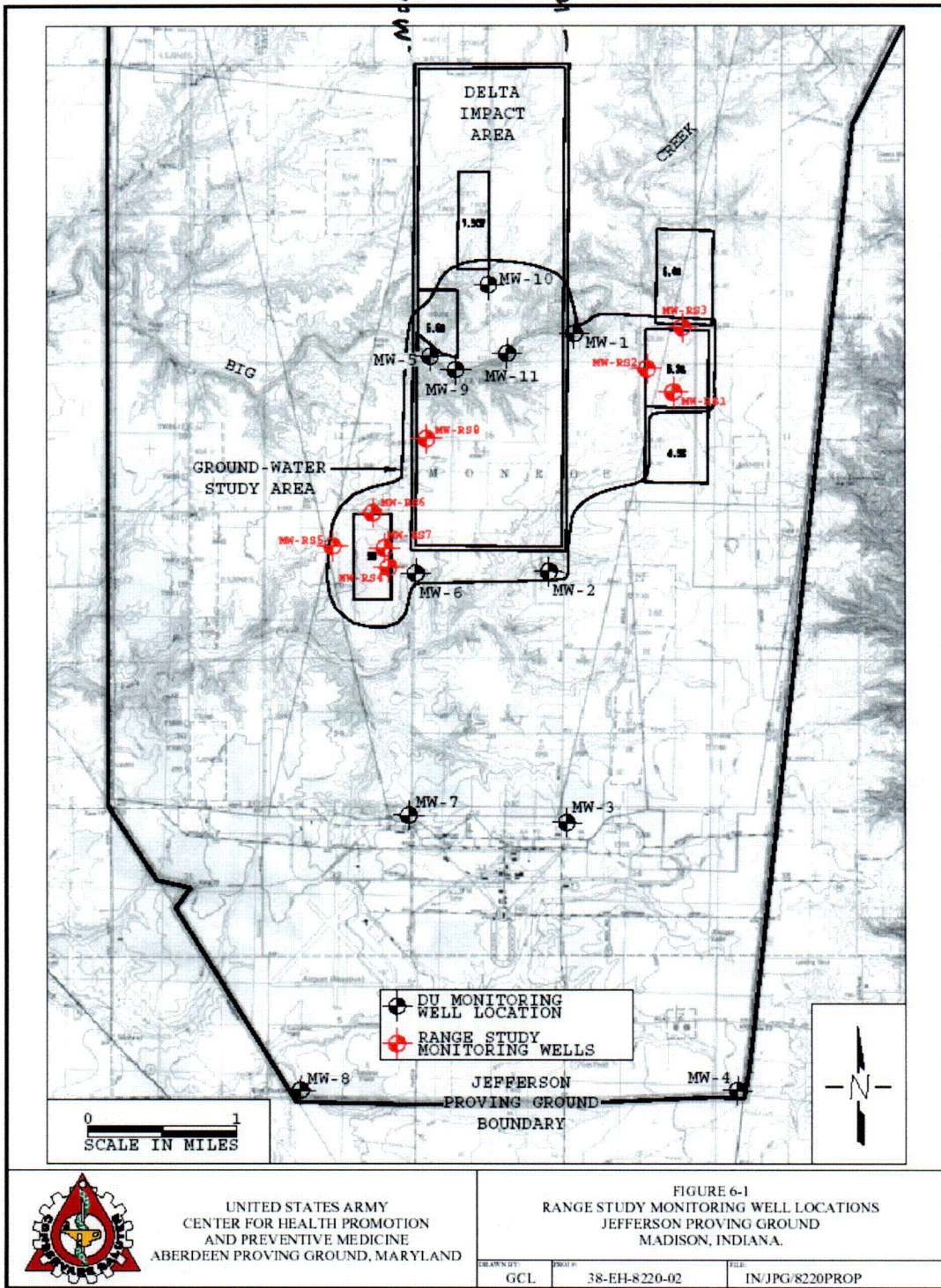
