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Economic Analysis: Proposed Revisions to the Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings Rule (40 CFR Part 192)

Draft Report

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EXECUTIVE SUMMARY

Section 206 of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) requires the U.S. Environmental Protection Agency (EPA) to develop health and environmental standards for both Title 1 sites (inactive uranium mills) administered by the U.S. Department of Energy and Title II sites (present and future operations) licensed by the U.S. Nuclear Regulatory Commission (NRC) or its Agreement States. EPA is proposing revisions to its regulations at 40 CFR Part 192 for in situ recovery/in situ leaching (ISR) facilities that produce uranium by injecting and extracting a solution that dissolves the uranium from the porous minerals in which it is found. ISR uranium production represents an increasing share of uranium production and poses special groundwater protection challenges compared with conventional uranium production abroad and particularly in the United States, because it solubilizes and mobilizes uranium and other constituents and changes the geochemistry within the aquifer containing the uranium deposit. If geochemistry and groundwater conditions are not restored after ISR operations cease and the restoration is not stable over time, the groundwater in aquifers surrounding the wellfield may become contaminated with uranium and other constituents. Currently, facilities monitor groundwater for only a year or two after the restoration effort is complete before decommissioning the site. This duration of monitoring may not be long enough to detect instability or trends in constituent concentrations over time, which poses a risk of contaminating groundwater resources and potentially exposing human or ecological receptors to hazardous constituents. Accordingly, EPA is proposing to add a new subpart to 40 CFR Part 192, establishing additional monitoring requirements during all phases at an ISR facility:

- Pre-operational monitoring: measuring background groundwater concentrations and establishing initial regulatory approved restoration goals
- Operational monitoring: monitoring to detect any excursions of contaminated groundwater to adjacent aquifers, either beside, above, or below the exempted aquifer
- Restoration monitoring: monitoring to document the progress of restoration through groundwater sampling
- Post-restoration stability monitoring, which has two parts:
  - Stability monitoring: monitoring, conducted after restoration efforts have ended to establish that wellfield groundwater characteristics are stable and meet restoration goals (at least 3 years)
  - Long-term stability monitoring: monitoring and statistical analyses to show that the concentration of each monitored constituent is not increasing with time and that the concentration is not statistically different from the restoration goals

EPA's proposed rule requires careful pre-operational monitoring to ensure that restoration goals are set appropriately, taking into account seasonal and other variability in analyte concentrations. The proposed rule also identifies the minimum 13 constituents that should be monitored and causes the standards to update automatically if standards under the Safe Drinking Water Act or the Resource Conservation and Recovery Act are updated.[1] Probably the most significant requirements in the proposed rule pertain to post-restoration stability monitoring. As noted above, currently ISR facilities monitor groundwater for periods of 6 months to 2 years before beginning the decommissioning process. EPA's proposed rule requires stability monitoring sufficient to demonstrate statistically with 95% confidence that wellfield conditions are stable and then continued long-term stability monitoring for 30 years, with provisions for shortening the monitoring duration based on geochemical modeling. EPA is proposing a provision that would allow the regulatory agency to shorten the monitoring period if the operator can both demonstrate geochemical stability through monitoring and support a conclusion of long-term stability through geochemical modeling. Geochemical modeling has the potential to provide confidence that a geochemical mechanism exists to prevent uranium and other constituents from remobilizing and migrating to aquifer locations that may be used for drinking water and, thus, provides additional assurance beyond that provided by longer monitoring periods and statistical modeling. Throughout this document, EPA uses the term "proposed rule" to refer to this set of monitoring requirements, along with other requirements such as corrective action in the event that an excursion is detected and more comprehensive monitoring at the preoperational phase. EPA also considered two other regulatory options for long-term stability monitoring:

- 30 years of long-term stability monitoring with no potential to change the duration
- a narrative standard with no fixed monitoring period

EPA chose to propose the standard that includes geochemical modeling because it has the potential to demonstrate that groundwater conditions will remain stable; the other two alternatives do not. Because the uranium deposits for which ISR methods are appropriate were created initially due to chemically reducing geological conditions, EPA considers it likely that many ISR facilities will be able to demonstrate, through geochemical modeling and monitoring, the existence of geochemical conditions that would promote long-term stability. However, EPA recognizes that in some cases, sampling and geochemical modeling will reveal that geological

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[1] Once an ISR facility is licensed and permitted, standards existing at the time of licensing are applied to the facility, but new license applications would be subject to the updated standards.

conditions would not guarantee long-term stability. In those cases, the regulatory agency may refuse to grant a license to conduct ISR operations; alternatively, the regulatory agency would likely require additional restoration and/or a 30-year monitoring period to demonstrate that conditions are stable. EPA estimated the costs that would be incurred should the owner/operator be required to monitor for 30 years in addition to conducting geochemical analyses.[2]

EPA examined the costs that could be incurred by ISR facilities to comply with two regulatory options, the proposed rule and the option characterized by 30 years of long-term stability monitoring with no potential to shorten the duration, under a variety of costing scenarios (see Appendix D for details on the range of costs). In addition, EPA estimated costs for a "worst case" scenario, under which post-operational geochemical modeling does not provide assurance that conditions would remain stable over time; in this case, EPA assumes that the facility would be required to continue long-term stability monitoring for 30 years to ensure that conditions remain stable. For reasons explained in Section 3, however, EPA believes this situation would be unlikely to arise; thus, the impacts of this third scenario are presented only in Appendix D. EPA did not estimate costs for the narrative standard with no fixed monitoring period because the specific compliance requirements and costs would be defined on a case-by-case basis and are, thus, too uncertain to model.

To estimate the incremental costs of compliance under each option considered, EPA used a model facility approach and developed a conceptual mine unit (CMU) derived from a section of one wellfield at an existing ISR facility. EPA then estimated the monitoring that such a mine unit would undertake under current practice and under each of the regulatory alternatives. The incremental costs for the CMU (computed as the costs under a regulatory alternative minus the costs under current practice) were then scaled up to costs that would be incurred by actual ISR facilities based on relative total acreage of wellfields at actual facilities to the acreage of the CMU. Total annualized costs for each regulatory option and cost scenario considered, annualized at 7%, are shown in Table ES-1. EPA presents low, average, and high monitoring cost estimates for each regulatory alternative. EPA computed estimated facility costs as if all wellfield acreage at ISR facilities in the country were simultaneously affected. EPA recognizes the fact that at

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[2] In tables such as ES-1 and throughout this report, the regulatory alternatives are described in terms of the required long-term stability monitoring; in fact, EPA expects that compliance requirements of the preoperational, operational, restoration, and stability monitoring may differ among the alternatives as well. The long-term stability monitoring requirements are used as a shorthand description of the regulatory alternative. The assumed requirements of each alternative are described in detail, along with the baseline regulatory requirements typically in practice at ISR facilities in the absence of the rule, and are presented in Tables 3-1 through 3-4, and the estimated costs under each alternative for the CMU are shown in Table 3-5.

many ISR facilities, there are wellfields in all stages of ISR operations from planning to decommissioned, so monitoring activities would not typically be required at every wellfield simultaneously. Thus, EPA's costs are believed to overestimate costs that would be incurred by actual facilities. Further, EPA's analysis defines these costs as incremental to the costs of current practice at ISR facilities; because many of the compliance requirements may already be embodied in license requirements, this may overestimate the incremental costs of the rule. However, EPA has chosen to analyze the costs and economic impacts under these conservatively high costing assumptions. As shown in Table ES-1, EPA estimates that nationally the cost of the proposed regulatory alternative ranges from \$11.6 million to \$17.9 million per year, depending on the cost scenario.

Table ES-1. Estimated Range of National Compliance Costs by Regulatory Alternative and Costing Scenario (Million 2011\$)

Regulatory Alternative	Low	Average	High
30 years with geochemical modeling to shorten	11.631	13.465	15.226
30 years with no shortening	12.865	15.072	17.901

EPA then examined the potential impact of the proposed rule on the market for uranium. Uranium is relatively homogeneous, so buyers do not care which mine or ISR facility produced it; the market for uranium is an international market, with suppliers and demanders in many countries. The United States has historically been the largest user of uranium for electricity production but has generally produced only a small share of the uranium it consumes, and foreign suppliers have provided the remaining 80% to 90%. Going forward, the U.S. Energy Information Administration (EIA) projects that the worldwide demand for uranium will grow substantially over the next 20 years, due largely to increased demand from China and India; prices are also projected to increase to approximately \$64 per pound U_3O_8 by 2018. Owners and operators of U.S. civilian nuclear power reactors ("civilian owner/operators" or "COOs") purchased a total of 57.4 million pounds of uranium during 2013 at a weighted-average price of \$51.99 per pound U_3O_8. Seventeen percent of the U_3O_8 delivered in 2013 was U.S.-origin uranium at a weighted-average price of \$56.3 per pound (EIA, 2014b). EPA projects the 2015 U.S. price of uranium will be \$57.00.

The proposed rule would increase the cost of producing uranium at ISR facilities by between \$1.30 and \$2.00 per pound, depending on the alternative and whether low, average, or high costs of compliance are considered. Because domestically produced uranium is a small share of the total U.S. supply (about 17% in 2013) and ISR operations are not the only suppliers of domestic uranium, ISR facility operators would have only a limited ability to pass these costs along to their customers. As a result, EPA estimates that the price of uranium is likely to increase by between $0.21 and $0.32 per pound as a result of the proposed rule.

EPA estimated the impact of the proposed rule on the market for uranium using a simplified model of the U.S. market for uranium in 2015, the base effective date for the proposed rule. The model estimated, based on the unit cost of the proposed rule and characteristics of the supply and demand for uranium in the United States, changes in the quantity of uranium purchased by U.S. COOs of nuclear power plants, changes in the domestic sales of uranium and imports, and changes in the market price for uranium. EPA found that overall the market quantity of uranium purchased for use in electric generation would decline by less than 0.1% and the market price would increase by approximately 0.5%. Domestic ISR facilities would decrease their production by approximately 3% to 6%, and imports of uranium would increase by less than 1%. Because the cost of uranium is a very small share of the cost of electricity, EPA estimates that the cost of generating electricity would increase by less than 0.1%. Table ES-2 summarizes the estimated market impacts based on the unit cost of the proposed rule under low-cost and higher cost sets of assumptions. As expected, the low-cost assumptions have a smaller impact on the market for uranium than the average-cost assumptions, while the high-cost assumptions have a greater effect on the market.

Although the national total annual cost of the proposed rule (approximately $13.5 million to $15.1 million based on average costs) is well below the $100 million threshold that is one of the criteria used to identify a significant regulatory action, the industry has only a small number of companies operating a small number of ISR operations. EPA used existing ISR operations and the companies that own them as models for the types of facilities and companies that would potentially be affected by the proposed rule. EPA thus estimated the ISR facilities would incur annual costs of compliance between $262,000 and $12.7 million, depending on the scale of the operation, the alternative, and the costing assumption used. For small firms owning ISR facilities, EPA estimated cost-to-sales ratios between 0.6% and 2.2%, which would likely not be significant based on the criteria for significance in EPA's final Regulatory Flexibility Act (RFA)/Small Business Regulatory Enforcement Fairness Act (SBREFA) guidance (EPA, 2006). Because EPA estimates that compliance costs would not cause a significant impact and because only a few small businesses (10 or fewer, based on current information) would be affected by the proposed rule, EPA concluded that the rule would not have a significant impact on a substantial number of small entities.

Table ES-2. Estimated Impacts on the U.S. Market for Uranium, 2014[a]

	Baseline	With Proposed Rule		
		Low	Average	High
Supply (million pounds)	57,630	57,616	57,614	57,612
U.S. origin	9,451	9,089	9,032	8,977
Foreign origin	48,179	48,527	48,582	48,635
Price	$57.00	57.21	57.24	57.27
Change in price		$ 0.21	$ 0.24	$ 0.27
Percentage changes				
Market quantity		-0.02%	-0.03%	-0.03%
U.S. origin		-3.8%	-4.4%	-5.0%
Foreign origin		0.7%	0.8%	0.9%
Price		0.4%	0.4%	0.5%
Incremental cost per pound of uranium		$1.30	$1.50	$1.70

[a] Costs and economic impacts are based on the proposed rule (30-year stability with geochemical modeling to shorten), and low, average, and high monitoring cost estimates. Market impacts based on other costing assumptions are provided in Appendix D.

EPA's qualitative benefits assessment presents a discussion of the expected effects of the proposed rule on human and environmental health. EPA expects that the improved monitoring program proposed will reduce the risk of contaminating valuable groundwater resources, thus also reducing potential exposure to radiological and nonradiological contaminants in groundwater and potentially in surface water to which affected aquifers discharge. Because the major risk of exposure to radiological constituents is cancer, the proposed rule has the potential to reduce cancer risks.

If uranium and other constituents remobilize in groundwater over time, and if monitoring ends too soon and sites are prematurely decommissioned, it is possible that groundwater in surrounding aquifers could be contaminated, and it might be many years before the contamination is detected. EPA simulated groundwater contamination using its CMU model facility under varying assumptions and estimated the costs of corrective action to remediate the groundwater contamination. Based on these simulations, the cost of remediation would far exceed the costs of complying with the proposed rule, both on an annual and total basis. For the model facility simulations, this subset of benefits (avoided remediation costs) exceeded the costs of complying with the proposed rule. Further, if contamination were detected after decommissioning, the costs of remediation could be borne by the taxpayer or the land owner rather than the uranium company owner/operator (if, for example, the company no longer exists or so much time has passed that the association is not made between the contamination and the former ISR operation). EPA was unable, however, to estimate potential avoided costs of remediation on a national scale and thus was unable to quantify the rule’s net benefits nationwide.

Section 1

INTRODUCTION

1.1 Background for the Proposed Rule

In accordance with Section 206 of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) Section 206, the U.S. Environmental Protection Agency (EPA) is authorized to develop generally applicable standards for the protection of public health, safety, and the environment from radiological and nonradiological hazards associated with the processing, possession, transfer, and disposal of by-product material (tailings or wastes) at sites where ores are processed primarily for their uranium content. In 1983, EPA promulgated regulations at 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, in response to the statutory requirements of UMTRCA. When the Agency promulgated 40 CFR Part 192, uranium recovery from ore was based almost exclusively on the conventional milling process, where a few pounds of uranium were recovered for each ton of ore mined and processed, and large quantities of radioactive by-product material, or “tailings,” accumulated in impoundments at the mill site. Concern that these impoundments would be a continuing source of radiation exposure unless properly reclaimed was the driving force behind the passage of UMTRCA, which mandated how they should be managed to avoid releases of radioactive material or other hazardous constituents to ground or surface water.

EPA last revised its regulations for uranium and thorium milling in 1995. Since 40 CFR Part 192 was promulgated, there has been a shift in uranium recovery technology from conventional mining and milling to in situ recovery (ISR) where, in a sense, a portion of the milling process is conducted underground within the ore body. In the ISR process (sometimes referred to as in situ leaching [ISL]),[3] oxidizing chemical solutions called lixiviants are pumped underground through an array of wells into the ore body, where the uranium is dissolved in place. The uranium-rich solutions are pumped to the surface where the uranium is extracted (EPA, 2012b).

EPA has reviewed the existing 40 CFR Part 192 standards to determine if the requirements are appropriate for ISR. As a result of this review, EPA determined that the requirements should be revised and is proposing a new subpart that establishes groundwater restoration goals and monitoring requirements at ISR facilities.

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[3] Throughout the rest of this report, the abbreviation ISR is used for simplicity; ISL is another widely used abbreviation for this uranium extraction and processing method.

1.2 Statement of Need for Policy Action

1.2.1 Protection of Human Health and the Environment

EPA has concluded, after reviewing the current language in 40 CFR Part 192, that Part 192 needs to be revised to specifically address the environmental risks posed by ISR uranium operations. The ISR process directly alters groundwater chemistry through injecting the aquifer in which the uranium is found with mobilizing agents. Mobilizing uranium in the formation can also liberate other elements, potentially contaminating surrounding aquifers. If such contamination occurs, the contaminants have the potential to move with the groundwater, reducing the quality of valuable groundwater resources and possibly ultimately reaching drinking water wells or surface water. To ensure that public health, safety, and the environment are protected, EPA must ensure that groundwater restoration is adequate after ISR operations cease; this is particularly important because current Nuclear Regulatory Commission (NRC) regulations allow ISR operators to terminate their licenses soon after restoration is complete (sometimes less than 1 year), essentially ending oversight of the site. After that, they may either sell the property or, if leased, return it to its owners. EPA's research (U.S. EPA, 2012a) indicates that there is a risk that the groundwater may once again become contaminated with uranium or other constituents after restoration and stability monitoring ends. For example a U.S. Geological Survey case study of pilot ISR projects documented that some constituent concentrations increased after the end of stability monitoring. (USGS, 2009) More recently, research conducted by U.S. Department of Energy's Office of Legacy Management found that groundwater flushing at UMTRCA sites is slower and more complex than originally thought. (Shafer et al., 2014) Depending on the exposure pathways, contaminated groundwater may pose a risk to human health, livestock health, or the environment. Thus, EPA has concluded that current standards in 40 CFR Part 192 should be revised to require, among other things, an adequate post-restoration monitoring period.

