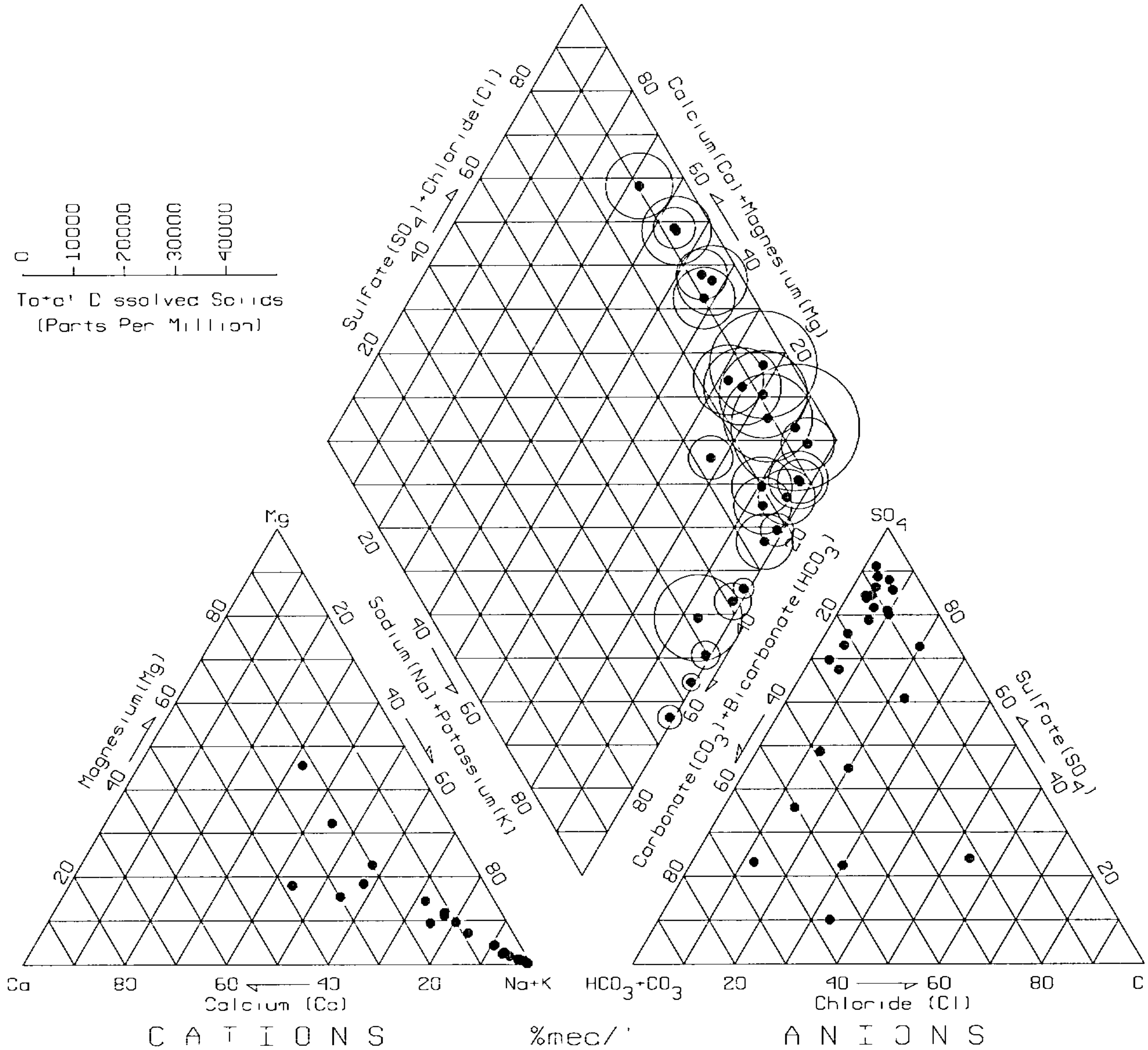
Most of the alluvial wells produced little water during the 2002 ground water sampling event. There was insufficient water production from monitor well 0194 to perform a complete analysis, thus, anions and radionuclide concentration data are not available.

C12



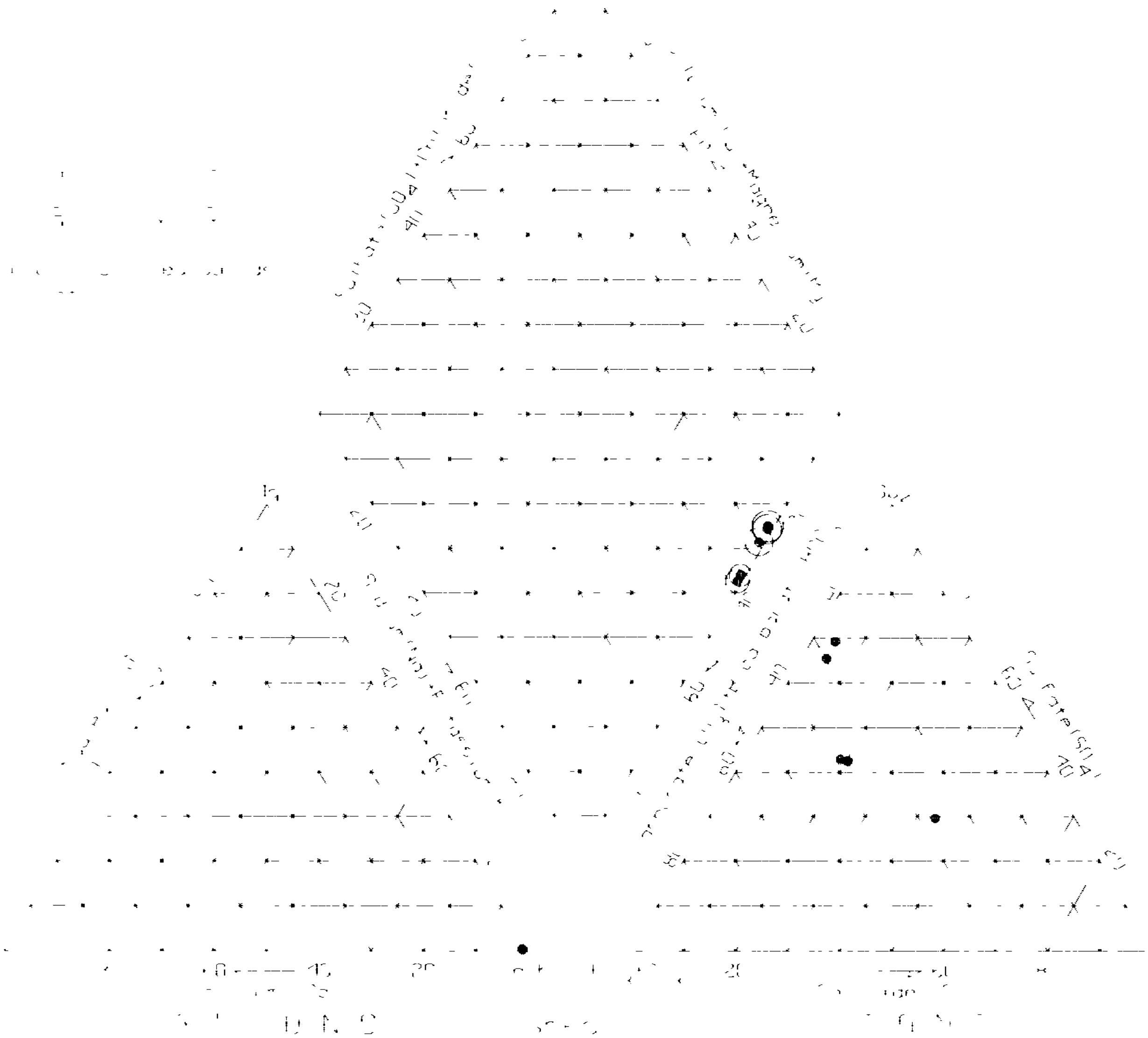
Using most recent data Radius of circles indicates concentrations of TDS 2002—Wells 0188, 0189, 0190, 0191 2001—Well 0707 1988—Wells 0563, 0702, 0704, 0705, 0708, 0701 1982—Well 0706

Figure 5–14. Piper Diagram of Alluvium Wells



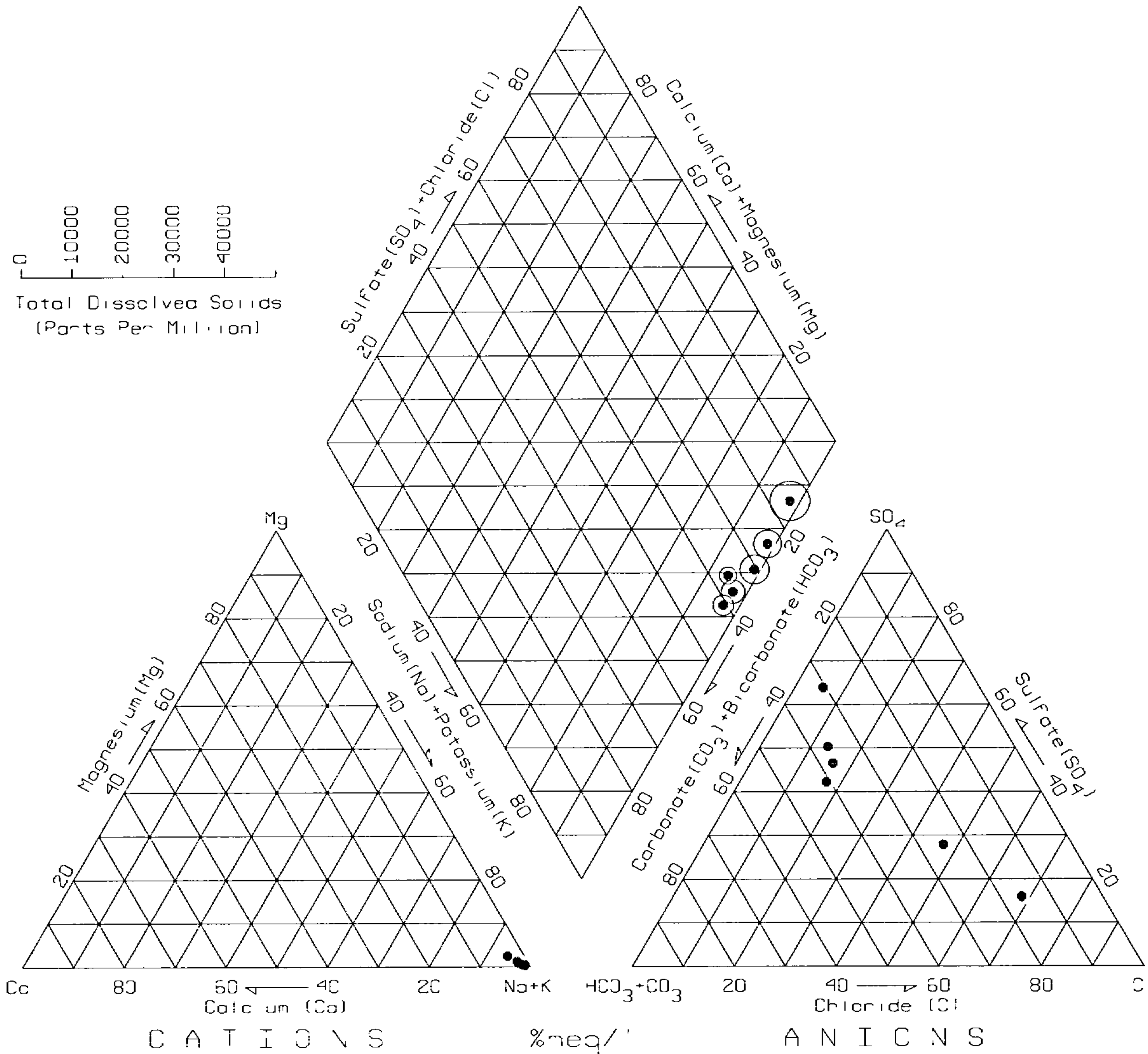
Using the most recent data Radius of circles indicates concentrations of TDS. 2002—Wells 0171, 0172, 0173, 0174, 0175, 0176, 0179, 0180, 0181, 0182, 0183, 0813, 0817, 0583, 0806, 0810, 0811, 0585, 0584: 1990—Well 0807: 1988—Wells 0562, 0815, 0809, 0816, 0581, 0808: 1987—Well 0703.

Figure 5–15 Piper Diagram of the Mancos Shale, Dakota Sandstone, and Upper Portion of the Cedar Mountain Formation (Including Upper Unit and Middle Sandstone Unit)



Using the most recent data. Radius of circles indicates concentrations of TDS 2002—Wells 0177, 0588, 0178 1988—Wells 0819, 0561

Figure 5–16 Piper Diagram of the Lower Portion of the Cedar Mountain Formation (Including Lower Unit and Stringer Sandstone)



Using the most recent data. Radius of circles indicates concentrations of TDS 2002—Wells 0184, 0185, 0582: 1988—Well 0818: 1988—Wells 0586, 0587.

Figure 5–17. Piper Diagram of the Basal Sandstone Unit of the Cedar Mountain Formation

Nitrate: Nitrate concentrations in the alluvium ranged from 10 to 313 mg/L (Figure 5–18). Two samples had nitrate concentrations that exceed the 44 mg/L MCL. Nitrate in the alluvium may be mill related; however, local sources such as septic systems, agricultural fertilizers, sewage lagoons, and munitions dumps may contribute some nitrate to the shallow ground water. Concentrations of nitrate often exceed 150 mg/L in ground water plumes associated with septic leach fields (Aravena et al. 1993)

Selenium: Selenium concentrations in the five alluvial wells ranged from 0 018 to 0.134 mg/L (Figure 5–19). Concentrations in all five alluvial ground water samples exceeded the 0.01 mg/L MCL. Selenium may result from millsite contamination; however, some selenium may be contributed from natural weathering of selenium-rich shales in the Mancos Shale and Dakota Sandstone. High selenium concentrations are common in ground water associated with Mancos Shale (Nolan and Clark 1997).

Sulfate: Sulfate concentrations in the four alluvial wells ranged from 5,970 to 7,040 mg/L (Figure 5–20). There is no MCL for sulfate, although the EPA secondary drinking water standard is 250 mg/L. Sulfate may result from millsite contamination, however, sulfate is often concentrated in shallow ground water in arid and semiarid regions such as the Green River desert. The high concentrations in shallow ground water result from deposition of salts on and near the ground surface due to evaporation and repeated dissolution of the salt deposits by infiltrating water High sulfate concentrations can also occur from leaching of sulfate minerals (such as gypsum) from the Mancos Shale and other geologic units.

Uranium: Uranium concentrations in the five alluvial wells ranged from 0.018 to 0.456 mg/L (Figure 5–21) Concentrations in samples from three alluvial monitor wells exceeded the 0.044 mg/L MCL, indicating mill-related contamination. Two alluvial wells (0190 and 0191) north of Browns Wash, had uranium concentrations of 0.019 and 0.018 mg/L, respectively These concentrations are characteristic of uranium concentrations in ground water contacting Mancos Shale (DOE 1999). Since these wells are screened across the contact of alluvium with Mancos Shale, the uranium may be naturally occurring.

5.3.3.2 Cedar Mountain Formation

Concentrations of constituents for all units of the Cedar Mountain Formation are plotted on a single figure for convenience. Zone of completion for each monitor well is shown on Plate 1.