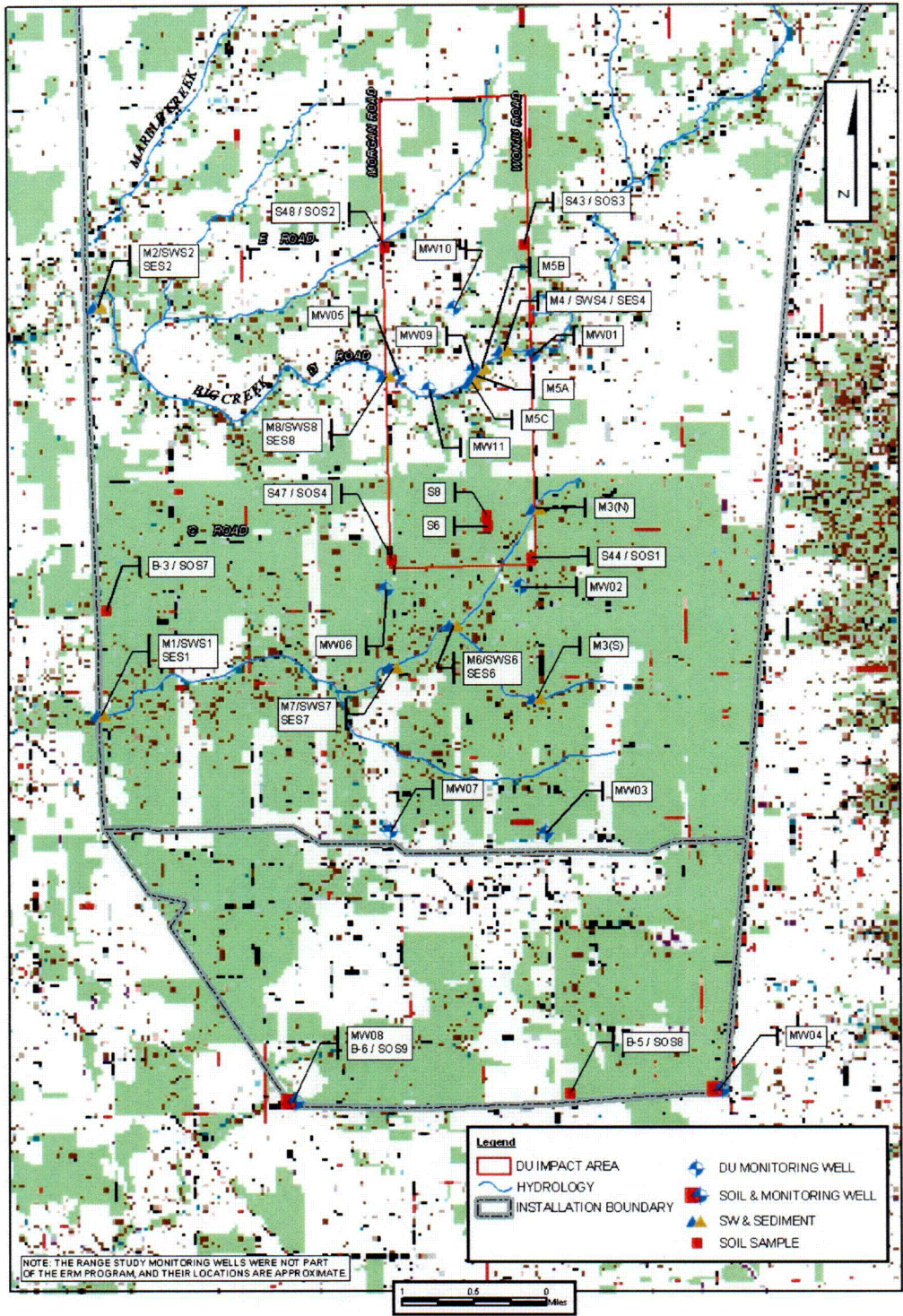