1.2.2 Need for Regulatory Intervention Because of Market Failure

In general, regulatory intervention is required only when markets fail to allocate resources efficiently. For markets to allocate resources efficiently, both buyers and sellers must have access to full information about the transaction; there must be many buyers and sellers so that neither buyers nor sellers have power to control prices; and the market must impose all the social costs of the transaction on the buyers and sellers in the market. In some situations, however, these conditions do not occur, and markets fail to allocate resources efficiently. One such market failure occurs in cases where a production or consumption activity imposes an external cost on members of society who are neither buyers nor sellers in the market for the good or service produced. In cases of external costs, or “externalities,” some costs are imposed on members of society who are not part of the market. Because the market is not affected by these costs, it fails to allocate resources efficiently, and government must intervene to make the outcome more efficient. Environmental pollution that results from a production process is an example of an external cost borne by members of society who are neither producers nor consumers of the good whose production is generating the pollution.

In the case of ISR uranium operations, a key market failure that requires regulatory intervention is the potential for operations to contaminate groundwater aquifers. If groundwater quality is not adequately restored and adequately monitored during and after the operating period, the ISR operations have the potential to degrade groundwater resources and to expose humans and ecological receptors to contaminated groundwater or surface water, imposing costs on members of society who are neither buyers nor sellers in the market for uranium. Further, if the contamination is discovered after an operation is decommissioned and its license terminated, and perhaps after the company that owned it is out of business, the costs of remediating the contamination may be incurred by the landowner or the taxpayer of the state in which the mine was located, rather than by the mine owners and operators, a violation of the “polluter pays” principal generally used to “internalize” the external costs of a polluting activity.

In the proposed rule, EPA is proposing to establish groundwater monitoring requirements for several phases of an ISR operation, including pre-operational monitoring to establish baseline groundwater conditions, ISR operation, wellfield restoration, and post-restoration stability monitoring to establish that restored groundwater quality is stable. In addition, if contamination is identified during the monitoring, the proposed rule requires the ISR facility owners and operators to undertake corrective action to correct the contamination and then to monitor to demonstrate that it has been successfully corrected.

1.3 Organization of the Report

The remainder of this economic analysis is organized as follows:

- Section 2 presents a profile of the uranium production industry.
- Section 3 describes the proposed rule and the estimated costs of complying with it.
- Section 4 presents a qualitative discussion of the benefits of the proposed rule.
- Section 5 describes the estimated economic impacts of the proposed rule.

- Section 6 describes analyses EPA conducted to assess impacts of statutes and Executive Orders.

- Section 7 presents EPA’s conclusions.

Section 2

PROFILE OF THE AFFECTED INDUSTRY: URANIUM EXTRACTION AND PROCESSING

This section describes the uranium extraction and processing industry, with particular emphasis on ISR producers. The section provides background information that supports EPA's economic impact assessment and also EPA's assessment of possible impacts on small entities under the Regulatory Flexibility Act and the Small Business Regulatory Enforcement Fairness Act (RFA/SBREFA).

The section is organized as follows. Section 2.1 provides a brief introduction to the domestic uranium extraction and processing industry. Section 2.2 describes processes involved in extracting and processing uranium using the ISR process. Section 2.3 describes the products and users of finished uranium oxide concentrate or yellowcake (U_3O_8) products. Section 2.4 discusses the organization of the industry as a whole, including facility- and company-level data. Within this section, small businesses are identified so that EPA can evaluate the impact of the proposed rule on these businesses under the requirements of SBREFA. Section 2.5 assesses market-level data on quantities and prices. The section discusses projections and trends within the uranium production industry.

2.1 Introduction

This section examines the market for uranium, including an examination of the production processes, production costs, and quantities or uranium supplied. In addition, this section examines the demand for uranium. The uranium extraction and processing sector produces uranium which, after undergoing conversion and enrichment, can be used as fuel in nuclear reactors. The industry being examined includes facilities that extract uranium using a variety of technologies and facilities that process the raw uranium into U_3O_8, or "yellowcake," which is then shipped to uranium conversion, enrichment, and fuel fabrication facilities. The main users (demanders) of uranium are utilities that operate nuclear reactors. Both supply and demand for uranium are discussed below.

2.1.1 Uranium Extraction and Processing Sector, NAICS 212291

Establishments engaged in the extraction and processing of uranium to produce fuel for electricity generation form the core of the industry. Fuel for nuclear power plants is the primary commercial use for uranium (EIA, 2014a). The U.S. industry falls under the North American Industry Classification System (NAICS) code of uranium-radium-vanadium mining (212291) (NAICS, 2012). Facilities in this industry extract uranium from uranium deposits and process it, producing uranium oxide concentrate or yellowcake, with the chemical formula U_3O_8. According to the 2009 Statistics of U.S. Businesses, a total of 28 establishments were operating under this NAICS code (Census, 2011).

2.1.2 Uranium Shipments

In 2013, a total of 4.7 million pounds of uranium concentrate were shipped in the U.S. industry, which is 0.8 million pounds more than in 2012 (Table 2-1). Shipments of uranium concentrate have fluctuated widely over the last 21 years for a variety of reasons, including changes in international demand for and supply of uranium.

2.2 Supply of Uranium

Uranium can be produced using conventional mining methods (underground or open-pit mining), coupled with either conventional milling or heap leaching. Conventional milling entails grinding the ore, placing it in a tank, and exposing it to an acid or alkaline solution to leach the uranium out of the ore. Heap leaching entails placing a pile of the ground ore on a pad and pouring the leaching solution over it. The uranium, in the form of U_3O_8 or “yellowcake,” is then physically separated from the other materials in the ore, chemically extracted, precipitated out of the solution, concentrated, dried, and packaged for shipment.

Alternatively, instead of conventional mining and milling, uranium can be produced using the ISR process. Some uranium ore bodies are located within porous material such as gravel or sandstone that is saturated in groundwater. The ore is accessible through mobilizing the uranium and pumping it out (World Nuclear Association [WNA], 2012a). Where the ore body is amenable to use of the ISR technology, uranium can be recovered economically without the extensive surface facilities, ore pads, large waste volumes, or expectations of long-term site maintenance associated with conventional milling. In the ISR process, oxidizing chemical solutions called lixiviants are pumped through an array of injection wells into the ore body where the uranium is solubilized. The uranium-rich solutions are pumped to the surface through extraction wells, then piped or transported to a processing plant where the uranium is recovered from the solution through an ion exchange process, and further processed prior to shipment, similar to the processing described in the previous paragraph. The solutions are then recharged with the lixiviant chemicals and pumped back into the ore body to recover additional uranium (EPA, 2012b). Any waste water that is not reinjected into the ore body may be injected into a deep well for disposal, sent to an impoundment or evaporation pond on site, or treated prior to land disposal.

Table 2-1. U.S. U_3O_8 Shipments (Million Pounds)

Year	Uranium Concentrate Shipments
1993	3.4
1994	6.3
1995	5.5
1996	6.0
1997	5.8
1998	4.9
1999	5.5
2000	3.2
2001	2.2
2002	3.8
E2003	1.6
2004	2.3
2005	2.7
2006	3.8
2007	4.0
2008	4.1
2009	3.6
2010	5.1
2011	4.0
2012	3.9
2013	4.7

E = Estimated data.

Note: The 2003 annual production and shipment amounts were estimated by rounding to the nearest 200,000 pounds to avoid disclosure of individual company data.

Source: U.S. Energy Information Administration: 1993–2002-Uranium Industry Annual 2002 (May 2003), Table H1 and Table 2. 2003–2012-Form EIA-851A, “Domestic Uranium Production Report” (2003–2014).

After extracting and processing, the final product of the ISR operation is uranium oxide concentrate (U_3O_8), commonly referred to as yellowcake (U.S. NRC, 2012b). Often, the extraction and processing are done at the ISR site. In some cases, one facility extracts the uranium and sends it to be processed in another location. One example of this is the La Palangana facility in Duval County, Texas, which extracts the uranium and sends it to the Hobson Processing Plant, located about 100 miles away in Karnes County, Texas, for processing and packaging. Section 2.2.1 provides more detail about the ISR uranium extraction process.

Total U.S. production of uranium is the sum of uranium produced using each technology. Table 2-2 presents historical data on quantities of U_3O_8 produced.

Table 2-2. Total U.S. Amount of U_3O_8 Produced (Million Pounds U_3O_8)

Year	Mine Production of Uranium	Uranium Concentrate Production
1993	2.1	3.1
1994	2.5	3.4
1995	3.5	6.0
1996	4.7	6.3
1997	4.7	5.6
1998	4.8	4.7
1999	4.5	4.6
2000	3.1	4.0
2001	2.6	2.6
2002	2.4	2.3
E2003	2.2	2.0
2004	2.5	2.3
2005	3.0	2.7
2006	4.7	4.1
2007	4.5	4.5
2008	3.9	3.9
2009	4.1	3.7
2010	4.2	4.2
2011	4.1	4.0
2012	4.3	4.1
2013	4.6	4.7

E = Estimated data.

Source: U.S. Energy Information Administration: Form EIA-851A, “Domestic Uranium Production Report,” 2003–2014.

Production of yellowcake is the first step in a multistep process to produce nuclear fuel. The yellowcake is shipped to conversion facilities that convert it into uranium hexafluoride (UF_6), which in turn is shipped to facilities that enrich it and fabricate it into fuel assemblies for nuclear power plants.

Total domestic supply is a sum of the annual amount of uranium mined in the United States and processed into yellowcake and the amount of uranium that was stockpiled in previous years and during the current year is converted to yellowcake. The annual amount of uranium mined and the amount processed into U_3O_8 do not always match; for example, in 1993 only 2.1 million pounds of uranium-equivalent was extracted, while 3.1 million pounds were actually processed into U_3O_8. The discrepancy is largely due to quantities of uranium added to inventories or taken out of inventories in response to market forces.

2.2.1 Production Process

The ISR process has been used since the 1960s in the United States for extracting uranium from sandstone type uranium deposits that were not suitable for open pit or underground mining. Many sandstone deposits are amenable to uranium extraction by ISR, which is now a well-established technology that accounted for more than 28% of the world's uranium production in 2009. The basic requirement for ISR is that the mineralization is located in water-saturated permeable formations that allow effective confinement of mining solutions (commonly confined between impermeable clay-rich strata) (DRET, 2010).

Figure 2-1 shows a simplified diagram of an ISR uranium operation. Uranium is extracted by means of an acid or alkaline leaching solution (lixiviant) that is pumped down injection wells into the permeable mineralized zone to mobilize uranium from the ore body. The uranium-rich solution is pumped to the surface via nearby recovery wells, and the uranium is recovered in the processing plant by hydrometallurgical processing, typically ion exchange or solvent extraction (particularly for highly saline waters). The mining solution is regenerated and recycled (DRET, 2010). The recovered uranium undergoes further processing and packaging and is shipped off site in the form U_3O_8, or yellowcake, to a facility where it will be converted into UF_6. Next, the UF_6 will be enriched to increase the amount of ^{235}U, after which it will undergo fabrication into fuel for nuclear reactors (NRC, 2012a).

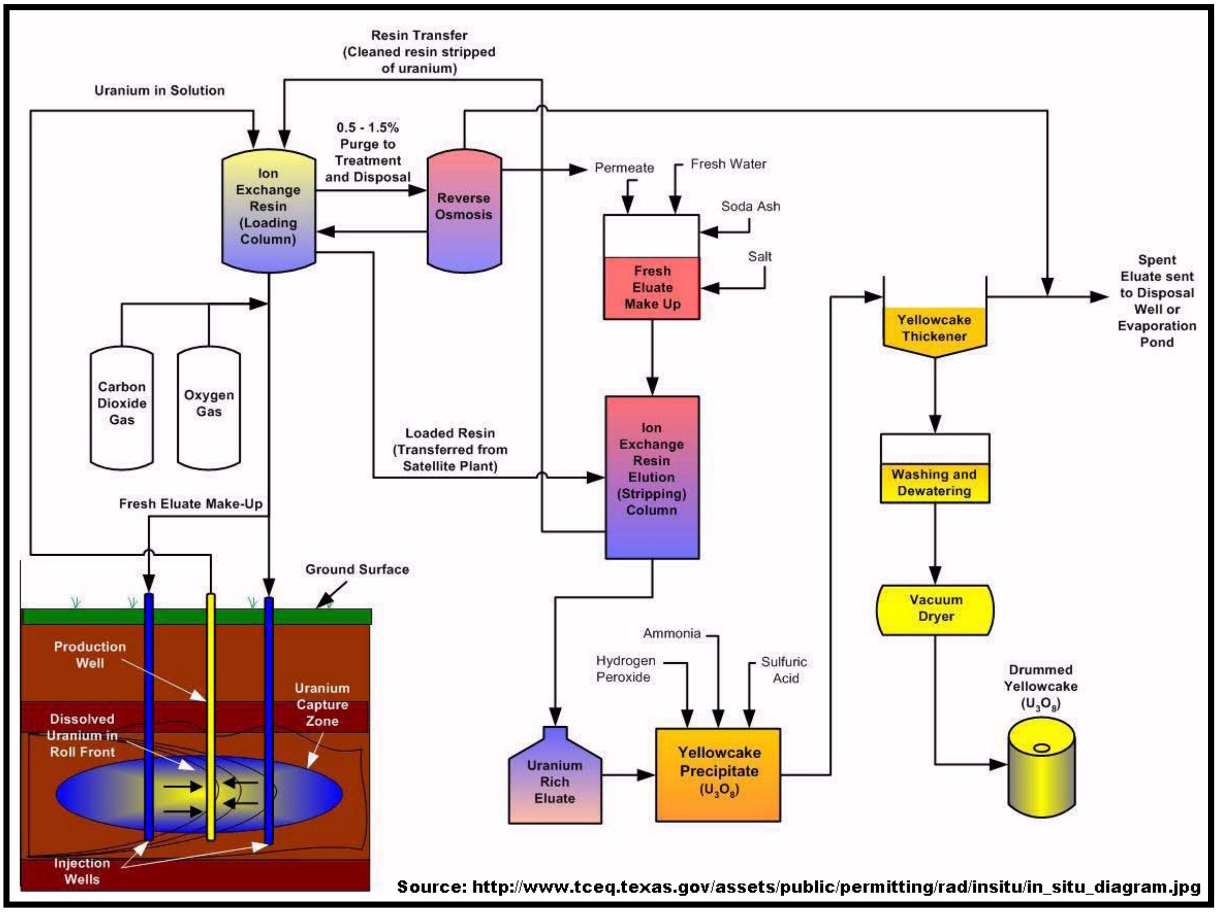
The life cycle of an ISR facility involves the following stages:

- Exploration and development to establish that a commercially viable operation is possible.
- Establishment of site baseline conditions for ISR (mining) of the ore body.
- Recovery of uranium from the ore body.
- Restoration of the groundwater to predetermined conditions.
- Demonstration that restored groundwater is stable.

- Long-term stability monitoring of the groundwater to ensure groundwater quality remains stable.

- Decommissioning of mined area and surface facilities.

Figure 2-1. Diagram of ISR Uranium Operation

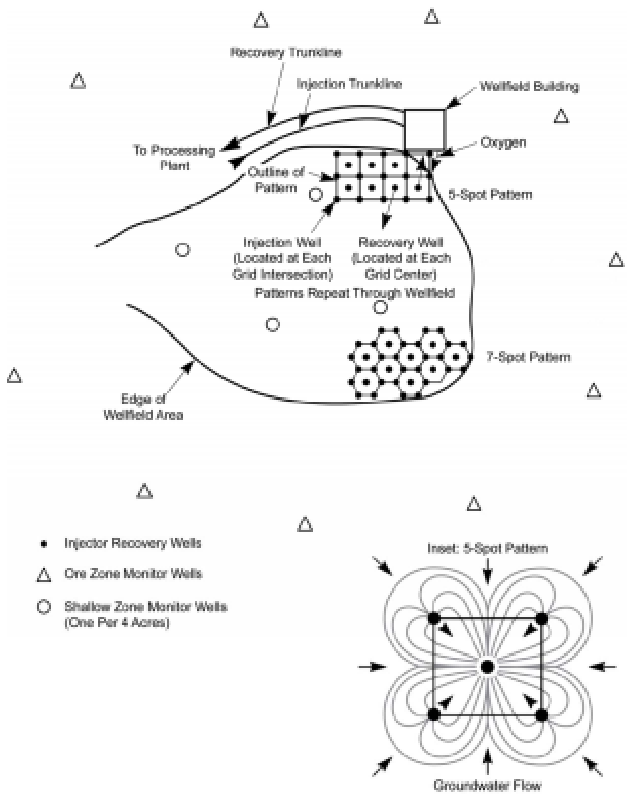


Source: http://www.tceq.texas.gov/assets/public/permitting/rad/insitu/in_situ_diagram.jpg

Source: DRET, 2010, p. 3.