Nitrate: Nitrate concentrations in ground water in the 25 Cedar Mountain Formation wells ranged from less than detection (0.02 mg/L) to 1,000 mg/L for the July 2002 sampling event (Figure 5–18). Concentrations exceeded the 44 mg/L MCL only in six wells; all six wells are close to the disposal cell The highest concentration (1,000 mg/L) was measured in monitor well 0172, which is immediately downgradient of the disposal cell. Well 0172 has had large historical fluctuations in nitrate concentrations (see Section 5.3 4.2). Well 0181 was drilled in 2002 to examine the nitrate concentration a short distance (20 ft) from well 0172. Well 0181 had a nitrate concentration of 335 mg/L indicating that nitrate is attenuating within a short distance of the disposal cell. Nitrate concentrations in wells farther downgradient were all less than 0.2 mg/L. The elevated concentrations in wells near the disposal cell indicate mill-related contamination

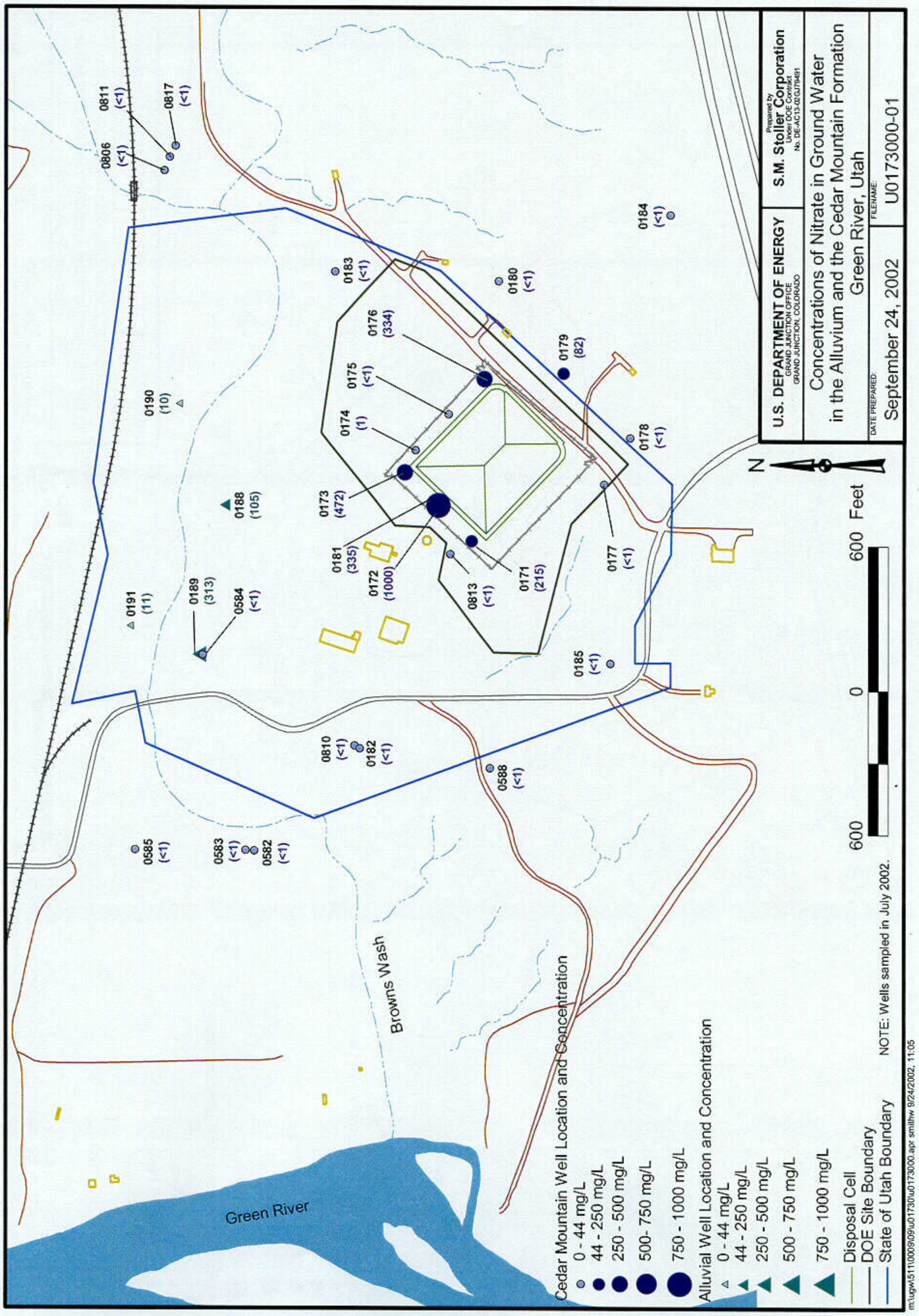


Figure 5–18. Spatial Distribution of Nitrate, July 2002

C13

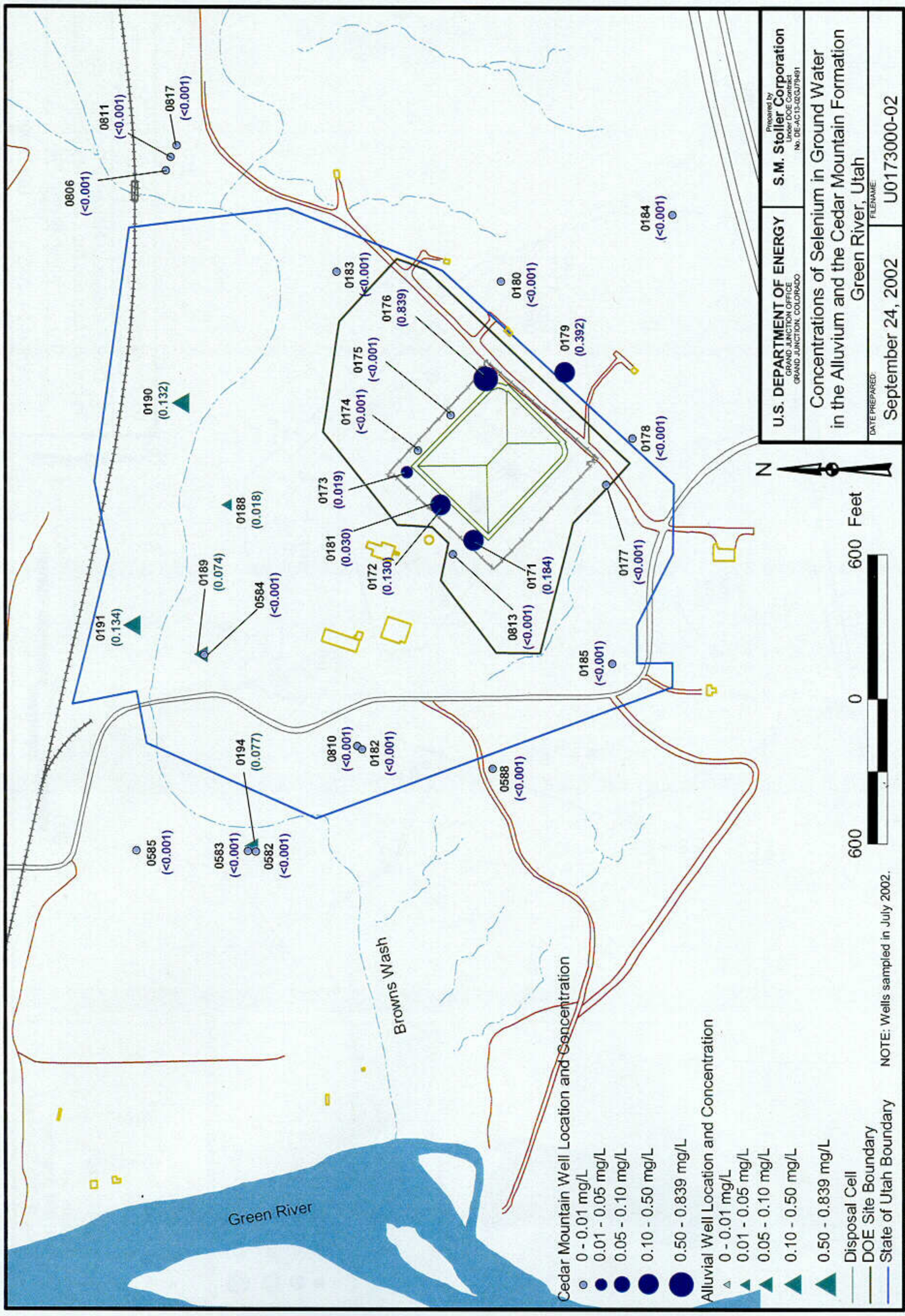


Figure 5–19. Spatial Distribution of Selenium, July 2002

C14

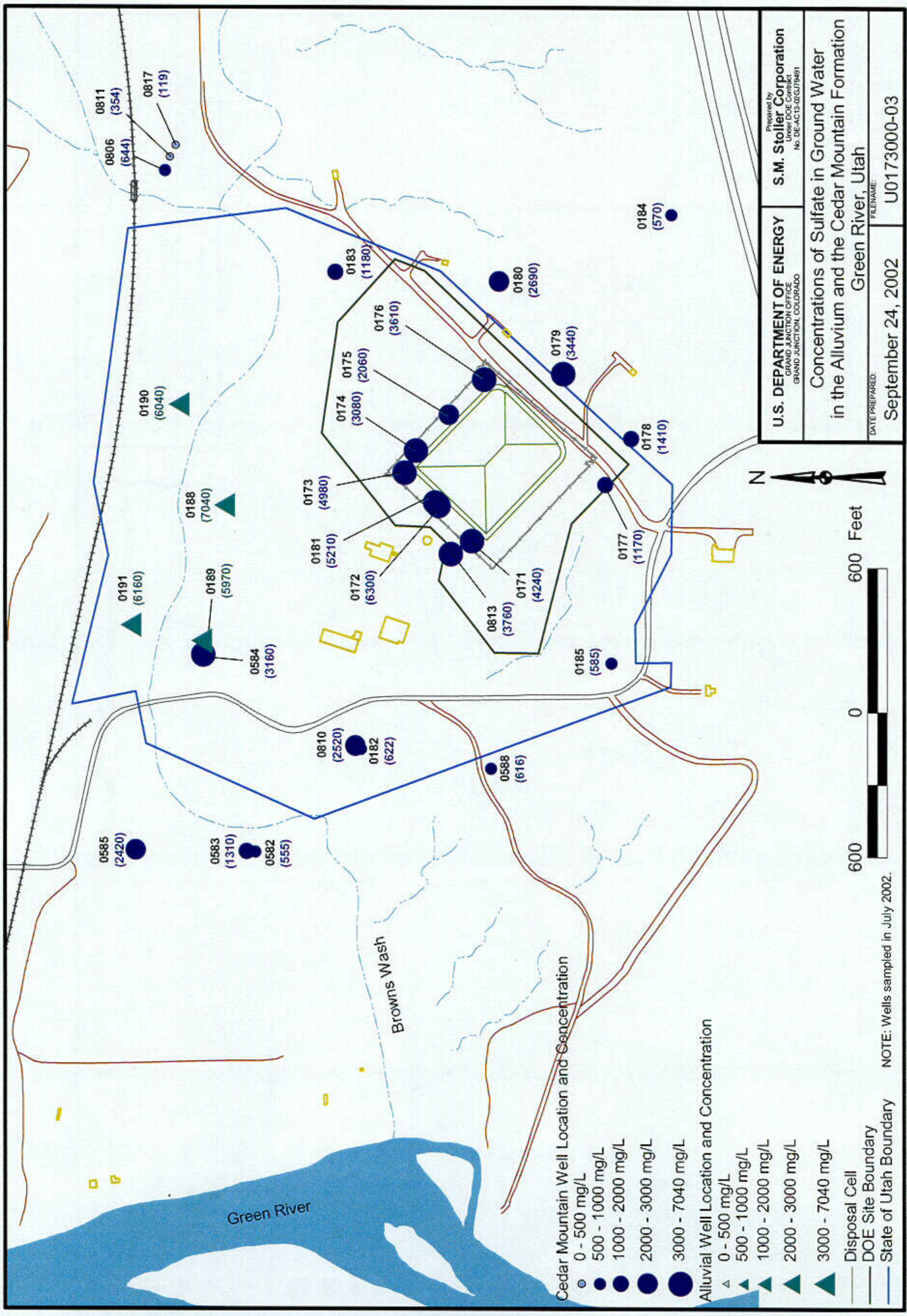


Figure 5–20: Spatial Distribution of Sulfate, July 2002

C15

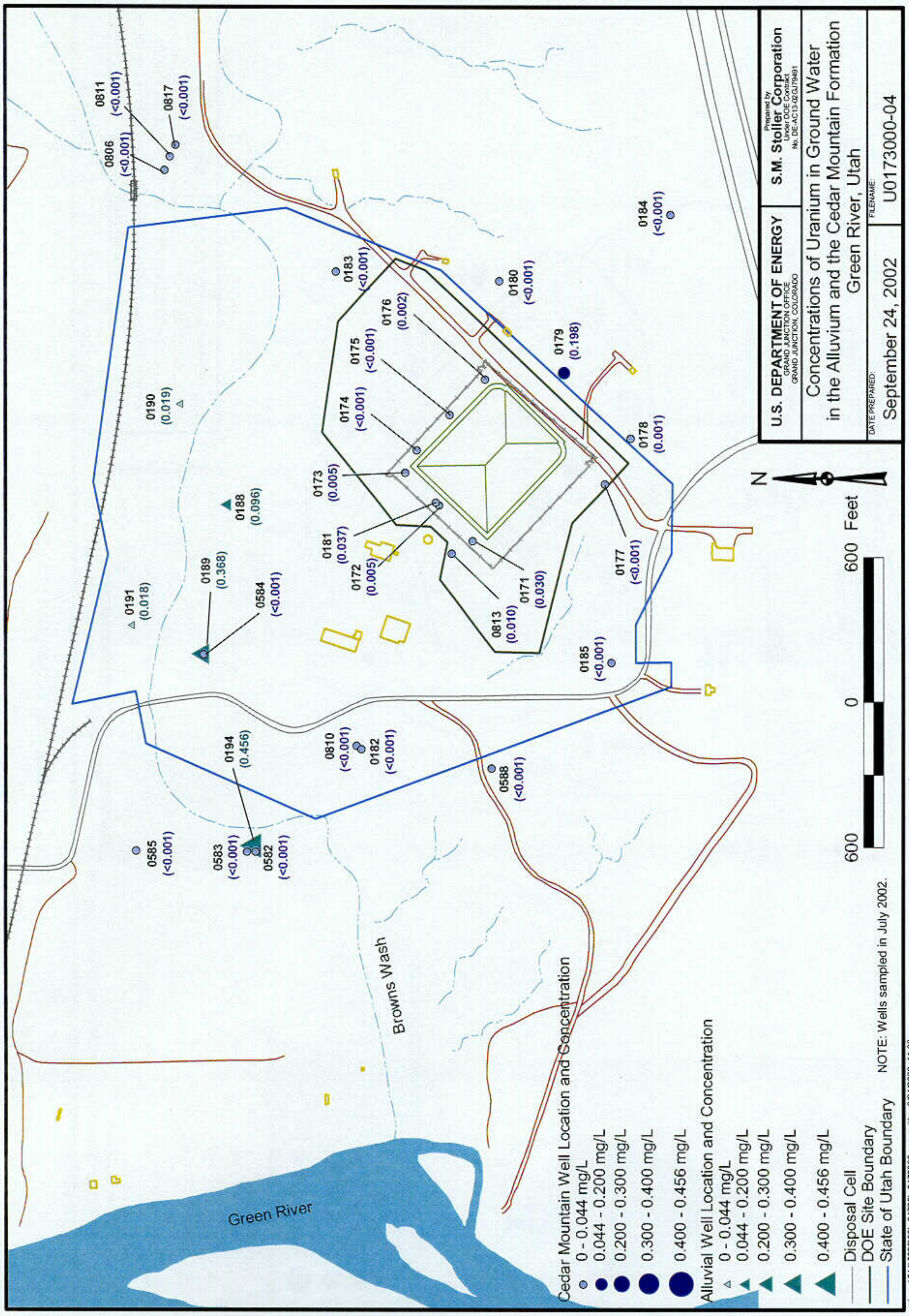


Figure 5–21. Spatial Distribution of Uranium, July 2002

C16

Selenium: Selenium concentrations in the Cedar Mountain Formation wells ranged from less than the detection limit (0.0001 mg/L) to 0.839 mg/L for the July 2002 sampling event (Figure 5–19). Selenium concentrations exceeded the MCL of 0.01 mg/L in six monitor wells, all of which are immediately adjacent to the disposal cell. Selenium concentrations in wells 0171 and 0172, located at the downgradient edge of the disposal cell, were 0.184 and 0.130 mg/L, respectively. Concentrations decreased to <0.001 and 0.030 mg/L in wells 0813 and 0181 located about 100 ft further downgradient. Wells further downgradient were mostly less than the detection limit of 0.0001 mg/L. The elevated concentrations in wells near the disposal cell indicate mill-related contamination.