FIGURE 6-1 GROUND-WATER STUDY AREA



Attachment B

C-01



**Figure 2-1. Sampling Locations Under the ERM Program (U.S. Army 2000a)  
Jefferson Proving Ground, Indiana**

C-02

**Monitoring Wells Total Uranium units pCi/L**

	No of Months	MW01	MW02	MW03	MW04	MW05	MW06	MW07	MW08	MW09	MW10	MW11	MW12
1999	4	1	1	1	1	1	4	0.4	0.4	1	0.7	1	1
1999	10	1	1	1	4	1	4	1	1	1	0.8	1	1
2000	16	2	2	2	1.05	2	2.17	1.45	2	2	1.08	2	2
2000	22	2	2	2	2	2	3.2	1	1	1	1	1	1
2001	28	0.68	0.68	0.68	0.68	0.68	2.72	0.68	0.68	0.68	0.68	0.68	0.68
2001	34	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
2002	40	1.005	1.005	1.005	1.005	1.005	0.368	1.005	1.72	1.72	2.365	1.72	0.79
2002	46	2	2	2	2	2	2.2	1	1	1	1	1	1

<i>Sample</i>	<i>year</i>	<i>half of year</i>	<i>Total U</i>	
MW04	2001	1	0 CHPPM	0.68 is MDC
MW05	2001	1	0 CHPPM	0.68 is MDC
MW06	2001	1	2.72 CHPPM	detect
MW07	2001	1	0 CHPPM	0.68 is MDC
MW08	2001	1	0 CHPPM	0.68 is MDC
MW09	2001	1	0 CHPPM	0.68 is MDC
MW10	2001	1	0 CHPPM	0.68 is MDC
MW11	2001	1	0 CHPPM	0.68 is MDC
MW12	2001	1	0 CHPPM	0.68 is MDC
MW01	2001	2	0 CHPPM	0.68 is MDC
MW02	2001	2	0 CHPPM	0.68 is MDC
MW03	2001	2	0 CHPPM	0.68 is MDC
MW04	2001	2	0 CHPPM	0.68 is MDC
MW05	2001	2	0 CHPPM	0.68 is MDC
MW06	2001	2	0 CHPPM	0.68 is MDC
MW07	2001	2	0 CHPPM	0.68 is MDC
MW08	2001	2	0 CHPPM	0.68 is MDC
MW09	2001	2	0 CHPPM	0.68 is MDC
MW10	2001	2	0 CHPPM	0.68 is MDC
MW11	2001	2	0 CHPPM	0.68 is MDC
MW12	2001	2	0 CHPPM	0.68 is MDC
MW01	2002	1	0 CHPPM	1.005 is MDC
MW02	2002	1	0 CHPPM	1.005 is MDC
MW03	2002	1	0 CHPPM	1.005 is MDC
MW04	2002	1	0 CHPPM	1.005 is MDC
MW05	2002	1	0 CHPPM	1.005 is MDC
MW06	2002	1	0.368 CHPPM	detect
MW07	2002	1	0 CHPPM	1.005 is MDC
MW08	2002	1	0 CHPPM	1.72 is MDC
MW09	2002	1	0 CHPPM	1.72 is MDC
MW10	2002	1	2.365 CHPPM	detect
MW11	2002	1	0 CHPPM	1.72 is MDC
MW12	2002	1	0.79 CHPPM	detect
MW01	2002	2	0 CHPPM	2 is MDC
MW02	2002	2	0 CHPPM	2 is MDC
MW03	2002	2	0 CHPPM	2 is MDC
MW04	2002	2	0 CHPPM	2 is MDC
MW05	2002	2	0 CHPPM	2 is MDC
MW06	2002	2	2.2 CHPPM	detect
MW07	2002	2	0 CHPPM	1 is MDC
MW08	2002	2	0 CHPPM	1 is MDC
MW09	2002	2	0 CHPPM	1 is MDC
MW10	2002	2	0 CHPPM	1 is MDC
MW11	2002	2	0 CHPPM	1 is MDC
MW12	2002	2	0 CHPPM	1 is MDC

### 3. ERM PROGRAM STRATEGY AND PLAN

In this section, the ERM program strategy and plans are presented. The overall goals of the program are presented (Section 3.1), followed by the presentation of the data quality objectives (DQOs) (Section 3.2). For each environmental medium, the rationale and basis for sampling is presented, including action levels and associated procedures if the action levels are exceeded (Section 3.3).

#### 3.1 ERM GOALS AND RATIONALE

The overall goals of the ERM program at JPG are to provide:

- A historical and current perspective of contaminant levels in various media
- An indication of the magnitude and extent of any DU release or migration from past operations
- A timely indication of DU contaminant release and migration.

Environmental monitoring activities are necessary at JPG to ensure that DU within the DU Impact Area does not pose a threat to human health and the environment through inadvertent or unanticipated release or migration. These monitoring activities include the surveillance of all credible transport pathways; the selection of suitable surveillance locations; and the application of appropriate sampling methods, techniques, and analyses. To achieve this goal, the program has been designed to meet the applicable requirements of applicable Federal and State regulations, including NRC regulations and requirements for License SUB-1435.

Because the radioactive material is isolated within the DU Impact Area and institutional controls are in place to prevent and control access to the area, exposure is not likely to occur. However, migration of this material through groundwater, surface water, soil, stream bed sediments, air, and biota is possible. The JPG ERM program was developed to provide direct surveillance of the most probable migration routes through periodic sampling and analysis of radioactive constituents. The following sections present the DQOs for this ERM program and discuss the rationale for the selection of the probable migration routes, sampling locations and frequencies, and action levels and associated steps to be taken if the action levels are exceeded.

#### 3.2 DATA QUALITY OBJECTIVES

The DQO process is a scientific data collection planning process designed to ensure that the type, quality, and quantity of data collected are appropriate for environmental decision-making. It consists of seven prescribed steps outlined in "Data Quality Objectives Process for Hazardous Waste Site Investigations" (U.S. Environmental Protection Agency [EPA] 2000). DQOs define the purpose of the data collection effort, clarify what the data should represent to satisfy this purpose, and specify the performance requirements for the quality of information to be obtained from the data. These outputs then are used in the final step of the DQO process to develop a data collection design that meets all requirements and constraints.

