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89353

FEBRUARY 28 2001

U.S. Department of Energy
Weldon Spring Site
Remedial Action Project
ATTN: Pamela Thompson
Project Manager
7295 Highway 94 South
St. Charles, MO 63304

SUBJECT: Contract No. DE-AC05-86OR21548
ADDITIONAL GROUNDWATER FIELD STUDIES IN SUPPORT OF THE GROUNDWATER OPERABLE UNIT (REV. 0)

Dear Ms. Thompson:

Attached please find 30 copies of the subject document for issue to the regulators and other interested parties. This field study is being performed to obtain data for use in deciding whether enhancement of a conventional pump and treat system through artificial recharge, or modification of the configuration of the system by using an angled extraction well can significantly improve contaminant removal as compared to the mass removed using a conventional system. This plan describes the hydrogeologic characterization and well installation activities being performed in support of this study, as well as the components of the study and the necessary water level and contaminant monitoring.

The drilling and well installation work for this study are already underway. It is anticipated that the field study will be started on March 7, 2001. The baseline sampling detailed in the plan will be completed prior to this date. In accordance with the *Federal Facilities Agreement*, notification of sampling (#01-001) has been submitted to the Environmental Protection Agency and the Missouri Department of Natural Resources.

If you have any questions or comments regarding this project, please contact Rebecca Cato at extension 3507.

Sincerely,

Douglas E. Steffen
Project Director

DES/rc/cju

Enclosure: as stated

89353

MK-Ferguson Company
Weldon Spring Site Remedial Action Project

TRANSMITTAL OF CONTRACT DELIVERABLE

Date: **February 28, 2001** Transmittal No.: **CD-0257-00**

Title of Document: **Additional Groundwater Field Studies In Support Of The Groundwater Operable Unit**

Doc. Num.: **885** Rev. No.: **0** Date of Document: **February 2001**

Purpose of Transmittal: Request for Department of Energy acceptance of contract deliverable.

In compliance with the Project Management Contract, MK-Ferguson Company hereby delivers the attached document to the U.S. Department of Energy, Weldon Spring Site Office. The document has been reviewed and approved by Project Management Contractor management.

The document will be considered accepted unless we receive written notification to the contrary within 30 days of the date of this transmittal.

Number of copies transmitted: **30**

Douglas E. Steffen
Project Director

TMP: Form Contract Deliverable

DOE/OR/21548-885
CONTRACT NO. DE-AC05-86OR21548

ADDITIONAL GROUNDWATER FIELD STUDIES IN SUPPORT OF THE GROUNDWATER OPERABLE UNIT

WELDON SPRING SITE REMEDIAL ACTION PROJECT
WELDON SPRING, MISSOURI

FEBRUARY 2001 **REV. 0**

U.S. Department of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

Prepared by MK-Ferguson Company and Jacobs Engineering Group

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MORRISON KNUDSEN CORPORATION MK-FERGUSON GROUP Weldon Spring Site Remedial Action Project Contract No. DE-AC05-86OR21548	
	Rev. No. 0
PLAN TITLE: Additional Groundwater Field Studies in Support of the Groundwater Operable Unit	

APPROVALS

Groundwater Operable Unit Coordinator	2/27/01 Date
Environmental Safety and Health Manager	2/27/01 Date
Data Administration Coordinator	2/27/01 Date
Engineering Manager	2-27-01 Date
Project Quality Manager	2/28/2001 Date
Deputy Project Director	2/28/01 Date

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DOE/OR/21548-885

Weldon Spring Site Remedial Action Project

Additional Groundwater Field Studies in Support of the Groundwater Operable Unit

Rev. 0

February 2001

Prepared by:

MK-FERGUSON COMPANY
and
JACOBS ENGINEERING GROUP
7295 Highway 94 South
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Prepared for:

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office
Under Contract DE-AC05-86OR21548

STATE OF MISSOURI
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REGISTERED GEOLOGIST

2/28/01

ABSTRACT

The purpose of the additional groundwater field studies is to obtain data to decide whether enhancement of a conventional pump and treat system through artificial recharge or modification of the configuration of the system by using angled extraction wells can significantly improve contaminant removal rates as compared to mass removed using a conventional system. This plan describes the hydrogeologic characterization and well installation activities to be performed to support these field studies. The components of the field study and the necessary water level and contaminant monitoring are defined. Data from this study will be used to quantify the mass of each contaminant of concern removed during each stage of testing.

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1. INTRODUCTION

Several technologies have been evaluated for groundwater remediation at the chemical plant in accordance with the *Feasibility Study for the Groundwater Operable Unit* (Ref. 1) and the *Supplemental Feasibility Study for the Groundwater Operable Unit* (Ref. 2). The evaluation focused on Zones 1 and 2 due to the presence of trichloroethylene (TCE) and elevated levels of nitrates, nitroaromatic compounds, and some uranium. Of particular interest was groundwater extraction via vertical wells for remediation of these zones. A pilot pumping study (Ref. 3) was performed in 1998 to support this evaluation.

Alternative 7 (removal and on-site treatment of groundwater in Zones 1 and 2) involves the extraction of groundwater in the vicinity of the raffinate pits. The practicality and effectiveness of pump and treat techniques are dependent upon hydrogeological characteristics of the affected aquifer and characteristics of the contaminants of concern. Approximately 15 vertical extraction wells were estimated to be required to achieve a reasonable extraction rate and to provide sufficient coverage to prevent bypass of contamination from Zones 1 and 2. This alternative estimated that complete aquifer restoration to the maximum contaminant levels (MCL) would not be attained for a long period of time (i.e., more than 100 years). This time frame was based on estimates of aquifer characteristics, contaminant characteristics, and site-specific data obtained through pumping tests. Hydrogeologic complexities such as heterogeneity, fractures, and weathering could not be incorporated into the evaluation; therefore, this alternative may be better or worse than suggested in the evaluation. The primary uncertainties associated with the evaluation of this alternative are relative to the capacity for groundwater extraction. Hydrogeologic data indicate low sustainable yields, possible dewatering of the aquifer in this area, and very slow recovery of the aquifer as observed during the pump test performed in 1998.

It is the position of the Missouri Department of Natural Resources (MDNR) that it appears it may be possible to extract contaminated groundwater from the shallow aquifer in substantial quantities, and perhaps even at sustainable yields (Ref. 4). The MDNR believes that remediation time frames shorter than those suggested in the *Supplemental Feasibility Study* might be achieved by increasing the likelihood of groundwater extraction from the preferential flow features and/or flushing of the aquifer through artificial or natural recharge.

Increasing the amount of water extracted from the area of groundwater impact through artificial recharge or angled wells could potentially shorten remediation time frames. The limiting factors on remediation time frames when using groundwater extraction methods in a heterogeneous aquifer are desorption of the contaminant from the aquifer matrix, movement of contaminated groundwater from the less permeable portions of the aquifer, and the degree of interconnection of the fracture system. If the contaminated groundwater is limited to the secondary porosity features (fractures, weathered zones, etc.) then desorption and/or slower groundwater movement will not play a large part in the determination of cleanup time frames. Conversely, if a large portion of the groundwater contamination is in the primary porosity

(intergranular), then desorption and/or slower groundwater movement from the lower conductivity portions of the aquifer matrix will control the remediation time frames. Field data relating to mass removal of contaminants, except TCE, were not collected during the pilot pumping test. Levels of TCE fluctuated around a baseline level of 420 mg/l during the 18-day long-term test. A temporary increase was observed near the end of the test that resulted from extraction of groundwater originating from MW-2037, which exhibited high TCE concentrations. Connection with this location was inferred by the presence of tracer dye, which was injected at that location prior to the pilot pumping test. After the study, TCE concentrations were similar to those observed prior to the study.