Sulfate: Sulfate concentrations in the Cedar Mountain Formation ranged from 119 to 6,300 mg/L for the July 2002 sampling event (Figure 5–20). The highest concentrations are clustered near the disposal cell. Sulfate concentrations were lowest in monitor wells 0806, 0811, and 0817 cross gradient of the site near Browns Wash, in monitor well 0184 upgradient of the disposal cell, and in 0182, 0185, 0582, and 0588 downgradient and crossgradient of the site. The elevated concentrations in wells near the disposal cell probably indicate mill-related contamination; however, concentrations up to 1,410 mg/L (well 0178) are present in ground water upgradient and concentrations up to 2,420 mg/L are present far downgradient of the disposal cell. High sulfate concentrations can occur from leaching of sulfate minerals (such as gypsum) from the Mancos Shale and other geologic units.

Uranium: Uranium concentrations in the Cedar Mountain Formation ranged from less than the detection limit (0.0001 mg/L) to 0.198 mg/L (Figure 5–21). Samples from only one monitor well (0179) had a concentration that exceeded the MCL of 0.044 mg/L. This well is near the disposal cell and the high concentration reflects mill-related contamination.

5.3.4 Variation in Contamination Over Time

5.3.4.1 Uranium Concentrations Immediately Downgradient of the Disposal Cell

The disposal cell was constructed during 1988 and 1989. Tailings water and water used as dust control during construction often seeps from disposal cells under transient conditions soon after construction, but transient drainage decreases with time. Thus, contaminant concentrations may show increasing trends in downgradient wells soon after construction, but the concentrations should decrease over time.

Uranium concentrations in samples from four POC wells (0171, 0172, 0173, and 0813) completed in the middle sandstone unit immediately downgradient of the disposal cell are plotted over time in Figure 5–22. The patterns are inconsistent. Since construction, uranium concentration has decreased in monitor well 0813 but has increased in monitor well 0171. These results suggest that the transient water may be seeping at differing rates into the downgradient areas.

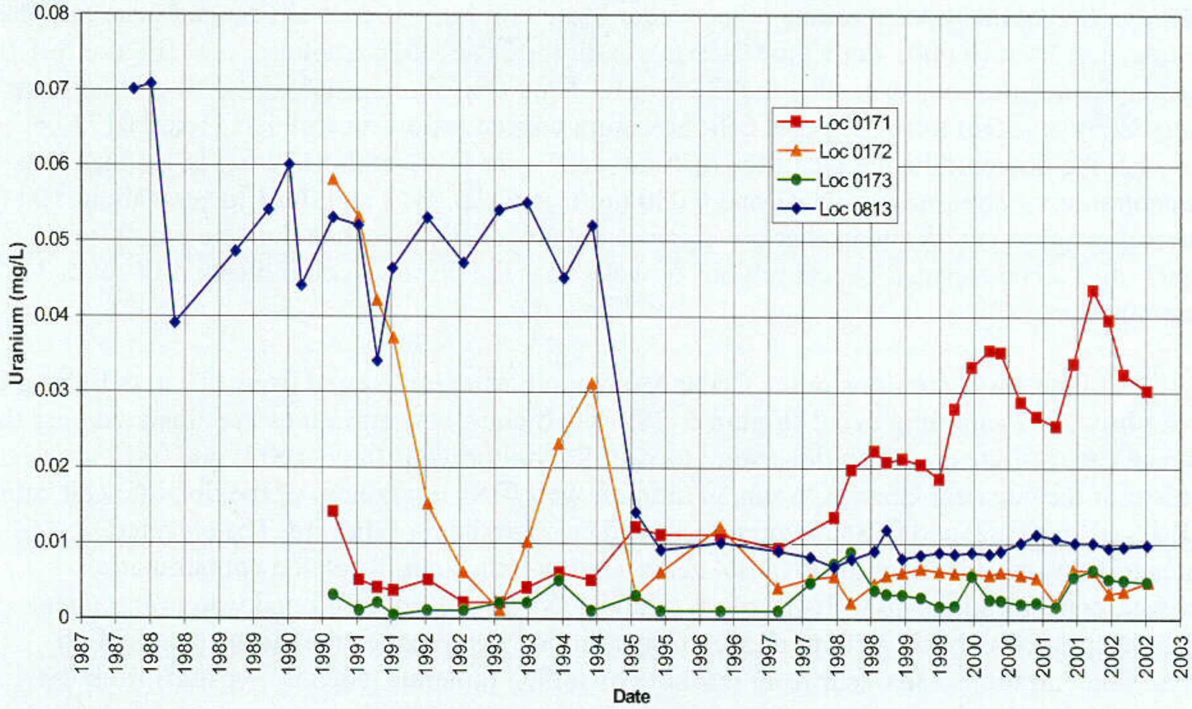


Figure 5–22. Uranium Concentrations in Ground Water Immediately Downgradient of the Disposal Cell

5.3.4.2 Anomalous Concentrations of Nitrate in POC Wells

Nitrate concentrations in monitor well 0172 were relatively low (less than 108 mg/L) from August 1990 to June 1994, but then began to increase and exceeded 1,000 mg/L from December 1997 through November 2000 (Figure 5–23). The changes in nitrate concentrations in monitor well 0172 appear to be anomalous and are possibly due to several factors: (1) monitor well construction, (2) sampling and analytical methods, (3) physical and geochemical characteristics of the aquifer, and (4) other sources of recharge into the well (DOE 2001a). The integrity of the monitor well appears to be good based on results of a down-hole camera survey. Monitor well 0172 recharges very slowly after the water is removed, which could be related to well construction or installation in a low-permeability section of the aquifer. The sampling method was changed late in 1994 with the installation of a dedicated pump and low-flow purging. Standard low-flow sampling procedure dictates removal of approximately 1 gallon of water prior to sampling. During the March 2001 sampling round, approximately 4 gallons of water were removed. The samples from this round had a significant decrease in nitrate (207 mg/L) and sulfate concentrations; the levels were consistent with those in the other POC wells (Figure 5–23). These results suggested that minimal purging in the low-yield well was not providing representative ground water from the aquifer. This possibility, however, was not substantiated during the subsequent sampling round in June 2001. During the June 2001 round a standard purge (3 bore volumes) method was used, but the nitrate concentration (1,590 mg/L) was similar to the values detected in the earlier low-flow purge sampling rounds (Figure 5–23). The cause of the extreme fluctuations in nitrate concentrations in this well is yet unresolved.

C17

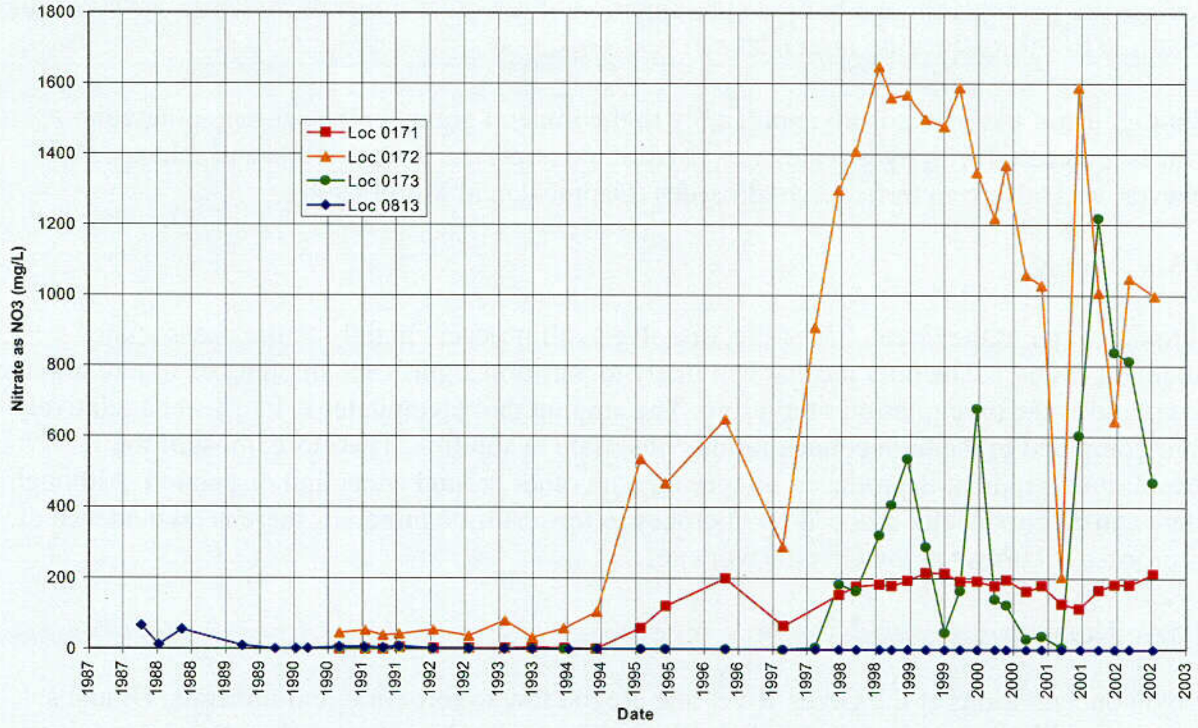


Figure 5–23. Nitrate Concentrations in Ground Water Immediately Downgradient of the Disposal Cell

5.3.5 Fate and Transport of COPCs

Chemical mechanisms that are most likely to control fate and transport of the COPCs in the aquifers at the Green River site, based on information from published literature, are summarized in this section.

5.3.5.1 Nitrate

Nitrate does not complex significantly with other ions in ground water. It will be transported without significant interaction with the rock matrix. If appropriate nitrate-reducing microbiota and nutrients are present, nitrate can undergo reduction to nitrogen gas, nitrite, or ammonium. Significant denitrification is not expected to occur in the alluvium or Cedar Mountain Formation without a suitable electron donor for microbes. Therefore, nitrate probably transports nearly conservatively through the aquifers. Some nitrate reduction may occur in portions of the aquifer containing coals or other humic materials. Concentrations decrease by mixing with other ground water and by dispersion. If the aquifer is within about 50 ft of the ground surface, deep-rooted plants will remove nitrate from the ground water.

Nitrate in the ground water may be mill related; however, local sources such as septic systems, agricultural fertilizers, sewage lagoons, and munitions dumps may contribute some nitrate to the shallow ground water.

5.3.5.2 Selenium

Aqueous selenium occurs predominately as selenate (SeO_4^{2-}) or selenite (SeO_3^{2-}); selenate is probably favored under the oxidized conditions at the Green River site. Concentrations of

C18

selenium are not high enough to cause precipitation of selenium minerals. Selenite can substitute for sulfide in sulfide-bearing minerals.

Selenium is not likely to adsorb appreciably to the mineral grains in the aquifers unless the surfaces are coated with hydroxide or oxyhydroxide minerals. Both selenite and selenate, however, will adsorb to ferric oxyhydroxides (Dzombak and Morel 1990).

5.3.5.3 Sulfate

In ground water at the Green River site, dissolved sulfur occurs mainly as the unassociated sulfate ion (SO_4^{2-}). The only mechanism likely to partition significant amounts of sulfate into the solid phase is the precipitation of gypsum. The amount that precipitates is likely to be relatively minor compared to the high concentrations of sulfate in solution Therefore, most of the concentration gradient is produced by mixing with other ground water and dispersion. Although sulfate can be chemically reduced by microbes to form sulfide minerals, there is no evidence of this process occurring at the Green River site.

5.3.5 4 Uranium

Uranyl concentrations at the Green River site are too low to form uranium minerals. Uranous minerals would precipitate if the oxidation state were lower; however, such reduced conditions do not currently exist except perhaps in small localized areas Adsorption of uranyl to mineral grains in the aquifers is likely to be insignificant unless the grains are coated by hydroxide or oxyhydroxide minerals. Uranyl is known to adsorb to ferric oxyhydroxide in relatively high concentrations (Morrison et al. 1995). It is likely that adsorption to ferric or manganese minerals is the principal mechanism that retards uranium migration in ground water at the site. The high concentration of carbonate in the ground water favors the partitioning of uranium to the dissolved phase. In distal portions of the plume where dissolved carbonate concentrations are lower, adsorption of uranyl to oxide or oxyhydroxide minerals may be a dominant process

5.4 Ecology

The Green River processing site is highly disturbed from past use and subsequent remediation activities. These disturbed areas were revegetated with selected seed, although vegetation has not been significantly reestablished (DOE 1995). Areas adjacent to the millsite are a mix of agricultural, ranching, and limited industrial activity. Due to the site's arid environment and proximity to the City of Green River, flora and fauna species diversity is somewhat limited. The *Environmental Assessment for Remedial Action at the Green River Uranium Mill Tailings Site, Green River, Utah* (DOE 1988) lists 34 species of mammals, 18 species of raptors, 51 species of nongame birds, 23 species of reptiles, 7 species of amphibians, and 14 species of fish that could occur in the vicinity of the site. The EA also identified six endangered wildlife species protected under the Endangered Species Act as potentially occurring in the vicinity of the site. Details on the ecosystem at the Green River site are provided in Section 6.2.

6.0 Risk Assessment

6.1 Human Health Risk Assessment

A BLRA was previously prepared for the Green River site (DOE 1995). Most of the methodology used in that risk assessment followed standard EPA risk assessment protocol (EPA 1989a), though the BLRA did not calculate potential risks for noncarcinogenic constituents. Instead, calculated exposure intakes were compared with a range of contaminant doses associated with various adverse effects. Most of the data used in that report were collected from 1986 to 1988, prior to surface remediation. Since that time, some additional data have been collected; some of the data were used to more completely characterize the site; others focused on demonstrating compliance of the on-site disposal cell. These data are used to reevaluate COPC identification and make a preliminary qualitative assessment of associated risks. Browns Wash alluvium and the Cedar Mountain Formation are considered separately in the following discussion.

6.1.1 Summary of 1995 BLRA Methodology and Results

The 1995 BLRA identified 31 constituents in the Browns Wash alluvium as being detected in ground water. Typically these concentrations would be compared to background values to determine if concentrations were elevated compared to non-milling ground water. However, for the Green River site, locations identified as background alluvium in some previous documents are questionable based on elevated concentrations of a number of constituents. High levels of uranium, nitrate, and sulfate in the alluvium were attributed to ore-processing activities. Maximum detected levels of selenium and molybdenum exceeded UMTRA Project ground water standards, or MCLs. Nitrate, uranium, and sulfate were retained for further evaluation in the risk assessment process. All radionuclides were retained for evaluation of potential carcinogenic risks.

The 1995 BLRA identified 35 constituents as having concentrations above background in ground water of the Cedar Mountain Formation. More reliable background wells were available for this hydrogeologic unit and were used for a statistical comparison. Nineteen of these 35 constituents had concentrations that exceeded background levels. This initial list of 19 constituents was screened to first eliminate constituents with concentrations within nutritional or dietary ranges. A second screening step then eliminated contaminants of low toxicity or low frequency of detection. These two screening steps eliminated five and four constituents, respectively, resulting in the following list of 10 COPCs: arsenic, manganese, molybdenum, nitrate, radium-226, selenium, sodium, sulfate, uranium, and vanadium. These contaminants were retained for further risk analysis. All radionuclides were evaluated for contribution to potential carcinogenic risks.

A number of potential routes of exposure were considered for both hydrogeologic units: ingestion of ground water as drinking water in a residential setting, dermal contact with ground water while bathing, ingestion of garden produce irrigated with ground water, and ingestion of meat and milk from livestock that consumed ground water. For both units, nitrate and sulfate concentrations in ground water were so high that livestock could not survive chronic ground water consumption. Therefore, this exposure route was considered not viable and was eliminated from further consideration from a human health perspective. Results of the exposure assessment indicated that intakes for all constituents were negligible from exposure routes other than drinking water. Therefore, only exposure through ingestion of ground water as drinking water was retained for more detailed evaluation. Children and adults were considered as likely receptors; infants were evaluated for exposure to nitrate and sulfate.

Calculated exposure intakes were presented along with contaminant intakes associated with a range of adverse health effects. Potential risks associated with exposure to noncarcinogenic constituents were discussed in a qualitative fashion; carcinogenic risks were quantified and compared to EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}.