The DQO process for the ERM program applies to the DU Impact Area at JPG and consists of the following elements corresponding to steps in the DQO process:

- ✓ • [The primary objective for environmental sample collection at JPG is to provide data of known and sufficient quality to determine if conditions have changed since the previous sampling events. The data will help define the nature and extent (horizontal and vertical) of DU contaminant migration if it occurs](*DQO Step 1 – State the Problem*).
- ✓ • [The environmental sampling will provide field measurements and analytical data sufficient to determine if DU contamination from the DU Impact Area is migrating to the groundwater or other areas of JPG.] The data will be used to support the development and selection of appropriate corrective actions if required (*DQO Step 2 – Identify the Decision*).
- ERM data from previous and current sampling events at JPG, along with data from the scoping and characterization surveys and other related studies, will provide additional inputs to meet the objectives (*DQO Step 3 – Identify Inputs to the Decision*).
- The boundaries of the DU Impact Area are depicted in Figure 2-1 (*DQO Step 4 – Define the Study Boundaries*).
- Contaminant concentrations at JPG ERM sampling locations will be compared with the concentrations detected in appropriate background media and specified in Federal regulations or defined in this ERM Program Plan to determine the extent of contamination migration at JPG (*DQO Step 5 – Develop a Decision Rule*).
- The sample analysis and validation will be performed in general accordance with the procedures contained in the QAPP (*DQO Step 6 – Specify Limits on Decision Errors*).
- The groundwater, surface water, and sediments will be sampled annually to provide sufficient data concerning contaminant concentrations and potential migration. Sampling results will be used to determine if there have been changes in contaminant trends or potential groundwater flow directions and gradients since the previous sampling event (*DQO Step 7 – Optimize the Design for Obtaining Data*).

### 3.3 RADIATION MONITORING STRATEGY AND PLANS

In this section, the rationale and plans for monitoring environmental media (i.e., groundwater, surface water, sediment, soil, air, and biota) are presented. **Table 3-1** summarizes the ERM program, including planned monitoring activities by environmental medium and associated action levels.

**Table 3-1. ERM Program Plan: Monitoring Plans and Associated Action Levels  
Jefferson Proving Ground, Indiana**

Environmental Medium	Monitoring Plan	Action Levels and Related Actions	
		Action Level (Unit)	Action
Groundwater	<i>Frequency: Annual</i> <i>Monitoring Plan:</i> Well sampling of where increasing DU concentrations are indicated (MW-3 and MW-4) and sampling of 50% of the remaining nine wells using a random lottery selection process.	20 pCi/L	<ul style="list-style-type: none"> <li>• If groundwater analytical results at any well exceed 50% of the limit (i.e., 10 pCi/L), the U.S. Army's SBCCOM will conduct an independent assessment of the results and any trends indicated by the ERM program. Additional sampling may be performed based on U.S. Army review of the results and associated recommendations.</li> <li>• If groundwater analytical results at any well exceed the action level limit of 20 pCi/L, the U.S. Army's SBCCOM will notify the U.S. Army Materiel Command and the NRC within 7 calendar days of receipt of analytical sampling results. Additional sampling will be performed within 30 calendar days of the U.S. Army's receipt of the analytical results. Further actions may be defined based on the results of confirmatory sampling.</li> </ul>
Surface Water	<i>Frequency: Annual</i> <i>Monitoring Plan:</i> This plan includes annual sampling of the exit points of the Big Creek and Middle Creek and 50% of the remaining six surface water monitoring points using a random lottery selection process.	300 pCi/L	<ul style="list-style-type: none"> <li>• If surface water analytical results from any sample location exceed 50% of the limit (i.e., 150 pCi/L), the U.S. Army's SBCCOM will conduct an independent assessment of the results and any trends indicated by the ERM program. Additional sampling may be performed based on U.S. Army review of the results and associated recommendations.</li> <li>• If surface water analytical results exceed the action level of 300 pCi/L, the U.S. Army's SBCCOM will notify the U.S. Army Materiel Command and the NRC within 7 calendar days of receipt of analytical sampling results. Additional sampling will be performed within 30 calendar days of the U.S. Army's receipt of the analytical results. Further actions may be defined based on the results of confirmatory sampling.</li> </ul>
Sediment	<i>Frequency: Annual</i> <i>Monitoring Plan:</i> Sampling of the exit points of the Big Creek and Middle Creek and 50% of the remaining six sediment monitoring points using a random lottery selection process.	94 pCi/g	<ul style="list-style-type: none"> <li>• If analytical results of sediment exceed 50% of the limit (i.e., 46 pCi/g), the U.S. Army's SBCCOM will conduct an independent assessment of the results and any trends indicated by the ERM program. Additional sampling may be performed based on U.S. Army review of the results and associated recommendations.</li> <li>• If analytical results for a sediment sample are greater than 94 pCi/g, the U.S. Army's SBCCOM will notify the U.S. Army Materiel Command and the NRC within 7 calendar days of receipt of analytical sampling results. Additional sampling will be performed within 30 calendar days of the U.S. Army's receipt of the analytical results. Further actions may be defined based on the results of confirmatory sampling.</li> </ul>

The next step in risk mitigation is developed from a consensus ranking of the importance of failure categories on operational effectiveness. This ranking comprises two components: the impact (or consequences) and the probability of the occurrence. MIL-STD-882D provides guidance on criteria for determining impact levels. Impact categories for the long-term monitoring program can include such factors as personnel safety, equipment safety, environmental damage, occupational illness, cost, performance, schedule, and political or public impact. Impact levels may be described as catastrophic, critical, marginal, or negligible. The probability of occurrence may include the following categories: frequent, probable, occasional, remote, or improbable.