During ISR operations, the most common injection/pumping patterns are five and seven spot (NRC, 2003). The shape of the mineralized ore body and surface topography, however, may give rise to other patterns (NRC, 1997). A typical five-spot pattern contains four injection wells and one recovery well. The dimensions of the pattern vary depending on the mineralized zone, but the injection wells are generally between 40 and 150 feet apart. To effectively recover the uranium and also to complete the groundwater restoration, the wells are often completed so that they can be used as either injection or recovery wells. During recovery operations, a slightly greater volume of water will be recovered from the mineralized zone aquifer than was injected to create a cone of depression or a flow gradient toward the recovery wells. This practice is intended to minimize excursions of leachate outside the production area. Groundwater monitoring is necessary to detect any excursions of lixiviant outside the mining area during operations. Figure 2-2 shows typical well arrangements using five- and seven-spot patterns and illustrates a typical wellfield. Piping connecting the individual wells to the header house may be run underground or on the surface.

Figure 2-2. Schematic Diagram of a Wellfield Showing Typical Injection/Production Well Patterns, Monitoring Wells, Manifold Buildings, and Pipelines



Source: NRC, 2009

Three types of wells are present at uranium ISR facilities during the operational (leaching) phase (see Figure 2-2), sometimes further classified by their location:

- Injection wells—Wells used to inject solutions into an ore-bearing aquifer to mobilize uranium.

- Extraction wells—Wells used to extract uranium-enriched solutions from the ore-bearing aquifer; also known as “production wells”; note that injection wells and extraction wells can be converted from one use to another.

- Monitoring wells—Wells used to obtain water samples for the purpose of determining the amounts, types, and distribution of constituents in the groundwater. Wells are located in the production zone, around the perimeter of the production zone (horizontal excursion monitoring wells), and in overlying and underlying aquifers (vertical excursion monitoring wells).

Some of these wells will be used to define initial baseline conditions, to monitor the progress of restoration, and to determine whether long-term stability has been achieved. Injection wells at ISR facilities are defined as Class III wells and are regulated under 40 CFR Part 146—Underground Injection Control Program: Criteria and Standards. Part 146 establishes construction, operating, and monitoring requirements that EPA must approve.

2.2.2 Inputs Used in ISR Uranium Production

This section summarizes briefly the inputs used to produce uranium at ISR facilities.

- Uranium resource. The most critical input is the uranium deposit itself; mining firms invest heavily in exploration and discovery of potentially economically viable uranium deposits.
- Availability of skilled, well-trained engineers and workers is another critical element, although operating an ISR facility is not labor intensive once the facility has been constructed.
- Capital equipment used to produce uranium at an ISR facility includes the production and monitoring wells, pipelines, and a building for administration, processing and packaging equipment, and storing the product. Additional surface facilities may include evaporation ponds and storage tanks, as well as deep-well injection for disposal of spent liquids. Upfront capital costs of construction can be considerable, but according to the World Nuclear Association (WNA), they are much lower when compared with conventional mining (WNA, 2012a).
- Materials, including chemicals for the lixiviant solution, and water.

2.2.3 Production Costs

Production costs at ISR uranium facilities depend on the prices and quantities of the inputs shown above. Although ISR facilities are expected to be the focus of the Part 192 revisions, we also looked at base costs for conventional mills and heap leach facilities. In general, current conventional mine and mill costs per pound of yellowcake produced are higher than ISR facility costs per pound of yellowcake. Numerous factors contribute to this range (e.g., capital investment requirements, ore grade, mining or recovery costs, distance to the mill or processing facility, long-term liabilities, and milling/processing costs). The lower cost of ISR technology per pound of uranium produced has led to its increased use over the past few decades.

2.2.4 Pollution Control

In addition to the cost of constructing and operating an ISR facility, additional costs are incurred to implement pollution controls, especially groundwater protection monitoring and remediation (where necessary).

During operations, there is a risk that the lixiviant and/or some mobilized constituent may spread beyond the wellfield, which poses a risk of groundwater contamination outside the facility. Monitoring wells are positioned around the production zone of the wellfield to detect any "excursion" of constituents beyond the wellfield. If excursions are detected, the operator will take corrective actions to remediate the excursion, such as stopping injection while continuing to pump water out of the wells near the excursion. When mining is no longer economically viable, the operator will stop injecting lixiviant and begin restoring the ore zone aquifer to pre-operational conditions to the extent practicable. (Pre-operational conditions will have been characterized by sampling the groundwater before operations begin.) The wellfield will be flushed with clean water (consuming a substantial amount of water) and will frequently be treated with reducing agents to attempt to restore the pre-operational geochemistry and immobilize any remaining uranium or other constituents. Then, groundwater conditions are monitored to ensure that they remain stable. When sufficient time has passed that the owner/operators can demonstrate that groundwater conditions are stable, the wells are plugged and abandoned, pipes and other infrastructure are removed, surface facilities are removed and shipped off site for disposal, and the site is decommissioned, including termination of the radioactive materials license.

Throughout the process, adequate monitoring is critical to protecting groundwater quality and thus human health and the environment. The proposed rule will modify the current practice for monitoring to more fully establish baseline conditions, monitoring to demonstrate restoration, and monitoring to demonstrate that the restored water quality is stable. The revised provisions and the associated costs of complying with them are described in Section 3.

Under current requirements, ISR operators must monitor groundwater conditions during pre-operational baseline characterization, facility operations, groundwater restoration, and stability monitoring. Provisions of the proposed rule will affect facility requirements during pre-operational monitoring, operations, restoration, and stability monitoring. Current monitoring practice in the industry is described below.

- **Pre-operational Monitoring**: To restore the groundwater to the condition it was prior to the mining operations, ISR facility operators must collect samples to characterize the pre-operational groundwater.

- **Monitoring for Excursions during Operations**: During operations, as discussed above, groundwater conditions surrounding the wellfield will be monitored for excursions of lixiviant ingredients or mobilized constituents, using wells outside the wellfield both horizontally and vertically.

- **Restoration Monitoring**: During groundwater restoration, monitoring is used to measure the progress of the restoration, as well as to demonstrate compliance with the restoration goals. Several alternatives for demonstrating compliance have been evaluated.

- **Stability Monitoring**: To demonstrate that the restored groundwater will remain stable below the restoration goals, ISR facility operators must collect groundwater samples. Historically, stability monitoring has continued for less than a year; recently licenses have begun to require stability monitoring of 1 year or longer (EPA, 2012a).

Table 2-3 provides summary expenditures by domestic uranium producers (including both conventional and ISR facilities) by expenditure category for the period 2003 to 2013.

2.3 Demand for Uranium

2.3.1 Characteristics of the Product (Yellowcake)

Demand for yellowcake is derived from the demand for nuclear energy, which in turn is derived from the demand for electricity. Yellowcake is a primary input into nuclear energy production, which ultimately uses nuclear fuel products. The direct demanders of yellowcake are generally conversion facilities.

Downstream processing operations must occur before the U_3O_8, or yellowcake, is able to be used as a fuel. The next step in the process is termed conversion and includes the refinement of yellowcake to eliminate impurities. The U_3O_8 is converted to gaseous uranium hexafluoride (UF_6). At this stage in the process, UF_6 is extremely corrosive, particularly when moist. The material is transferred to steel cylinders with thick walls. The cylinders are shipped to enrichment facilities.

Table 2-3. Domestic Uranium Industry Production Expenditures ($Million)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Drilling	W	10.6	18.1	40.1	67.5	81.9	35.4	44.6	53.6	66.6	49.9
Production	W	27.8	58.2	65.9	90.4	221.2	141.0	133.3	168.8	186.9	168.2
Total land and other	31.3	48.4	59.7	115.2	178.2	164.4	104.0	99.5	96.8	99.4	90.6
Land	NA	NA	NA	41.0	77.7	65.2	17.3	20.2	19.6	16.8	14.6
Exploration	NA	NA	NA	23.3	50.3	50.2	24.2	34.5	43.5	33.3	21.6
Reclamation	NA	NA	NA	50.9	50.2	49.1	62.4	44.7	33.7	49.3	54.4
Total Expenditures	W	86.9	136.0	221.2	336.2	467.6	280.5	277.3	319.2	352.9	308.7

Drilling: All expenditures directly associated with exploration and development drilling.

Production Land and Other: All expenditures for land; geological research; geochemical and geophysical surveys; costs incurred by field personnel in the course of exploration, reclamation, and restoration work; and overhead and administrative charges directly associated with supervising and supporting field activities. All expenditures for mining, milling, processing of uranium, and facility expense.

NA = Not available

W = Data withheld to avoid disclosure of individual company data.

Notes: Expenditures are in nominal U.S. dollars. Totals may not equal sum of components because of independent rounding. Expenditures refer to all U.S. uranium production, including conventional mines and mills.

Source: U.S. Energy Information Administration: Form EIA-851A, “Domestic Uranium Production Report” (2003–2013).

The enrichment process uses gaseous UF_6 as a feed. After this process is concluded, two products are formed: the actual product that contains higher levels of ^{235}U and the “tails” with lower levels of ^{235}U. The enriched ^{235}U product is now ready to be processed and fabricated into a reactor fuel. Uranium dioxide (UO_2) powder is produced. The powder is processed and formed into ceramic pellets. The pellets are loaded into fuel rods and pressurized with helium gas and finally sealed (WNA, 2012c).

2.3.2 Uses and Consumers

The primary end use for uranium is as fuel for nuclear power plants. U.S. civilian nuclear power reactors are the end users of uranium. They are also referred to as “civilian owner/operators” or COOs (EIA, 2013c). Over the last 20 years, about 20% of the country’s total energy supply has been generated by nuclear power. The Energy Information Administration (EIA), in its Reference case, projects that the output of nuclear power will increase, partially due to the Energy Policy Act of 2005, which guarantees construction loans to nuclear power plants. By 2040, the EIA projects that nuclear capacity will increase by about 10.4 gigawatts, with approximately 9.7 gigawatts coming from new reactors and 0.7 gigawatts coming from power uprates at existing reactors (EIA, 2014a). In February 2012, NRC voted to approve the

Combined Operating License (COL) to build two new Westinghouse AP1000 reactors, Vogtle Units 3 and 4. In March 2012, NRC voted to approve the COL to build two new AP1000 reactors, Virgil C. Summer Units 2 and 3. The Vogtle and Virgil C. Summer units are expected to be online between 2016 and 2018. In addition to the four new AP1000 reactors, the Tennessee Valley Authority anticipates completion of the construction of Watts Bar Unit 2 in late 2015. These five reactors are the first to be constructed in the United States in over 30 years and will account for approximately 5.5 GWe of the projected 9.7 GWe projected to be online by 2040. Thirty-one other countries also generate nuclear power, but the largest generator remains the United States. France is the second largest country in terms of usage, followed by Russia and Japan.

2.3.3 Substitutes

Uranium produced by conventional mines and mills is a perfect substitute for uranium produced by ISR facilities. Similarly, imported U_3O_8 would be a perfect substitute for uranium produced by ISR facilities. Imported low-enriched-uranium (LEU) and downblended LEU would be substitutes for LEU produced using domestic uranium.[4] Other fuels used to generate electricity, and other forms of energy, are imperfect substitutes for uranium. This analysis focuses on the market for uranium, not the market for electricity or the market for energy, so these imperfect substitutes are not explicitly considered.

2.4 Industry Organization

This section describes the organization of the uranium mining and milling industry, including the market structure and the characteristics of the facilities and firms producing uranium oxide in the United States.

2.4.1 Market Structure

Market structure describes the way in which suppliers and demanders of a commodity interact; markets may range from perfectly competitive (many sellers and buyers of a homogeneous product, none large enough to affect market price by their actions) to monopolistic (only one supplier who sets the price and quantity in the market to maximize his profit). The market for grain is an example of a perfectly competitive market; individual farmers or purchasers are “price-takers,” deciding what quantity to sell or buy based on a market price they take as given. Electric utilities are examples of regulated monopolies; only a single electric

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[4] See discussion of international trade in uranium and the Megatons-to-Megawatts agreement with Russia, below. When the Megatons-to-Megawatts program ends, Russia is expected to sell the United States uranium from their production sector.

utility serves each geographic market, and its rates are set through negotiation with regulatory bodies. Most markets actually fall somewhere between these two extreme examples. The market for uranium is global, imperfectly competitive, and highly regulated.

2.4.1.1 Barriers to Entry

Globally, there are relatively few suppliers of yellowcake, and only six facilities are currently operating in the United States. The small number of facilities indicates that firms wishing to enter the uranium market face several barriers to entry. Barriers facing potential entrants in the United States include the following:

- They must have access to a uranium deposit, which are limited in number. Uranium is a scarce resource, and a significant ore body must first be located, which requires investing considerable time and money.
- They must obtain a license from the NRC or an Agreement State. The NRC regulates ISR facilities. The NRC has developed a suite of regulations to reduce threats to human health and the environment, such as 10 CFR Part 20, 10 CFR Part 40, and Appendix A of 10 CFR Part 40, which are based on EPA regulations at 40 CFR Part 192 (NRC, 2013). To begin extracting uranium at an ISR facility, the potential supplier must go through many time-consuming and costly steps. The applicant must follow NRC's regulatory guides that present guidance on various aspects of the process, such as license applications, environmental impact statements and analyses, calculation models, financial assurance and construction requirements. Each of these steps is also expensive and requires substantial amounts of time. The environmental impact statement is part of the National Environmental Policy Act process, which may be duplicated by Bureau of Land Management requirements if the project is on public lands.
- Prior to getting a license from the NRC, the applicant must also get an aquifer exemption from the EPA's Underground Injection Control Program, or its delegated agency, which can be the state or the regional EPA office.

Some states have additional barriers, such as Virginia's moratorium on uranium mining and milling[5] (Virginia Statute 45.1-283). Agreement State regulations may be stricter than NRC regulations, which can be important with respect to protecting groundwater resources.

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[5] In 1982, the Virginia General Assembly passed Statute 45.1-283, which states "permit applications for uranium mining shall not be accepted by any agency of the Commonwealth prior to July 1, 1984, and until a program for permitting uranium mining is established by statute."

2.4.2 Small Businesses

The RFA as amended by SBREFA requires federal departments and agencies to evaluate if and/or how their regulations affect small business entities. Specifically, the agency must determine if a regulation is expected to have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions. The business is defined as the owner company, rather than the facility; the size of the owner company determines the resources it has available to comply with the rule.

If a rulemaking is determined to have a significant economic impact on a substantial number of small entities, then the agency must conduct a formal regulatory flexibility analysis. However, if the agency determines that a rulemaking does not have a significant economic impact on a substantial number of small entities, then it makes a certification of that finding and presents the analyses that it made to arrive at that conclusion. The ISR uranium operations fall under the NAICS code of uranium-radium-vanadium mining (212291) (NAICS, 2012). For NAICS 212291, the Small Business Administration (SBA) (2012) defines a small business as one having fewer than 500 employees.

Because the proposed revisions to Part 192 do not involve conventional mills, the economic impact analysis focuses on ISR facilities. In 2013, there were six ISR facilities in operation (EIA, 2014b): Crow Butte and Smith Ranch-Highland-Reynolds owned by Cameco Resources; Alta Mesa owned by Mestena Uranium, LLC; Willow Creek owned by Uranium One, Inc.; Hobson-La Palangana owned by Uranium Energy Corp.; and Lost Creek owned by Ur-Energy. Because they have fewer than 500 employees, Mestena Uranium, LLC, Ur-Energy, and Uranium Energy Corp. are considered small businesses according to the criteria for NAICS 212291, while both Cameco Resources and Uranium One, Inc. are large businesses.

Table 2-4. Owner Companies for ISR Facilities: Existing and Planned

Parent Company	Facility Name	Number of Employees	Annual Revenue (Million $)	Small Business?
Cameco Corporation	Crow Butte, Smith Ranch-Highland	3,300	2,400	No
Mestena Uranium	Alta Mesa	125	x	Yes
Uranium One, Inc.	Willow Creek, *Moore Ranch, Antelope-Jab*	2,200	530.4	No
Uranium Energy Corp.	Hobson-La Palangana, *Goliad*	98	9.00	Yes

(continued)

Table 2-4. Owner Companies for ISR Facilities: Existing and Planned (continued)

Parent Company	Facility Name	Number of Employees	Annual Revenue (Million $)	Small Business?
Powertech Uranium Corp.	*Dewey-Burdock*	25	5.04	Yes
Uranerz Uranium Corp.	*Nichols Ranch*	54	0.00	Yes
Strata Energy/Peninsula Energy Ltd	*Ross*	<30	0.85[a]	Yes
Uranium Resources	*Crownpoint, Kingsville Dome, Rosita, Vasquez, Church Rock*	37	x	Yes
Ur-Energy	Lost Creek	51	x	Yes
Bayswater E&P	*Reno Creek*	x	x	Yes

x = No annual sales data

Note: ISR projects listed in italics are not currently in operation; see Table 2-7 for status. Those in regular print were operating during the summer of 2013.