1.1 Purpose

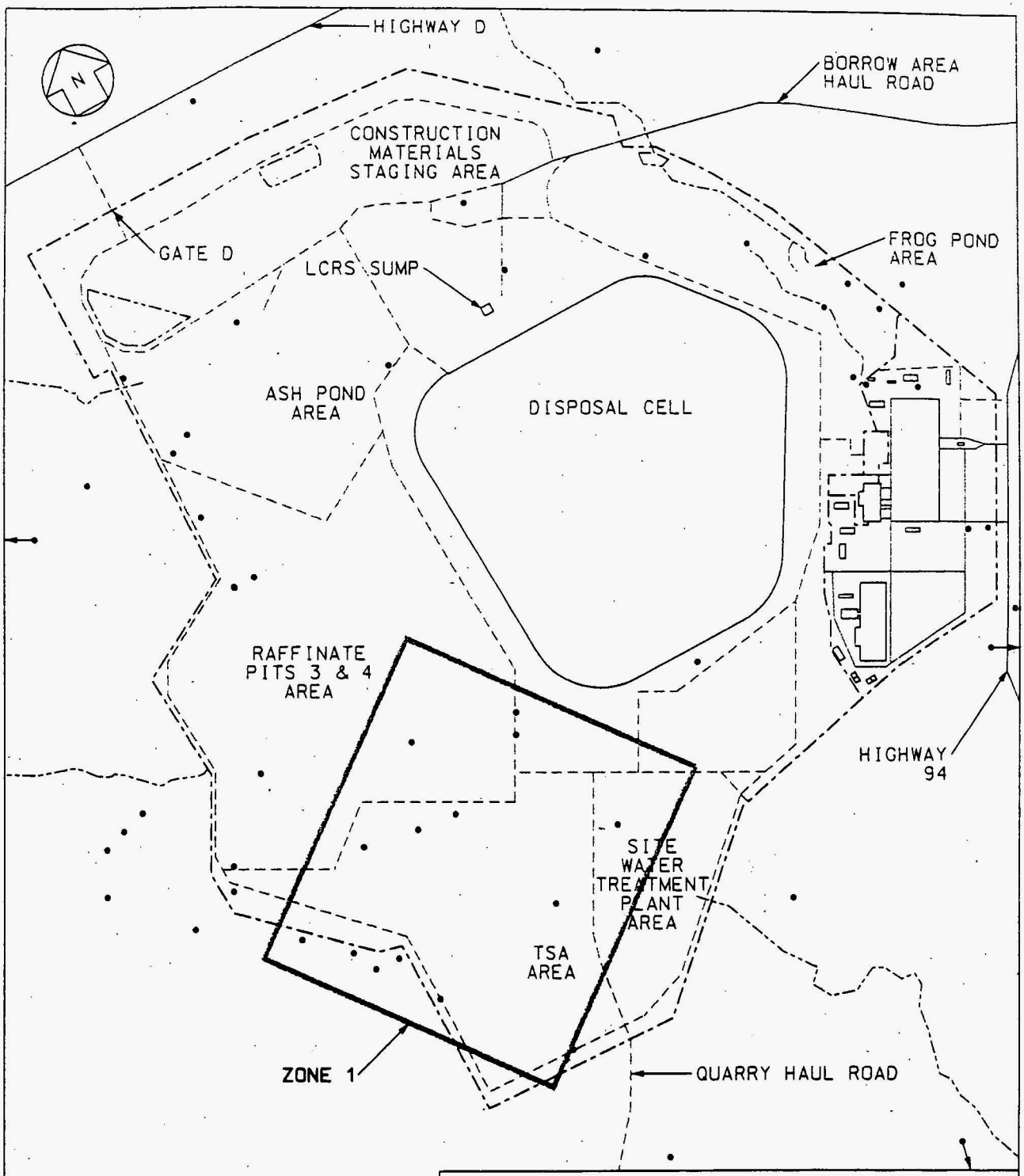
The purpose of the additional groundwater field studies is to obtain data to decide whether enhancement (artificial recharge) to a conventional pump and treat system (extraction using vertical wells) or modification of the configuration of the system (using an angled well) can significantly improve contaminant removal rates as compared to the mass removed using conventional pump and treat methods. Variations that will be evaluated include injection of water to provide additional recharge to the aquifer and use of an angled extraction well to increase the likelihood of intersecting vertical flow paths in the subsurface. Improvement to the conventional system will be determined by comparison of the mass of each contaminant of concern that can be removed under each scenario. The results of this field study will be used to decide whether modifications to a conventional pump and treat method improve contaminant mass removal in Zone 1.

1.2 Scope

This field study will be limited to the area of groundwater impact in Zone 1 (Figure 1-1), as depicted in the *Supplemental Feasibility Study* (Ref. 2). The study will focus on impacted groundwater in the weathered Burlington-Keokuk Limestone and overburden, if saturated.

Data from these tests will be used to better evaluate active remedial options for nitrate, nitroaromatic compounds, and uranium in groundwater. Data to be used in the decision include:

- Geologic information obtained during drilling activities in the study area.
- Groundwater volumes extracted during each scenario.
- Mass of each contaminant of concern extracted under each scenario.



STUDY AREA
CHEMICAL PLANT AREA
MONITORING WELL NETWORK

FIGURE 1-1

0 600 1200
SCALE FEET

REPORT NO.: DOE/OR/21548-885		EXHIBIT NO.: A/CP/031/0201	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 2/26/01	

- Groundwater levels and potentiometric surfaces from the study area.
- Trends in concentrations of the contaminants at extraction locations before, during, and after the studies.
- Trends in concentrations of the contaminants at nearby monitoring wells before, during, and after the studies.
- Hydrogeologic data obtained from previous drilling and aquifer testing.

Testing will be performed in the area where the pilot pumping test (Ref. 3) was performed because the agencies agreed that this was the most optimal location in Zone 1. This field study will evaluate groundwater extraction by wells, both vertical and angled. Extraction of groundwater by other methods is not included. Artificial recharge through the use of vertical wells at upgradient locations will also be included in the study. Several different system configurations and methods to enhance groundwater recovery were evaluated for this study. These were:

- Angled wells (both injection and extraction).
- Horizontal wells.
- Interceptor trench.
- Hydrofracturing.
- Larger diameter wells (both injection and extraction).

Angled wells may enhance performance of the system by increasing the likelihood of intersecting and therefore extracting groundwater from permeable vertical fractures. Intercepting permeable vertical fractures in the injection well could result in a "short-circuiting" of the system and flushing water through the large fracture system only. The use of an angled extraction well has been included in the study, but angled injection wells have not been included.

The use of horizontal wells was suggested to increase the likelihood of intersecting vertical fractures and weathering features. However, most of the fractures in the weathered limestone are along horizontal bedding-plane features (20:1, horizontal to vertical). The horizontal fractures intersected by a horizontal well would be limited based on the installation depth, and therefore, would intersect only a small number of the horizontal groundwater flow paths. Also, groundwater extraction from the well may be limited by the vertical hydraulic conductivity, which is significantly less than the horizontal conductivity because of the horizontal bedding of the limestone aquifer. Vertical or angled wells will provide better connection with the fracture system for this study.

Well diameter is typically selected to accommodate the pump being used. For this field study, a 6-in. diameter well will accommodate the pumps being used to obtain the target

extraction rates (see Section 3). Increases in the diameter of the well can result in a greater screened intake area resulting in better production, but at the production rates expected, the intake area of a 6-in. well screen is not a limiting factor. Also, the larger diameter well will not result in intersection of more vertical features, due to the relatively wide spacing of the vertical fractures. The angled boring being used in the study will increase this likelihood.

Hydrofracturing is commonly used to improve well productivity in the water production and oil production industry. Hydrofracturing is accomplished by injecting water in discrete zones at pressures (greater than 500 psi) capable of fracturing rock. The concern for this project is the use of hydrofracturing at the shallow depths (maximum 60 ft) where the extraction wells will be installed. Use of the high pressures needed to fracture the rock could result in fracturing the overlying weathered rock and unconsolidated materials, and not the bedrock because of the lack of confining pressure. For this reason, hydrofracturing is not recommended for this study.

Also, connection of the fracture system with the pumping well is not the limiting factor for sustainable well yield in this area. During the pilot pumping test, drawdown and capture occurred quickly in a large area around the well, indicating that the local area was in communication with the pumping well. Additional fracturing of the bedrock in the vicinity of the pumping well will not result in a larger sustainable yield, which is limited by the rate of recharge from the surrounding less permeable bedrock.

The option of an interceptor trench is not included in the study. An interceptor trench would not provide additional benefit over wells because the results of the pilot pumping test indicate that the local area (paleochannel) is in communication with the pumping well. Intercepting across a larger cross section would not result in a larger sustainable yield because of limitations of recharge from the surrounding bedrock. Also, costs associated with the construction of a trench in the bedrock and to the depths required to intercept groundwater would be prohibitive.

