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# Project Summary

# Groundwater Monitoring Recommendations for Oil Shale Development

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**EPA has completed a five-year project to develop groundwater quality monitoring recommendations for western oil shale development. Five major reports have been published. The compendium reports consider the various production processes (mining, retorting, and oil upgrading) and key environmental factors (organic and inorganic characterization, environmental control, and limitations) related to oil shale development. Each of the potential sources of pollution and specific pollutants associated with each source have been identified.**

**Based upon the EPA monitoring methodology, a preliminary groundwater monitoring program for Utah oil shale tracts U-a and U-b, and a monitoring strategy for modified** *in situ* oil shale retorting was developed. Using federal lease tracts C-a and C-b in Colorado, an exhaustive review of strategies and monitoring recommendations for modified *in situ* (MIS) oil shale retorting has been conducted, and groundwater monitoring recommendations have been developed for geophysical logs and hydraulic testing methods. Sampling protocols covering well design, sampling costs, sample collection procedures, and sample preservation and handling have been developed.

***This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in five separate reports (see Project Report ordering information at back).***

## Introduction

EPA is completing a five-year project to develop groundwater quality monitoring recommendations for Western U.S. Oil Shale Development (Figure 1). Four reports have been published previously by EPA. Another report, which is emphasized in this summary, has been published at this time. All five reports are described in this project summary so that the reader can be aware of the relationship of the reports to each other.

## Previously Published Reports

### *Compendium Reports on Oil Shale Technology (EPA-600/7-79-039)*

Currently, petroleum companies are becoming more optimistic about the commercial prospects of the 95.4 billion m$^3$ (600 billion bbl) of syncrude locked in the Green River Formation of the tristate area of Colorado, Utah, and Wyoming. This optimism is based on technological and economic factors that may give shale oil a good chance to compete with conventional crude oil. The compendium reports consider the various production processes (mining, retorting, and oil upgrading) and key environmental factors (organic and inorganic characterization, environmental control, and limitations) related to oil shale development. This state-of-the-art survey supports a study designing groundwater quality monitoring programs for oil shale operations such as that proposed for Federal Oil

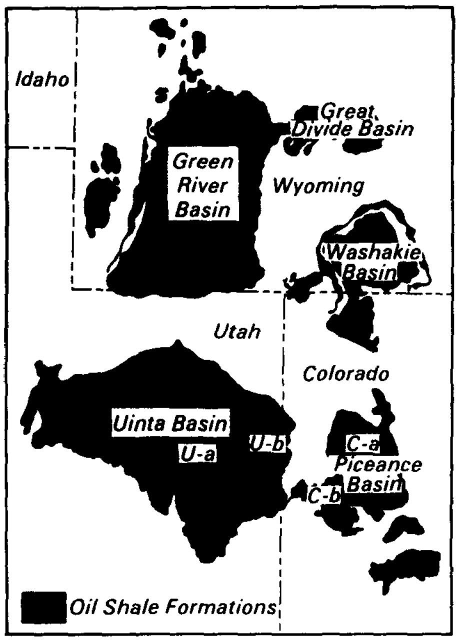


*Figure 1.* *Locations of Federal oil shale tracts U-a, U-b and C-a, C-b.*

Shale Lease Tracts U-a and U-b and C-a, C-b. Hence, the reports emphasize technologies applicable to this development while also providing a general overview of oil shale technology.

## *Groundwater Quality Monitoring of Western Oil Shale Development: Identification and Priority Ranking of Potential Pollution Sources (EPA-600/7-79-023)*

This document reports the field survey and literature research performed during the first phase of the design process. The goal of this phase is to identify and rank the major sources of groundwater quality degradation. The site for which the monitoring system is being designed is the Federal prototype lease tracts U-a and U-b in eastern Utah. The oil shale operation proposed for this site includes room-and-pillar mining, surface retorting by the Paraho and TOSCO II process, and surface disposal of spent oil shale.