Sources: Data on total number of employees and annual sales were gathered from Hoover's, U.S. Securities and Exchange Commission, and various company annual reports and websites (Cameco, 2013; Uranium One, 2013; Uranium Energy Corporation, 2013; Peninsula Energy Ltd, 2013;Uranerz Energy Corporation 2013; Uranium Resources, Inc.2013, Ur-Energy 2013).

In addition to the six ISR facilities listed above, several ISR facilities are in various stages of planning or licensing (see Table 2-4); most of these are also owned by small businesses. Thus, of the existing or planned ISR uranium recovery facilities identified in Table 2-4, most are owned by small businesses. Of the 10 owner companies listed in Table 2-4, 8 are small, based on available information about their employment.

EPA recognizes that several of the small businesses have investors in some of their ISR operations that are large businesses. Although the presence of these large company investors may provide additional resources for complying with the rule, EPA nevertheless evaluated the potential for small business impacts based on data for the small business that is the owner of the operation.

2.5 Market for U_3O_8

2.5.1 U.S. Consumption

In 2012, U.S. COOs of nuclear power plants purchased a total of 57 million metric tons of U_3O_8 equivalent, an increase of 0.7% from the prior year (see Table 2-5). The majority of the U_3O_8 equivalent (approximately 80%) was purchased through the use of short-, medium-, and long-term contracts. Under these contract types, at least one delivery is set to occur after a year following the date the contract was established. The remaining uranium sales were purchased through the use of spot contracts, which are one-time deliveries, set to occur within a year of the contract's signing date. While the weighted-average prices of uranium purchased by U.S. COOs dropped slightly as well, from $54.99 per pound in 2012 to $51.99 in 2012 (see Table 2-8), spot prices have dropped since early 2011. The spot price for uranium fell to $43.83 in 2013 (Table 2-8); for contracts signed in 2013 by U.S. COOs, the long-term contract price was approximately $43.20 (U.S. EIA, 2014c).

Table 2-5. Uranium Purchased by U.S. COOs, 1994–2013 (Million Pounds U_3O_8 Equivalent)

Delivery Year	Spot Contracts	Short-, Medium-, and Long-Term Contracts	Total Purchased
1994	8.5	29.8	38.3
1995	13.6	29.8	43.4
1996	9.1	38.3	47.3
1997	5.5	36.5	42.0
1998	7.8	34.9	42.7
1999	8.0	40.0	47.9
2000	10.4	39.1	51.8
2001	14.4	40.0	55.4
2002	8.6	41.4	52.7
2003	8.2	46.7	56.6
2004	9.2	53.3	64.1
2005	6.9	58.8	65.7
2006	6.3	59.4	66.5
2007	6.6	43.7	51.0
2008	8.7	42.8	53.4
2009	8.1	41.0	49.8
2010	8.2	37.9	46.6
2011	12.0	42.3	54.8
2012	8.1	48.9	57.0
2013	11.3	46.1	57.4

Sources: U.S. Energy Information Administration: 1994–2002-Uranium Industry Annual, Tables 10, 11 and 16. 2003–2013-Form EIA-858, "Uranium Marketing Annual Survey."

As shown in Table 2-6, domestic production of U_3O_8 is a small share of total COO purchases. Some comes from domestic inventories, but the majority of uranium purchased by COOs is from foreign sources.

Table 2-6. Total Amount U_3O_8 Produced in the United States (Thousand Pounds U_3O_8)

Production	Total Mine Production	Total Mines and Sources
2003	E2,200	4
2004	2,452	6
2005	3,045	10
2006	4,692	11
2007	4,541	12
2008	3,879	17
2009	4,145	20
2010	4,237	9
2011	4,114	11
2012	4,335	12
2013	4,577	12

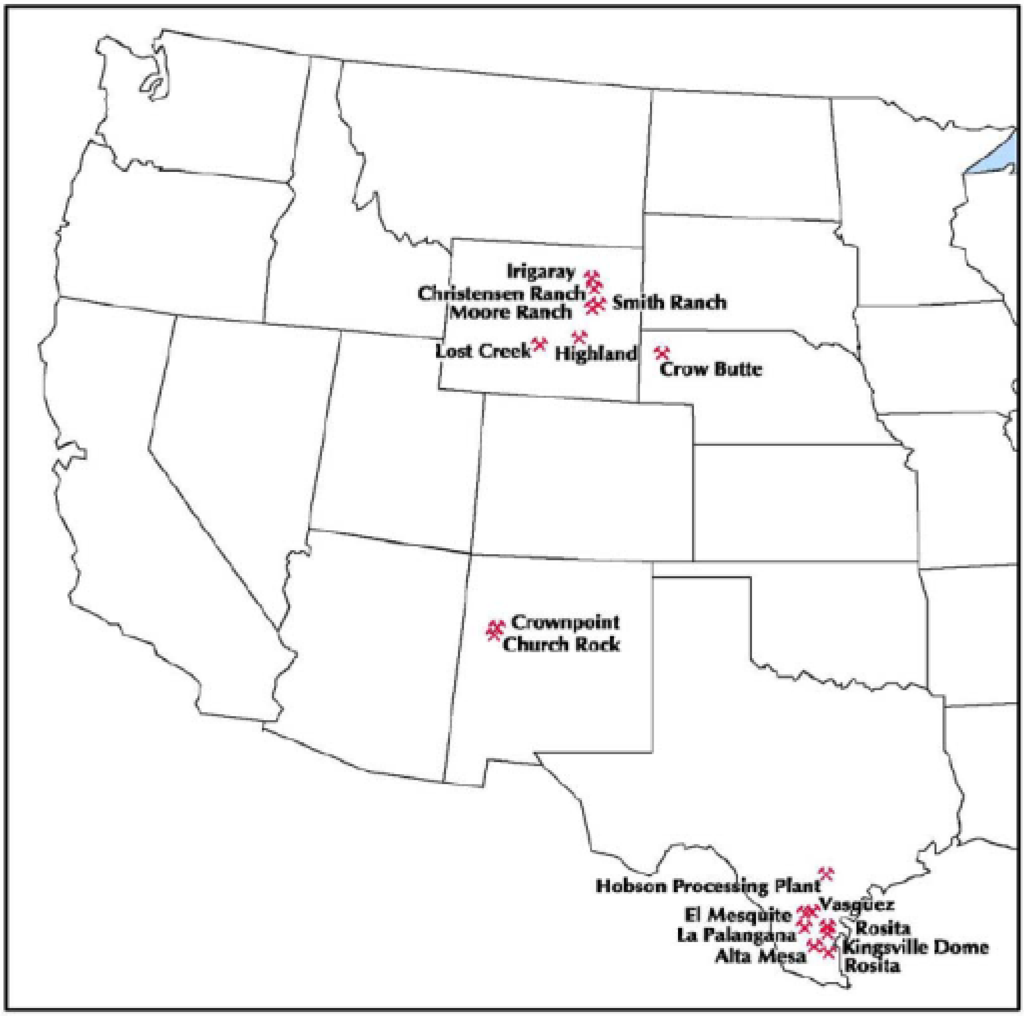
E = Estimated data.

Source: U.S. Energy Information Administration: Form EIA-851A, “Domestic Uranium Production Report” (2003–2013).

2.5.2 U.S. Uranium Production

In the United States, uranium producers are concentrated in the West and Southwest, including the states of Texas, New Mexico, Arizona, Utah, Colorado, Wyoming, South Dakota, and Nebraska. Figure 2-3 shows the approximate locations of uranium production facilities (including not only operating ISR facilities, but also those that are currently on standby or pre-operational).

Figure 2-3. Location of ISR Uranium Production



Source: EPA, 2012a

Table 2-7 provides a list of ISR facilities in the United States, together with their location, capacity, and operating status. As shown in the table, there are six currently operating or producing ISR facilities in the United States; several others are licensed or partially licensed. Of the 23.1 million pounds capacity shown in the table, U.S. facilities have typically produced less than 10 million pounds per year over the past 10 years.

Table 2-7. In situ Recovery Plants in the United States, and Status (2013)

In situ Recovery Project Name	State	Production Capacity (pounds U_3O_8 per year)	Status
Operating, Summer 2013			
Crow Butte	Nebraska	1,000,000	Operating
Smith Ranch-Highland	Wyoming	5,500,000	Operating
Alta Mesa	Texas	1,500,000	Operating
Hobson-La Palangana	Texas	1,000,000	Operating
Willow Creek (Christensen Ranch and Irigaray)	Wyoming	1,300,000	Operating
Lost Creek	*Wyoming*	2,000,000	Operating
Not Operating, Summer 2013			
Crownpoint	*New Mexico*	1,000,000	Partially permitted and licensed
Church Rock	*New Mexico*	1,000,000	Partially permitted and licensed
Dewey Burdock	*South Dakota*	1,000,000	Developing
Ross	*Wyoming*	3,000,000	Partially permitted and licensed
Kingsville Dome	Texas	1,000,000	Restoration
Rosita	Texas	1,000,000	Restoration
Vasquez	Texas	800,000	Restoration
Nichols Ranch ISR	Wyoming	2,000,000	Under construction
Goliad ISR Uranium	*Texas*	1,000,000	Permitted and licensed
Antelope-Jab	*Wyoming*	2,000,000	Developing
Moore Ranch	*Wyoming*	500,000	Permitted and licensed
Reno Creek	*Wyoming*	--	Developing
Total Domestic Production Capacity:		**26,600,000**	

– = No data reported.

[a] According to owner company (Ur-Energy, Uranium Energy Corporation) websites.

Notes: Production capacity for 2011. An operating status of “Operating” indicates the *in-situ* leach plant usually was producing uranium concentrate at the end of the period. The Hobson ISR Plant processed uranium concentrate that came from La Palangana. Hobson and La Palangana are co-owned, but not co-located, and are considered in this analysis as one project. Christensen Ranch and Irigaray are part of the Willow Creek Project.

Source: U.S. Energy Information Administration: Form EIA-851A, “Domestic Uranium Production Report” (2007–2013).

2.5.3 International Trade

Uranium is a relatively homogeneous commodity that is valued for its energy content, and the market for uranium is genuinely an international market. Uranium produced in the United States may be sold abroad or sent abroad for processing and then returned to the United States. Typically, domestic-origin uranium has been a relatively small share of total uranium purchased in the United States. In addition to uranium mined abroad, low-enriched uranium for use in fuel fabrication facilities is also imported, especially from Russia.

In 1993, the United States and Russia entered into a government-industry agreement whereby Russian nuclear weapons containing HEU are dismantled and converted to LEU for use as fuel in nuclear power reactors domestically (United States Enrichment Corporation [USEC], 2012). A commercial company, USEC, has acted on behalf of the U.S. government. Techsnabexport (TENEX) is the commercial agent for the Russian government. Since the program's inception, ~12,380 metric tons of HEU have been converted. In 2013, purchases under the program ended (USEC, 2014).

In 2013, TENEX will begin to supply LEU under a new contract with USEC. The new amount that will be supplied will increase until it reaches approximately one-half the currently supplied levels (under the Megatons to Megawatts Program) in 2015. Within the agreement, there is an option to scale up to the currently supplied levels through the year 2022. Under the new contract, Russia will be supplying commercially enriched uranium instead of uranium from dismantled weapons (World Nuclear News, 2011; Pravda, 2012).

2.5.3.1 Imports

Most of the uranium used by COOs domestically is purchased from foreign suppliers. In 2012, the 9.8 million pounds of U_3O_8 produced in the United States amounted to only 17.0% of the total 57.5 million pounds of U_3O_8 purchased. Kazakhstan, Russia, and Uzbekistan comprised 40% of total deliveries. The share of uranium that is of foreign origin has fluctuated over time (EIA, 2013c).

2.5.3.2 Exports

In addition to imports of uranium into the United States, the NRC licenses exports of processed uranium from the United States. In 2012, of 18.0 million pounds delivered to foreign suppliers and utilities, only 4.8 million pounds of the uranium exported was of U.S. origin. The remaining 13.2 million pounds exported were of foreign-origin uranium[6] (EIA, 2013c).

2.5.4 Market Prices

Uranium is traded under various contractual arrangements, including spot contracts and short-, medium-, and long-term contracts. Contract prices and spot prices vary, with spot prices

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[6] Note that data provided for production, imports, exports, and purchases in a given year appear inconsistent. This occurs because some production may go into inventory, and some purchases may be from inventory.

being much more volatile than contract prices. Table 2-8 presents historical data on uranium prices. Most contracts are based not based on the spot price but rather the long-term price. It should be noted that uranium is not traded on recognized exchanges; rather the price is set by two independent companies based on their market research. Contract prices exhibit more stability than spot prices. In 2007, the spot price rose to more than $88 per pound, while the weighted average short-, medium-, and long-term contract price was less than $25 per pound. In 2011, however, the spot price and weighted average price had converged to within $2 per pound, and in 2012 the spot price and weighted average price were within $5 per pound (EIA, 2013c). In 2013, the difference between the spot price and weighted average price increased again to approximately $10 per pound.

Table 2-8. Weighted-Average Price of Uranium Purchased by U.S. COOs Based on Contract Type

Delivery Year	Total Purchased	Spot Contracts	Short, Medium, and Long-Term Contracts
1994	10.40	9.01	NA
1995	11.25	10.30	NA
1996	14.12	14.22	NA
1997	12.88	11.61	NA
1998	12.14	10.56	NA
1999	11.63	9.52	NA
2000	11.04	8.54	11.70
2001	10.15	7.92	10.96
2002	10.36	9.29	10.58
2003	10.81	10.10	10.94
2004	12.61	14.77	12.24
2005	14.36	20.04	13.70
2006	18.61	39.48	16.38
2007	32.78	88.25	24.45
2008	45.88	66.95	41.59
2009	45.86	46.45	45.74
2010	49.29	43.99	50.43
2011	55.64	54.69	55.90
2012	54.99	51.04	55.65
2013	51.99	43.83	54.00

Sources: U.S. Energy Information Administration: 1994–2002-Uranium Industry Annual, Tables 10, 11, and 16. 2003–2013-Form EIA-858, “Uranium Marketing Annual Survey.”

2.5.5 Industry Trends

In March 2011, a massive earthquake and tsunami struck the coast of Japan, causing more than 20,000 deaths and leading to the Fukushima Daiichi nuclear power plant meltdown. The disaster was the largest of its kind since the Chernobyl accident in 1986. In the aftermath of the disaster, the viability and safety of nuclear power were questioned. The event led to a comprehensive examination of energy policies throughout the world. One year later, however, the EIA (2013b) reported that the nuclear power industry is in fact projected to expand, with greater safeguards being established to protect from future disasters (WNA, 2012b).

Worldwide, demand for uranium is projected to grow as nations such as China and India increase their use of nuclear power. Meanwhile, exploration for new sources of uranium is ongoing, both in the United States and elsewhere. Several years ago, the U.S. Nuclear Waste Technical Review Board (U.S. NWTRB, 2010) examined the supply and demand for uranium, and noted that 2009 uranium resources were sufficient to meet 2009 levels of demand for 90 years. The overall impact on future uranium prices depends on whether demand for uranium or supply of uranium grows more rapidly.

The largest uranium producers globally are Kazakhstan (36%), Canada (17%), and Australia (11%) (WNA, 2012d). The United States accounts for close to 3% of world production.

2.5.6 Projections

The EIA, in its 2014 Annual Energy Outlook (EIA, 2014a), provides projections about energy production and use through the year 2040, under a variety of assumptions about economic growth and other future conditions. In its reference case projections, EIA projects that energy supplied from uranium will grow over the period 2011 to 2040 from 8.26 quadrillion Btu to 8.49 quadrillion Btu, a rate of growth of approximately 0.2% per year. Applying the reference case rate of growth to 2012 uranium purchases, projected 2040 uranium purchases by COOs would be approximately 65 million pounds. As noted above, increasing demand for uranium from China and other countries is expected over the long term, in spite of recent developments such as the Fukushima tsunami and the global economic downturn. Similarly, the price of uranium is projected to increase over the next few years as demand increases and the Megatons to Megawatts program ends. Under the Megatons to Megawatts program, a 20-year agreement between USEC (representing the United States government) and Techsnabexport (TENEX, representing the Russian government), weapons-grade highly enriched uranium from Russian nuclear warheads (HEU) was processed and down-blended to low-enriched uranium and sold to USEC for use as nuclear fuel. On average, The Megatons to Megawatts program supplied about

13% of world uranium requirements during this period. The program ended in 2013. (See WNA, 2013 for more information.) Although a follow-on agreement with TENEX permits USEC to continue to purchase uranium from Russia, future uranium purchased will be from conventional supplies and the expected quantity will be smaller. Assuming that the global economy recovers from its recession and planned nuclear energy projects go forward, demand for uranium is projected to increase, while supplies may lag (although uranium reserves are estimated to be ample to meet projected needs, they will need to be extracted and processed to supply the market, and development and production has slowed during 2011 to 2012). Longer term, the price is projected to increase. The Australian Bureau of Research and Energy Economics, cited by the Australian Uranium Association, projects the price of uranium to rise to about $64 per pound by 2018 (Australian Uranium Association, 2013) . If either the recovery from the global recession lags or excess demand for uranium is slower to develop, these prices might not be realized by 2018, but they do represent likely levels going forward.