For the Browns Wash alluvium, it was concluded that adverse noncarcinogenic effects could result from ingestion of nitrate and sulfate in ground water Nitrate levels could lead to serious detrimental effects on infants. Levels of sulfate present could result in diarrhea and dehydration in infants; adults could also experience laxative effects at those levels. Although uranium was present at levels above EPA health advisory levels, it was not present at levels known to be associated with adverse health effects in humans. Additional studies on uranium, conducted since completion of the BLRA, provide additional data on uranium toxicity These data will be discussed in the BLRA update in the following section. For additional discussion on the toxicity of the Green River COPCs, refer to the original BLRA (DOE 1995). Pathways other than ground water ingestion (e.g., ingestion of garden vegetables or meat and milk) did not contribute appreciably to site risks Carcinogenic risks associated with ingestion of ground water from Browns Wash alluvium exceeded EPA's acceptable upper bound risk value of 1×10^{-4} by more than one order of magnitude; uranium and, to a lesser degree, lead-210 were the major risk contributors. The drinking water pathway was the only pathway of significance in calculating carcinogenic risks.

For the Cedar Mountain Formation, it was determined that the most notable adverse noncarcinogenic health effects could result from chronic ingestion of nitrate, sulfate, and sodium in drinking water. Nitrate levels were high enough that they could be potentially lethal to infants, sulfate levels could cause severe dehydration and diarrhea in infants Sodium concentrations would contribute to hypertension. Manganese was present at levels that could result in mild neurological disorders; mild toxic effects are associated with about 80 percent of the range of selenium concentrations. The remaining constituents would be expected to result in few, if any, adverse health effects from chronic ground water ingestion. For additional toxicological information, refer to the original BLRA (DOE 1995) Pathways other than ground water ingestion were determined to not appreciably contribute to site risks Carcinogenic risks calculated for the Cedar Mountain Formation were determined to be 6 times the upper bound of EPA's acceptable risk range. The major contributor to this risk is lead-210. Only the ground water ingestion pathway contributed significantly to carcinogenic risks.

6.1.2 BLRA Update

As noted in the previous section, the original BLRA considered several potential routes of exposure to contaminants and eliminated all but one—ingestion of ground water in a residential setting—as insignificant. Based on this analysis, only the ground water ingestion pathway is evaluated in this BLRA update. The update will address only the Browns Wash alluvial ground water and the upper portion (including the middle sandstone unit) of the Cedar Mountain Formation. As noted in the discussion of ground water geochemistry (Section 5.3.2), these two systems may be interconnected, but are hydraulically separate from the lower unit and the basal sandstone unit of the Cedar Mountain Formation Thus, site-related contamination is likely confined to just the upper systems. Additionally, the Browns Wash alluvial ground water and ground water from the upper portion of the Cedar Mountain Formation have the greatest potential for discharge to Browns Wash where exposures could occur.

The goal of this BLRA update is to identify COPCs for which a compliance strategy must be selected and that will require monitoring in the future from a human health and ecological standpoint. Because of the limited amount of data and the complex nature of the hydrogeologic system, risks will not be quantified through the standard risk assessment process. Concentrations of COPCs in ground water will instead be compared with relevant benchmarks (e.g., MCLs, risk-based concentrations [RBCs]).

Analytical results for nitrate presented in this document are concentrations of nitrate reported as NO_3. Other references may report nitrate values as N (nitrogen), also referred to as nitrate-nitrogen. The conversion factor for these different reported quantities is 1 milligram (mg) N (or nitrate-nitrogen) is equal to 4.4 mg nitrate (as NO_3). Thus, the UMTRA Project ground water standard for nitrate is 10 mg/L as N or 44 mg/L as NO_3. For consistency in this BLRA update and for ease in use of reported analytical data, all concentrations of nitrate are expressed as NO_3.

Table 6–1 and Table 6–2 summarize water quality data for Browns Wash alluvium and the upper portion of the Cedar Mountain Formation, respectively. Recent data and historic data are provided for comparison to demonstrate how ground water quality has changed since surface remediation has occurred. Historic data for the Cedar Mountain Formation is from wells formerly in the area where the disposal cell is now located. For the Browns Wash alluvium (Table 6–1), all constituents that had historic concentrations exceeding some human health benchmark (e g., ground water standard, health advisory) in at least one sample are included. Radionuclides were either not detected or not analyzed due to insufficient sample volume. For the Cedar Mountain Formation, all detectable COPCs that passed the screening from the original BLRA are included (Table 6–2). Also provided for comparison are the applicable UMTRA Project and Utah ground water standards (if available) as well as human-health RBCs (EPA 2002).

Table 6–1 Ground Water Quality Data for the Browns Wash Alluvium

Contaminant	Maximum Detected 2002 (mg/L)	Maximum Detected 1986-1988 (mg/L)	UMTRA/Utah Standards (mg/L)	Risk-based Concentration (mg/L)
Cadmium	0 00088	0.072	0 01/0 005	0 018
Manganese	3 15	0 98	0 05[b]	1 7
Molybdenum	0 0893	0 27	0 1[a]	0 18
Nitrate (as NO_3)	313	440	44/44	255
Selenium	0 134	0 50	0 01/0 05	0 18
Sodium	2,420	2,540	none	30-60[c]
Sulfate	7,040	6,890	250[b]	~1,200[d]
Uranium	0 456	1 96	0 044[a]	0.11

[a]UMTRA Project Standard (40 CFR 192)
[b]Federal Secondary Drinking Water Standard
[c] EPA Advisory based on esthetic effects (EPA 2002)
[d]Concentration demonstrated to cause no adverse health effects (EPA 1999)

Table 6–2 Ground Water Quality Data for the Upper Portion of the Cedar Mountain Formation

COPC from Original BLRA	Maximum Detected 2000–2002 (mg/L)	Maximum Detected 1986-1988 (mg/L)	UMTRA/Utah Standards (mg/L)	Risk-based Concentration (mg/L)
Arsenic	0 161 (well 0813)	0 023	0 05/0 05	0 000045
Manganese	0 741 (well 0813)	0 49	0.05[a]	1 7
Molybdenum	0 047 (well 0813)	0 22	0 1[b]	0 18
Nitrate (as NO_3)	815 (well 0173)	1 280	44/44	255
Selenium	0 839 (well 0176)	0 32	0 01/0 05	0 18
Sodium	2,890 (well 0173)	2,450	none	30-60[c]
Sulfate	6,150 (well 0173)	6,450	250[a]	~1,200[c]
Uranium	0 198 (well 0179)	0 146	0 044[b]	0 11
Vanadium	nd	0 12	none	0 33
Ra-226 & Ra-228[e]	4 63 pCi/L[f] (well 0813)	5 5 pCi/L	5/5 pCi/L	na

[a]National Secondary Drinking Water Standard
[b]UMTRA Project Standard
[c]EPA Advisory based on esthetic effects (EPA 2002)
[d] Concentration demonstrated to cause no adverse health effects (EPA 1999)
[e]BLRA identified Ra-226 as a COPC, combined here with Ra-228 for comparison to standards
[f]pCi/L = picocuries per liter
nd = not detected

The RBC for a given contaminant represents a concentration in drinking water that would be protective of human health provided that

- The residential exposure scenario is appropriate. Default equations and values for exposure factors used in calculating RBCs are standard EPA equations and default values (EPA 1989a and 1989b)

- Ingestion of contaminated drinking water is the only exposure pathway.

- The contaminant contributes nearly all the health risk

- EPA's risk level of 1×10^{-6} for carcinogens and a hazard quotient (HQ) of 1 for noncarcinogens is appropriate

If any of these assumptions is not true, contaminant levels at or below RBCs cannot automatically be assumed to be protective. For example, if multiple contaminants are present in drinking water, a single contaminant may be below its RBC but still be a significant contributor to the total risk posed by drinking the water However, if an RBC is exceeded, it is an indication that further evaluation of the contaminant is warranted For noncarcinogens, the ratio of the contaminant concentration to its RBC (i.e., contaminant concentration divided by RBC) is a rough estimate of the HQ for a constituent For carcinogens, this ratio represents the number of times the concentration exceeds the lower end of EPA's acceptable risk range RBCs are intended for use in screening-level evaluations such as this one to provide some indication of the potential risk posed by a given constituent

The RBC provided for uranium in Table 6–4 and Table 6–5 is based on the reference dose (RfD) currently in EPA's Integrated Risk Information System (IRIS). IRIS is the most accepted and preferred source of toxicity data for chemicals. Some recent studies of uranium toxicity suggest that uranium is chemically more toxic than previously believed (*Federal Register*, December 7, 2000; 65 FR 76708). Using these more current data, EPA calculated that a more acceptable RfD for ingestion of uranium in drinking water would be 0.0006 milligram per kilogram per day (mg/kg/day)—one-fifth the RfD of 0.003 mg/kg/day currently reported in IRIS. If the IRIS RfD is eventually changed to this lower value, the RBC for uranium in drinking water would also be reduced by a factor of 5 to 0.022 mg/L. This is half the current UMTRA Project ground water standard. Until the RfD in IRIS is officially changed (if it is changed), however, the RfD of 0.003 mg/kg/day will continue to be used in calculating potential site risks.

No ground water or drinking water standards exist for sodium and EPA has recently decided that no benefits are to be achieved by establishing one (67 FR 38222; June 3, 2002). No toxicity data are available to calculate an RBC for sodium, though EPA has recently established an Advisory for sodium of 30-60 mg/L based on esthetic effects (EPA 2002). EPA has also established a guidance level for sodium of 20 mg/L for individuals with sodium-restricted diets of 500 milligrams per day. The National Research Council has recommended that sodium intake be limited to no more than 2,400 milligrams per day. If drinking water were the sole source of sodium intake, 1,200 mg/L in 2 liters of water ingested per day (EPA default water intake for adults) would result in this intake. However, because much of the sodium in a typical diet is consumed in food, concentrations in drinking water should probably be lower than 1,200 mg/L to meet the recommended intakes. The U.S. Food and Drug Administration estimates that most American adults tend to eat between 4,000 and 6,000 mg of sodium per day (FDA 1995). A few states have guidelines for sodium content in drinking water; those levels range up to 250 mg/L. A sodium concentration less than 200 mg/L for drinking water would probably be desirable to prevent excessive sodium intake

EPA has recently made the decision not to regulate sulfate in drinking water (67 FR 38222; June 3, 2002). Toxicity data are also lacking from which to calculate an RBC for sulfate, though EPA has made a health-based advisory for acute effects (laxative effects) of 500 mg/L sulfate (EPA 2002); however, studies have shown that these effects are temporary for most people (EPA 1999) and would mainly be of concern for sensitive populations (e g., infants or the elderly). The secondary standard for sulfate is not based on health concerns, but rather on esthetic values—in particular, taste and odor. Studies conducted by the Centers for Disease Control in conjunction with EPA (EPA 1999) have shown that no adverse effects from sulfate ingestion occur at levels up to 1,200 mg/L (the highest concentration used in the study). As noted in the report of that study, other studies have shown that concentrations ranging over 2,000 mg/L of sulfate may have little to no adverse effect on human or animal subjects. Therefore, although 1,200 mg/L sulfate can be considered "safe," it is not clear what the maximum permissible concentration of sulfate in drinking water might be. Even at "safe" concentrations of sulfate in drinking water, its poor taste and odor would probably be a deterrent to its use

6.1.3 Discussion

6.1.3.1 Browns Wash Alluvium

Historic data collected for the Browns Wash alluvium represent the water quality beneath the tailings pile prior to surface remediation. To some extent, data collected for alluvial ground water at that time reflect the chemistry of fluids in the pile. Table 6–3 provides chemical analyses for a lysimeter installed in the pile in the mid-1980's, only two rounds of sampling took place and

Table 6–3 Chemical Analyses for Lysimeter 714[a]

Parameter	Date of Analyses	
	09/11/86	03/12/87
Aluminum	6 300	1,840
Ammonium	14	11
Antimony	–	0 003
Arsenic	–	0 03
Barium	–	0.1
Boron	0 5	0 1
Cadmium	–	0 032
Calcium	457	385
Chloride	113	2 900
Chromium	2 61	1 14
Cobalt	–	30 9
Copper	–	45 8
Fluoride	0 1	0 2
Iron	2,200	267
Lead	–	0 02
Magnesium	2,640	1 090
Manganese	360	122
Mercury	–	0 00
Molybdenum	0 2	0 10
Nickel	–	25 3
Nitrate	4,500	2
Nitrite	–	0 1
Phosphate	–	0 1
Potassium	0 19	16 0
Selenium	0 092	0 208
Silica	–	60
Silver	–	0 01
Sodium	89 2	111
Strontium	–	0 1
Sulfate	56 200	16,000
Tin	–	0 005
Total Dissolved Solids	80,800	26,100
Uranium	675	221
Vanadium	–	178
Zinc	–	259

[a]All values in mg/L

only a limited amount of water could be obtained for the 1986 sampling event These analyses probably provide only a rough estimate of major tailings-related constituents; ores processed at the Green River site were known to contain significant amounts of selenium and also some arsenic-bearing accessory minerals (Hawley and others 1965), neither of these constituents appears to be significantly elevated in the pore fluids. Nonetheless, levels of uranium, nitrate, sulfate, molybdenum, and manganese in the pile could very well have been the source of these constituents in the Browns Wash alluvium However, concentrations of some of these constituents, such as sodium, sulfate, and nitrate, have not appreciably changed in the 12 years since pile removal On the other hand, uranium and selenium have decreased significantly since completion of surface remediation, as would be expected if the pile were the source of uranium and selenium contamination. It is possible that sodium, sulfate, and nitrate have some other source. As noted in Section 5.3.1.1, the alluvial background well 0707 is elevated in these constituents, consistent with the alluvial ground water in the vicinity of the former tailings pile. For purposes of the risk assessment, however, these constituents will be retained for further evaluation.

Noncarcinogenic risks are estimated here by comparing maximum Browns Wash alluvium concentrations with RBCs. The ratio of ground water concentration to RBC roughly equates to a hazard quotient calculated for drinking water in a residential scenario. Carcinogenic risks have not been quantified here. In the original BLRA, carcinogenic risks for all constituents but uranium were within or below EPA's acceptable risk range. Uranium risks were an order of magnitude higher than the high end of EPA's acceptable range. Concentrations of uranium in Browns Wash alluvium have decreased less than an order of magnitude; therefore, risks would still be higher than acceptable.

Table 6–4 presents contaminant/RBC ratios for the noncarcinogenic constituents based on historical and current data As expected, based on the significant decreases in uranium and selenium, corresponding ratios have decreased as well. Ratios for sulfate, sodium, and nitrate have remained relatively constant. Sodium exceeds its recommended advisory to a greater degree than any other constituent, but at current concentrations is within the range of normal dietary intakes. Sodium concentrations are probably an order of magnitude or so above desirable levels but would not be considered a risk driver based on toxicity. Sulfate level is significantly elevated above its secondary drinking water standard but is less than an order of magnitude above concentrations deemed to be "safe" (see discussion in Section 6.1.2). Levels of sulfate present would cause the water to taste and smell bad, but based on potential risk, sulfate is not expected to be an important driver. Ratios for the remaining constituents are all less than 10 with uranium contributing the greatest risks. If the RfD for uranium were lowered to the currently recommended level, the ratio would go up by a factor of 5 to 20.5 This, in combination with its unacceptable carcinogenic risks, makes uranium the constituent that poses the greatest potential risk in a residential setting. This is consistent with conclusions reached in the original BLRA. However, the fact that the Browns Wash alluvium cannot sustain adequate flow to serve a household (see Section 5.1.2.1), makes this scenario irrelevant.

If future monitoring of the Browns Wash alluvium is required, the constituents listed in Table 6–4, with the exception of cadmium and molybdenum (both of which are below applicable standards), would be appropriate for monitoring.

Table 6–4. Contaminant/RBC Ratios for the Browns Wash Alluvium

Contaminant	Contaminant Concentration/RBC	
	Historic Data	*Current Data*
Cadmium	4 0	0 048
Manganese	0 58	1 85
Molybdenum	1 5	0 5
Nitrate (as NO_3)	1 7	1 23
Selenium	2 8	0 74
Sodium	>10, <100[a]	>10, <100[a]
Sulfate	<10[a]	<10[a]
Uranium	17 8	4 1

[a]Rough estimate based on available data, see text discussion

6.1.3.2 Cedar Mountain Formation (Upper Portion)

Constituents in Table 6–3 are those that passed the screening steps in the original BLRA and were identified as COPCs. Data are for the highest concentrations detected during historic (1986–1988) monitoring and the 2000–2002 monitoring events. Well 0172 had the highest levels of several contaminants but is not included here because water levels and concentrations from that well have fluctuated dramatically and are of questionable representativeness. An offset well (0181) in that same general area was constructed during the 2002 characterization activities to better understand the water chemistry.