The priority ranking is based on a sequence of data compilation and evaluation steps. These steps include identification of potential pollution sources, methods of waste disposal, and potential pollutants associated with the various waste sources, and an assessment of the potential for infiltration and subsequent mobility of these pollutants in the subsurface. The three basic criteria used to develop the source-pollutant ranking are:

- Mass of waste, persistence, toxicity, and concentration
- Potential mobility
- Known or anticipated harm to water use

From the rankings developed for each of these three criteria, a preliminary priority ranking of potential pollution sources and causes and potential pollutants was developed. The *highest* priority potential pollutant sources were associated with the spent shale disposal area: spent shale; high TDS wastewater, sour water, and retort water used to moisten the spent shale; and spent catalysts deposited in the disposal area. Associated with these sources are numerous chemical constituents of which total dissolved salts, selected microinorganics (sodium, sulfate, and chloride), selected trace elements (arsenic, fluoride, selenium, and molybdenum), and organics (polycyclic aromatic hydrocarbons and carboxylic acids) are considered the most significant potential pollutants. In the process area, the proposed effluent holding pond that drains the process area watershed, raw shale storage, and the tankage area were ranked. Dissolved salts, organics, selenium, arsenic, and tankage contents (fuel, oil additives, and ammonia) were evaluated.

## *Groundwater Quality Monitoring of Western Oil Shale Development: Monitoring Program Development (EPA-600/7-80-089)*

This report presents the development of a preliminary design of a groundwater quality monitoring program for oil shale operations, such as proposed for Federal Prototype Lease Tracts U-a and U-b in eastern Utah. The methodology used begins with a priority ranking of potential pollutant sources and includes assessments of existing or proposed monitoring programs, identification of alternative monitoring approaches, and the selection of recommended monitoring programs (Figure 2).

A preliminary decision framework for monitoring design for this type of oil shale operation is presented. Included under the broad topic of the monitoring plan are recommendations for developing background data bases on pollutant source characteristics, the hydrogeologic framework of the study area, existing water quality, and infiltration, as well as recommendations for monitoring pollutant mobility. Hence, needs for baseline characterization are identified and evaluated in addition to direct operational monitoring needs. A field and laboratory testing program based on these preliminary design recommendations will lead to development of a final monitoring design strategy.

## *Monitoring Groundwater Quality: The Impact of* In Situ *Oil Shale Retorting (EPA-600/7-80-132)*

This report presents the initial phase of a research program that will develop a planning methodology for the design and implementation of cost-effective groundwater quality monitoring programs for modified *in situ* (MIS) oil shale retorting. This initial phase includes (1) a review of MIS development with regard to potential impacts and a review of current MIS monitoring programs, and (2) identification of key issues, uncertainties, and unknowns with regard to design and implementation of monitoring programs.

### General Monitoring Strategy

The basic goals are to (1) detect and measure groundwater flow within the abandoned retort interval, and (2) detect changes in groundwater quality from waste residuals (e.g., spent shale, retort water) within the abandoned retort zone.

General monitoring strategy recommendations are as follows:

1. *Source-specific orientation.* Groundwater quality monitoring networks should be designed specifically for detecting groundwater inflow to the abandoned retort zone and related effects on groundwater quality. For the most part, existing hydrogeologic characterization and baseline monitoring programs have a regional-scale focus.

2. *Routine monitoring of selected "indicator" constituents.* This is considered more cost-effective than the extensive water quality analysis programs currently implemented. Extensive inorganic and organic analyses are indicated as a response to impacts detected by such routine monitoring but are not needed as part of the routine monitoring program.