Section 3

THE PROPOSED RULE AND ITS ESTIMATED COSTS

EPA reviewed the existing regulations affecting ISR uranium projects and concluded that 40 CFR Part 192 should be amended to add a subpart F that specifically addresses groundwater protection at ISR operations, which are now the dominant form of uranium extraction in the United States. The ISR process presents different environmental concerns than conventional milling; ISR does not result in large volumes of waste materials or the need for permanent impoundments. However, the process directly alters groundwater chemistry, posing the challenge of groundwater restoration and long-term stabilization after ISR operations end. In developing the proposed rule, EPA's objective was to provide long-lasting protection of groundwater aquifers surrounding ISR wellfields. EPA's proposed rule specifies how to determine pre-operational background conditions that will be used to set appropriate restoration goals, applicable standards, and alternative concentration limits. The proposed rule also provides specifications for long-term groundwater stability monitoring to ensure that ISR sites do not become a source of groundwater contamination after the operation is terminated. In addition, the proposed rule explicitly requires corrective action if monitoring reveals that constituents have left the exempted aquifer during operations or have become mobile again after restoration is complete.

3.1 Description of Proposed Regulation

EPA's proposed regulation includes provisions addressing three issues: pre-operational monitoring to establish baseline conditions, establishing and updating groundwater protection standards, and monitoring to demonstrate that the restored water quality is stable. Below, we describe these three aspects of the proposed rule. EPA considered several regulatory options before selecting its preferred approach to each issue.

3.1.1 Groundwater Protection Standards

EPA's proposed rule identifies the minimum 13 constituents for which groundwater protection standards must be met: arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, nitrate (as N), molybdenum, combined radium-226 and radium-228, uranium (total), and gross alpha-particle activity (excluding radon and uranium). The concentration of each listed constituent must remain at or below the most protective standards under the Safe Drinking Water Act (SDWA), values from Resource Conservation and Recovery Act (RCRA) standards, or Table 1 to subpart A of Part 192, except in cases where the measured pre-operational wellfield background concentration (commonly referred to in the industry as “baseline”) is higher than the most stringent value in the applicable regulations. In such cases, the measured background concentration will serve as the restoration goal. The proposed language allows for the regulatory agency to set standards for additional constituents as necessary, consistent with site conditions, and provides clarity and consistency by referring to existing standards under each act at the time of licensing. Under the proposed rule, Subpart F standards would automatically update if any of the referenced standards (SDWA or RCRA) were revised (see Table 3-1).

Table 3-1. Table 1 to Subpart F of Part 192—Maximum Concentration of Constituents for Groundwater Protection at ISR Facility Sites

Constituent	Maximum
Arsenic	The restoration goal is the primary or secondary MCL listed in 40 CFR 141.61, 141.62, 141.66, 141.80, and 143.3, the maximum concentration of hazardous constituents for groundwater protection under 264.94, or the maximum constituent concentration specified in Table 1 to subpart A of this Part, whichever is most stringent. Where a background concentration is determined to be higher, the background concentration will serve as the restoration goal.
Barium	
Cadmium	
Chromium	
Lead	
Mercury	
Selenium	
Silver	
Nitrate (as N)	
Molybdenum	
Radium-226 and radium-228 (combined)	
Uranium (total)	
Gross alpha particle activity (excluding radon and uranium)	

3.1.2 Monitoring Requirements

To ensure that groundwater in the vicinity of ISR operations is protected, EPA’s proposed rule specifies groundwater monitoring requirements for each phase of the ISR operation.

3.1.2.1 Pre-operational Monitoring: Adequate Characterization of Groundwater Prior to Uranium Recovery

EPA’s proposed rule specifies requirements for thorough pre-operational monitoring at ISR sites. This monitoring serves several purposes. To design and operate an ISR facility, the chemical composition and hydrology of the groundwater in and around the ore body must first be rigorously characterized. Defining the configuration of the ore zone and designing the production zone for uranium recovery require detailed subsurface information obtained from geophysical investigations, including but not limited to logs and cores (U.S. EPA, 2013). In addition, the groundwater in the production zone is also characterized to determine the proposed chemical composition of the lixiviant and to determine pre-operational groundwater chemistry by which to set restoration goals for the post-production phase of the ISR operation (i.e., the efforts to return the groundwater chemical conditions in the production zone to those that existed prior to the uranium recovery efforts). EPA's proposed rule requires:

- A sufficient number of wells, at appropriate locations and depths, to be installed in such a manner as to yield representative samples in order to define the groundwater flow regime and measure pre-operational hydrogeochemical conditions and water quality for use in statistical tests during licensing, operations, restoration, stability, and long-term stability.
- The pre-operational background monitoring effort must include immediately overlying aquifers, immediately underlying aquifers, and background monitoring inside and outside of the exempted aquifer, including both the up- and down-gradient areas outside of the production zone.
- During the monitoring effort, relevant data documenting geology, hydrology, and geochemistry for radiological and nonradiological constituents shall be collected, both in the production zone and in surrounding areas that may be affected by the ISR operations.
  - The monitoring effort must be of sufficient duration of no less than 1 year and of sufficient scope to adequately characterize temporal and spatial variations in groundwater and to account for impacts of well installation and development on background concentrations of constituents and values of indicator parameters, where applicable.
  - Pre-operational monitoring must be focused on determining background concentrations of constituents and indicator parameters in point of compliance wells within the proposed production zone, in immediately overlying and immediately underlying aquifers, and outside the production zone, in wells within the exempted aquifer and in up-gradient and down-gradient wells within non-exempt portions of the adjacent aquifer.
  - The owner/operator must employ appropriate statistical techniques to analyze background concentrations measured in individual wells within the proposed production zone for the purpose of determining restoration goals for groundwater restoration and long-term stability. As determined by the owner/operator and approved by the regulatory agency, background concentration limits may be representative of individual wells, multiple wells, or all wells within the proposed production zone.

3.1.2.2 Operational Phase Monitoring

The proposed rule requires monitoring during the operational phase to detect excursions. The rule calls for monitoring of indicator parameters in horizontal and vertical monitoring wells. If an excursion is detected, corrective action must be undertaken and all constituents listed in Table 3-1 must be monitored until the excursion is controlled.

3.1.2.3 Restoration Phase Monitoring

During the active restoration phase, all constituents listed in Table 1 of this subpart or otherwise specified by the regulatory agency must be monitored through quarterly sampling or other time interval specified by the regulatory agency. Indicator parameters must be monitored in horizontal and vertical excursion wells. If an excursion is detected, corrective action must be undertaken, and all constituents listed in Table 3-1 must be monitored until the excursion is controlled.

3.1.2.4 Stability Phase Monitoring

The proposed rule requires that constituents be monitored throughout the stability phase of an ISR facility in points of compliance wells in the production zone, as determined by the regulatory agency, including

- all constituents listed in Table 1 of the new subpart and
- any additional constituents required by the regulatory agency, such as constituents and parameters necessary for geochemical calculations of the groundwater chemistry in order to demonstrate that a stable groundwater chemistry has been achieved after restoration; components of the lixiviant fluids injected during uranium recovery and any fluids injected during restoration; or metals potentially mobilized by the uranium recovery process.

The owner/operator must collect sufficient data and apply appropriate statistical methods to demonstrate that the aquifer conditions within the production zone are stable (i.e., there are no temporal trends in the constituent concentration data considering natural variation in compositions). Stability must be demonstrated for 3 consecutive years at a 95% confidence level and based on sampling no less frequently than quarterly.

If the owner/operator demonstrates 3 consecutive years of stable concentrations of constituents but is unable to meet the restoration goal for one or more of these constituents, the owner/operator may request an alternate concentration limit (ACL) from the regulatory agency. The regulatory agency may then approve an ACL or it may require that the owner/operator resume active restoration efforts in an attempt to bring down the constituent concentrations.

3.1.2.5 Long-Term Stability Phase Monitoring

After stability has been demonstrated, EPA's proposed rule requires that owner/operators continue quarterly monitoring to ensure that groundwater conditions remain stable.

The proposed rule requires long-term stability monitoring to be maintained for a period of 30 years. The regulatory agency may shorten the long-term stability monitoring period if, after stability is documented for a period of 3 consecutive years, the owner/operator demonstrates through hydrogeological and geochemical modeling of the site that the subsurface conditions within the production zone will remain stable into the future. In evaluating such modeling, the regulatory agency must determine that there is a reasonable expectation that restoration goals will not be exceeded and that subsurface conditions in the future will not cause the remobilization of uranium, radium, or other constituents into the groundwater and their migration beyond the boundaries of the production zone. The owner/operator must notify the regulatory agency and undertake corrective actions if, during the course of long-term stability monitoring, one or more monitored groundwater constituents exceeds a groundwater protection standard or shows statistically significant increasing trends that would threaten groundwater quality if left unabated. The proposed rule also specifies the components of a corrective action program.

3.1.3 Other Regulatory Alternatives for Long-Term Monitoring Considered but Rejected

EPA also considered two additional regulatory alternatives:

- Requiring long-term stability monitoring to continue for 30 years without the opportunity to use hydrogeological and geochemical modeling to shorten the monitoring period. This alternative was not selected for proposal because EPA felt it was unnecessarily burdensome, because modeling may be able to demonstrate that geochemical mechanisms exist to prevent uranium and other constituents from remobilizing and migrating beyond the boundaries of the production zone. In addition, while monitoring for 30 years would enable a determination about whether the wellfield chemistry is remaining stable over a longer period of time, it does not provide any assurance that the groundwater will remain stable after 30 years, such as geochemical modeling may be able to do.

- Using a narrative long-term stability monitoring standard, with no fixed duration. EPA chose not to propose this regulatory alternative because statistical analyses alone would provide no assurance that groundwater systems will remain chemically stable over a longer period of time. In addition to being somewhat ambiguous, a narrative standard poses a higher risk of prematurely terminating the license.

This analysis examines the costs of complying with the proposed rule and the costs of complying with the required 30-year long-term stability regulatory alternative. In addition, EPA recognizes that it is possible that geochemical modeling may demonstrate that geological conditions in and around the wellfield may not ensure long-term stability; in this case, if operations have begun at the ISR facility, EPA expects that the regulatory agency would require 30 years of long-term stability monitoring to ensure that conditions are stable within the wellfield. EPA also estimated the cost of geochemical modeling, followed by an extended 30-year period of long-term stability monitoring.

3.2 Estimated Incremental Costs of Compliance with Proposed Rule

EPA reviewed the existing regulations affecting ISR facilities and concluded that 40 CFR Part 192 should be amended to add a subpart F that specifically addresses groundwater protection at ISR operations, which are now the dominant form of uranium extraction in the United States. The ISR process directly alters groundwater chemistry, posing the challenge of groundwater restoration and long-term stabilization after ISR operations end. EPA is evaluating the range of cost estimates associated with proposed groundwater monitoring options. The current costs associated with groundwater monitoring at ISR facilities under the existing regulatory scheme were calculated and then compared against three groundwater monitoring scenarios that implement alternative groundwater monitoring approaches proposed by the regulation:[7]

- 30-year post-restoration stability monitoring with option to reduce monitoring duration using hydrogeological and geochemical modeling
- 30-year post-restoration stability monitoring with no option for shortening the duration

In addition, costs were considered for a third monitoring scenario that is not a regulatory option but rather a worst case scenario for an owner/operator under the proposed regulatory approach:

- Geochemical modeling followed by 30 years of required stability monitoring

EPA does not consider that this worst-case scenario is likely to occur. The proposed regulatory approach requires thorough characterization of hydrogeochemical conditions within the production zone and down-gradient during the pre-operational phase. EPA expects that, if the conditions are found to be insufficiently reducing (so that any constituents carried down-gradient

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[7] Throughout the document, the cost estimates are labeled based on the long-term stability monitoring phase requirements for convenience. As shown below in Tables 3-2 through 3-7, requirements and estimated costs for other phases also differ among alternatives and between alternatives and current practice.

by groundwater would not be stabilized there), the owner-operator might decide not to develop the deposit and the licensing agency would likely not grant the license. This worst-case scenario would only occur if the sampling and geochemical modeling conducted after operations are complete gives a negative signal, after geochemical modeling during pre-operations signaled that development would be safe. Thus, this worst case likely overestimates the costs that a site would incur. Because EPA regards this worst case as unlikely, and because it does not represent a regulatory alternative, EPA presents the estimated impacts under the worst case scenario only in Appendix D.

A third regulatory alternative was considered by EPA but not analyzed in this economic analysis. EPA also considered a narrative standard with no fixed monitoring period. The actual compliance activities that might be required under this alternative would depend entirely on negotiations between the owner/operator and the licensing agency. Because they would be site specific and thus uncertain, EPA concluded that it would not be possible to assess what the compliance requirements and associated costs for a given facility would be. For this reason, although EPA considered this regulatory approach, its costs and impacts are not analyzed in this document.

Although the above scenarios address proposed monitoring requirements during the stability monitoring phase, these changes also affect the numbers of wells and analytical constituents that must be monitored during earlier phases of an ISR project. These costs have also been estimated as they relate to each of the scenarios.

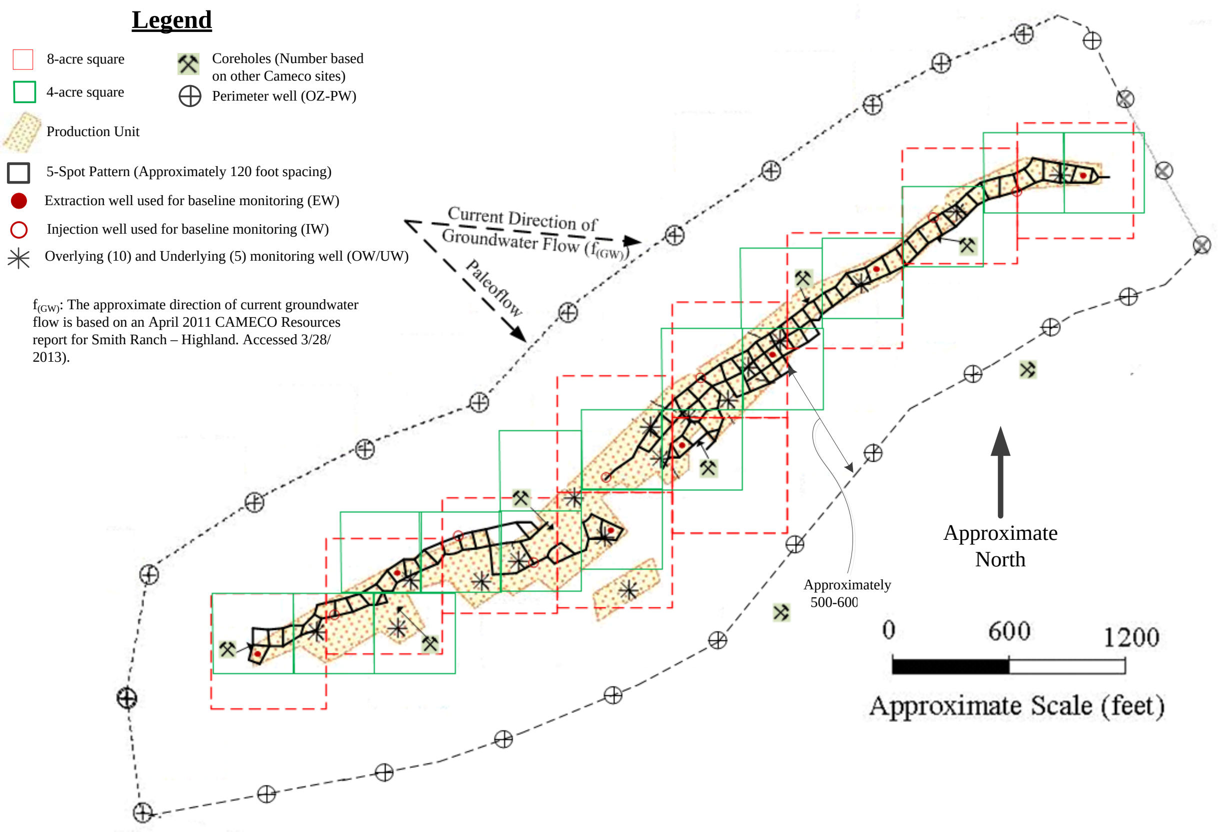
3.2.1 Technical Approach: Conceptual Site Model Facility

A conceptual model was used to help frame the costs for each of these scenarios that are described below. The design of one production unit and the hydrogeology of the associated 50-sand ore bearing layer within Wellfield-E at the Highland Site in Wyoming were used as a basis for constructing the CMU model. The CMU model (Figure 3-1) was developed based on the actual design of the Wellfield-E production and mine units (Cameco Resources, 2008) but also considering standard wellfield design practice (NRC, 2003). The conceptual model was used as a basis for developing the costing scenarios. A general layout of the CMU model for the different scenarios showing the well locations is provided in Figures 3-1 and 3-2.