2. HYDROGEOLOGIC CHARACTERIZATION

Drilling and well installations will be performed to provide additional hydrogeologic characterization data related to the study area. In addition, the completed wells will be used as an extraction well and observation wells during the study to monitor changes in water levels and contaminant concentrations.

Subsurface data indicate the presence of linear bedrock lows on the surface of the Burlington-Keokuk Limestone. These lows resemble surface drainages and appear to be preglacial channels formed by surface erosion of the exposed Mississippian limestone. Testing indicates that hydraulic conductivity is typically highest in wells completed in these bedrock lows (Ref. 3).

2.1 Drilling Locations

Angled drilling will be performed in the vicinity of the existing pumping well to determine the optimal location for the angled extraction well and to obtain additional information regarding the paleochannel in this area. Based on the most recent bedrock topography, the bedrock low is immediately east of MW-3028 (Figure 2-1).

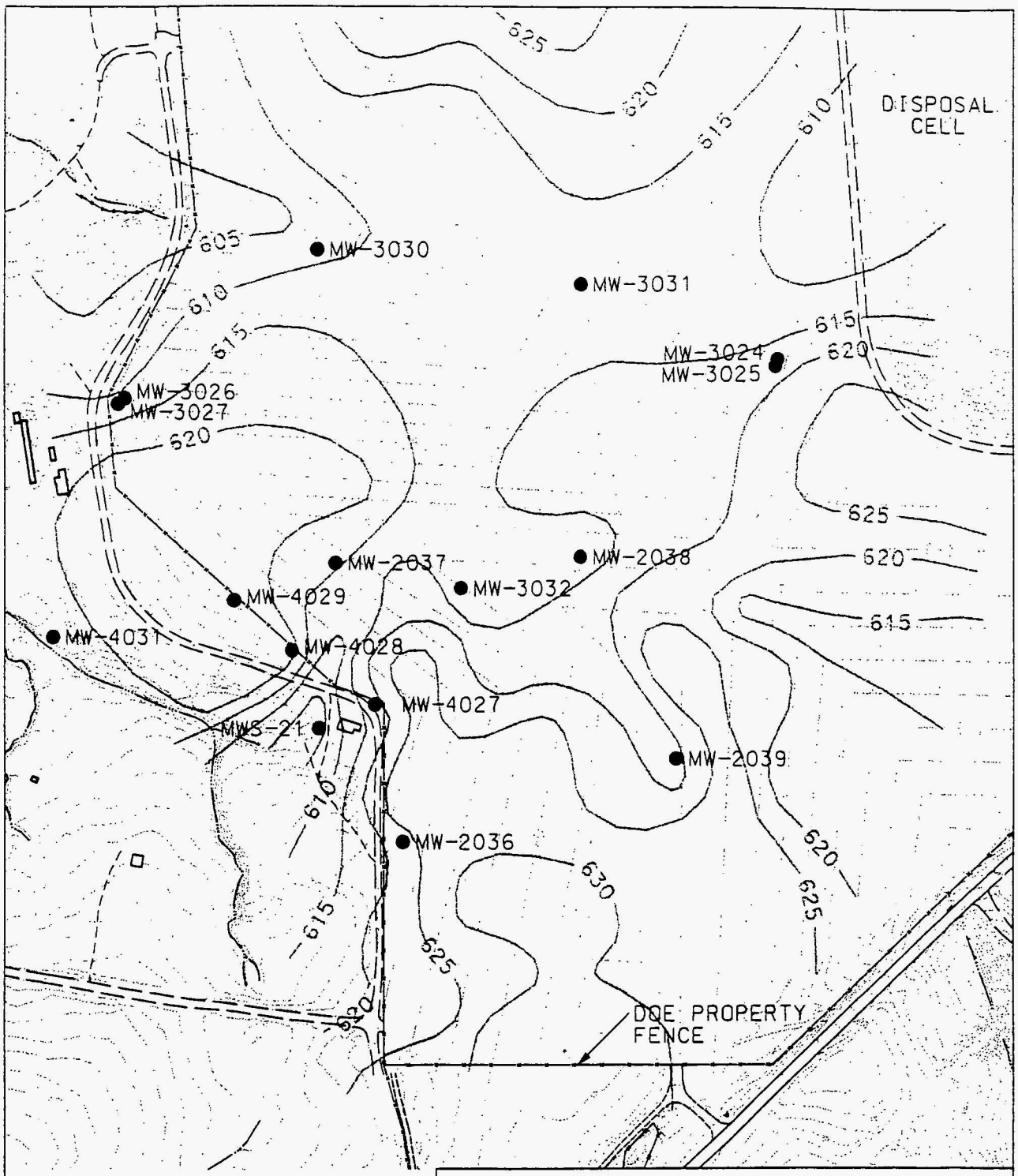
Two angled borings will be cored into the bedrock low in the southwestern portion of the site (Figure 2-2) to locate vertical fracture or weathering features in this area. A summary of the boring IDs, coordinates, borehole orientations, and estimated depths are provided in Table 2-1. Drilling will be performed in accordance with procedure ES&H 9.1.3, *Monitoring Well Installation and Development,* and as specified in the task description for Work Package WP-487A, *Subsurface Drilling Services* (Task 8).

Table 2-1 Proposed Angled Borings

WELL ID	NORTHING	EASTING	BEARING	ANGLE	TOTAL DEPTH (ft)[1]	DEPTH TO ROCK (ft)[1]
AH-2006	1042070	753305	N 100° E	45°	90	65
AH-2007	1042050	753410	N 80° W	45°	85	60

Note 1: Apparent depths along angle

Drilling will also be performed to support installation of additional observation wells. These wells will be installed in close proximity to the pumping and injection wells. Additional information regarding hydrogeologic conditions in the study area will be obtained during installation of these wells.



● - MONITORING WELL

——— - BEDROCK TOPO

N

0 300 600

SCALE FEET

BEDROCK TOPOGRAPHY OF THE BURLINGTON-KEOKUK LIMESTONE

FIGURE 2-1

REPORT NO.: DOE/OR/21548-885		EXHIBIT NO.: A/CP/034/0201	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 2/27/01	

Four additional observation wells will be installed to support this study (Figure 2-2). A summary of the boring IDs, coordinates, and estimated depths is provided in Table 2-2. Drilling activities will be performed in accordance with procedure ES&H 9.1.3, *Monitoring Well Installation and Development,* and as specified in the task description for WP-487A, *Subsurface Drilling Services* (Task 8).

Table 2-2 Proposed Observation Wells

WELL ID	NORTHING	EASTING	TOTAL DEPTH[1]	DEPTH TO ROCK[1]
MW-3034	1042400	753480	65	40
MW-3035	1042170	753310	62	38
MW-3036	1042125	753480	65	38
MW-4032	1041950	753125	45	20