3. *Relatively small spatial scale.* Monitoring well networks should be withir

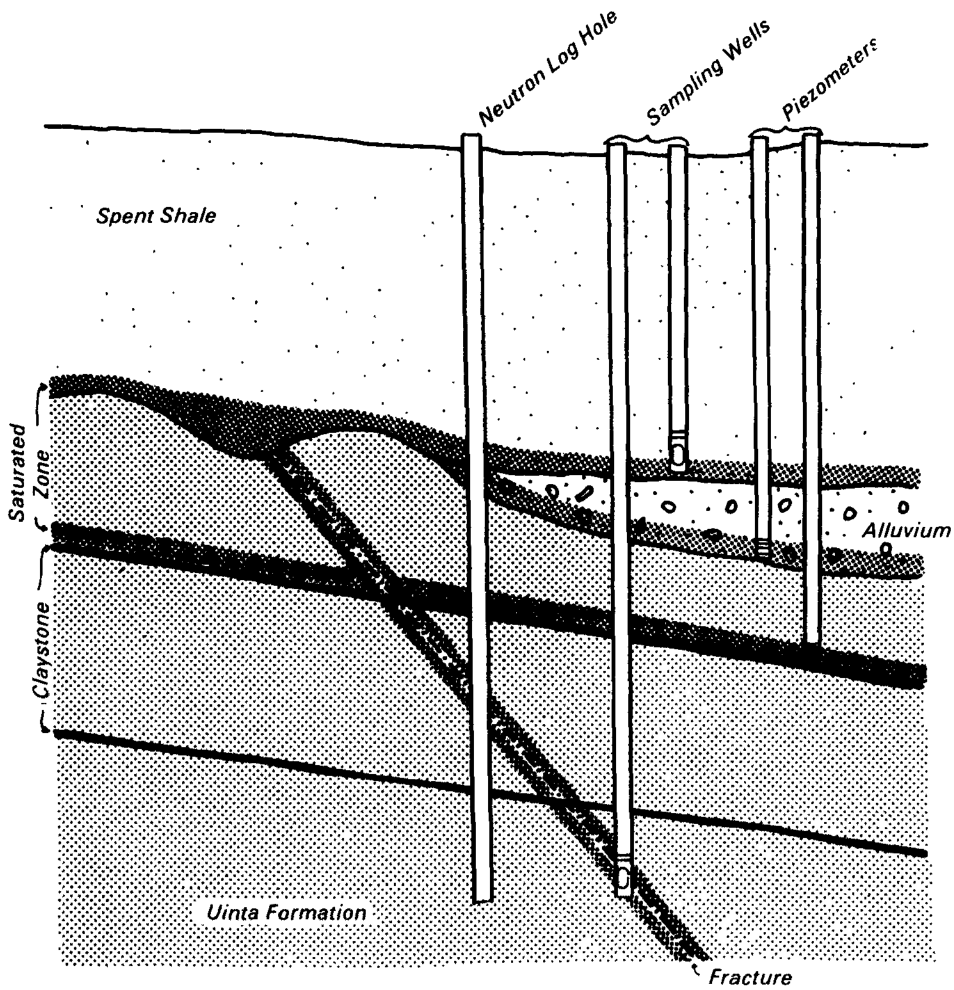


*Figure 2. Proposed monitoring in the spent-shale pile, Uintà Formation*

and directly adjacent to abandoned retort fields.

4. *Interactive design process.* The monitoring design process is initiated with site exploration and resource evaluation activities. Hydrogeologic data will continue to be collected during the mine and retort construction phases. These data, in addition to MIS design changes, may require revision of groundwater quality monitoring designs. Wells used for baseline studies provide for initial hydrogeologic characterization but may not be adequate for operational monitoring needs. This is particularly true where baseline programs have a regional-scale orientation. An iterative (planning-implementation-reevaluation) procedure to address monitoring needs is recommended.

## Recently Published Report

### *Groundwater Quality Monitoring Recommendations for* In Situ *Oil Shale Development (EPA-600/4-83-045)*

This report includes the design to characterize the hydrogeology of an oil shale tract, a proper suite of geophysical logs, proper aquifer testing methods, and recommendations to aid developers of commercial oil shale tracts.