3.2.1.1 Conceptual Mine Unit (CMU) Model Description

The CMU area, inside the perimeter monitoring well ring, is approximately 200 acres with a 44-acre production area. Approximately 243 wells (166 injection and 77 extraction wells) were assumed for the production area of the CMU model. This assumes that a 5-spot pattern was used for the wellfield grid with a well spacing of approximately 120 feet, which is similar to the design of the production units in Wellfield-E. A distance of approximately 600 feet from the edge of the production unit was used to locate the perimeter-well ring. This was consistent with the configuration and design of Wellfield-E. The spacing of perimeter wells was also patterned after the Wellfield-E design.

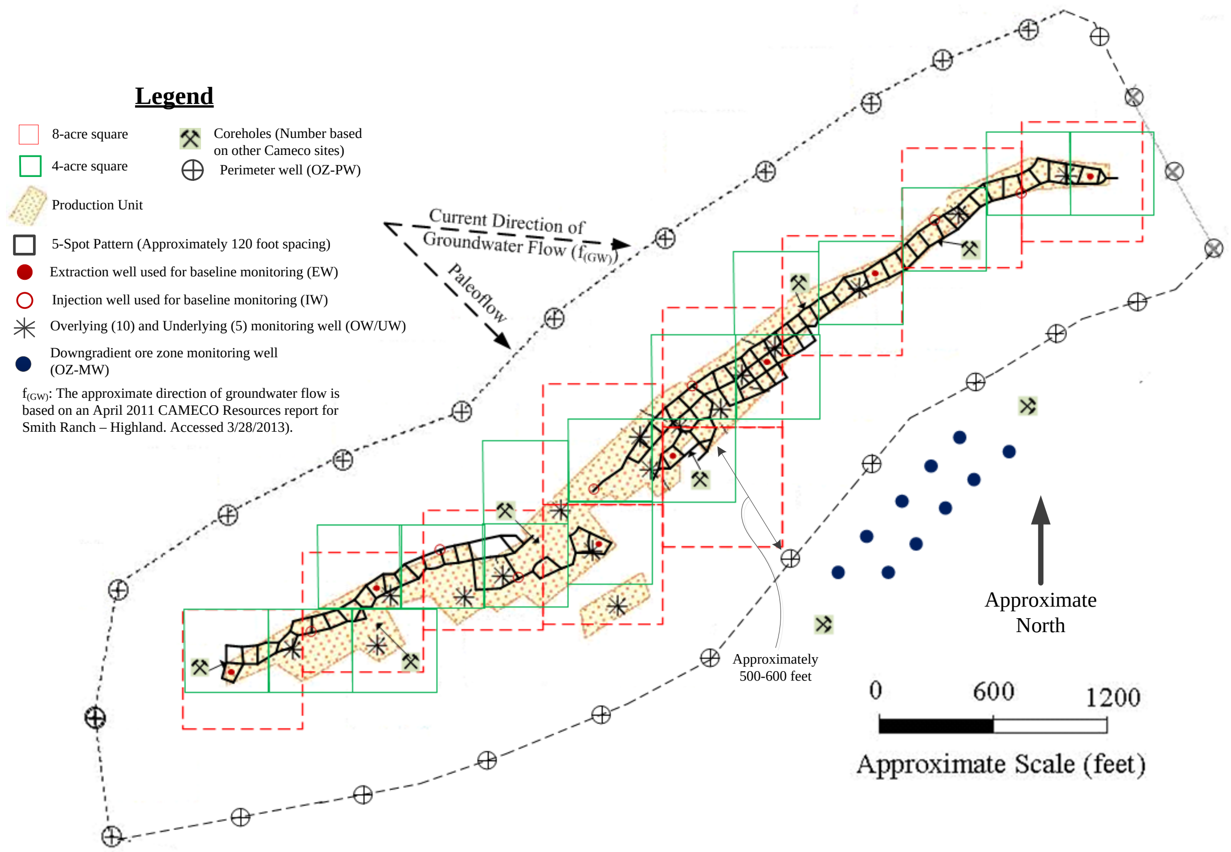
Figure 3-1. ISL/ISR Conceptual Site Model Applicable to Current Practice and 30-Year Monitoring



Note: Site model is loosely based on actual conditions for one production area within Wellfield E of the Highland Ranch site. Configuration of the perimeter well ring has been adjusted.

Sandstone aquifers were assumed to be overlying and underlying the ore zone (also sandstone) aquifer. For simplicity of modeling, it was assumed that laterally continuous shale beds served to hydraulically separate the aquifers from the consolidated ore sand. Such a stratigraphy is typical of ISR situations. The ore zone sandstone layer was assumed to have an average thickness of approximately 35 feet with an average base-of-bed depth of about 600 feet. The overlying aquifer base-of-bed average depth is approximately 490 feet below ground surface, and the underlying aquifer top-of-bed depth is approximately 650 feet below land surface. These depths are roughly similar to the Highland site geology (Michel and Hoffman, 1991). The 60-sand and 40-sand aquifers, overlying and underlying the 50-sand aquifer unit, respectively, are also ore sand layers at the Highland site, and production units for one or both of these sands are co-located within the boundaries of and near Wellfield-E; however, operational strategy that may be used when mine units are co-located was not considered in the CMU model or modeled scenarios because these considerations would make the model very site specific, and a more generalized model of an ISR wellfield was needed. The concept of these scenario analyses was to make assessments of a generic nature but framed within the bounds of characteristics associated with actual sites. In practice, the size of the prospective ore zone and the configuration of the production wells will be determined by site-specific conditions.

Figure 3-2. ISL/ISR Conceptual Site Model Applicable to Geochemical Modeling Scenario



Note: Site model is loosely based on actual conditions for one production area within Wellfield E of the Highland Ranch site. Configuration of the perimeter well ring has been adjusted and ore zone monitoring wells have been added down-gradient.

Assumptions used for evaluating groundwater monitoring costs included:

- the number of wells to be sampled
- the duration of the period of sampling (or operation phase)
- the sampling frequency (i.e., weekly, biweekly, monthly, quarterly) and
- the list of parameters that must be sampled.

The duration of groundwater stability monitoring would in reality be site specific and is typically specified in the license(s) (U.S. EPA, 2012a); however, past and current practice assumed a monitoring and sampling period between 6 months and approximately 2 years. Typically one injection, extraction, or other ore zone well is monitored per acre of the production unit along with the perimeter monitoring wells surrounding the mining unit. Additional monitoring wells were also assumed for other ISR phases for the geochemical modeling scenario, which assumes that additional geochemical characterization would be needed. Samples are generally collected on at least a quarterly basis during the stability phase for the same analytes that were sampled during baseline monitoring. The specific lists of chemical analytes that operators sample are those specified in the NRC's ISR Standard Review Plan (NRC, 2003) along with analytes required by regulating state agencies. Stability sampling would be extended to a minimum of 30 years under the proposed rule unless it could be demonstrated using appropriate geostatistical tests, and a minimum of 3 years of stability monitoring data, that the groundwater chemistry has reached baseline levels (or other regulatory supported groundwater quality standards) and is stable at those levels for at least 3 years. Geochemical testing and monitoring would also be required by the proposed rule to further demonstrate and ensure long-term stability of groundwater quality in and around the wellfield. A demonstration of geochemical stability based on monitoring data and a geochemical model would allow the regulator to require less than a 30-year post-restoration monitoring period. In this analysis of the proposed rule, EPA assumes that the long-term stability monitoring phase is reduced to 7 years. During the restoration phase, groundwater chemical compositions are also monitored to follow the course of the restoration effort and identify when constituents of particular interest appear to be reaching a relatively constant level. At that point the restoration effort may be ending and stability phase monitoring may be appropriate.

Tables 3-2 through 3-6 summarize specific assumptions about the CMU configuration used in estimating the costs for each proposed groundwater monitoring scenario considered. The number of wells that are sampled during each operational phase (i.e., pre-operational, operations, restoration, stability, and long-term stability monitoring) is assumed to vary among scenarios as indicated in the tables. These numbers were selected based on professional judgment about the data needs for each of the scenarios examined. The total number of wells also varies for each groundwater monitoring scenario. Unit costs assumed for construction of a well are summarized in Appendix A.

The assumed numbers of wells, duration, and frequency of groundwater monitoring were combined with the analytical costs for the required parameter lists and the cost for groundwater sample collection, as summarized in Appendix B (Sampling and Analysis Unit Costs), to calculate the groundwater monitoring costs by operational phase under

- current practice (Table 3-2),
- 30-year long-term stability monitoring with potential to shorten based on geochemical modeling (Table 3-3), and
- 30-year long-term stability monitoring with no potential to shorten (Table 3-4).[8]

As shown in Table 3-2, under current practice, pre-operational monitoring was assumed to last for 1 year, sampling from 85 wells for constituents required by the NRC and by Agreement States. In contrast, under the regulatory alternatives examined in both Tables 3-3 and 3-4, samples are drawn from 100 wells, and the full suite of constituents is analyzed. In addition, under the proposed rule (30 years long-term stability monitoring with potential to shorten using geochemical modeling), we assumed that 10 additional wells, located down-gradient from the wellfield, are also sampled to gather data on the geochemistry of the groundwater in that area for use in modeling (for a total of 110 wells in Table 3-3). During operations under current practice, we assumed that 41 wells are sampled; under the proposed rule, we assumed that 56 wells are sampled, including 15 additional vertical excursion wells. ISR extraction operations were assumed to last for 6 years. The 6-year duration is consistent with the range of times seen at ISR sites; actual duration of uranium extraction depends on site-specific conditions. After extraction operations end, the facility is assumed to begin restoration of groundwater to pre-operational characteristics. This process involves flushing the production area with clean water (the extracted water is often processed by reverse osmosis techniques before the water is reinjected to continue

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[8] EPA also analyzed the costs that might be incurred if geochemical modeling failed to demonstrate conditions favorable for long-term stability. These costs combine the costs estimated for the proposed rule under Phases 1 through 4 and the costs of Phase 5 (long-term stability monitoring) estimated for the 30-year long-term stability monitoring alternative.

Table 3-2. ISR Conceptual Mine Unit: Current Practice

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	Frequency		Average	Low	Median	High
Phase 1: Pre-operations								
1 extraction/injection wells (EW/IW) (1 well per acre)	44	1 year	Quarterly (4 events)	NRC and state	200	160	198	247
Down gradient ore zone monitoring wells (OZ-MW)	0				0	0	0	0
All perimeter ore zone wells (OZ-PW)	26				118	95	117	146
All vertical excursion wells (OW/UW)	15				68	55	68	84
Total wells sampled	85				386	309	383	478
Phase 2: Operations								
All perimeter ore zone wells (OZ-PW)	26	6 years	Biweekly (156 events)	Indicator parameters	2,327	2,137	2,293	2,587
Vertical excursion wells (Overlying/underlying wells: OW/UW)	15				1,343	1,233	1,323	1,493
Total wells sampled	41	6			3,670	3,370	3,616	4,080
Phase 3: Restoration (or compliance monitoring)								
All extraction wells (EW)	77	2 years	Quarterly (8 events)	Indicator parameters	353	325	348	393
Down-gradient perimeter wells (OZ-PW)	6				28	25	27	31

(continued)

Table 3-2. ISR Conceptual Mine Unit: Current Practice (continued)

		Sampling			Parameter Analysis Cost (Thousand $2011)			
Well Type	**Numbers of Wells**	**Period**	**Frequency**	**Parameters**	**Average**	**Low**	**Median**	**High**
Down-gradient ore zone monitoring wells (OZ-MW)	0				0	0	0	0
Total wells sampled	83				381	350	375	424
Phase 4: Stability (or post-restoration)								
All extraction wells (EW)	77	6 months	Quarterly (2 events)	NRC and state	175	140	173	216
Down-gradient perimeter wells (OZ-PW)	6				14	11	14	17
Monitoring wells (OZ-MW)	0				0	0	0	0
Total wells sampled	83				189	151	187	233
		Duration of Activities	**Total Number of Sampling Events**					
		9.5 years	170	Total costs:	4,626	4,180	4,562	5,213

Note: The "Well Type," "Sampling Period," "Sampling Frequency," and "Parameters" criteria were based on discussions with the ISR project team during a phone conference on 3/26 and 4/16/2013. Total parameter costs include indirect labor, direct labor, travel, fee (8%), and contingency (10%).

[1] There are approximately 243 injection (166) and extraction (77) wells shown in the model production area.

[2] The "full suite" of chemical parameters includes EPA, NRC, and state required parameters. Based on parameter lists provided in the BID for Revision of 40 CFR Part 192, Revision 6, November 26, 2012. Indicator parameters are Alkalinity, Conductivity, TDS, Chloride, Uranium, and Radium 226 and Radium 228.

[3] Range for duration of operations provided by EPA as documented during WA 2-04, Task 2B (contract No. EP-D-10-042).

Table 3-3. ISR Conceptual Mine Unit: 30-Year Stability Shortened with Geochemical Modeling

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	Frequency		Average	Low	Median	High
Phase I: Pre-operations								
Extraction/injection wells (EW/IW) (1 well per acre)	44	1 year	Quarterly (4 events)	Full suite plus geochemical parameters and modeling	253	205	250	312
Down-gradient ore zone monitoring wells (OZ-MW)	10				58	47	57	71
All perimeter ore zone wells (OZ-PW)	26				150	121	148	184
All vertical excursion wells (OW/UW)	30				173	140	170	213
Total wells sampled	110				633	512	625	781
Phase 2: Operations								
All perimeter ore zone wells (OZ-PW)	26	6 years	Biweekly (156 events)	Indicator parameters	2,327	2,137	2,293	2,587
Vertical excursion wells (Overlying/underlying wells: OW/UW)	30				2,685	2,466	2,646	2,986
Total wells sampled	56				5,013	4,603	4,940	5,573
Phase 3: Restoration								
All extraction wells (EW)	77	2 years	Quarterly (8 events)	Indicator parameters	353	325	348	393
Down-gradient perimeter wells (OZ-PW)	6				28	25	27	31

(continued)

Table 3-3. ISR Conceptual Mine Unit: 30-Year Stability Shortened with Geochemical Modeling (continued)

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	Frequency		Average	Low	Median	High
Down-gradient ore zone monitoring wells (OZ-MW)	10				46	42	45	51
Total wells sampled	93				427	392	421	475
Phase 4: Stability								
All production unit wells (IW/EW)	77	3 years	Quarterly (12 events)	Full suite plus geochemical parameters	1,330	1,075	1,312	1,639
All perimeter ore zone wells (OZ-PW)	26			Indicator Parameters	242	196	239	298
All vertical excursion wells (OW/UW)	30			Indicator Parameters	403	326	398	497
Total wells sampled	133				1,716	1,430	1,692	2,068
Phase 5: Long-Term Stability								
All extraction wells (EW)	77	7 years	Quarterly (28 events)	Full suite plus geochemical parameters and modeling	3,105	2,509	3,062	3,825
Down-gradient perimeter wells (OZ-PW)	6				242	196	239	298
Monitoring wells (OZ-MW)	10				403	326	398	497
Total wells sampled	93				3,750	3,031	3,698	4,619

(continued)

Table 3-3. ISR Conceptual Mine Unit: 30-Year Stability Shortened with Geochemical Modeling (continued)

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	Frequency		Average	Low	Median	High
		Duration of Activities	**Total Number of Sampling Events**					
		19 years	208	Total Costs:	11,539	9,968	11,375	13,515

Note: The “Well Type,” “Sampling Period,” “Sampling Frequency,” and “Parameters” criteria were based on discussions with the ISR project team during a phone conference on 3/26 and 4/16/2013. Total parameter costs include indirect labor, direct labor, travel, fee (8%), and contingency (10%).

[1] There are approximately 243 injection (166) and extraction (77) wells shown in the model production area.

[2] The “full suite” of chemical parameters includes EPA, NRC, state, and additional parameters needed for geochemical modeling. Based on parameter lists provided in the BID for Revision of 40 CFR Part 192, Revision 6, November 26, 2012. Indicator Parameters are Alkalinity, Conductivity, TDS, Chloride, Uranium, and Radium 226 and Radium 228.

[3] Range for duration of operations provided by EPA as documented during WA 2-04, Task 2B (contract No. EP-D-10-042).