Note 1: Approximate depths

2.2 Geologic Description

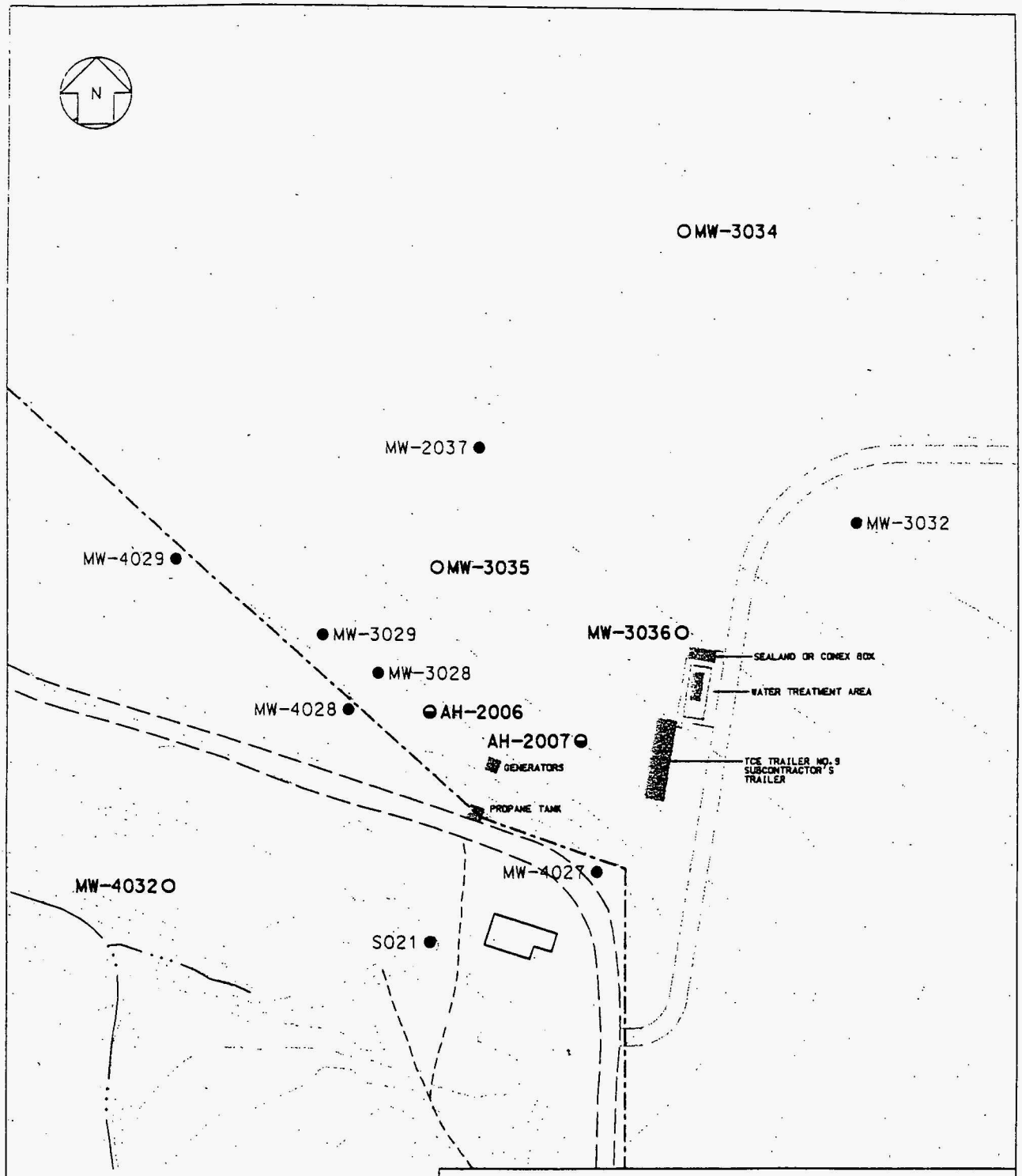
The unconsolidated materials and bedrock will be sampled for descriptive purposes. The PMC field geologist, in accordance with procedure ES&H 4.4.7, *Soil, Rock Core, and Rock Chip Borehole Logging*, will describe the soil and bedrock. During description of the materials, emphasis will be placed on identifying horizontal and vertical fractures, highly weathered zones, and evidence of groundwater movement (solutioning, staining, etc.).

2.3 Packer Testing

Packer tests will be performed on the bedrock portion of the borings during coring operations. Testing will be performed on 5-ft to 10-ft intervals, as determined by the PMC geologist. Tests will be conducted using an inflatable packer inflated with inert gas. Generally, three to five tests of approximately 5-minute duration will be performed at each interval. It is recommended that pressures greater than 1 psi per foot of overburden not be used on test sections less than 10 ft long. Increases in testing pressure should be on 5 to 10 psi increments. For each test, the influent pressure, average flow, length of test interval, and total head will be recorded on test logs.

2.4 Well Installation

The angled boring exhibiting the greatest permeability (packer tests) and/or visual evidence of groundwater movement (rock core logging) will be converted to an angled monitoring well. If testing and visual inspection of the two rock borings indicate that neither of these locations is suitable, the data will be evaluated and an alternate location will be suggested for installation of the angled monitoring well.



LEGEND

- ANGLED BORING
- NEW OBSERVATION WELL
- EXISTING MONITORING WELL

0 100 200

SCALE FEET

LOCATION OF ANGLED BORINGS AND OBSERVATION WELLS

FIGURE 2-2

REPORT NO.: DOE/OR/21548-885		EXHIBIT NO.: A/CP/032/0201	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 2/27/01	

All of the monitoring wells will be screened in the weathered portion of the Burlington-Keokuk Limestone. The screened interval will be maximized in order to intercept the permeable portions of the aquifer, based on the results of the packer tests and rock core logging. The angled monitoring well will be constructed of 6-in. polyvinyl chloride (PVC) well casing and screen (Schedule 40). The screen will be 0.020-in. continuous slot. The observation wells will be constructed of 2-in. PVC well casing and screen (Schedule 40). The screen will be 0.010-in. continuous slot. Well construction will be performed in accordance with the Missouri Well Drillers' Law (10 CSR 23). The angled monitoring well will be given the designation MW-3033. The observation wells will be given the designations indicated in Table 2-2.

2.5 Well Development

Well development will proceed after a period of at least 24 hours from grout placement. Development will be performed until the produced water is clear (turbidity less than 100 NTUs) and the pH and temperature stabilizes, or until the PMC field geologist determines that the well is adequately developed, in accordance with procedure ES&H 9.1.3, *Monitoring Well Installation and Development*. Disposition of developed groundwater is discussed in Section 2.6.

2.6 Investigation Derived Wastes

All waste streams generated during these activities will be managed in accordance with ECDI-18, *Handling and Disposition of Site Generated Wastes*. Wastes generated during this activity include soil and rock cuttings, drilling and development water, personal protective equipment, and miscellaneous trash, which will be handled as specified in the task description for WP-487A.

Soil and rock cuttings and drill water will be collected and dispositioned as described for this task in WP-487A. Handling of these materials will be the responsibility of the respective subcontractor. Dispositions will be approved by the PMC prior to transport of the materials.

2.7 Borehole Abandonment

If for any reason a borehole is not converted to a monitoring well, the borehole will be plugged in accordance with Procedure ES&H 4.4.4, *Subsurface Monitoring Device Plugging and Abandonment*, and 10 CSR 23, *Missouri Well Construction Rules*. Borings less than 10 ft deep will be backfilled with native soils. Borings greater than 10 ft deep will be backfilled with bentonite material, with compacted soil comprising the upper 2 ft of the borehole.

3. FIELD STUDY

The additional study will consist of six stages of testing to evaluate methods to improve a pump and treat option for remediation of groundwater in Zone 1. The stages are as follows:

Stage 1: Determine the sustainable yield of the shallow aquifer in Zone 1. Vertical well MW-3028 will be tested to establish the maximum pumping rate that can be sustained by the aquifer in this zone without causing unacceptable decline in the hydraulic head in the aquifer (dewatering).

Stage 2: Extract groundwater at the sustainable yield. The vertical pumping well, MW-3028, will be pumped at this rate to (1) establish a hydraulic capture zone in this area, (2) determine the aquifer response (verify boundaries), and (3) quantify the mass of contaminants removed using conventional pumping methods.

Stage 3: Introduce artificial recharge at a pre-determined rate (5 gpm) and extract groundwater from the vertical well. Water will be injected at two upgradient locations to provide artificial recharge to the aquifer and increase the hydraulic gradient in the area. Groundwater will be extracted from the vertical well at an increased rate to (1) determine the increase in yield due to artificial recharge, (2) quantify the mass of contaminants removed using artificial recharge, and (3) determine if providing artificial recharge to the aquifer increases the mass of contaminants removed.

Stage 4: Introduce artificial recharge at an increased rate (10 gpm) and extract groundwater from the vertical well. Water will be injected at an increased rate from Stage 3 at two upgradient locations to provide additional artificial recharge to the aquifer and increase the hydraulic gradient in the area. Groundwater will be extracted from the vertical well at an increased rate to (1) determine the increase in yield due to increased artificial recharge, (2) quantify the mass of contaminants removed using increased artificial recharge, and (3) determine if increasing the amount of recharge increases the mass of contaminants removed.

Stage 5: Introduce artificial recharge at a pre-determined rate (5 gpm) and extract groundwater from an angled well. Water will be injected at two upgradient locations to provide artificial recharge to the aquifer and increase the hydraulic gradient in the area. Groundwater will be extracted from the angled well at a rate to (1) determine the yield due to artificial recharge, (2) quantify the mass of contaminants removed using artificial recharge, and (3) determine if extraction using an angled well with artificial recharge increases the mass of contaminants removed over using a vertical well.