### Geophysical Methods

The following logs were evaluated to determine their overall effectiveness in providing pertinent and reliable hydraulic data:

| | |
|---|---|
| Temperature Log | Velocity log |
| Caliper log | Sonic (acoustic) log |
| Gamma log | Density log |
| Spinner log | Electric log |
| Radioactive tracer log | Seisviewer log |

The following log suite is recommended: temperature, caliper, sonic, and electric logs. Of more limited value and receiving secondary or lower priority ranking are gamma, velocity, density, and spinner logs. The radioactive tracer and seisviewer logs are not recommended for obtaining hydraulic data for oil shale development.

### Hydraulic Methods

Four general methods of hydraulic testing procedures have been evaluated and are classed as follows:

Drill stem tests
Dual-packer tests
Long-term pump tests
Single-packer tests.

Review of the testing procedures, equipment costs, and utility of the resulting data has produced the following priority ranking:

1. *Dual Packer Tests* provide specific hydrologic data at a minimal cost when multiple tests are conducted in a single bore-hole. Downhole test equipment assembly allows for pumping, injection tests, and discrete water quality sampling.

2. *Long-Term Pump Tests* produce the most representative data on boundary conditions and flow patterns.

### Sampling Methods

The objective of a groundwater monitoring strategy in the oil shale region is to (1) provide baseline groundwater quality data, (2) detect and measure groundwater flow within the abandoned retort interval, and (3) detect changes induced by waste residuals (e.g., spent shale, retort water) within the abandoned retort zone. Compilation of the baseline data and accurate evaluation of the latter two aspects requires the collection of representative groundwater quality samples. However, a number of factors can influence the representative nature of the groundwater samples collected. These factors include well design, sample collection methods, and sample handling procedures.

A network of multiple completion wells is the recommended approach for a groundwater monitoring program near the retort fields. Multiple completion well design will enable the collection of representative data from each of the intervals potentially affected by the oil shale retorting operation. The suggested specifications for each multiple completion well are:

- Steel casing and polyvinylchloride (PVC) well construction material. Although the structural properties of PVC may preclude its use as a casing material, the inert characters of PVC make it ideal as a well construction material. PVC is also inexpensive compared with other materials.
- The diameter of the PVC should be large enough to accommodate a submersible pump. The recommended diameter and wall thickness of the PVC is about 15 centimeters (6 inches) and schedule 40 (5.5 millimeters of 14/64 inch), respectively.
- Each well of the multiple completion should be completed in a different interval; cement grout should be used to prevent the interconnection of the different intervals.
- Wells should be developed thoroughly to remove any traces of drilling fluid or other materials that may affect water quality samples.

## *Sample Collection Procedures:*

Sampling of the deep aquifer wells on Tracts C-a and C-b is accomplished by bailing and swabbing, respectively. Although these techniques obtain the desired results of collecting a sample, there is some question as to the representative nature of the sample collected.

The recommended procedure for bailing groundwater samples is as follows:

1. Use a flow-through type bailer (e.g., Kemmerer sampler). Bailers that are open at the top and sealed at the bottom do not have this flow-through characteristic and will generally be filled with the first water encountered in the well (i.e., water near the static water level).
2. Compile well completion data. Of particular importance are the well diameters, casing perforations or screened interval, depth to aquifer, aquifer thickness, and total depth.
3. For shallow wells with very slow groundwater movement, estimate the well volume from the well completion data and extract at least one well volume prior to sample collection. For both shallow and deep wells with rapid groundwater movement, select a sampling point adjacent to the aquifer.
4. Consistently sample from the same depth and adjacent to the aquifer during every sampling effort.
5. Measure temperature, specific conductance, and pH in the field.

If these guidelines are followed, bailing is a very effective method for collecting groundwater quality samples.

The following problems are associated with swabbing:

- There is high potential for introducing organics into the sample from the oil field equipment. Care must be taken to clean the swabbing equipment thoroughly.
- The amount of water swabbed from a well is difficult to determine and can result in obtaining inconsistent and non-representative samples. If possible, the discharge should be carefully measured to provide the necessary data for collecting consistent and representative samples.
- Swabbing may accelerate the plugging of perforations in the well.
- Swabbing is extremely expensive and time consuming.