Table 3-4. ISR Conceptual Mine Unit: 30-Year Stability with No Provision to Shorten

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	Frequency		Average	Low	Median	High
Phase I: Pre-operations								
1 Extraction/injection wells (EW/IW) (1 well per acre)	44	1 year	Quarterly (4 events)	Full suite	227	182	225	281
Down-gradient ore zone monitoring wells (OZ-MW)	0				0	0	0	0
All perimeter ore zone wells (OZ-PW)	26				134	107	133	166
All vertical excursion wells (OW/UW)	30				155	124	153	191
Total wells sampled	100				516	413	512	638
Phase 2: Operations								
All perimeter ore zone wells (OZ-PW)	26	6 years	Biweekly (156 events)	Indicator parameters	2,327	2,137	2,293	2,587
Vertical excursion wells (Overlying/Underlying wells: OW/UW)	30				2,685	2,466	2,646	2,986
Total wells sampled	56				5,013	4,603	4,940	5,573
Phase 3: Restoration (or Compliance Monitoring)								
All extraction wells (EW)	77	2 years	Quarterly (8 events)	Indicator parameters	353	325	348	393
Down-gradient perimeter wells (OZ-PW)	6				28	25	27	31

(continued)

Table 3-4. ISR Conceptual Mine Unit: 30-Year Stability with No Provision to Shorten (continued)

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	Frequency		Average	Low	Median	High
Down-gradient ore zone monitoring wells (OZ-MW)	0				0	0	0	0
Total wells sampled	83				381	350	375	424
Phase 4: Stability (Post-restoration)								
All production unit wells (IW/EW)	77	3 years	Quarterly (12 events)	Full suite	1,110	954	1,182	1,387
All perimeter ore zone wells (OZ-PW)	26			Indicator parameters	179	164	176	199
All vertical excursion wells (OW/UW)	30			Indicator parameters	207	190	204	230
Total wells sampled	133				1,495	1,308	1,562	1,816
Phase 5: Long-Term Stability								
All extraction wells (EW)	77	30 years	Quarterly (120 events)	Full suite	11,910	9,535	11,818	14,728
Down-gradient perimeter wells (OZ-PW)	6				928	743	921	1,148
Monitoring wells (OZ-MW)	0				0	0	0	0
Total wells sampled	83				12,838	10,278	12,739	15,876

(continued)

Table 3-4. ISR Conceptual Mine Unit: 30-Year Stability with No Provision to Shorten (continued)

Well Type	Numbers of Wells	Sampling		Parameters	Parameter Analysis Cost (Thousand $2011)			
		Period	**Frequency**		**Average**	**Low**	**Median**	**High**
		Duration of Activities	**Total Number of Sampling Events**					
		42 years	300	Total Costs	20,243	16,952	20,128	24,325

Note: The “Well Type,” “Sampling Period,” “Sampling Frequency,” and “Parameters” criteria were based on discussions with the ISR project team during a phone conference on 3/26 and 4/16/2013. Total parameter costs include indirect labor, direct labor, travel, fee (8%), and contingency (10%).

[1] There are approximately 243 injection (166) and extraction (77) wells shown in the model production area.

[2] The “full suite” of chemical parameters includes EPA, NRC, and state required parameters. Based on parameter lists provided in the BID for Revision of 40 CFR Part 192, Revision 6, November 26, 2012. Indicator parameters are Alkalinity, Conductivity, TDS, Chloride, Uranium, and Radium 226 and Radium 228.

[3] Range for duration of operations provided by EPA as documented during WA 2-04, Task 2B (contract No. EP-D-10-042).

the restoration process) and frequently introducing reducing agents to attempt to recreate the conditions that caused the deposit to form in the first place. Under all scenarios, wellfield restoration is assumed to last 2 years. Under current practice and under the 30-year alternative, 83 wells are sampled for the purpose of obtaining data needed to construct a geochemical model of the groundwater chemistry. Under the proposed rule, 10 additional down-gradient ore zone monitoring wells are sampled for the purpose of constructing a geochemical model. Thus, during pre-operations, operations, and restoration, EPA's costing assumptions result in somewhat higher costs under the proposed rule than would be incurred under current practice.

The major differences between current practice and the regulatory alternatives that were considered occur after restoration is assumed to be completed. Under current practice, facilities typically monitor conditions for 6 months to 2 years (we assumed 6 months), before decommissioning the wellfield and petitioning to have their license terminated. As discussed above, examination of the data has led EPA to conclude that this may not be a sufficiently long period of time to ensure that, as natural oxygenated groundwater begins to infiltrate the wellfield, uranium, radium, and other constituents may not remobilize. Thus, the two regulatory alternatives examined incorporate a considerably longer period of post-restoration stability monitoring. Initially, EPA's proposed rule requires that sufficient data be collected to demonstrate with 95% confidence that conditions are stable for a period of at least 3 years. The data required would depend on site-specific conditions; based on the model site, EPA has assumed for the purposes of estimating costs that monitoring all production wells for the full suite of constituents and monitoring perimeter and vertical excursion wells for indicator parameters, on a quarterly basis for 3 years, would develop enough information to provide a 95% level of confidence that conditions are stable. Finally, both regulatory alternatives specify a period of long-term stability monitoring to ensure that conditions remain stable. Under the proposed rule, facilities have the option of reducing the 30-year long-term stability monitoring period by demonstrating through sampling and hydrogeochemical modeling that conditions down-gradient are sufficiently reducing that any constituents remobilized would be trapped down-gradient, preventing widespread contamination beyond the production zone. In the analysis, EPA assumes that this period of sampling and modeling (the long-term stability monitoring period) lasts for 7 years.[9] In practice, this period may be longer or shorter depending on the natural variation observed in the monitoring data collected over that period and during the

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[9] The assumption was made based on EPA's professional judgment that 7 years represents a reasonable mid-range value, because EPA has reviewed at least one case study showing that monitoring with geochemical modeling at an ISR site has taken 15 years.

preceding stability phase monitoring. The larger the natural variation observed, the longer it would take to demonstrate that temporal trending is not present in the data. Under the other regulatory alternative, facilities would be required to conduct long-term stability monitoring for a period of 30 years, with no possibility for shorting the duration. Thus, the capital and analysis costs are higher under the proposed rule (as shown in Table 3-5), but the duration is much longer under the 30-year alternative.

Table 3-5 summarizes the differences in anticipated costs by phase, comparing the estimated costs under current practice with the estimated costs of the regulatory option being proposed and for another regulatory option considered but not selected. Costs for each phase are estimated to be lower under current practice than under the regulatory alternatives. Post-restoration stability monitoring, in particular, is estimated to have higher annualized costs and longer duration under the regulatory alternatives relative to current practice. Comparing the regulatory alternatives to each other, annualized costs are estimated to be higher for the proposed rule, because it entails more wells and cores, geochemical modeling, and analyzing for more constituents. Only the operations phase has estimated costs that do not differ between the two alternatives. Although it does not appear in Table 3-5, the other difference between the two alternatives is that the selected alternative (30 years of long-term stability monitoring with the possibility to shorten the duration using geochemical modeling) is estimated to have a shorter duration than the alternative that was not selected (30 years of long-term stability monitoring with no potential to shorten the duration).

Table 3-5. ISR Conceptual Mine Unit: Annual Monitoring Cost by Scenario and Phase (Thousand $2011)

	Current Practice		
	Low	**Average**	**High**
Phase 1. Pre-operational	$309	$386	$478
Phase 2: Operations	$562	$612	$680
Phase 3. Restoration	$175	$191	$212
Phase 4. Stability	$151	$189	$233
	30-Year Stability with Geochemical Modeling		
Phase 1. Pre-operational	$512	$633	$781
Phase 2: Operations	$767	$835	$929
Phase 3. Restoration	$196	$213	$237
Phase 4: Stability	$477	$572	$689
Phase 5. Long-term stability	$433	$536	$660

(continued)

Table 3-5. ISR Conceptual Mine Unit: Annual Monitoring Cost by Scenario and Phase (Thousand $2011) (continued)

	Current Practice		
	Low	**Average**	**High**
	30-Year Stability with No Provision to Shorten		
Phase 1. Pre-operational	$413	$516	$638
Phase 2: Operations	$767	$835	$929
Phase 3. Restoration	$175	$191	$212
Phase 4: Stability	$436	$498	$605
Phase 5. Long-term stability	$343	$428	$529

3.2.1.2 Annualized Capital Costs and Incremental Costs of the Rule for the CMU

After the capital (well construction) and monitoring costs were estimated for the CMU under each regulatory alternative for each phase of ISR operations, the next step involves comparing the costs of each alternative with the costs incurred under current practice. To do this, EPA created a time series of monitoring costs under the current practice and under the three regulatory alternatives. EPA then annualized the capital cost under current practice and under the three regulatory alternatives, using a 7% interest rate and an assumed loan duration of 15 years (for current practice, which in our illustration is expected to have an overall duration of between 10 and 15 years) or 20 years (for all regulatory alternatives). In each year, total annualized costs of compliance are the sum of the monitoring cost for that year and the annualized capital cost estimated to be incurred in that year. To measure the cost impact of each regulatory alternative, EPA computed the incremental compliance cost by subtracting the costs of compliance under the regulatory alternative minus the costs that would be incurred absent the proposed rule. For each stream of costs, EPA computed the total sum across all years and the discounted present value of each stream of costs using a 3% and a 7% discount rate. Finally, to obtain a single annualized cost value for current practice and for each regulatory alternative, EPA annualized the costs using a 7% interest rate over a period of 42 years. This treats all the costs in an equivalent manner and provides a single uniform annualized value for the monitoring costs under each regulatory alternative, which can be added to the annualized capital cost to provide a total annualized value that is uniform across time. Table 3-6 shows the annual cost, the sum, and the discounted values under 3% and 7% discount rates for monitoring costs, capital costs, and incremental costs.

Table 3-6. ISR Conceptual Mine Unit: Annualized Monitoring and Capital Costs for Current Practice and Each Regulatory Scenario (Thousand $2011)

	With-Regulation Monitoring Costs				Annualized Well Costs				Incremental Total Annualized Costs by Scenario, Relative to Current Practice		
	Current Practice	**30 year, Geo-chemical Modeling**	**30-Year Long-Term Stability**	**Geo-chemical Modeling, Extended**	**Current Practice**	**30 year, Geo-chemical Modeling**	**30-Year Long-Term Stability**	**Geo-chemical Modeling, Extended**	**30 year, Geo-chemical Modeling**	**30-Year Long-Term Stability**	**Geo-chemical Modeling, Extended**
Summed cost	$4,626	$11,739	$20,243	$20,935	$8,418	$10,684	$10,522	$10,684	$9,379	$17,721	$20,935
NPV, 3%	$4,029	$9,087	$12,155	$12,703	$6,699	$7,947	$7,703	$7,947	$6,306	$9,130	$12,703
NPV, 7%	$3,396	$6,787	$7,487	$7,908	$5,111	$5,659	$5,429	$5,659	$3,939	$4,409	$7,908

Notes:

Capital costs are annualized as follows:
Current Practice capital costs are annualized at 7% over 15 years, reflecting assumption that operations at a site would last at most 15 years.
Geochemical capital costs are annualized at 7% over 20 years, consistent with expected life of capital equipment.
30-year capital costs are annualized at 7% over 20 years, with an assumed 10% of wells requiring replacement after 20 years.

Incremental total annualized costs subtract the estimated annualized monitoring and capital costs for each regulatory scenario minus the estimated annualized monitoring and capital costs under current practice.

3.3 Estimated National Costs of Proposed Rule

The final step in estimating the costs of the rule and evaluating how they compare with the costs of current practice requires extrapolating from the costs estimated for the CMU to estimated costs that apply to ISR facilities projected to exist in 2014. As mentioned in Section 2, above, six ISR facilities currently operate: La Palangana, Alta Mesa, Willow Creek (Christensen and Irigaray), Crow Butte, Lost Creek, and Smith Ranch-Highland-Reynolds. Several other ISR facilities are in various stages of licensing and are not in operation. The cast of ISR facilities in operation can be expected to vary over time, depending on uranium market conditions and how long it takes to extract the uranium from deposits at each facility. EPA has chosen to use the existing ISR operations in 2013 and the companies that own them as models for ISR facilities and owner companies likely to exist in the future and thus be affected by the proposed rule. EPA had some information about existing ISR facilities, but not sufficient information to estimate their costs on a facility-specific or wellfield-specific basis. Thus, it was necessary to extrapolate or scale up the costs estimated for the CMU to estimate costs that would be incurred by existing ISR facilities.

EPA examined three possible bases on which to extrapolate the CMU costs to estimate the costs that would be incurred at ISR facilities:

- facility capacity
- uranium production
- wellfield acreage

After considering these options, as described below, EPA determined that extrapolation based on wellfield acreage is the most reasonable basis.

Facility capacity is reported by the EIA in its Uranium Production Report, so it is available for all planned and actual ISR facilities. However, facility capacity is measured in terms of the production capacity of the processing plant. Although this may be correlated to the size and complexity of the wellfield, and thus to the capital and operating costs of monitoring, the link is not close and would not seem to provide a reliable method of scaling site-specific costs to nationwide estimates.

Uranium production at a particular facility may vary widely from year to year because of changing conditions in the uranium market or facility-specific factors. We do not, however, expect monitoring requirements or costs to vary significantly from year to year, although we recognize that they vary depending on the phase of the ISR operation.

Some correlation can generally be assumed between the size of the wellfield and the numbers of wells required for monitoring and, therefore, between the size of the wellfield and the corresponding well and groundwater sampling costs. Thus, EPA chose to use wellfield acreage as the basis on which to scale up costs from the CMU to the facility level. EPA obtained maps of wellfields or used available published information for the five existing ISR facilities to estimate the acreage of each wellfield. There is a large variation in the size of existing wellfields based on the information available from a variety of sources. Individual wellfield size for the sites considered ranges between approximately 7 acres and 750 acres. The total acreage of all the individual wellfields at each of the ISR sites considered is shown in Table 3-7.

The costs that would be incurred by each ISR facility under current practice and under each regulatory alternative were estimated based on the ratio of the ISR facility's total wellfield acreage to that of the CMU (see Table 3-7).

Table 3-7. Estimated Total Acreage of All Wellfields at ISR Sites

ISR Operation	Acres
La Palangana[a]	210
Alta Mesa	330
Willow Creek	409
Crow Butte	1,524
Smith Ranch-Highlands-Reynolds	6,582
Lost Creek	254
Conceptual model unit	202

[a] Palangana total acreage scaled up by 50% to estimate area including PAA3.

Note: Most site acreages computed using site map and planimeter.

Table 3-8 shows estimated costs for each of the ISR facilities, based on the total acreage of the wellfield at each facility. EPA recognizes that not all the wellfields at all facilities may be in the same phase of uranium recovery at a given time; some may be in a planning stage, others actively being mined, while others are undergoing restoration and still others may be decommissioned. To evaluate potential impacts based on a conservatively high range of costs, we estimated costs using 100% of wellfield acreage at each facility to analyze the economic impacts of the proposed rule; generally, this overstates annual costs. An uncertainty in this approach relates to the potential for ISR sites to contain multiple ore zones within the same surface area (i.e., ore bodies located at different depths and separated by isolating beds), thereby allowing sequential uranium recovery within the same surface footprint. In that situation, acreage would not be as closely correlated with costs of complying with the rule. Facility-level incremental total annualized costs are estimated to range from $304,000 to $9.52 million[10] under the proposed rule (30-year with geochemical shortening option), and from $340,000 to $10.7 million under the required 30-year monitoring option, when costs are calculated based on the entire wellfield acreage. Facility-level incremental total annualized costs were also estimated for the worst case scenario, under the proposed regulatory approach, to be from $390,000 to $12.2 million with the failure of geochemical modeling to predict a stabilized condition in the wellfield then requiring 30-years of long-term monitoring.

Table 3-8. Total Average Annualized Incremental Costs for Individual ISR Operations (Thousand 2011$)

Regulatory Scenario	30 year, Geochemical Modeling to Shorten	30 Years, No Shortening	Geochemical Modeling, Extended
Cost per acre	$1.45	$1.62	$1.86
ISR operation			
La Palangana	$304	$340	$390
Alta Mesa	$477	$534	$613
Willow Creek	$591	$661	$759
Crow Butte	$2,205	$2,468	$2,832
Smith Ranch-Highland-Reynolds	$9,521	$10,657	$12,229
Lost Creek	$367	$411	$472
National Cost	$13,465	$15,072	$17,296

National costs computed using this assumption are $13.5 million for the proposed rule, 30 years with geochemical modeling, and $15.1 million under the 30-year long-term stability monitoring alternative. Under the scenario where geochemical modeling is followed by 30 years of long-term stability monitoring, average national total annualized costs are estimated to be $17.3 million. The well costs and the duration and frequency of sampling assumed for costing these scenarios are different. The geochemical scenario incorporates additional well and boring

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[10] This represents the sum of estimated costs for Smith Ranch, Highland, and Reynolds.

costs and assumes fewer years of sampling are needed. The frequency of sampling is consistent between the scenarios considered but the geochemical modeling scenario accounts for additional constituents that will need to be sampled and monitored. Labor and other routine costs were held constant between the scenarios considered. Table 3-9 presents summary values for national-level costs, including annualized, summed, and discounted present value of costs. Finally, national well development capital costs are presented in Table 3-10. The well development costs for geochemical modeling with required 30-year monitoring are based on the well development costs for geochemical modeling.

Table 3-9. Estimated Average National Incremental Cost Summary (Thousand 2011$)

Regulatory Scenario	30 Year, Geochemical Modeling to Shorten	30 Years	Geochemical Modeling, Extended
Total annualized cost	$13,465	$15,072	$17,296
Total cost, summed across LOM	$431,284	$814,903	$854,177
Present value, 3% discount rate	$289,991	$419,826	$456,257
Present value, 7% discount rate	$181,135	$202,754	$232,673

Scaled up from CMU costs to national costs based on estimated total acreage. LOM is life of mine.