The stakeholder team defines these terms in the context of the long-term monitoring program. Assembly of these components into an overall decision matrix is accomplished and processed using the analytical hierarchy process or other decision support algorithm to produce a rank-ordered list of the potential risks and associated severity. This approach provides the stakeholder team with the knowledge and ability to mitigate the impacts of potential model failure to an acceptable level.

Any model of a system is an imperfect representation. The degree to which a model is needed to represent the real system, and its fidelity, are defined early in the evaluation process. The difficulty of developing a high fidelity numerical model for this site is acknowledged. During model development, the American Society for Testing and Materials (ASTM) and DMSO guidance is used to verify and validate that the model solves the right problem correctly. Model verification and validation reduces development risks to an acceptable level. This process entails concept or code testing, the use of subject matter experts, and peer review. An example of testing a conceptual or numerical model/representation is to show a subject matter expert output from the real system and the model, with the goal of differentiation between the two systems. If the subject matter expert can differentiate the one from another with a certain degree of statistical confidence, then the results are used to improve the model of the system.

[ In the case of the DU Impact Area, approximately 20 years of sampling data represent site conditions. Data indicate that the uranium contamination is well below the trigger levels defined in this ERM Program Plan. The question posed is whether the conceptualized site model that was used to locate the monitoring wells in the first place is correct. Because these wells are showing stable/declining concentrations of uranium significantly far below any action level, the conceptual site model used to define, test, and validate the DU Impact Area is hypothesized to be valid.] Formal application of the DMSO guidance to the groundwater monitoring system for the DU Impact Area may be an appropriate next step. This process would be used to confirm this hypothesis, expand understanding of the site and the conceptual model, and evolve the monitoring system's capabilities.

## **A.6 RECOMMENDATIONS**

The current groundwater monitoring system should be used to assess the status and trends of uranium contamination employing the action levels and procedures defined in the ERM Program Plan. In addition, a stakeholder group (e.g., Restoration Advisory Board), composed of the Army, regulatory community, and subject matter experts, should be formed and convened to review the results of the monitoring program annually and to assess the potential risks in the



TABLE 6-9 INORGANIC ANALYSES RESULTS OF UNFILTERED SAMPLES

Compound	Drinking Water Standard	Mean Background	MW-1	MW-2	MW-5	MW-6	MW-9	MW-10	MW-11	MW-RS1	MW-RS2	MW-RS3	MW-RS4	MW-RS5	MW-RS6	MW-RS7	MW-RS8	MW-RS9 (D.S.)
Perchlorate			<0.337	<0.337	<0.67	<0.337	NA	<0.337	<3.4	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337
<b>Metals</b>																		
Antimony, (g/L)	6P	30.0	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Arsenic, (g/L)	10 P	4.00	<1.00	3.69	1.12	NA	NA	<1.00	NA	7.42	<1.00	6.88	5.43	1.14	<1.00	2.02	1.06	<1.00
Barium, (g/L)	2,000 P	263	48.4	154	82.4	NA	NA	245	NA	33.8	38.6	285	128	15.8	159	74.0	158	73.8
Cadmium, (g/L)	5P	3.39	<1.00	<1.00	<1.00	NA	NA	<1.00	NA	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Calcium, (g/L)	NS	96,041	111,000	81,900	157,000	NA	NA	88,700	NA	80,900	172,000	81,200	115,000	74,100	83,800	73,100	97,700	74,700
Chromium, µg/L	100 <sup>P</sup>	11.1	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Copper, µg/L	1,300 <sup>Su</sup>	9.40	2.16	<2.00	<2.00	NA	NA	6.15	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	2.06	<2.00	<2.00
Lead, µg/L	15 <sup>pu</sup>	2.24	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	2.44	<2.00	<2.00	<1.00	<2.00	<2.00	<2.00
Magnesium, µg/L	NS	39,516	29,700	36,200	56,700	NA	NA	34,200	NA	70,600	18,400	31,900	39,400	28,100	30,600	45,400	34,200	46,400
Manganese, µg/L	50 <sup>S</sup>	311.2	<2.00	17.8	15.4	NA	NA	19.4	NA	72.0	28.1	2,690	1,210	252	150	799	2,060	800
Mercury, µg/L	2 <sup>P</sup>	0.05	<0.200	<0.200	<0.200	NA	NA	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200
Molybdenum, µg/L	NS	26.4	<2.00	<2.00	<2.00	NA	NA	6.06	NA	7.63	3.64	22.2	16.6	8.36	<1.00	17.9	7.60	17.7
Nickel, µg/L	NS	17.8	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	3.70	4.68	<2.00	2.18	3.34	15.4	3.19
Silver, µg/L	100 <sup>S</sup>	0.17	<1.00	<1.00	<1.00	NA	NA	<1.00	NA	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Vanadium, µg/L	NS	13.8	<1.00	<1.00	<1.00	NA	NA	<1.00	NA	<1.00	<1.00	2.55	1.78	1.18	<1.00	1.92	1.66	2.02
Zinc, µg/L	5,000 <sup>S</sup>	12.8	<100	<100	<100	NA	NA	<100	NA	<100	<100	<100	<100	<100	<100	<20	<100	<100
Uranium (Total), µg/L	30 <sup>pu</sup>	NS	0.632	1.15	0.430	NA	NA	2.42	NA	3.28	0.856	14.0	10.9	8.12	1.68	22.4	6.36	24.6
Uranium, U235/U238 ratio	NS	NS	0.00627	0.00713	0.00702	NA	NA	0.00720	NA	0.00724	0.00708	0.00727	0.00722	0.00720	0.00720	0.00725	0.00727	0.00725
Uranium ratio uncertainty	NS	NS	0.000190	0.000110	0.000450	NA	NA	0.000100	NA	0.0000900	0.00021	0.0000600	0.0000700	0.0000400	0.000100	0.0000500	0.0000400	0.0000500
Calculated Hardness, µg/L	NS	NS	399,000	354,000	626,000	NA	NA	362,000	NA	493,000	172,000	334,000	449,000	301,000	335,000	369,000	385,000	378,000
Total Dissolved Solids, µg/L	500,000 <sup>S</sup>		394,000	382,000	3,120,000	NA	NA	456,000	13,800,000	540,000	232,000	518,000	496,000	388,000	562,000	1,150,000	486,000	1,110,000