Table 6–5 presents ratios of maximum contaminant concentrations to their respective RBCs. Since the time of the original BLRA, vanadium concentration has decreased to nondetectable levels, and radium-226+228 and molybdenum levels have decreased below standards. Manganese exceeds the secondary drinking water standard, but is well below its RBC. These constituents can therefore be eliminated from further consideration in the risk assessment and compliance strategy selection processes.

Table 6–5 Contaminant/RBC Ratios for the Upper Portion of the Cedar Mountain Formation

Contaminant	Contaminant Concentration/RBC	
	Historic	*Current*
Arsenic	3,577	3,578
Manganese	0 29	0 44
Molybdenum	1 2	0 26
Nitrate (as NO_3)	5 0	4 1
Selenium	1 8	4 7
Sodium	>10, <100[a]	>10, <100[a]
Sulfate	<10	<10
Uranium	1 3	1 8
Vanadium	0 36	nd

[a]Rough estimate based on available data, see text discussion

Arsenic is the constituent that most greatly exceeds its RBC. However, concentrations are elevated above the UMTRA Project standard in only one well and is near the detection limit at most locations. Arsenic was not elevated in Browns Wash alluvium or in historic tailings pile fluids; however, arsenic-bearing minerals were known to occur in ores processed at Green River (Hawley and others 1965). Arsenic is probably tailings-related, but because of its very limited extent arsenic is probably not a significant risk driver.

Uranium is elevated above the UMTRA Project standard in only one Cedar Mountain Formation well (0179) though two others are just below the standard (0171 and 0181). Compared to the RfD currently in IRIS, noncarcinogenic risks from ingestion of uranium-contaminated ground water would only marginally exceed acceptable levels (using maximum uranium concentration). However, as noted in the Browns Wash discussion, if the more recently recommended RfD is appropriate, risks would go up by a factor of 5. Carcinogenic risks calculated for ingestion of uranium-contaminated ground water in the original BLRA were determined to be an order of magnitude higher than the high end of EPA's acceptable risk range. Uranium levels in the Cedar Mountain Formation in the vicinity of the disposal cell are currently more than an order of magnitude lower than the concentration used in that calculation. Therefore, exposures to current levels of uranium in the Cedar Mountain Formation would probably be within EPA's acceptable risk range.

Only nitrate, selenium, sodium, and sulfate have been detected at significantly elevated levels in more than one well in the Cedar Mountain Formation. Although nitrate and selenium levels have exceeded standards, associated risks are relatively small. Sodium and sulfate, though more pervasive, have not been demonstrated to be a significant health threat. The greatest risks would probably be through ingestion of nitrate and sulfate by sensitive populations (e.g., infants and the elderly).

6.1.4 Summary and Recommendations

It is likely that ground water in the vicinity of the Green River site is naturally poor, although this cannot be substantiated because of a lack of reliable background data. Quality of the water varies considerably in both the Browns Wash alluvium and the Cedar Mountain Formation both temporally and spatially. A number of the wells in both units are poor producers; several wells constructed into the alluvium were dry. Water levels have been on the decline in both the alluvium and the upper portion of the Cedar Mountain Formation over the last several years.

Only limited data for the Browns Wash alluvium are available. Current data indicate that uranium concentrations in the alluvium probably present the greatest risks if used for drinking water. Manganese, nitrate, sodium, and sulfate are also elevated. Presumed background well 0707, though dry during the most recent round of sampling, has historically been elevated in sulfate, sodium, and nitrate, suggesting that the source of these constituents may be something other than uranium milling. However, without more data, milling as the source of contamination cannot be ruled out. If monitoring is required in the future, COPCs should include manganese, nitrate, selenium, sodium, sulfate, and uranium. The low yield of the aquifer allows it to be classified as limited use; the main concern for monitoring is to assure that contaminated ground water is not adversely affecting surface water habitats near the mouth of Browns Wash and in the Green River.

Concentrations of most constituents in the upper portion of the Cedar Mountain Formation have fluctuated unpredictably in the vicinity of the disposal cell. Arsenic and uranium exceed MCLs in only one well each. Selenium and nitrate exceed standards in several compliance wells. Sulfate and sodium are elevated in nearly all wells. It appears that some constituents such as selenium and nitrate have been generally increasing in selected wells over the last several years, though concentrations have shown significant fluctuations. Future monitoring of the Cedar Mountain Formation should be conducted for arsenic, nitrate, selenium, sodium, sulfate, and uranium It is not likely that the Cedar Mountain Formation would be used for drinking water in the future. As with the Browns Wash alluvium, the main concern for monitoring is to assure that discharge of ground water to the surface does not adversely affect surface water near the mouth of Browns Wash and in the Green River.

6.2 Ecological Risk Assessment

6.2.1 Introduction

Ecological risk assessment (ERA) is a process that evaluates the likelihood that adverse ecological effects are occurring or may occur in the future as a result of exposure to one or more environmental stressors. A stressor is defined as any physical, chemical, or biological entity that can induce an adverse ecological response. The risk assessment process is outlined in EPA guidance documents, particularly the *Guidelines for Ecological Risk Assessment* (EPA 1998) and the *Framework for Ecological Risk Assessment* (EPA 1992). The ERA for the Green River UMTRA Project site generally follows this EPA framework and guidance.

The overall goal of this risk assessment is to identify ecological COPCs (E-COPCs) that can be related to the dispersal of contaminants in the ground water underlying the Green River site. Once E-COPCs are identified, the potential for adverse effects of these E-COPCs on the ecosystems at this site, including Browns Wash and the Green River, can be characterized. In particular, potential effects on special status species and sensitive environments are considered. This assessment is an update and expansion of the BLRA screening-level assessment conducted in 1995 (DOE 1995). However, it is still a screening-level assessment to identify E-COPCs and areas for which future monitoring may be necessary. This section will evaluate data from new studies as well as updated ecological benchmarks and regulatory requirements that have been developed since completion of the BLRA.

Predicting the effects of chemicals on ecological receptors is complicated by the variable interactions and influences within an ecosystem. To a great extent, ERA is an emerging science. Little data exist for most chemicals and their effects on ecological receptors. Therefore, attempting to integrate and evaluate individual and synergistic chemical effects with other stressors (predation, drought, disease, etc.) is problematic. Generally, for ecological risks to occur there must be a contaminant source, which is assumed to be limited to ground water, and a pathway for exposure of ecological receptors to contaminated ground water. The simplified ecological risk scenario gives a generalized overview of the ERA process.

Simplified Ecological Risk Scenario

Contamination Source	→	Release	→	Contaminated Media	→	Pathway	→	Receptor	→	Effect
(Green River millsite)		(Migration into soil and ground water)		(Ground water surface water and sediments)		(Ingestion or absorption)		(Plants, wildlife)		(No effect, non lethal effects, or mortality)

The following sections provide an evaluation of potential risks to ecological receptors based upon a review of current data, with emphasis on the 1995–2002 data. Appendix G provides a detailed overview of the ERA process and a summary of the historical data included in the BLRA. The BLRA focused on data collected prior to 1995.

Generally there are three major phases or steps in the ERA process:

(1) problem formulation,
(2) analysis, and
(3) risk characterization.

The key elements of these phases are discussed below as they are relevant to the Green River site.

6.2.2 Problem Formulation

In the problem formulation phase, the need for a risk assessment is identified and the scope of the problem is defined. Available data are evaluated to identify potential stressors (in this case, the potential stressors are E-COPCs associated with the ground water at the Green River processing site), key ecological receptors, and potential exposure pathways linking the receptors to the stressors. Table 6–6 provides the comprehensive history of surface water and sediment sampling. Prior surface remediation at the site eliminated air and soils and potentially contaminated media. Therefore, the emphasis of this update is on surface water and sediments that may be influenced by ground water.

Table 6–6 History of Surface Water and Sediment Sampling Locations

Location	Description	Surface Water Sampling	Sediment Sampling	Comments
		Browns Wash		
0526[a]	Downgradient, may be considered a backwater of the Green River periodically	1982–1992, 2001	1993	This location was moved to the west of the original location during 2001 sampling
0709	Cross gradient, north of site	1982–1993	1993	
0710	Downgradient	1982–1993	1993	Exposed bedrock area
0711	Upgradient, background	1982–1993	1993	
0717	Downgradient	NA	1993	
0718	Downgradient	1993–1996	1993–1995	Exposed bedrock area
0720	Cross gradient	1994–1996	1994–1995	
0847[a]	Upstream +/-300 ft of confluence with Green River	2002	NA	Selected to determine influence of site-related constituents
		Green River		
0801	Upstream of Browns Wash, background	1984–1992, 1994, 1997–2001	1994	This location was moved to the north during 1997 sampling
0802	Downstream of Browns Wash	1986–1992, 1994, 1997–2001	1994	
0846	Confluence with Browns Wash	2002	NA	Selected to determine influence of site-related constituents

[a] Location 0847 replaced location in 2002 because 0526 was dry Data originally posted for location 0526 from 2001 sampling have been moved to location 0847

6.2.2.1 Potentially Affected Habitats and Population

Due to the site's arid environment and proximity to the city of Green River, flora and fauna species diversity is somewhat limited. The exceptions are the riparian zones along Browns Wash and the Green River to the north and west of the site, respectively. Along Browns Wash and the Green River, the habitat is a mix of riparian species dominated by tamarisk, cottonwoods, and willow. Although Browns Wash was evaluated in the BLRA as a potential surface water medium, it is an ephemeral stream with very limited capability for supporting an aquatic ecosystem. The exception is the mouth of Browns Wash where it empties into the Green River. This area could be considered a backwater of the Green River because of the presence of water most of the year. The surface remediation EA identified six endangered wildlife species protected under the Endangered Species Act as potentially occurring in the vicinity of the site. The species are the peregrine falcon (*Falco peregrinus*), bald eagle (*Haliaeetus leucociphalus*), black-footed ferret (*Mustela nigripes*), Colorado pikeminnow (*Ptychocheilus lucius*), bonytail chub (*Gila elegans*), and humpback chub (*Gila cypha*) The razorback sucker was mentioned briefly, but dismissed as not potentially occurring in the Green River area. Of the remaining species, the peregrine falcon has since been delisted, and the black-footed ferret, humpback, and bonytail chubs are not believed to currently inhabit the site area Therefore, the Colorado pikeminnow and bald eagle are the only endangered species that will be considered further in this assessment

Because of the ephemeral nature of Browns Wash and its limited potential to support an aquatic community, the upper reaches of the wash will not be evaluated as an aquatic community. However, the pooled area at the mouth of the wash, where it empties into the Green River, is considered a viable aquatic community and will be assessed as such Therefore, the only relevant surface water data in Browns Wash is that collected at location 0847. Although this sampling location is in Browns Wash, it could be considered a backwater to the Green River, which will be discussed in more detail later in this assessment. Three surface water locations in the Green River (0801, 0802, and 0846), which serve as background will be retained for purposes of this assessment.

Further review of sediment data indicates that the value of these data in assessing potential risks to benthic organisms in Browns Wash is questionable. Prior to the BLRA, it was suspected that ground water may have been surfacing in the form of seeps into Browns Wash However, attempts to collect sediment data in the past have typically resulted in collecting samples from dry locations where there are no benthic organisms Recent (2001 and 2002) inspections of the site also found no evidence of seeps, and ground water, therefore, has limited potential to influence Browns Wash sediments Sediment sampling data at other Browns Wash locations will not be assessed due to limited potential for ecological risk

6 2.2.2 Update of the Ecological COPCs

The BLRA had identified 20 ground-water-based constituents as possible E-COPCs for further screening and evaluation. Since the 1995 BLRA, information regarding ERA has grown significantly, including additional guidance concerning benchmarks, receptors, and assessment methodologies As a result, all 20 ground water E-COPCs (Table 6–7) that were identified in the BLRA will be reevaluated

Table 6–7 Constituents Retained as E-COPCs from the BLRA

Aluminum	Ammonium
Arsenic	Calcium
Cadmium	Magnesium
Chloride	Potassium
Iron	Radium-226
Manganese	Sodium
Molybdenum	Sulfate
Nickel	Vanadium
Nitrate	
Selenium	
Uranium	
Zinc	

For purposes of current risk assessment, ground water and surface water collected subsequent to completion of the BLRA (1995 – 2002) are used to reevaluate the list of E-COPCs and to further assess these constituents for potential ecological risk at the Green River site. Soils and air are not considered contaminated media due to completion of surface remediation prior to the BLRA.

On the basis of E-COPCs identified in ground water (see Appendix G), additional surface water samples were collected from two locations near the mouth of Browns Wash in July 2002. Although the State of Utah requested the collection of surface water samples at the mouth of Browns Wash for ammonia analysis, this analyte was inadvertently omitted. However, upon examination of historic data, it appears that ammonia is no longer of concern for the Green River site. Though ammonia was used in processing the ores, ammonia has not been detected in significantly elevated levels in ground water. Additionally, only a fraction of the total ammonia that has been measured is actually present as unionized ammonia (upon which the surface water standard is based). It is probable, based on high levels of nitrate associated with the site, that ammonia has largely been oxidized to nitrate. Since the completion of surface remediation, ammonia (total) in surface water samples that have been collected has been very low (generally less than 1 mg/L) or below detection. Therefore, DOE does not believe that ammonia is a viable E-COPC.

Sampling location 0846 was at the confluence of Browns Wash and the Green River and sampling location 0847 was approximately 300 ft upstream of the confluence on Browns Wash This inlet is potentially important habitat for fish, possibly including the Colorado pikeminnow. Concurrently with these samples, a surface water sample was collected at the upstream (background) location on the Green River (location 0801)

Appendix G presents a comparison of the maximum concentrations of the analytes measured at the two locations at the mouth of Browns Wash to the measured concentrations from the Green River background location. Twelve of the 16 analytes at the mouth of Browns Wash exceeded the background location concentration for at least one of the two locations, indicating the possibility that they are influenced by the millsite Two of these, however, (cadmium and strontium) were close enough to the background concentration that they considered not significantly elevated above background In the case of strontium, the sample exceeding background was from the confluence, while the upstream sample was less than background. Four of the analytes were essential nutrients (calcium, magnesium, potassium, and sodium) The remaining seven analytes were identified and E-COPCs for this wetland area and are further evaluated for potential risk to aquatic, wetland, and terrestrial receptors.

6.2.3 Analysis

This assessment focuses on the potential risks posed to aquatic, wetland, and terrestrial species that may be exposed to the seven E-COPCs identified in the surface water at the mouth of Browns Wash. Only complete exposure pathways are quantitatively and qualitatively evaluated in an ERA. In this assessment, the following potential exposure pathways were considered for evaluation:

- Surface water ingestion and direct contact
- Dietary ingestion of forage or prey, as appropriate, by receptor

The contaminants associated with the site are inorganics. Estimations of potential exposures to key ecological receptors are based on the dominant pathways from these media for the specific receptor. Exposures in wetland plants and aquatic organisms are based on direct contact with the surface water in which they live and, in the cases of aquatic animals, also include the ingestion of food associated with this medium. In all of these cases (plants and animals), potential exposure to an E-COPC is based on the concentration of that E-COPC in the surface water

Exposures in wildlife involve multiple potential pathways that may include ingestion of food, water, and soil/sediment; direct contact and dermal absorption, and inhalation. In this assessment, the inhalation and dermal absorption pathways are assumed to be minor pathways with respect to the combined exposures based on ingestion Most wildlife of the area have very little and infrequent direct dermal contact with potentially contaminated media due to their protective covers of feathers or fur and their habits and behaviors, such as preening and grooming, and (in the cases of most birds) living principally in trees and shrubs. The E-COPCs are not highly volatile Therefore, their occurrence in the air is minimal. Exposures in wildlife through inhalation was considered a minor exposure pathway relative to sediment ingestion. Although both dermal absorption and inhalation will contribute to the overall exposure in these receptors, these contributions are assumed to be included within the conservatisms incorporated in the estimation of exposures through the ingestion pathways. Sediment is not identified as a medium of concern, and therefore, sediment-based pathways are not evaluated

In the estimation of ingestion-related exposure for the wildlife receptors, the E-COPCs are assumed to be 100 percent bioavailable, and the receptors are assumed to be exposed only at the selected exposure point concentration, regardless of home range size or seasonal use patterns. The exposure through multiple ingestion pathways is modeled using the methods described in EPA's *Wildlife Exposure Factors Handbook* (EPA 1993). Specific exposure calculations and assumptions are provided in Appendix G.