Stage 6: Introduce artificial recharge at an increased rate (10 gpm) and extract groundwater from an angled well. Water will be injected at an increased rate from Stage 5 at two upgradient locations to provide additional artificial recharge to the aquifer and

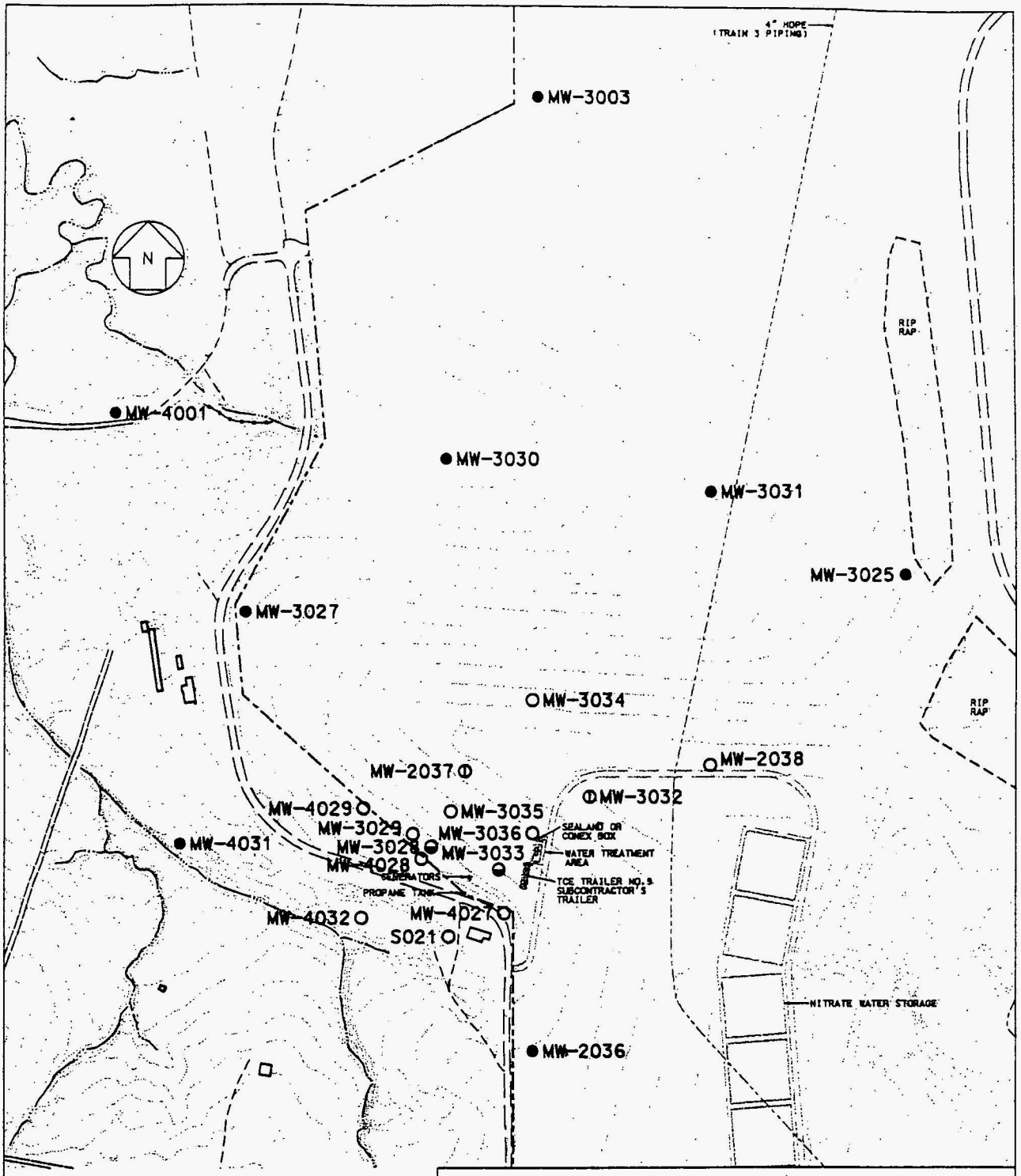
increase the hydraulic gradient in the area. Groundwater will be extracted from the angled well at an increased rate to (1) determine the increase in yield due to increased artificial recharge, (2) quantify the mass of contaminants removed using increased artificial recharge, and (3) determine if extraction using an angled well with increased artificial recharge increases the mass of contaminants removed.

Testing will be performed utilizing existing well MW-3028, which was installed for the pilot pumping test, and angled well MW-3033 to be installed in support of this study (Section 2). Maximum drawdown in the well will be set at a level to maintain approximately 5 ft of water in the screened interval of each pumping well. Efforts will be made throughout each stage to maintain this drawdown (target drawdown). This maximum drawdown level has been selected by the MDNR as a level that should result in an optimal yield from the well and extraction in a thicker sequence of the aquifer. Although most of the available groundwater and groundwater movement occurs in the upper portions of the weathered Burlington-Keokuk Limestone because of higher transmissivity (Ref. 3), this level will be maintained throughout the study.

One of the proposed injection wells will be MW-2037, which is located north of MW-3028. This well is being used because it shows communication with the pumping well. During the pilot pumping test, tracer dye that was injected into MW-2037 prior to the start of the test was observed in MW-3028. There is a concern that during injection, rapid transfer of water may occur in permeable fracture features and could potentially "short-circuit" the system by flushing too rapidly. However, it is suspected that the connection between these two wells is not rapid since visual evidence of dye was not observed until 15 days into the last stage of the initial pilot pumping test (Ref. 3). The other injection well will be MW-3032, which is northeast of MW-3028. This well was originally installed to further delineate TCE impact in this area. This well is screened in the strongly weathered Burlington-Keokuk Limestone.

Injection will be performed at pre-determined rates of 5 gpm and 10 gpm. These rates will be maintained unless the water level in the injection well rises to levels above an elevation of 614-ft MSL, which corresponds with the historic static water levels in the area of both of these wells. Since removal of the raffinate pits, static water levels have lowered 3 to 4 ft in this area. If water levels exceed the elevation of 614 ft in either well, the injection rate for that well will be decreased until this level is achieved. It is important to note that the introduction of water and attempting to create a mounding of water could result in saturation of higher elevation fractures that may lead water away from the pumping well and increase the potential of water to bypass the extraction well and possibly push contaminants outside the capture zone of the extraction well.

Observation wells (2038, 3029, 3034, 3035, 3036, 4027, 4028, 4029, 4032, and S021) located in close proximity to the injection wells and extraction wells will be used to establish that near steady-state conditions exist prior to and during Stages 3 through 6 (Figure 3-1). Water levels in these wells and other wells farther from the pumping and injection wells, will be monitored throughout each stage and during a recovery period after the completion of this study.



LEGEND

- PUMPING WELL
- INJECTION WELL
- OBSERVATION WELL
- MONITORING WELL

0 300 600

SCALE FEET

LOCATION OF PUMPING, INJECTION, OBSERVATION, AND MONITORING WELLS

FIGURE 3-1

REPORT NO.: DOE/OR/21548-885		EXHIBIT NO.: A/CP/017/0201	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 2/19/01	

Pressure transducers and data loggers will be used, where possible, to measure changes in water levels as the tests proceed. Water levels will be measured manually where transducers are not installed. Barometric pressure readings will also be recorded during the testing period because of the relatively high barometric efficiency of the aquifer (approximately 50%). An inverse correlation between barometric pressure change and the relative water level in the aquifer was observed during the pilot pumping test due to the semi-confining effect of the horizontal bedding of the limestone bedrock (Ref. 3).

Near steady-state conditions in the area of the test will be determined using water level measurements in the observation wells. Monitoring of the water levels in observation wells MW-3035 and MW-3036 will be used to show evidence of the injected water moving toward the pumping well. When the discharge rate in the pumping well must be varied to compensate for the artificial recharge, water levels in the observation wells (Figure 3-1) will be monitored for near-steady state conditions. The system will be considered near steady state or stable once the shape of the potentiometric surface as determined from the observation wells, the gradients between the injection wells and pumping well, and the discharge rate in the extraction well show minimal variation for a period of 24 hours. These conditions will be monitored throughout the 20-day period to demonstrate that near steady-state conditions were maintained. If it is determined that unanticipated variations have occurred, the study may be extended to maintain a 20-day near steady-state test period. Variations due to barometric pressure changes and recharge from precipitation will not warrant extension of the study period.