NOTES:

- D.S. Duplicate sample, sample was collected from MW-RS7.
- NA - Not analyzed.
- NS - No drinking water standard.
- P - Maximum Contaminant Level. National Primary Drinking Water Regulations, USEPA.
- Pu - Primary MCL at point of use.
- S - National Secondary Drinking Water Regulation or secondary standards, USEPA.
- Su - Secondary MCL at point of use.
- \* Uranium MCL as of 8 December 2003
- <0.300 - indicates the compound was not detected at the indicated method reporting level.
- Due to inadequate water volume, samples were not collected from MW-6 and MW-9, and only mercury was collected from MW-11.

corrosion and dissolution rates of DU dusts depend upon their chemical composition and size distribution. Uranium oxides constitute the main component of dusts produced from DU during impacts or fires, although such dusts can also contain a mixture of major or trace impurities such as iron, silicon and titanium. These impurities are not present in uranium dusts in the nuclear industry, so studies of the corrosion and dissolution of dusts from the nuclear industry might not necessarily be relevant to DU dusts.

In penetrators, DU is alloyed with a small amount of titanium, which can make its corrosion properties significantly different from those of pure uranium metal. Alloying with titanium reduces corrosion and oxidation, retarding the release of soluble DU into the environment.

Much of our knowledge of the environmental behaviour of DU introduced into the environment comes from studies at sites where DU munitions were tested. For example, a series of experiments and geochemical modelling were used to determine corrosion rates, solubility and sorption (a generic term describing the chemical and physical binding of DU to soil components) of DU in soil at the Aberdeen Proving Ground in Maryland and the Yuma Proving Ground in Arizona. Results from these studies, and from studies performed in the UK at Kirkcudbright, indicate that corrosion rates are highly variable and that under conditions that favour corrosion a 1 cm diameter by 15 cm long penetrator (eg about the same as that in a 30 mm round) would release approximately 90 g of DU per year. For a larger projectile, such as a 120 mm round (3 cm by 32 cm penetrator), this equates to a release of approximately 500 g of DU per year. Based on these corrosion rates, the penetrators will only remain as metallic DU for between five and ten years. Reaction products from the corrosion of DU can be transported as a solid phase by physical processes such as resuspension or can be dissolved in soil water that might become, depending upon local hydrological and environmental conditions, transported into plants, surface waters or groundwaters. During the latter process the migration of dissolved DU is controlled by its solubility under local chemical conditions within the soil water and its sorption onto the immobile soil matrix (both of which could vary significantly over a scale of centimetres). Hence, corrosion rates, the solubility of the corrosion products and the degree of movement of DU in the environment will vary between locations and environments.