6.2.4 Effects Characterization

Specific effects were evaluated for different receptors by the use of appropriate toxicity benchmarks For surface water, either ambient water quality criteria (EPA 1999) or Utah Department of Environmental Quality Water Quality Standards (whichever was less) were used as the principal benchmarks for evaluating potential risk to aquatic life When neither was available for an E-COPC, other values are used as noted For plants, toxicity benchmarks are based primarily on the information provided in Efroymson and others (1997) For the wildlife receptors, no-observed-adverse-effect levels (NOAELs) for chronic oral exposure are used as benchmarks for toxic effects. NOAELs are defined as the maximum dosage tested that produced no effect that would be considered adverse to the receptor's survival, growth, or reproductive capacity. Because the NOAELs for the wildlife receptor species are based on NOAELs from test species, the latter are scaled to NOAELs specific to the wildlife receptor species using a power function of the ratio of body weights, as described by Sample and others (1996) and Sample and Arenal (1999)

6.2.5 Risk Characterization

The potential for risk to ecological receptors is determined through HQs. HQs are specific to a particular receptor for exposure to a particular E-COPC An HQ is defined by:

$$HQ = \frac{\text{Exposure}}{\text{Benchmark}}$$

For aquatic and benthic organisms and plants, exposures are equivalent to media concentrations (surface water or sediment) with which the organism is in contact. For wetland wildlife, exposures are modeled from multiple pathways. The value of the HQ is greater than 1.0 if the magnitude of the exposure is greater than the corresponding benchmark, and conversely, the HQ is less than or equal to 1.0 if the exposure is less than or equal to the benchmark. An HQ value less than or equal to 1.0 is interpreted as evidence of no potential risk to that receptor for that E-COPC. If the HQs for an E-COPC are less than unity for all receptors, that E-COPC is eliminated from further consideration as a potential ecological risk driver. However, because exposure for the screening of E-COPCs is conservatively estimated, an HQ value greater than unity is not interpreted as evidence of risk, but only as evidence that the potential for risk cannot be ruled out.

For the purposes of this evaluation, potential exposures were conservatively based on the maximum measured E-COPC in surface water at the mouth of Browns Wash. The following are summaries of the risk assessment results for specific receptor groups.

6.2 5.1 Risk to Ecological Receptors Associated with Surface Water at the Mouth of Browns Wash

Table 6–8 presents the HQs for aquatic organisms and wetland plants exposed to surface water at the mouth of Browns Wash. With one exception (plant exposure to arsenic), all of these HQs are less than 1. The single exception is only slightly above 1. Because these HQs are based on the maximum of the two samples collected at this site, with the other data point for arsenic (0.00088 mg/L) being less than the plant toxicity benchmark, the potential for risk to plants is considered negligible.

Table 6–8 Hazard Quotients for Aquatic Organisms and Wetland Plants at the Mouth of Browns Wash Based Upon Comparison of Surface Water Concentrations to Water Quality and Plant Toxicity Benchmarks[a]

E-COPC	Aquatic Organisms		Wetland Plants	
	Water Quality Benchmark (mg/L)	Hazard Quotient	Plant Toxicity Benchmark (mg/L)	Hazard Quotient
Arsenic	0 15	0 00933	0 001	**1.40**
Chloride	230	0 146	--	--
Manganese	0 08	0 498	4 0	0 00995
Molybdenum	0 24	0 0229	0 5	0 0110
Nitrate	0 23	0 199	--	--
Selenium	0 005	0 220	0 7	0.00157
Sulfate	250	0 772	--	--

[a]Hazard quotients based on maximum surface concentration as shown in Appendix G
-- = No benchmark value available
Hazard quotient greater than 1 shown in **Bold**

Table 6–9 and Table 6–10 present the HQs for exposures to wetland and terrestrial wildlife to surface water and associated prey organisms at the mouth of Browns Wash. None of the E-COPCs at this site are at concentrations that pose a potential risk to either wetland or terrestrial wildlife that may exposed to surface water at the site or to food organisms eaten from the site.

Table 6–9 Hazard Quotients for Wetland Wildlife at the Mouth of Browns Wash[a]

E-COPC	Muskrat	Raccoon	Mallard	Spotted Sandpiper	Bald Eagle
Arsenic	0 00386	0 00929	0 000316	0 00451	0 000335
Chloride	--	--	--	--	--
Manganese	0 00648	0 00321	0 000224	0 000356	0 0000309
Molybdenum	0 0312	0 0249	0 00142	0 00429	0 00124
Nitrate	0 0000675	0 0000667	--	--	--
Selenium	0 00108	0 0616	0 00408	0 165	0 0251
Sulfate	--	--	--	--	--

[a]Exposure based on surface-water-based pathways, including direct ingestion of water, and ingestion of plants, invertebrates, and fish with tissue concentrations estimated from water concentrations

-- = No toxicity benchmark available.

Table 6–10 Hazard Quotients for Terrestrial Wildlife at the Mouth of Browns Wash[a]

E-COPC	Deer Mouse	Coyote	Mule Deer	Northern Harrier
Arsenic	0 000372	0 000292	0 000271	0 0000399
Chloride	--	--	--	--
Manganese	0 0000554	0 0000435	0 0000404	0 00000352
Molybdenum	0 00300	0 00236	0 00219	0 000247
Nitrate	0 0000464	0 0000365	0 0000338	--
Selenium	0 000673	0 000529	0 000491	0 000403
Sulfate	--	--	--	--

[a]Exposure based on direct ingestion of water only

-- = No toxicity benchmark available

6.2 5 2 Potential Risk to Ecological Receptors Associated with Non-Radionuclides

Few, if any, complete exposure pathways potentially exist between ground water at the Green River site and ecological receptors The most credible of these is the potential for contact with contaminated ground water by deep-rooted plants, such as phreatophytes (e.g., greasewood). Comparisons of the plant toxicity benchmarks shown in Appendix G to the maximum ground water concentrations from the two downgradient wells (0588 and 0810) show that only the maximum concentration of arsenic from location 0588 (0 0127 mg/L) exceeded the plant toxicity benchmark, resulting in an HQ of 12 7. However, arsenic was not detected at location 0810 (For completeness, it should be noted that the plant toxicity benchmark for uranium is 40 mg/L [Efroymson and others 1997], which is well above the maximum ground water concentrations for this element shown in Appendix G) Based on these comparisons, it can be concluded that arsenic in ground water could pose a potential risk to deep-rooted plants that may contact it; however, this potential risk is limited in extent over the Green River site, and does not appear to extend as far as the mouth of Browns Wash to a significant degree

6.2.5.3 Potential Risk to Ecological Receptors Associated with Radionuclides

In addition to the nonradiological analytes measured in surface water at the mouth of Browns Wash, radiological parameters were also measured, including gross alpha and gross beta activity, lead-210, radium-226, radium-228, and thorium-230. None of these analytes except gross beta activity were at detectable levels. The maximum gross beta activity (4.24 picocuries per liter [pCi/L]) is very low, and unlikely to be of potential concern to ecological receptors. As noted in Appendix G, radium-226 has been detected in the past in both surface and ground water samples from the Green River site at concentrations as high as 3.0 pCi/L. However, this is well below the screening-level benchmark for aquatic biota (160 pCi/L) derived by Oak Ridge National Laboratory (Bechtel Jacobs Company 1998), based on the methodology for estimating dose rates for aquatic biota (specifically large and small fish) developed by Blaylock et al. (1993). Therefore, analysis of radionuclides in surface water and ground water samples from the site indicates no potential ecological risk

6.2.5.4 Potential Risks to Sensitive Species

The Colorado pikeminnow is an endangered species that has the potential for occurring in the Green River near the site. The bald eagle is a threatened species that could also occur in this area. Both of these species would be associated with the aquatic habitats of the Green River, the bald eagle potentially using this habitat to catch prey (fish). Because the HQs for aquatic organisms and the bald eagle exposed to E-COPCs at the mouth of Browns Wash were all less than 1, neither of these sensitive species appears to be at risk from these potential exposures

6.2.6 Ecological Risk Summary

This ERA has determined that there is little potential for site-related constituents to affect surface water or sediments. There is the possibility that ground water arsenic concentrations could affect deep-rooted plants if an exposure pathway exists. This assessment further concludes that there is limited, if any, potential for sensitive species to be adversely affected by site-related constituents.

End of current text

7.0 Ground Water Compliance Strategy

7.1 Compliance Strategy Selection Process

The framework defined in the PEIS (DOE 1996) for the UMTRA Ground Water Project governs selection of the strategy to achieve compliance with the EPA ground water cleanup standards (DOE 1996). This section presents the selection process used to determine the appropriate ground water compliance strategy for the Green River site and is summarized in Figure 7–1. The process involved evaluating conditions at the Green River site and proposing a compliance strategy for ground water cleanup that is protective of human health and the environment and meets the regulatory requirements in subpart B of 40 CFR 192 for Title I sites. A step-by-step approach is followed until one or a combination of the three general compliance strategies is selected. The three compliance strategies are:

- *No remediation*—Compliance with the EPA ground water protection standards would be achieved without altering the ground water or cleaning it up in any way. This strategy could be applied for those constituents at or below background levels or MCLs, or for those constituents above background levels or MCLs that qualify for an ACL or supplemental standards (see Section 2.1.2).

- *Natural flushing*—This strategy relies on natural ground water movement and geochemical processes to decrease contaminant concentrations to regulatory limits. The natural flushing strategy could be applied at a site if ground water compliance can be achieved within 100 years, where effective monitoring and ICs can be maintained, and where the ground water is not currently and is not projected to become a source for a public water system.

- *Active ground water remediation*—This strategy requires application of engineered ground water remediation methods such as gradient manipulation, ground water extraction and treatment, and in situ ground water treatment to achieve compliance with the standards.

7.2 Proposed Green River Compliance Strategy

DOE's goal is to implement a cost-effective ground water compliance strategy at the Green River site that is protective of human health and the environment and returns contaminated ground water to its maximum beneficial use. After evaluating existing site information and following the decision framework in the PEIS, DOE proposes the compliance strategy of no ground water remediation and application of ACLs for constituents with concentrations that exceed MCLs or applicable benchmarks in ground water in the Cedar Mountain Formation, and no remediation with the application of supplemental standards based on limited yield for ground water in the Browns Wash alluvium.

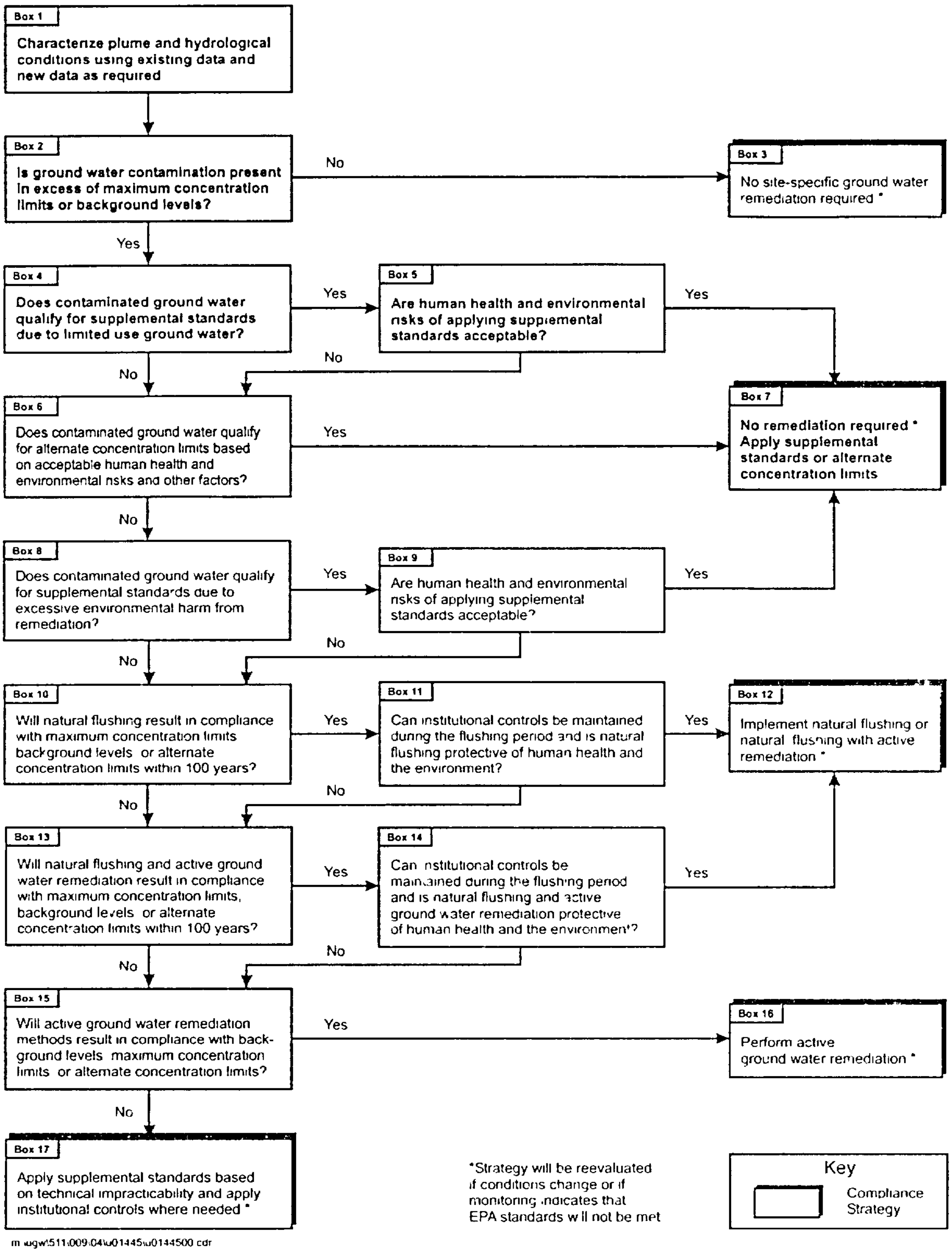


Figure 7–1 Compliance Strategy Decision Framework

The compliance strategy will be implemented in conjunction with monitoring to observe the effectiveness of the strategy and ICs, if necessary, to provide adequate control of nearby land use and ground water withdrawals.

Ground water in the vicinity of the site is not a current or potential source of drinking water The Browns Wash alluvium is of insufficient yield to serve as a drinking water aquifer; the quality of water in the upper portion of the Cedar Mountain Formation is questionable. Background wells located in this highly variable unit display concentrations of sulfate and fluoride that exceed drinking water standards; sodium and chloride exceed recommended levels based on esthetic concerns. Because there is no current or projected use of ground water as a drinking water source and no unacceptable risk to human health and the environment, there is no practical justification for actively cleaning up the contaminated ground water in the vicinity of the site. There would be no economic or risk-reduction benefit by performing any active remediation of ground water at the site. However, protection of surface water is of importance as the portion of the Green River adjacent to the site and associated backwater areas are habitat for several endangered fish. The compliance strategy proposed for the Green River site addresses this concern.

7.2.1 ACLs for the Cedar Mountain Formation

The proposed compliance strategy for ground water in the Cedar Mountain Formation is no remediation with the application of ACLs This strategy is explained in Table 7–1.