The following procedure is recommended for collecting a representative sample from a well when using a submersible pump:

1. Compile well construction data, including well diameter, total depth, and perforated interval, or aquifer interval in an open well.
2. Measure static water level and estimate well volume.
3. The pump intake should be placed approximately 1.5 meters (5 feet) above the open, perforated, or screened aquifer interval.
4. The discharge rate should be maintained at a moderately low rate to prevent excessive drawdowns in the aquifer and well and to minimize turbulent mixing in the annulus.
5. At least one well volume should be extracted from the well.
6. The parameters most easily monitored in the field are specific conductance, pH, and temperature. These parameters should be measured continuously throughout the pumping period. Continuously monitoring these parameters is particularly important for little-used groundwater quality monitoring wells.
7. A sample should be collected only after the field parameters have stabilized for a period of time. It is suggested that all of the parameters (i.e., pH, temperature, and specific conductance) be utilized to determine representative aquifer water and prevent premature sample collection due to the failure of field apparatus.
8. The sample should be collected as close to the well head as possible to avoid potential contamination, precipitation of solutes, and the loss of dissolved gases.

## *Sample Preservation and Handling:*

Delayed receipt of the samples at the analytical laboratory and incorrect preservation techniques can adversely affect the sample chemistry greatly. To reduce potential sample modification, the following sample preservation and handling procedures are recommended:

- Sample volumes, preservatives, and containers should be selected according to the EPA-recommended procedures presented in *Methods for Chemical Analyses of Waters and Wastes* (U.S. Environmental Protection Agency Report EPA-600/4-79-020, 1979).
- The samples should be filtered in the field through a 0.45-micron filter before preservation.
- Data on past water quality trends should be consulted to detect any anomalies during the sampling effort
- Specific conductance, pH, and temperature should be measured in the field at the time of sample withdrawal This also applies to reduction-oxidation potential and dissolved oxygen determinations, if desired.
- Accurate field notes should be maintained for future data evaluation. These notes should include: specific time and dates the activities were performed, water levels, source of sample weather conditions, well completion data, sample collection method, fiel

observations, reason for sampling, field measurements, problems encountered, and the sample collector's identity.

- The samples should be shipped each day from the field to the analytical laboratory via commercial plane or bus. Both methods are reliable and inexpensive, and provide reasonable assurance against prolonged sample storage. If the samples cannot be shipped and received at the laboratory within 24 hours, on-site analytical facilities should be provided.
- The chain of custody for the sample should be as limited as possible to prevent excessive sample handling, which can result in shipment and analysis delays. Individuals should be designated both in the field and at the laboratory to maintain adequate quality control with respect to sample handling and analysis.

If these procedures are followed, sample handling and preservation techniques should not affect the analytical results.

*This Project Summary was prepared by L. G. Everett, who is with Kaman Tempo, Santa Barbara, CA 94060.*
***L. G. McMillion** is the EPA Project Officer (see below).*
*This Project Summary covers five different reports entitled:*
*"Compendium Reports on Oil Shale Technology," (Order No. PB 293279/AS; Cost: $19.00)*
*"Groundwater Quality Moniitoring of Western Oil Shale Development: Identification and Priority Ranking of Potential Pollution Sources," (Order No. PB 300536; Cost: $20.50)*
*"Groundwater Quality Monitoring of Western Oil Shale Development: Monitoring Program Development," (Order No. PB 203219; Cost: $17.50)*
*"Monitoring Groundwater Quality: The Impact of* In Site *Shale Retorting," (Order No. PB 177453; Cost: $25.00)*
*"Groundwater Monitoring Recommendations for* In Situ *Oil Shale Development," (Order No. PB 84-120 351; Cost: $17.50)*
*The above reports will be available only from: (costs subject to change)*
*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*
*The EPA Project Officer can be contacted at:*
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