## 2.5 Environmental pathways

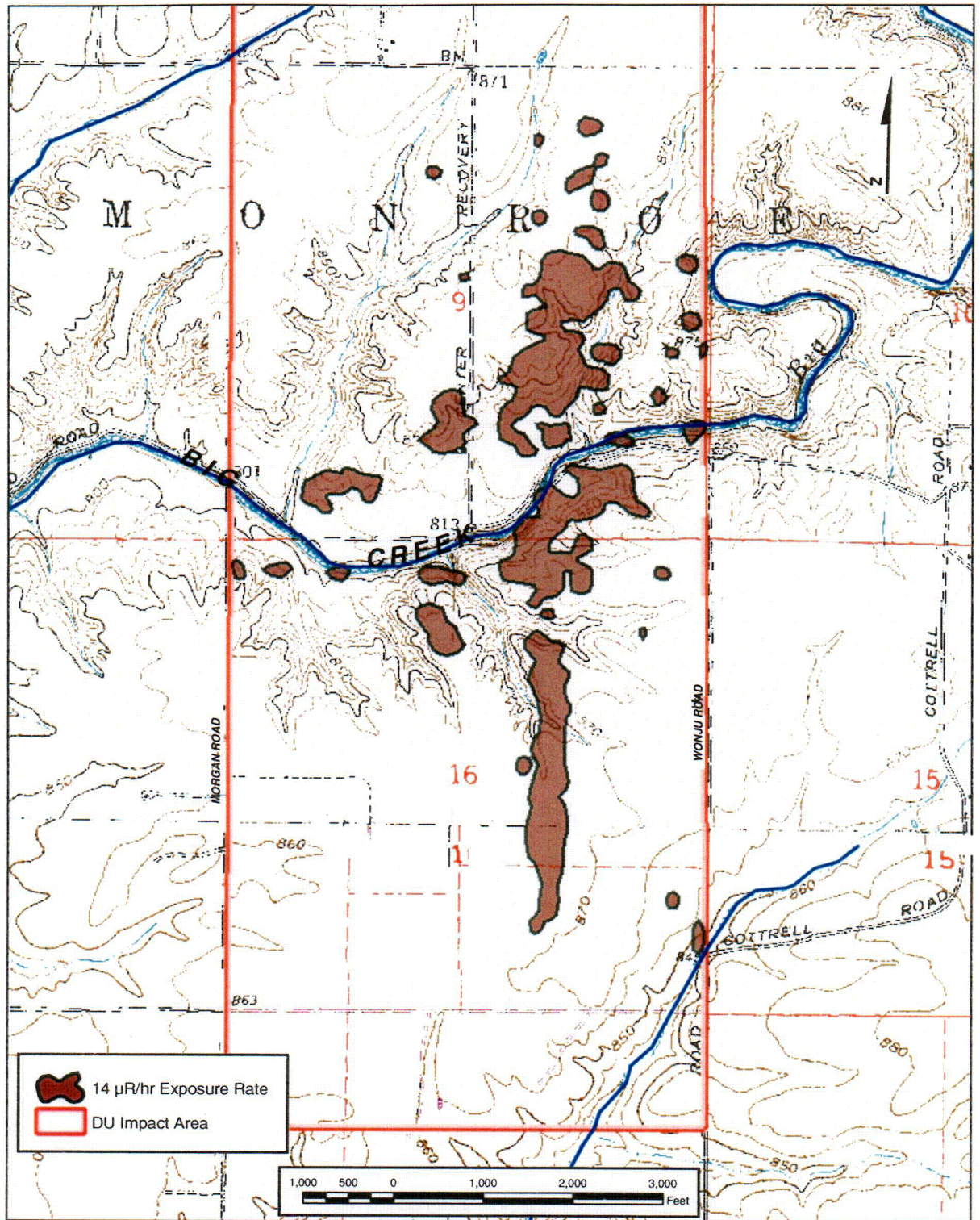
Natural uranium and DU differ only in the proportions of the different uranium isotopes and would therefore be expected to behave similarly in the environment. However, when introduced into the environment, DU is

present in significantly different chemical and mineralogical forms to those encountered in natural systems in which much of the easily leached or 'labile' natural uranium has already been removed. Consequently, the release of DU into the environment by military conflict can have a far greater impact on the concentration of labile uranium in soil and water than would be expected from its concentration relative to that of natural uranium.

Differences in chemical form between DU and natural uranium, and uranium used within the nuclear industry, also limit the applicability to DU of models and scenarios developed for predicting the behaviour of uranium from nuclear waste. For example, studies of nuclear waste disposal usually focus on transport processes that occur at depths of greater than 100 m below the earth's surface (compared with less than 10 m in the case of DU), and on forms of uranium that are chemically and mineralogically distinct from those likely to be introduced during the use of DU in a military conflict.

The environmental behaviour of uranium is strongly affected by many environmental variables, such as soil composition and chemistry, the level of the water table, the amount of resuspension into the air, climate and agricultural practices. For example, the parameters describing sorption of uranium by different soils vary by a factor of up to one million, even amongst broadly similar soil types. Whilst some authors have suggested that the use of DU munitions is unlikely to add significantly to environmental baseline levels of uranium in soils, it is important to consider that uranium derived from the fragmentation or corrosion of munitions might be more bioavailable, and possibly more mobile in the environment, than the residual uranium naturally present in weathered soils. Such differences have been demonstrated during investigations of soils contaminated by uranium from the Fernald site and at military firing ranges. Also, the relative importance of any additional environmental uranium depends on the depth at which the material is introduced and then how much it is moved into the upper soil layers as a result of agricultural practices.