Table 7–1. Compliance Strategy Selection Process for Ground Water in the Cedar Mountain Formation

Box from Figure 7–1	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions	See conceptual site model presented in Section 5 0 and contaminant screening presented in Section 6 0 of this document Move to Box 2
2	Is ground water contamination present in excess of maximum concentration limits or background levels?	Arsenic, nitrate, selenium, sodium, sulfate, and uranium exceed the MCLs or appropriate benchmarks at one or more monitoring points Move to Box 4
4	Does contaminated ground water qualify for supplemental standards due to limited use ground water?	Ground water in the Cedar Mountain Formation is not classified as limited use. Move to Box 6
6	Does contaminated ground water qualify for alternate concentration limits based on acceptable human health and environmental risks and other factors?	Yes (1) a disposal cell is located above the contaminated area of the aquifer, (2) the State of Utah owns the surrounding land, (3) ICs can be implemented that would prevent use of contaminated water, and (4) outside the IC boundary at the point of exposure, ground water would be suitable for unrestricted use Move to Box 7
7		No remediation required Apply alternate concentration limits

EPA provided for applying ACLs at UMTRA Ground Water Project sites, particularly in instances where a disposal cell is present. As noted in the preamble to the final rule (60 FR 2854), "EPA has decided not to delete the ACL provision because it is clearly needed, if for no other reason than to deal with the possibilities of unavoidable minor seepage over the extremely long-term design life (1,000 years) of the disposal required …". Although it is not clear if the contaminants detected in the Cedar Mountain Formation are a result of disposal cell seepage or if they pre-date cell construction, the fact that a cell exists at the site makes it unreasonable to expect that MCLs or background levels should be met

In establishing an ACL, two locations must be defined—the POC and point of exposure (POE) The POC is defined as the site-specific locations in the uppermost aquifer where the ground water protection standard must be met. In contrast, the POE is defined as the locations where humans, wildlife, or other environmental species could reasonably be exposed to hazardous constituents from the ground water (NRC 1996) In the ACL guidance for Title II sites, the NRC notes that "The POE, in most situations, will be located at the down-gradient edge of the land that will be transferred to either the Federal government or the State where the site is located for long-term institutional control .. ". In the case of the Green River site, the disposal site itself is currently owned by DOE, and the State of Utah owns the land surrounding the site Thus, an appropriate POE would be at the downgradient extent of State-owned land Well 0182 was installed into the basal sandstone unit (first significant water-bearing unit) of the Cedar Mountain Formation near the downgradient edge of the State-owned land and can serve as the POE well. If the State of Utah eventually transfers the property between the disposal cell and the POE well, it may elect to restrict use of ground water in this portion of the Cedar Mountain Formation to provide longer term institutional control.

Though it does not appear that ground water from either the Browns Wash alluvium or Cedar Mountain Formation can discharge into Browns Wash, additional surface water POEs are established at the confluence of Browns Wash and the Green River and in Browns Wash at the uppermost reach of the backwaters from the Green River (this location will vary based on stage of the river). Monitoring will be scheduled to coincide with the time of year during which this habitat is most critical to the endangered fish If contaminants are detected or if increases of key constituents are observed, mitigative actions can be taken This monitoring strategy will ensure continued protection of critical habitat.

Though data are limited, it appears that contaminants in the Cedar Mountain Formation migrating from the vicinity of the disposal cell attenuate within a short distance. Nitrate concentration at monitor well 0171 was 215 mg/L in the July 2002 sampling round but was less than 1 mg/L at downgradient monitor well 0813. Similarly, the selenium level at well 0171 in July 2002 was at 0.184 mg/L while at 0813 the concentration was barely above detection at 0.00035 mg/L. Uranium levels have only exceeded the MCL at a single monitor well (0179) in the Cedar Mountain Formation. Arsenic concentration has been above the MCL in monitor well 0813 only

Since the site will be under long-term IC because of the disposal cell, no benefit is to be gained by undergoing active ground water remediation of the Cedar Mountain Formation DOE will retain control of the property immediately surrounding the disposal cell in perpetuity The State of Utah owns the downgradient property to the north and west of the cell and can control ground water use The Green River provides a ready source of potable water As long as application of ACLs does not result in contamination of ground water outside of the IC area, the no remediation compliance strategy with application of ACLs can be considered protective of human health and the environment

Constituents that require ACLs because concentrations exceed their respective UMTRA Project ground water standards are arsenic, nitrate, selenium, and uranium Sulfate and sodium levels also are elevated, although no health-based drinking water standards have been established for these constituents. Section 7.3.3 describes the ACL approach for the Green River site and presents proposed numerical values for each constituent.

To summarize, a no remediation compliance strategy with the application of ACLs for the Cedar Mountain Formation at the Green River site is supported by the following:

- A disposal cell is located at the site. Minor seepage during long-term disposal may result in somewhat elevated concentrations of mill-related constituents though tailings did not contain appreciable moisture when disposed. Estimates are that the tailings were 15 to 25 percent saturated when placed in the cell (DOE 1991); no slimes were present. Therefore transient drainage should be minimal and probably confined to the immediate vicinity of the cell.

- The Green River disposal site itself is DOE-owned. The State of Utah owns the surrounding property. Government ownership of land overlying contaminated ground water ensures that effective ICs can be maintained to prevent inappropriate use of contaminated ground water.

- Site-related contamination of the Cedar Mountain Formation is not widespread or pervasive. Distribution of contaminants is spotty, both temporally and spatially. This may indicate that contaminants attenuate rapidly, that movement through the formation is affected by hydrostratigraphy, fractures, or some other limiting feature, or some combination of these or other factors.

- The area affected by contamination appears to be relatively limited. With ICs in place and the Green River providing a ready source of potable water, little benefit is to be gained by pursuing an active remediation strategy. If it can be ensured that contamination will not migrate beyond the ICs area, the no remediation compliance strategy will be protective of human health and the environment. Monitoring will be conducted to ensure the effectiveness of the compliance strategy.

7.2.2 Supplemental Standards for the Browns Wash Alluvium

The proposed compliance strategy for the Browns Wash alluvium is no remediation with application of supplemental standards. The strategy for Browns Wash alluvium is explained in Table 7–2.

Ground water in Browns Wash alluvium qualifies for supplemental standards based on limited yield (less than 150 gallons per day) as demonstrated by observations of ground water availability in the alluvial aquifer system during recent field investigations (see Section 5 1.2.1) Currently it appears that the ground water levels in Browns Wash alluvium are below the elevation of the wash itself; therefore, no ground water is discharging to the wash. However, the surface water monitoring to be performed in conjunction with ACLs for the Cedar Mountain Formation would also detect any contaminants from discharge of Browns Wash alluvium, should water levels become more elevated. Although the State of Utah expressed concern that a supplemental standards strategy would not address surface water concerns, the monitoring proposed for the Cedar Mountain Formation ACL compliance strategy should sufficiently address this issue. Therefore, no numerical standards are proposed for the Browns Wash alluvium.

Table 7–2 Compliance Strategy Selection Process for Ground Water in the Browns Wash Alluvium

Box from Figure 7–1	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions	See conceptual site model presented in Section 5 0 and contaminant screening presented in Section 6 0 of this document. Move to Box 2
2	Is ground water contamination present in excess of maximum concentration limits or background levels?	Manganese, nitrate selenium sodium, sulfate, and uranium exceed the MCLs or appropriate benchmarks at one or more monitoring points Move to Box 4
4	Does contaminated ground water qualify for supplemental standards due to limited use ground water?	Yes Ground water in the Browns Wash alluvium qualifies for limited use because the aquifer is not capable of a sustained yield of 150 gallons per day Move to Box 5
5	Are human health and environmental risks of applying supplemental standards acceptable?	Yes The quantity of ground water available would not result in unacceptable exposures Ground water currently does not discharge to the surface so all exposure pathways are incomplete Move to Box 7
7		No remediation required Apply supplemental standards

7.3 Implementation

ACLs and supplemental standards will be implemented in conjunction with ground water monitoring and ICs. Ground water monitoring would be implemented to ensure that the compliance strategy is effective and remains protective of human health and the environment. The ICs would be established, if necessary, to prohibit anyone from accessing potentially contaminated ground water along the flow path from the former processing site

7.3.1 Institutional Controls

ICs are needed in situations where cleanup does not result in unrestricted use and unlimited exposure to ground water at a site Since active remediation of ground water at the Green River site is not warranted for reasons discussed in Section 7 2 1, effective ICs may be needed to protect human health and the environment The need for ICs will be determined in coordination with state and local agencies who will be responsible for implementing, monitoring and enforcing the ICs

DOE owns the disposal site and will maintain control over this property in perpetuity The State of Utah currently owns the remainder of the former processing site and consequently can maintain an effective IC in this area If the State decides to dispose of the property in the future, an appropriate type of IC, such as a deed restriction, will be put in place to prevent exposure to or use of contaminated ground water As requested in the State of Utah opinion regarding control of access to contaminated ground water along the flow path between the site and the Green River, DOE will identify all landowners and holders of surface water and ground water rights and provide effective ICs, as needed, to prohibit access to and use of contaminated ground water Figure 3–1 shows the ownership of property surrounding the site.

7.3.2 Monitoring

Ground water and surface water will be monitored at select locations annually to observe the effectiveness of the compliance strategy and ensure long-term protection of human health and the environment (Figure 7–2) A summary of monitoring requirements is presented in Table 7–3.

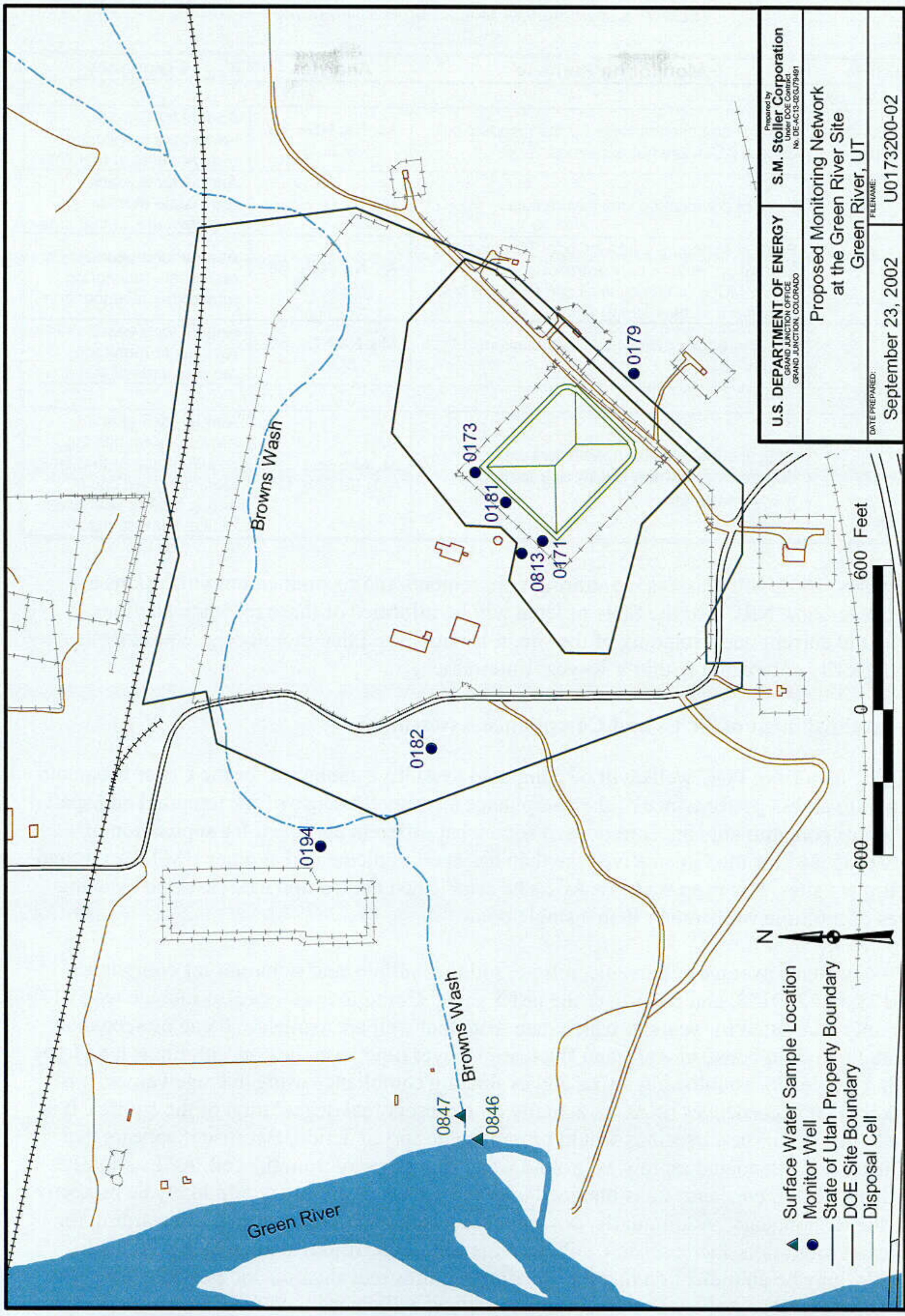


Figure 7–2. Proposed Monitoring Network at the Green River Site

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Table 7–3. Summary of Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency
Ground Water			
0171, 0173, 0181, 0813	Point of compliance wells for the disposal cell, ensure ACLs are not exceeded	As, Na, NO_3, Se, SO_4, U	Annual for 5 years, reevaluate monitoring requirements at that time
0179	Point of compliance well for uranium	U	Annual for 5 years, reevaluate monitoring requirements at that time
0182	Point of exposure well for Cedar Mountain Formation; ensure concentrations remain below MCLs or RBCs Well completed in first significant water-bearing unit	As, Na, NO_3, Se, SO_4, U	Annual for 5 years, reevaluate monitoring requirements at that time
0194	Leading edge of Browns Wash alluvium plume	Mn, Na,NO_3, Se, SO_4, U	Annual for 5 years, reevaluate monitoring requirements at that time
Surface Water			
0846, 0847	Critical surface water habitat; ensure no degradation of water quality due to ground water discharge	As, Mn, Na, NO_3,Se,SO_4, U	Annual for 5 years, reevaluate monitoring requirements at that time Monitoring will occur during time of year when habitat is most critical.

After 5 years, DOE will reassess monitoring requirements and recommend modifications as deemed necessary NRC and the State of Utah will be informed of these recommendations. Based on the current understanding of the site, it is anticipated that monitoring requirements may be satisfactorily completed within a 30-year timeframe

7.3.3 Establishment of ACLs and Compliance Assessment

Monitoring data from POC wells will be compared to ACLs established for the Cedar Mountain Formation to assess performance of the compliance strategy. Because of the temporal and spatial variability of contaminant concentrations, a somewhat different approach for application of ACLs is proposed for the Green River site than has been implemented at other UMTRA Ground Water Project sites. It is proposed that ACLs be established and compliance assessed by using averages of multiple wells rather than a single point.

Table 7–4 presents averages of arsenic, nitrate, sodium, sulfate, and selenium for compliance wells 0171, 0172, 0173, and 0813 over the last 5 years. Uranium averages also include well 0179 and are only computed for years in which data from that well are available. It can be seen that despite the variation between wells and fluctuations over time, average concentrations tend to be somewhat stable By establishing ACLs and evaluating compliance using average values, it is more likely that exceedences of ACLs actually do represent real degradation of the aquifer. It is less likely that minor perturbations would prompt some sort of action. Because it appears that contamination is attenuated rapidly as ground water moves away from the cell, ACLs slightly higher than average concentrations obtained over the last several years would likely be protective outside the IC boundary. Additionally, downgradient well 0182 serves as an early warning for contaminant migration. Increases in COPCs in this well, even if they remain below ACLs in POC wells, may be an indication that the situation requires reevaluation and possible corrective action. This overall compliance strategy suits the site-specific needs of the Green River site and should be adequately protective of human health and the environment. Numerical values proposed as ACLs are also included in Table 7–4.

Table 7–4. Average Concentrations of COPCs in Compliance Wells (all in mg/L)

	9/98	9/99	9/00	9/01	3/02	Proposed ACL
As	0.037	0.048	0.041	0.040	0.033	0.075
NO_3	538	488	314	599	512	650
Na	2,125	1,960	2,175	2,302	2,147	2,500
SO_4	4,795	4,625	4,942	5,727	5,235	6,000
Se	0.097	0.106	0.074	0.126	0.115	0.18
	12/97	**6/01**	**12/01**	**7/02**		
U	0.037	0.050	0.053	0.057		0.075

Wells to be averaged for compliance with arsenic, nitrate, sodium, sulfate, and selenium ACLs are 0171, 0173, 0181, and 0813. Those same wells along with 0179 should be averaged for comparison to the uranium ACL.

7.4 Subpart A Compliance

The Green River site also contains the disposal cell, which is regulated under Subpart A of 40 CFR 192. The long-term surveillance activities and ground water monitoring program for the disposal site are presented in the LTSP, which is the regulatory document required by NRC when the disposal site was licensed (DOE 1998b).