Groundwater samples will be collected for TCE, nitrate, 2,4-DNT, and total uranium analysis before, during, and after the field study. Measurements for pH, Eh, dissolved oxygen, and specific conductance will also be made at each sampling event. Contaminant data will be used to calculate the mass of each contaminant removed during each stage of testing and determine whether any upward or downward trends in contaminant concentrations become apparent as the aquifer responds to pumping and/or injection. Contaminant levels in the wells and springs will also be monitored to identify any major change in contaminant migration as early as possible. If necessary, the study will be modified to minimize negative impacts. Specifics regarding sampling locations, frequency, and collection procedures are in Section 4.

3.1 Stage 1: Sustainable Yield in MW-3028

During the pilot pumping test, a step-drawdown test was performed in an effort to determine a sustainable yield for the test period. After examination of the data from this test, it was determined that a sustainable yield for continuous pumping for an extended period was not determined (Ref. 3).

Testing will be performed to determine the sustainable yield of the shallow aquifer in Zone 1. In an attempt to deplete storage in the more permeable fractured and highly weathered portion of the paleochannel, the aquifer will initially be pumped at an accelerated rate. Groundwater will be extracted from MW-3028 at a rate of approximately 20 gpm until the

drawdown in the pumping well is near the target drawdown as determined by water level measurements. At that point, the discharge rate of the pump will be throttled back to a lower rate (1 gpm). This procedure is based on yields determined from three earlier aquifer tests performed at the chemical plant (Ref. 3). Water levels will be monitored to determine if the drawdown in the well increases or decreases. If levels increase, the discharge from the well will be increased, and static water levels will continue to be monitored. If levels decrease, the discharge from the well will be decreased. When the water level in the pumping well stabilizes for a period of 24 hours, the corresponding rate will be considered the sustainable yield for this localized portion of the aquifer.

3.2 Stage 2: Pumping at the Sustainable Yield in a Vertical Well

After attaining a sustainable yield in the pumping well, the second stage of the test will be started. The discharge rate of the pump in MW-3028 will be set at the sustainable yield and the drawdown in the well will be maintained at the target drawdown elevation. Pumping will be performed until a capture zone has been achieved around the injection wells (MW-2037 and MW-3032) to be used in subsequent stages. It is expected, based on results from the pilot test, that adequate drawdown to develop the capture zone will already have been achieved or will be achieved within the first few days of this stage. Attainment of the capture zone about these wells will be based on the potentiometric surface in the area. From that point, sustained pumping will be performed for 20 days.

3.3 Stage 3: Pumping with Artificial Recharge in a Vertical Well

Upon completion of Stage 2, injection will begin in MW-2037 and MW-3032. Artificial recharge will be introduced at a rate of 5 gpm in each well. The discharge rate of the pump in MW-3028 will be adjusted until the drawdown in the well is maintained at the target drawdown elevation. The 20-day testing period will begin when near steady-state conditions have been maintained for a period of 24 hours.

3.4 Stage 4: Pumping with Increased Artificial Recharge in a Vertical Well

Upon completion of Stage 3, the injection rate will be increased to 10 gpm in MW-2037 and MW-3032. The pumping rate in MW-3028 will be increased to compensate for the increased recharge until the drawdown in the well is maintained at the target drawdown elevation. The 20-day testing period will begin when near steady-state conditions have been maintained for a period of 24 hours.

3.5 Stage 5: Pumping with Artificial Recharge in an Angled Well

Upon completion of Stage 4, injection in MW-2037 and MW-3032 will be decreased to 5 gpm in each well. Pumping will be discontinued in MW-3028 and will begin in MW-3033 (angled well), and the rate will be adjusted until the drawdown in the well is maintained at the

target drawdown elevation. The 20-day testing period will begin when near steady-state conditions have been maintained for a period of 24 hours.

3.6 Stage 6: Pumping with Increased Artificial Recharge in an Angled Well

Upon completion of Stage 5, the injection rate in MW-2037 and MW-3032 will be increased to 10 gpm in each well. The pumping rate in MW-3033 will be adjusted to compensate for the additional recharge until the drawdown in the well is maintained at the target drawdown. The 20-day testing period will begin when near steady-state conditions have been maintained for a period of 24 hours.

3.7 Aquifer Recovery Monitoring

At the end of the study, water levels in the area will be measured to monitor the recovery of the aquifer. Monitoring will be performed for a period of 3 months or until 90% of the drawdown has been recovered, whichever is the shorter period. During the pilot pumping study, the aquifer recovered approximately 90% of the drawdown by the end of 3 months.

4. GROUNDWATER SAMPLING

Three sampling events will be performed in support of this study. Prior to the start of the study, groundwater samples will be collected from the pumping, observation, and monitoring wells to establish baseline concentrations. Selected springs in the 5300 and 6300 drainage will also be sampled during this event. During the study, samples will be collected from the pumping wells. Observation and monitoring wells and springs will also be sampled to monitor the concentrations of nitrate, 2,4-DNT, trichloroethylene (TCE), and uranium during the study period. At the completion of the field study, samples will be collected from the wells and springs to evaluate any long-term changes in contaminant levels due to groundwater removal and potential migration of contaminants due to injection of water.

4.1 Sampling Locations

Contaminant data obtained from the pumping wells will be used to calculate the mass of each contaminant removed during each stage of testing. Data collected from the observation and monitoring wells and springs will be used to determine whether any upward or downward trends in contaminant concentrations become apparent as the aquifer responds to pumping and/or injection or if unacceptable contaminant migration is occurring.

4.1.1 Pumping Wells

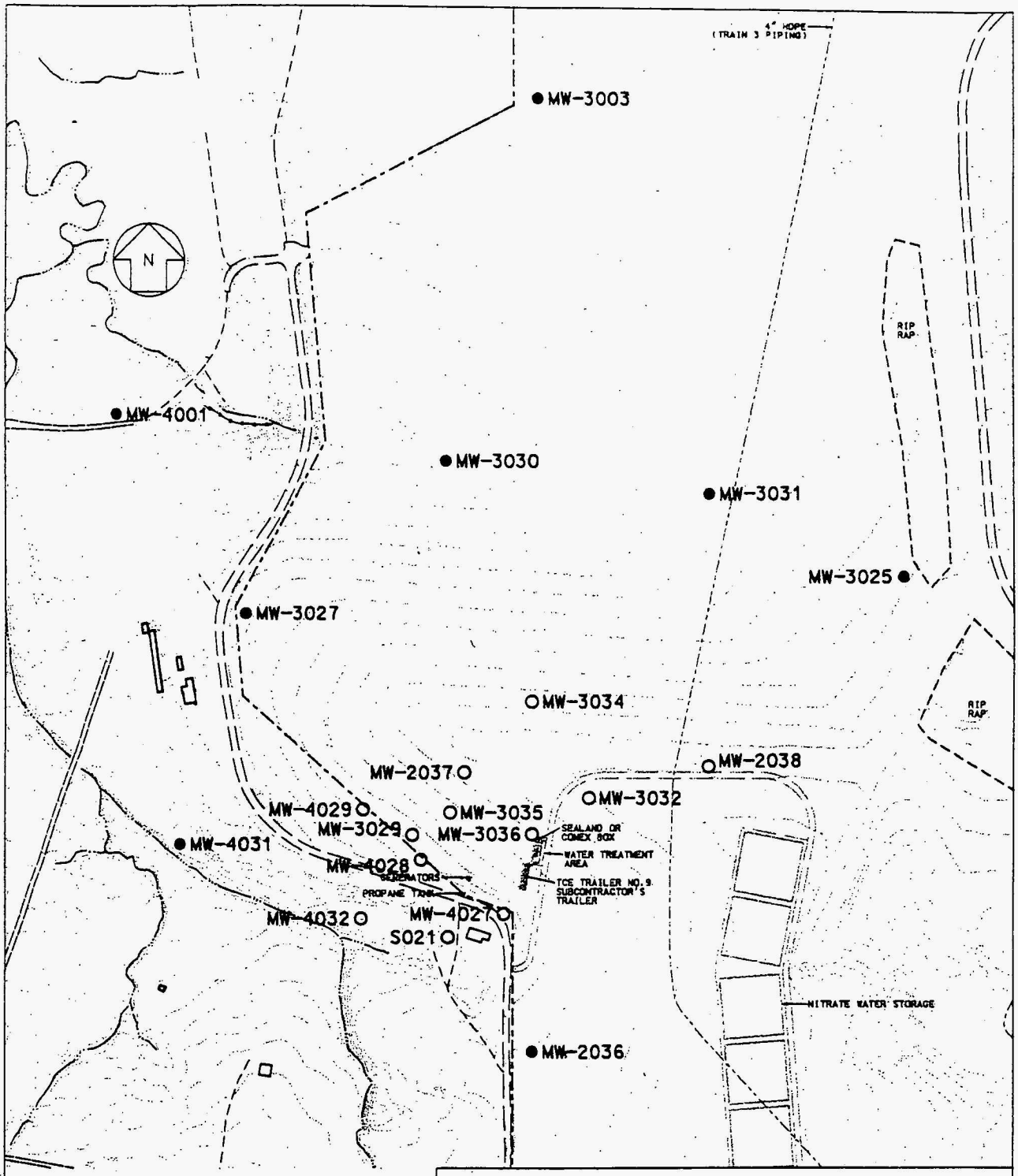
Sampling activities will consist of collecting discharge water from the pumping wells during each stage of testing. Samples will be collected from the operating pumping wells, either MW-3028 or MW-3033, during the appropriate testing stage (Figure 4-1).