For example, if 20% of the DU from the impact of a large calibre (4.85 kg) penetrator is converted into dust, as was assumed in the worst-case scenario in Part I of the report, and is evenly dispersed over a radius of 10 m to a depth of 10 cm, it would produce a uranium concentration in the soil of approximately 17 mg per kg. This value is above that observed in most natural soils (typically between 0.5 and 10 mg per kg). However, if a similar release of uranium was restricted to the upper 1 cm or less of soil, as might be expected from the deposition of DU dust on uniform soils of a high clay content, then the resultant concentration, assuming even airborne dispersal, would be in excess of 170 mg per kg. The restriction of elevated concentrations to the

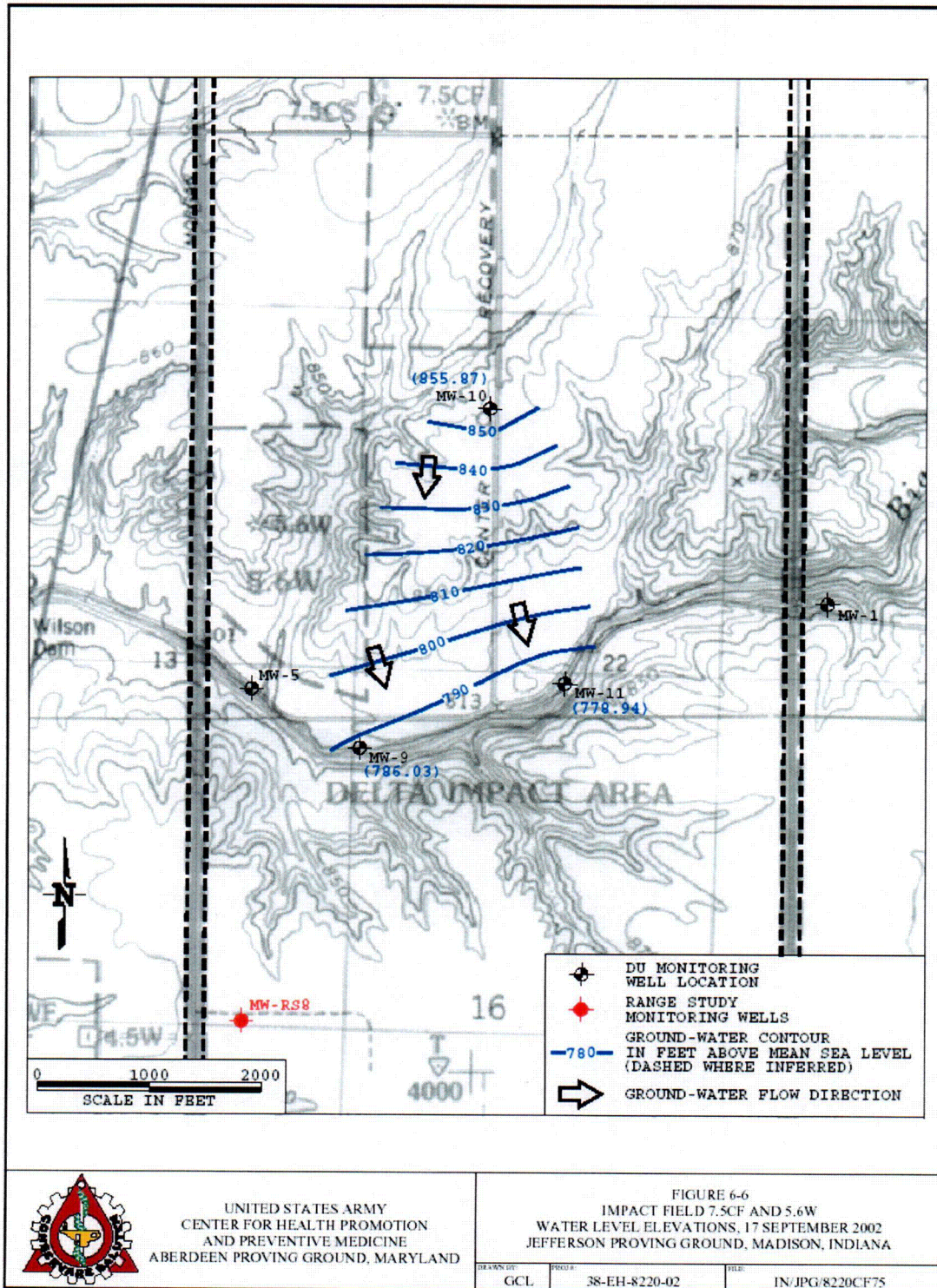


2002 Decommissioning Plan

Figure 4-3, page 4-13

C-03

Figure 6-6 Impact Field 7.5CF and 5.6W Water Level Elevations



C-04