DOE is currently monitoring ground water in four POC wells (0171, 0172, 0173, and 0813) in the uppermost aquifer in the Cedar Mountain Formation (middle sandstone unit) downgradient from the disposal cell. Ground water samples are collected on a quarterly basis and analyzed for nitrate, uranium, and sulfate. Proposed concentrations limits were established and are presented in Table 5.1 of the LTSP (DOE 1998b). At the end of 3 years (2001) sampling results were evaluated and a report submitted to NRC and the State of Utah (DOE 2001). The conclusion reached was that concentrations were currently within a reasonable range of compliance relative to MCLs and proposed concentration limits, and the preexisting levels of nitrate, uranium, and sulfate in ground water beneath and downgradient from the disposal cell. At that time, the investigation for Subpart B compliance (subject of this report) was in the planning stages, and it was proposed that monitoring of the four POC wells continue on a quarterly basis until the current investigation is complete and the site-wide compliance strategy and monitoring program are revised and approved. It was also stated that insufficient data were available to confirm or deny the "harvest water leaching hypothesis" proposed in the LTSP and Modification No. 2 to the RAP (DOE 1998b and 1998a).

Specifically, the harvest water leaching hypothesis was proposed as one of three possible explanations for elevated concentrations of nitrate in ground water in several POC wells downgradient from the disposal cell; the other two being transient drainage from the disposal cell or sources unrelated to uranium processing activities. The harvest water leaching hypothesis was explained as follows: (1) high concentrations of nitrate may be present in the vadose zone beneath and downgradient from the disposal cell; (2) water from precipitation running off the disposal cell cover collects in the toe drain along the northwest side of the cell; and (3) this water will then infiltrate into the vadose zone, mobilizing nitrate, which then migrates to the water table and into the ground water (DOE 1998b).

Based on results of this investigation it does not appear that the harvest water leaching hypothesis is valid because: (1) there is very little precipitation in the area to facilitate this activity—precipitation data from an onsite rain gage indicate 3.05 inches during the past year, with no obvious correlation with ground water elevations measured by dataloggers (Figure 7–3); (2) levels of nitrate, particularly in monitor well 0172 appear to be anomalous (as discussed in Section 5.3.4.2 and in the 3-year evaluation report [DOE 2001]); and (3) there may be a component of transient drainage contributing some contamination to ground water in the uppermost aquifer since the bottom of the disposal cell is approximately 35 ft below grade and blasting during construction may have resulted in enhanced fracturing and subsequent pathway formation.

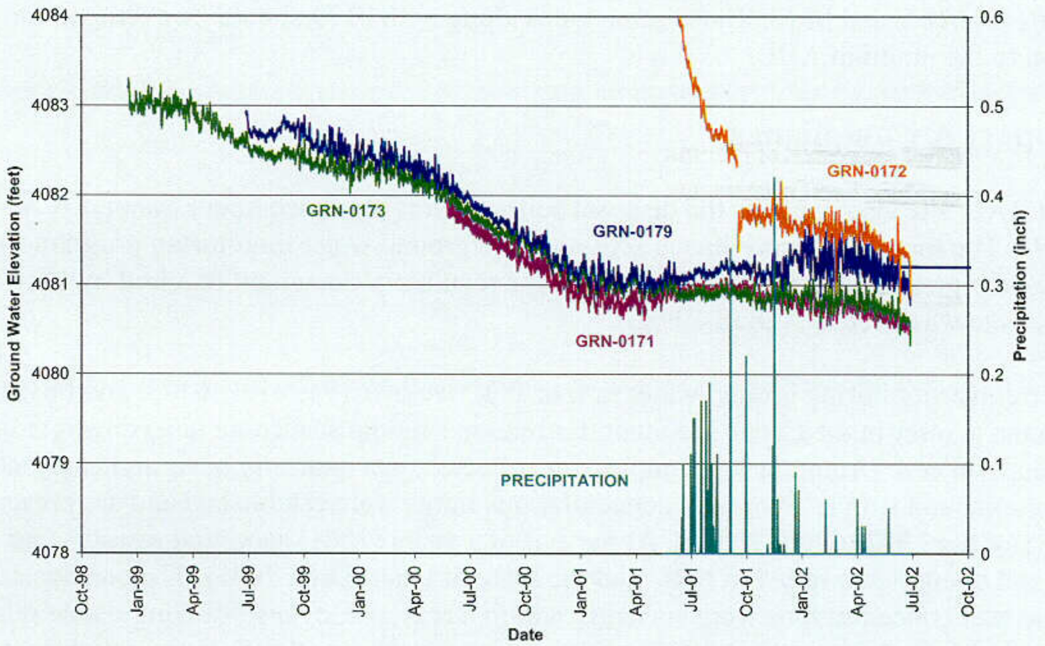

Figure 7–3. Ground Water Elevations and Daily Precipitation at the Green River Site

The summary for the no remediation compliance strategy with the application of ACLs for the Cedar Mountain Formation in Section 7.2.1 provides justification for the possible occurrence of contamination in ground water in the uppermost aquifer in this area and why the proposed compliance strategy and implementation thereof (including ongoing monitoring) is reasonable and protective of human health and the environment. This supports the objective of establishing a comprehensive site-wide compliance strategy for both Subparts A and B. This concept will also be presented in the GCAP, which is the NRC concurrence document for Subpart B. When NRC and the State of Utah concur with the proposed compliance strategy, DOE will modify the LTSP to reflect the new comprehensive compliance strategy and monitoring program, and will then implement the long-term stewardship program.

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Appendix A

Summary of Monitor Well Information

MONITOR WELL REPORT (USEE300) FOR SITE GRN01, GREEN RIVER
REPORT DATE 9/24/2002 9 03 am

LOCATION CODE	NORTH COORD (FT STATE-PLANE)	EAST COORD (FT STATE-PLANE)	GROUND ELEV (FT NGVD)	BORE HOLE DEPTH (FT BLS)	BORE HOLE DIA (INCHES)	TOP OF CASING ELEV. (FT NGVD)	CASING LENGTH (FT)	CASING DIAMETER (INCHES)	SCREEN DEPTH (FT BLS)	SCREEN LENGTH (FT)	FLOW CODE	ZONE OF COMPL	DECOM-MISSION DATE
0171	237922 42	2387199 50	4138 30	88 00	7 9	4140.10	89 80	4 0	76 00	10 00	D	CM	
0172	238061 51	2387346.57	4138 70	96 00	7.9	4140 53	97 83	4 0	84 00	10 00	D	CM	
0173	238203.72	2387483 41	4139 40	104 00	7 9	4141 23	105 83	4 0	92 00	10 00	D	CM	
0174	238155 67	2387576 77	4140 50	85 00	7 9	4142.12	86 62	4 0	73 00	10 00	D	CM	
0175	238018 89	2387722 87	4140 30	90 00	7 9	4142 86	92 56	4 0	78 00	10 00	D	CM	
0176	237870 77	2387871.15	4141 40	84 00	7.9	4143 40	86 00	4 0	72 00	10 00	D	CM	
0177	237368 10	2387436 10	4145 00	115 00	7.9	4147.62	117 62	4 0	103.00	10 00	C	CL	
0178	237259 77	2387627 48	4153 40	110 00	7.9	4156 77	113 37	4 0	98 00	10 00	C	CL	
0179	237541 30	2387895 92	4158 70	90 00	7 9	4161.39	92 69	4 0	78 00	10 00	C	CM	
0180	237809 90	2388277.74	4156 20	90 00	7.9	4159 11	92 91	4 0	78 00	10 00	C	CM	
0181	238075 43	2387359 16	4138 90	96 00	8 0	4141.10	94 20	4 0	77 00	15.00	D	CM	
0182	238388 52	2386337 03	4099.80	162 00	8 0	4101.52	151 72	4 0	140 00	10 00	D	CB	
0183	238494 88	2388316 67	4097.90	170 00	8.0	4100 60	88 70	4.0	76 00	10 00	C	CM	
0184	237094 00	2388555 47	4189 80	187 00	8 0	4192 98	187.18	4 0	169 00	15 00	C	CB	
0185	237342 13	2386693 70	4133 00	144 00	8 0	4135 46	143 46	4 0	131 00	10 00	U	CB	
0186	239649 79	2388829 31	4086 00	15 00	8 0	4088 40	13 40	4 0	6 00	5 00	U	AL	
0188	238955.39	2387344 53	4072 70	12 50	8 0	4075 11	14 91	4 0	7 50	5 00	O	AL	
0189	239061 15	2386726 24	4073 80	20 00	8 0	4075 96	21 16	4 0	14 00	5 00	O	AL	
0190	239146 28	2387763 87	4076 60	14 00	8 0	4079 00	16 40	4 0	9 00	5 00	C	AL	
0191	239349 01	2386844 67	4073 60	20 00	8 0	4075.91	19 31	4 0	12.00	5 00	C	AL	
0193	239338 19	2385934 50	4067.30	15 00	8 0	4069 73	17 43	4.0	10 00	5 00	D	AL	
0194	238851 09	2385932.37	4065 40	17.50	8 0	4067.76	19 86	4 0	12 50	5 00	D	AL	
0561	238234 61	2386506 87	4108 70	150 00	7 9	4111 20	146 00	2 0	108 50	30 00	C	CL	10/20/1988
0562	237969 62	2387489 16	4143 60	150 00	7.9	4147.70	131.10	2 0	82 00	43 00	U	CM	10/24/1988
0563	239131.47	2388492 83	4079 70	16 00	2 0	4081.10	16 00	2 0	8 60	5 00	U	AL	10/24/1988

MONITOR WELL REPORT (USEE300) FOR SITE GRN01, GREEN RIVER
REPORT DATE: 9/24/2002 9 03 am

LOCATION CODE	NORTH COORD (FT STATE-PLANE)	EAST COORD (FT STATE-PLANE)	GROUND ELEV. (FT NGVD)	BORE HOLE DEPTH (FT BLS)	BORE HOLE DIA (INCHES)	TOP OF CASING ELEV. (FT NGVD)	CASING LENGTH (FT)	CASING DIAMETER (INCHES)	SCREEN DEPTH (FT BLS)	SCREEN LENGTH (FT)	FLOW CODE	ZONE OF COMPL	DECOM-MISSION DATE
0564	239312.65	2386591 53	4064 60	11 00	2 0	4068 10	11.00	2 0	1 50	5 00	D	AL	10/31/1988
0581	238834 86	2387418 48	4083 30	85.00	9 5	4084 60	86 30	4.0	63 00	20 00	O	CU	10/26/1988
0582	238830 30	2385911.82	4065 70	170 00	9 0	4067 00	169 80	4 0	146 50	20.00	C	CB	
0583	238865 87	2385913 20	4065.60	50 00	5 8	4067.02	51.42	2 0	28 00	20 00	D	CU	
0584	239046.93	2386726 17	4073 80	50.00	5 8	4075 34	51 54	2.0	28 00	20 00	D	CU	
0585	239328 59	2385916 67	4067 50	50 00	5 9	4068 53	51 03	2 0	38 00	10.00	D	CU	
0586	237556.77	2387385 44	4142 40	170.00	7 9	4143 40	167.50	4.0	144 50	20 00	U	CB	10/25/1988
0587	237554 43	2388010 25	4167 90	190 00	7 9	4169 40	186 50	4 0	163 00	20 00	C	CB	10/19/1988
0588	237843 57	2386257 84	4112 20	145 00	7 9	4113 92	146.72	4 0	123 00	20 00	U	CB	
0701	238715 62	2387413 30	4087 00	57 00	5.1	4087 90	57 90	4 0	29 00	1 00	O	AL	10/25/1988
0702	238735 98	2387779 48	4081.80	43 00	8 0	4082 60	24 80	4 0	15 00	8 00	O	AL	10/26/1988
0703	238737.80	2387786 10	4081 60	28 00	8 0	4082 60	29 00	4 0	22 00	6 00	O	CU	10/24/1988
0704	238940 95	2387427 89	4080 70	23 00	8.0	4082 10	24 40	4.0	15 00	8 00	O	AL	10/25/1988
0705	239028 06	2387153 65	4076 10	20 00	8 0	4078 30	22 20	4 0	14.00	6 00	O	AL	10/26/1988
0706	239170 50	2386868 89	4069 80	34 00	8 0	4070 90	15 10	4 0	8 00	6.00	O	AL	10/25/1988
0707	239119 52	2388713 62	4081 80	37.00	8 0	4083 03	16 23	4 0	9 00	6 00	U	AL	
0708	238986 51	2387706 08	4073.10	11 00	8 0	4074.70	12 60	4 0	7 00	4.00	C	AL	10/31/1988
0806	239207.71	2388735 11	4082 10	68 00	7 9	4084 01	68 71	4.0	55 20	10 00	U	CU	
0807	237543 24	2387138 35	4139 14	102 25	7 9	4141.03	101 69	4 0	78 00	20 00	U	CM	07/06/1990
0808	238697 61	2387817 71	4082 27	25 00	7 9	4084 41	27.14	4 0	13 00	10 00	O	CU	10/26/1988
0809	238760 90	2387003 83	4080 30	71.00	7 9	4083 03	72 33	4 0	47 80	20 00	D	CU	10/26/1988
0810	238409 04	2386349.88	4099 00	80.00	7.9	4101 08	82 08	4.0	58 00	20 00	D	CU	
0811	239186 22	2388790 92	4082 80	79 30	7 9	4085 04	81 54	4 0	62.50	15 00	U	CU	
0812	238119 85	2387826 85	4142 75	60 00	7 9	4145 26	61 51	4 0	46 30	10 00	U	CU	07/06/1990
0813	238010 09	2387146 38	4134.50	99 50	7 9	4136 36	101 36	4 0	77 70	20 00	D	CM	

MONITOR WELL REPORT (USEE300) FOR SITE GRN01, GREEN RIVER
REPORT DATE 9/24/2002 9 03 am

LOCATION CODE	NORTH COORD (FT STATE-PLANE)	EAST COORD. (FT STATE-PLANE)	GROUND ELEV (FT NGVD)	BORE HOLE DEPTH (FT BLS)	BORE HOLE DIA. (INCHES)	TOP OF CASING ELEV (FT NGVD)	CASING LENGTH (FT)	CASING DIAMETER (INCHES)	SCREEN DEPTH (FT BLS)	SCREEN LENGTH (FT)	FLOW CODE	ZONE OF COMPL	DECOM-MISSION DATE
0814	237756.50	2387884 75	4143 03	60 00	7 9	4145 27	62.24	4 0	48 00	10 00	U	CM	10/19/1988
0815	239132 11	2386714 80	4071.53	100 00	7 9	4073 55	102 02	4 0	88 00	10 00	D	CM	07/06/1990
0816	237776 17	2387476 26	4141 26	82 30	7.9	4143 91	62 35	4 0	47 70	10 00	U	CU	10/24/1988
0817	239161 51	2388838 50	4083 20	157 00	7 9	4085 31	133 91	4 0	100 00	30 00	C	CM	
0818	237526 68	2387659 08	4150 58	187 00	7.9	4152 47	188 89	4 0	165 00	0 00	U	CB	07/07/1990
0819	238976 65	2386718 08	4072 70	177 00	7 9	4074 88	169 98	4 0	146 00	20 00	D	CL	10/20/1988
0821	239087 14	2386405 22	4065 32	7 00	2 0	4068 17	7 00	2.0	-0 85	5 00	D	AL	10/31/1988
0822	237750 68	2387475 15	4140 64	35 00	7 9	4143 46	37.12	4 0	12 50	20 00	U	CU	10/24/1988
0823	237798.72	2386923 20	4132 86	30 00	7 8	4135 48	31 92	4 0	17.50	10 00	U	CU	07/06/1990

RECORDS SELECTED FROM USEE300 WHERE site_code='GRN01' AND location_code in('0171','0172','0173','0174','0175','0176','0177','0178','0179','0180','0181','0182','0183','0184','0185','0186','0188','0189','0190','0191','0193','0194','0561','0562','0563','0564','0581','0582','0583','0584','0585','0586','0587','0588','0701','0702','0703','0704','0705','0706','0707','0708','0806','0807','0808','0809','0810','0811','0812','0813','0814','0815','0816','0817','0818','0819','0821','0822','0823')

FLOW CODES C CROSS GRADIENT D DOWN GRADIENT O ON-SITE U UPGRADIENT

ZONES OF COMPLETION

AL ALLUVIUM
CM MIDDLE SANDSTONE UNIT
CB CEDAR MOUNTAIN BASAL SANDSTONE MEMBE
CU CUTLER FORMATION
CL LEAN CLAYS, SANDY CLAYS, OR GRAVELLY CL

Appendix B

Monitor Well Lithologic and Completion Logs

Included in CD-ROM format

Appendix C

Static Ground Water Levels

Included in CD-ROM format

Appendix D

Ground Water Analytical Results

Included in CD-ROM format

Appendix E

Surface Water Analytical Results

Included in CD-ROM format