4.1.2 Monitoring and Observa tion Wells

Groundwater samples will be collected from the observation and nearby monitoring wells (2036, 2037, 2038, 3003, 3025, 3027, 3029, 3030, 3031, 3032, 3034, 3035, 3036, 4001, 4027, 4028, 4029, 4031, 4032, and S021) screened in the weathered Burlington-Keokuk Limestone (Figure 4-1). Samples will be collected to establish baseline concentrations prior to the study, to assess the influence of the various stages of the pumping test on the groundwater quality in the shallow aquifer during and after completion of the study, and to monitor for possible contaminant migration.

4.1.3 Springs

Water samples will be collected from two springs in the 6300 drainage, 6301 (Burgermeister Spring) and 6303 (Figure 4-2). Samples will also be collected from spring 5304 in the Southeast Drainage. Samples will be collected to establish baseline concentrations prior to the study and to assess possible contaminant migration during and after the study.



LEGEND

O - OBSERVATION WELL

● - MONITORING WELL

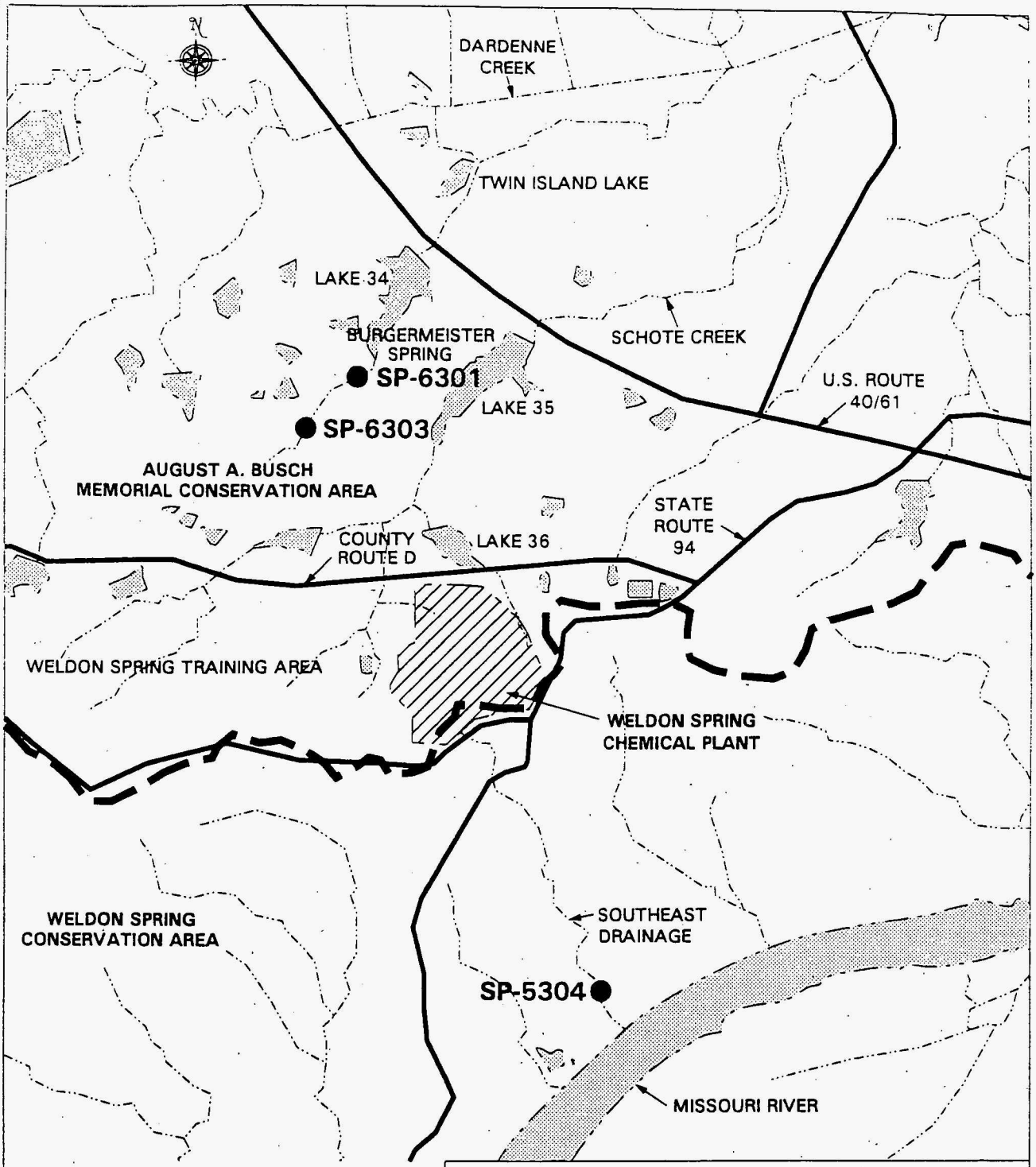
0 300 600

SCALE FEET

SAMPLING LOCATIONS - MONITORING WELLS

FIGURE 4-1

REPORT NO.: DOE/OR/21548-885		EXHIBIT NO.: A/CP/033/0201	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 2/26/01	



LEGEND

- SPRING
- GROUNDWATER DIVIDE
- SURFACE WATER CHANNEL

0 1 MI
0 1.6 KM
SCALE

SAMPLING LOCATIONS - SPRINGS

FIGURE 4-2

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ORIGINATOR:	RC	DRAWN BY:	GLN	DATE:	2/26/01

4.2 Parameters

Samples from wells and springs will be analyzed for nitrate, nitroaromatic compounds (1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, and nitrobenzene), trichloroethylene (TCE), tetrachloroethylene (PCE), 1,2-dichloroethylene (DCE) and total uranium. Field parameters (pH, Eh, dissolved oxygen, and conductivity) will be measured at each of the observation and monitoring wells during each sampling event.

4.3 Sampling Frequency

The wells and springs selected for monitoring during this study will be monitored at the frequency indicated in Table 4-1. Sampling frequency may be modified if analytical data or changes in water levels indicate changing conditions.

Table 4-1 Sampling Frequency for Well and Springs

Locations	Sampling Event		
	Baseline	Field Study	Post Study
Pumping Wells 3028 and 3033	Yes	Daily	Every 2 weeks
Observation Wells 2037, 2038, 3029, 3032, 3034, 3035, 3036, 4027, 4028, 4029, 4032, and S021	Yes	Weekly	Every 2 weeks
Monitoring Wells 2036, 3003, 3025, 3027, 3030, 3031, 4001, and 4031	Yes	Every 2 weeks	Monthly
Springs 5304, 6301, and 6303	Yes	Every 2 weeks	Monthly

4.4 Sample Identification

All containers will be labeled in accordance with procedure ES&H 4.1.1, *Numbering System for Environmental Samples and Sampling Locations*. Sample forms from ES&H 4.4.1 will be completed for each sample, with at least the following information:

- Sample ID number
- Location
- Date
- Time of collection

- Sample collection method
- Preservation
- Name(s) of sampler(s)

4.5 Sample Collection

Samples from the pumping wells will be collected in accordance with the technical operations procedure and safe work plans for operation of the pumping/injection system and treatment system. Sample labeling will be completed in the field. Quality control samples will be collected as specified in Section 5.

Samples from wells and springs will be collected in accordance with the appropriate procedure:

- Monitoring Wells Procedure ES&H 4.4.1, *Groundwater Sampling*
- Springs Procedure ES&H 4.3.1, *Surface Water Sampling*

4.6 Sample Containers and Preservation Methods

The appropriate containers and preservation methods for each sample are summarized in Table 4-2.

Table 4-2 Sample Containers and Preservation

Parameter	Container	Preservation
Uranium, total	250 ml, plastic	Nitric Acid (pH<2)
Nitrate as N	250 ml, plastic	Sulfuric Acid (pH<2)
Nitroaromatic Compounds	1 liter, amber glass(1)	Cool (4°C)
TCE/PCE/1,2-DCE	2-40 ml, glass vial (no headspace)(2)	Cool (4° C) and 2 drops HCl

(1) 3 liters when QC required
(2) 6-40 ml vials when QC required

4.7 Static Water Level Measurements

Static water level measurements will be made in each of the observation and monitoring wells and recorded prior to each sampling event. Measurements will be performed in accordance with procedure ES&H 4.4.2, *Groundwater Level Monitoring and Well Integrity Inspection.*

Static water level measurements will be made in the observation and monitoring wells by using pressure transducers. The transducers will be calibrated and operated in accordance with

the manufacturer's recommendations. The transducers will be programmed to collect measurements every 15 minutes in the observation wells and every 2 hours in the monitoring wells.

4.8 Volume Measurements

A volume totalizer will be located at the pumping well and injection wells to monitor the quantity of water extracted or injected throughout the test. The totalizer measurement at each well will be recorded at each sampling event. Additional measurements will be made in accordance with the technical operating procedures for the system.

5. QUALITY CONTROL

The Project Management Contractor (PMC) at the Weldon Spring Site Remedial Action Project (WSSRAP), has developed the *Environmental Quality Assurance Project Plan* (EQAPjP) (Ref. 5) to guide all environmental activities conducted at the WSSRAP in accordance with the U.S. Environmental Protection Agency guidelines. The *Sample Management Guide* (Ref. 6) has been developed following the guidelines listed in the EQAPjP. This guide establishes the approach to sample planning, collection, and data analysis.

5.1 Chain-of-Custody

Chain-of-Custody forms will be completed and placed in the sample coolers in accordance with procedure *ES&H 4.1.2, Initiation, Generation, and Transfer of Environmental Chain-of-Custody.*

5.2 Analytical Procedures

The on-site laboratory conducting the radiological analysis for this sampling effort uses approved methodologies in accordance with site standard operating procedures (SOPs).

The off-site quantitative laboratories conducting radiological and chemical analysis have submitted controlled copies of their site-specific quality assurance project plans (QAPjP) and SOPs. The plans and SOPs have been reviewed and accepted by the PMC. The WSSRAP and contract laboratory SOPs comply with the accepted standards and methodologies for performing analytical processes, operations, and activities. The laboratory QAPjPs and SOPs specify quality control requirements to demonstrate the precision, representativeness, and accuracy of the analytical data.

5.3 Quality Control Samples

Quality control samples will be collected to ensure consistent and accurate performance of sample collection and laboratory analysis. Table 5-1 provides a summary list of the quality control samples that will be collected to support this effort.

Table 5-1 Field Quality Control Sample Summary

QC SAMPLE TYPE	FREQUENCY	PURPOSE
Field Replicate (on-site and off-site)	1 per 20 samples	Assess matrix, intralaboratory, and field operations variability
Matrix Spike/Matrix Spike Duplicate or Matrix Duplicate (off-site only)	1 per 20 samples	Assess matrix and possible intralaboratroy variability
Trip Blanks (VOA analysis only)	1 per shipment	Assess possible introduction of VOAs during handling, transportation, and receipt at the laboratory.

5.4 Data Evaluation

Data packages received from the off-site contract laboratories undergo several processes to evaluate the quality of the data. When data are first received, copies will be distributed to the Verification/Validation Group and data users for review as described in the following sections.

5.4.1 Data Verification

Analytical results received from the laboratory will be reviewed in accordance with procedure *ES&H 4.9.1, Environmental Monitoring Data Verification*. The following factors will be evaluated to verify if a sample has been properly handled according to WSSRAP protocol:

- Chain-of-custody
- Holding times
- Sample preservation requirements
- Sample analysis request form
- Quality control samples
- Laboratory receipt forms

5.4.2 Data Review

The data package will be distributed to the data users for review. The data will be reviewed to identify discrepancies in the field quality control samples, inconsistencies with characterization data, and apparent abnormalities. Deficiencies identified by data users will be reported to the Verification Group. Data users may request validation of any data that appear to be of questionable quality. These reviews will be done in accordance with procedure *ES&H 1.1.7, Data Review and Above-Normal Data Reporting*.

5.4.3 Data Validation

Randomly selected laboratory data and data selection by verification personnel or data users will undergo thorough review of the analytical process in accordance with procedure *ES&H 4.9.2, Environmental Monitoring Data Validation*. The Validation Group will conduct these reviews.

The validation procedure will provide a consistent means for reviewing and evaluating the data resulting from laboratory analyses and will provide a consistent means of documenting the evaluation and reporting the usefulness of the data to data users. This will be accomplished by a thorough review of the analytical data using laboratory records to assess laboratory conformance to quality control criteria, data quality requirements for data quality objectives, and procedural requirements.

6. DATA REPORTING, ANALYSIS, AND EVALUATION

At the completion of the field study, the data from this study will be summarized in the *Completion Report for the Additional Groundwater Field Studies in Support of the Groundwater Operable Unit.* This report will detail the testing and sampling activities, pump test data analyses, analytical results, and quality control issues for this field study. Deviations and modifications to this plan will also be discussed. Modifications may include, but are not limited to, changes in sampling frequencies, sampling methods, or analyses.

For each stage, the mass of each contaminant of concern removed will be determined. Comparisons of the mass of contaminants removed during each scenario (Stages 2 through 6) will be made to determine if the modifications resulted in an improvement in the mass removed.

Trends in contaminant levels in the study area will be evaluated during and after completion of the study. These trends will be studied in an effort to decide whether the bulk of groundwater contamination is in the primary or secondary porosity of the limestone aquifer or the effects of description of contaminants from the aquifer in aquifer remediation.

7. REFERENCES

1. MK-Ferguson Company and Jacobs Engineering Group. *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri.* No Rev. DOE/OR/21548-569. Prepared for the U.S. Department of Energy, Weldon Spring Remedial Action Project and U.S. Department of the Army, Corps of Engineers. March 1998.

2. Argonne National Laboratory. *Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri.* No. Rev. DOE/OR/21548-783. Prepared by the Environmental Assessment Division for the U.S. Department of Energy. June 1999.

3. MK-Ferguson Company and Jacobs Engineering Group. *Completion Report for the Pilot Pumping Test for the Groundwater Operable Unit at the Weldon Spring Site.* Rev. 0. DOE/OR/21548-757. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. October 1998.

4. Letter from Jim Williams (MDNR-DGLS) to Dennis Grams (EPA, Region VII) – March 10, 2000.

5. MK-Ferguson Company and Jacobs Engineering Group. *Environmental Quality Assurance Project Plan.* Rev. 5. DOE/OR/21548-352. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. November 2000.

6. MK-Ferguson Company and Jacobs Engineering Group. *Sample Management Guide.* Rev. 2. DOE/OR/21548-499. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. June 2000.

PROCEDURES

ES&H 1.1.7	Data Review and Above-Normal Data Reporting
ES&H 4.1.1	Number System for Environmental Samples and Sampling Locations
ES&H 4.1.2	Initiation, Generation, and Transfer of Environmental Chain of Custody
ES&H 4.3.1	Surface Water Sampling
ES&H 4.4.1	Groundwater Sampling
ES&H 4.4.2	Groundwater Level Monitoring and Well Integrity Inspection
ES&H 4.4.4	Subsurface Monitoring Device Plugging and Abandonment
ES&H 4.4.7	Soil, Rock Core, and Rock Chip Borehole Logging
ES&H 4.9.1	Environmental Monitoring Data Verification
ES&H 9.1.3	Monitoring Well Installation and Development
ECDI-18	Handling and Disposition of Site Generated Wastes