Table 3-10. Incremental Total Capital Costs (Thousand 2011$)

	Cost, $
30 years with geochemical modeling	$25,203
30 years long-term stability monitoring	$19,339

Scaled up from CMU costs to national costs based on estimated total acreage.

3.4 Uncertainties and Limitations

EPA illustrated three regulatory alternatives using a CMU. As part of this exercise, we assumed the duration of each phase of the ISR monitoring operation. These durations are reasonable, but arbitrary assumptions. All could be longer, and all except the 30-year post-monitoring schedule under those regulatory alternatives could be shorter.

A major set of uncertainties arises from the process used to extrapolate from the estimated costs of each regulatory alternative at the CMU to costs that would be incurred by other ISR facilities. Due to limited resources and data accessibility, EPA’s cost estimates are based on a model facility approach, with the model derived from the characteristics of a single wellfield at one ISR facility. Additional data collection could help to refine these cost estimates; however, despite these limitations we believe that the cost estimates presented here would generally approximate those for mine units characteristic of other ISR sites. EPA also recognizes that compliance actions required at a particular site depend on the characteristics of the site; the characteristics of the CMU may not closely correspond to characteristics of other existing or new ISR facilities. Thus, the costs actual ISR facilities incur may differ from the costs described here. Further, EPA is using existing ISR facilities as models for future ISR facilities that may be subject to the proposed rule at different times in the future. Although future ISR facilities may differ in various ways from existing ISR facilities, EPA nevertheless believes that the existing facilities provide the best guide available as to what future ISR facilities may be like.

Another uncertainty is the cost savings a facility may experience if it applies for and receives an ACL. EPA recognizes that ISR facilities that are attempting to restore and stabilize an ISR site may determine that they are unable to return contaminant concentration levels for all constituents to baseline/pre-operational levels as required. In that situation, facilities may apply for an alternative concentration limit for those constituents. Receiving approval of ACLs would likely enable the facility to stop its restoration/stabilization activities, rather than continuing efforts to achieve pre-operational levels of all constituents. This arrangement would likely reduce the number of years over which the site would have to be monitored. Obtaining an ACL would also entail some additional effort and cost associated with negotiating the ACL with the licensing agency. As an example of such costs, if a constituent (e.g., radium or a trace metal) remains above the restoration goal, the owner/operator may make an argument that the adverse health effects of the higher concentration level are not significant. In that example, a dose assessment would be part of the operator’s case to obtain an ACL and such an assessment would entail costs to gather data and perform the assessment. EPA does not have enough information to enable it to estimate the cost savings associated with ACLs, but we do recognize that there could be cost savings, relative to extensive efforts to achieve pre-operational levels for all constituents.

Requirements for licensing are described in 10 CFR Part 171.16, and financial assurance requirements for ISR operations are described in 10 CFR Part 40, Appendix A, Criterion 9. EPA’s proposed rule will not change the substance of the requirements affecting ISR facilities, but it will potentially change the duration over which a facility is subject to the requirements and thus incurs the costs. Because both types of requirements are set for the entire facility (although they vary depending on the activities currently under way at a facility), as long as any activity is under way at a facility, the facility will incur the costs of complying with the requirements. License fees range from $35,400 to $40,000 per year, but drop to zero if only decommissioning is occurring. Financial assurance costs continue through decommissioning, but decline as more of the site is decommissioned. Throughout the life of an ISR operation, the costs associated with licensing and financial assurance would, in EPA’s assessment, be unaffected by the proposed rule, until only one wellfield is still in operation or undergoing decommissioning. . The longer duration of monitoring required would cause the firms to incur the costs associated with financial assurance for a longer period of time (potentially 30 years). However, as the number of wellfields in operation declines, and the amount of radioactive material onsite declines, the magnitude of the financial assurance required would decline proportionally. EPA thus believes that the additional costs associated with payment of license fees and financial assurance would be small relative to other incremental costs and thus we did not include them in our quantitative estimate of costs and impacts.

Section 4

BENEFITS ANALYSIS

The benefits from revising Part 192 will primarily result from measures to prevent future occurrences of groundwater contamination and protection of groundwater resources for future generations. By requiring owners and operators of ISR facilities to take actions that ensure the long-term stability of geochemical conditions in on-site and nearby aquifers, the revisions will (1) help preserve the quality and quantity of increasingly scarce groundwater resources in the U.S., (2) reduce potential human and environmental health risks associated with contaminant exposures, and (3) avoid potential future remediation costs, which would be required if the existence and migration of groundwater contaminants were not detected prior to decommissioning the site. In addition, by incorporating constituent-specific standards that are flexibly referenced to SDWA and RCRA standards for groundwater contaminants, the proposed revisions will reduce the Agency's administrative burden from periodically reviewing and revising standards to ensure consistency. In so doing, they will also incorporate recently revised and more protective standards for arsenic and uranium, which will also contribute to reduced risks to human health and the environment.

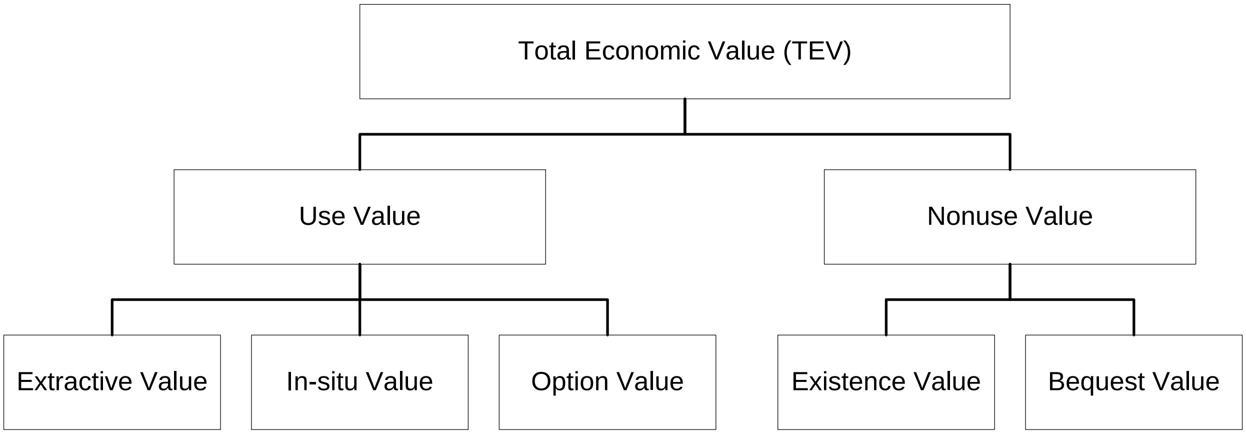
Due to data limitations and resource constraints the monetary value of these benefits cannot be fully quantified and aggregated across ISR sites in the U.S. However, it is possible to provide a detailed qualitative discussion and partially quantified description of the expected benefits of the proposed rule. The purpose of this chapter is to assist decision makers by providing this discussion and description of benefits.

4.1 Conceptual Framework and Methods for Valuing Groundwater Resources and Groundwater Protection

Water is vital to a productive and growing economy in the United States, directly and indirectly affecting the production of goods and services in many sectors. Current economic literature provides many insights into the importance of water to various sectors, including agriculture, tourism, fishing, manufacturing, and energy production, but this information is dispersed and, in many cases, incomplete. To take stock of what is currently known and where the main knowledge gaps lie, EPA has been conducting a study on the importance of water in the U.S. economy (U.S. EPA, 2012d). The main objectives of the study include (1) summarizing existing knowledge about the role and importance of water to the U.S. economy; (2) providing information that supports private and public sector decision-making, and (3) identifying areas with additional research needed. The draft findings show that, although water plays an essential and vital role in the economy, it is enormously difficult to place a monetary value on its contribution, in part because the value of water varies greatly both within and across sectors of the economy.

Although groundwater resources play a vital role in the U.S. economy, the economic *value* of these resources extends beyond their current contribution to market production. To understand and fully account for the contributions of groundwater to human well-being is useful to refer to the concept of "total economic value" (TEV) (Young, 2005). As shown in Figure 4-1, TEV includes both use and nonuse values.

Figure 4-1. Main Components of the Total Economic Value (TEV) of Groundwater Resources



Use values include the well-being that is derived from direct use of the resource by individuals or households, for example as a source of drinking water. It also includes values from indirect use, such as through groundwater's contribution to the production of goods or services people enjoy (e.g., agricultural commodities). As noted in a 1997 National Academy of Sciences study of groundwater valuation (NAS, 1997), use values for groundwater can also be divided into extraction value and *in-situ* value (also described as consumptive vs. nonconsumptive use values). Extraction value is widely recognized, and includes the value of groundwater used for drinking water, industrial water supply, and agriculture. Values for *in-situ* services are (or were in 1997) less well-known. They represent services or values that occur or exist as a consequence of water remaining in place within the aquifer. They include the capacity of groundwater to (1) buffer against periodic shortages in surface water supplies; (2) prevent or minimize subsidence of the land surface from groundwater withdrawals; (3) protect against sea water intrusion; (4) protect water quality by maintaining the capacity to dilute and assimilate groundwater contaminants; (5) facilitate habitat and ecological diversity; and (6) provide discharge to support recreational activities. One potential additional source of use values is “option value,” which refers to the value that humans derive *today* from preserving the option to use the resource (directly or indirectly) in the *future*.

Nonuse values refer to well-being derived from the resource that is not associated with an individual’s current or future use of the resource. Two main types of nonuse values are (1) the “existence” value that individuals may derive simply from knowing that a resource exists and is being protected, even if they do not or have no intention to use the resource directly or indirectly and (2) the “bequest” value individuals derive from know that a resource is being preserved for future generations to use.

One of the main challenges with valuing groundwater resources and their services is that they are typically not privately owned or exchanged in markets. As a result, one cannot rely on market prices for groundwater to infer its values. To address this problem, which is common for many public goods and natural resources, economists have developed variety of nonmarket valuation method. These methods are typically divided into two main categories: revealed and stated preference methods.

To infer nonmarket use values, revealed preference (RP) methods rely on information from market activities or other human behaviors that are *related* to the resource of interest. For example, the value of groundwater as an irrigation resource can be inferred from the value it contributes to products sold in agricultural markets. Similarly, the value of protecting groundwater quality as a source of household drinking water may be inferred from substitute sources of drinking water (e.g., bottled water prices) or from differences in housing prices in areas with different groundwater quality. Unfortunately, RP methods cannot be used to estimate nonuse values for natural resources, because they require a behavioral connection to the resource of interest in order to infer values.

The value of protecting groundwater quality may also, in some cases, be inferred from the avoided future costs of restoring the resource. This approach, which is sometimes grouped with RP methods, is meaningful if there is a high likelihood that (1) restoration activities will be implemented if groundwater contamination occurs and (2) restoration activities will not be needed if the groundwater is protected.

Stated preference (SP) methods employ household surveys to more directly measure people’s nonmarket values. To address the lack of existing markets for the good or service of interest, SP surveys present respondents with hypothetical markets or scenarios and elicit their willingness to pay (WTP) for defined changes (e.g., improvement in groundwater quality). One of the main advantages of SP methods is that they allow researchers to specifically define the nonmarket "commodity" of interest. Moreover, unlike RP methods, they can be used to capture and estimate nonuse value. The main drawback of these methods is that it is difficult to validate WTP estimates based on responses to hypothetical conditions.

A number of studies have used SP methods to estimate U.S. households' WTP for protecting and improving groundwater quality; however, most of these studies were conducted in the 1980's and 1990's. Using meta-analysis, Poe et al. (2001) reviewed and synthesized key findings from this empirical literature. In particular, they identified and analyzed 105 WTP estimates from 12 studies. They found that the types of groundwater changes described and analyzed in these SP studies varied widely, and consequently the mean annual WTP estimates also varied significantly from \$46 to \$1,316 (in 1997 dollars). Using a consumer price index adjustment, this range is equivalent to \$64 to \$1,844 in 2011 dollars.

Poe et al. used regression methods to investigate the main determinants of this variation in WTP. For example, they differentiated between studies that focused mainly on use-related values associated with drinking water protection and those that used a broader environmental perspective and included nonuse values related to aquifer protection. They found that including a nonuse perspective had a significantly positive effect on WTP. They also differentiated studies that specifically mentioned cancer risks associated with groundwater contamination. They found that WTP estimates were higher in these studies, but only at a moderate level of statistical significance.

4.2 The Benefits of Proposed Changes in Monitoring Requirements

The purpose of the proposed change in monitoring requirements, including requiring improved characterization of groundwater prior to uranium recovery and more extensive restoration and post-restoration stability monitoring, is to reduce the probability and magnitude of potential groundwater contamination incidents resulting from ISR operations.

Currently NRC allows ISR operators to terminate their license at the end of a relatively short (one to two years) stability monitoring phase. However, this practice means that any later contamination might not be detected and corrected in a timely manner. If oversight at these facilities ends before groundwater conditions have in fact stabilized, there is the potential for ongoing contamination.

Thus, the proposed rule's provisions help to ensure that any potential excursions occurring after the completion of production operations are detected and corrected. As a result, they would ensure that groundwater and, potentially, the surface water to which it discharges, remain at levels the groundwater was restored to. Stability period monitoring ensures that the long-term trends in the groundwater concentrations stay within the target restoration concentrations ensuring the stability of the aquifer water quality and class of use required by regulatory authorities (Davis, 2007). This monitoring reduces the probability of water quality degradation within the exempted aquifer, prevents further degradation of the overlying or underlying aquifer, and reduces the probability of aquifer degradation outside the ore zone. By ensuring that groundwater conditions within the exempted aquifer are in fact stable, the proposed stability monitoring program will reduce the likelihood of undetected degradation of conditions in the exempted aquifer and adjacent aquifers. Thus, the proposed stability monitoring program would result in a higher probability that adverse human health and environmental impacts will be avoided.

There are several potential benefits associated with preventing groundwater contamination due to post-restoration exceedances/excursions at ISR facilities. The following discussion describes three main areas and offers insights into the potential magnitude of these benefits.

4.2.1 Reducing Potential Human Health Risks Associated with Contaminant Exposures

If excursions occur from ISR facilities and aquifers are contaminated, the main potential risks for human health would be those associated with exposures to radionuclides in well water used for drinking or agriculture in areas located down-gradient from an ISR site. Most importantly, EPA considers all radionuclides to be known (category A) human carcinogens, and exposures to radiation can cause cancers in almost all tissues and organs in humans.[11]

To evaluate the potential human health risks that would occur if groundwater contamination were to result from ISR operations, EPA evaluated a number of exposure scenarios and pathways (U.S. EPA, 2012c). The findings of this analysis indicate that the migration of contaminants into aquifers in the vicinity of an ISR site has the potential to cause significant exposures and risks for selected receptors. For example, the maximum of the estimated adult cancer risks from these scenarios was an increased latent cancer fatality risk of almost 5 in 1000 per year of exposure. However, due to the slowness of the groundwater

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[11] See for example EPA's Users Guide for Radionuclide Carcinogenicity, found at http://www.epa.gov/radiation/heast/docs/heast_ug_0401.pdf

transport process, it could take several decades or more for the contaminants to reach down-gradient wells that could potentially be used by humans. Also, the exposure scenarios examined in the analysis deal with failures of the ISR operations during the operating phase, such as leaks from extraction wells into overlying potable water aquifers or surface spills during operations. These scenarios can pose exposure risks, but implementing a robust regulatory regime during operations (the responsibility of the NRC or Agreement States) would minimize the potential for significant exposures.

Estimating the monetary value of health benefits from the proposed rule requires estimates of the expected number of cancer cases and fatalities that would be avoided. To estimate the benefits of avoided mortality risks from its programs and policies, EPA recommends multiplying the number of avoided deaths by a "value of statistical life" (VSL) concept, with a central default estimate of $8 million per avoided premature death. This VSL estimate is based on a review and synthesis of findings from several empirical nonmarket valuation studies, which estimate individuals' WTP to reduce their own probability of premature death. Unfortunately, due to uncertainties and data limitations, including lack of certainty regarding the size of future populations in proximity to ISR operations, it is not possible to estimate these population-level risk changes for this rule; however, the VSL of $8 million at least provides a point of reference for understanding the potential value of health benefits of the proposed rule. It is also worth noting that the unit value for avoided *cancer* fatalities may be even higher than the $8 million VSL. Economic studies of VSL suggest that people value reductions in cancer risks by more than similar reductions in noncancer risks of mortality, because individuals fear the pain and other symptoms associated with cancer more than they fear, for example, traffic or work-related accidental death (U.S. EPA, 2010). Moreover, as previously described, the findings from the Poe et al. (2001) meta-analysis of groundwater valuation studies suggest that individuals place a particularly high value on avoiding groundwater contamination when cancer risks are involved.

4.2.2 Protecting Groundwater Resources for Future Generations

As described above, groundwater resources provide a wide variety of extractive, *in-situ* uses, and nonuse values and services to human populations in the U.S.; however, the ability to sustain these services over the long term is being threatened by groundwater scarcity. Due to population growth and technological advances, the pace of groundwater extraction in the U.S. has increased significantly in the last 75 years (Reilly et al, 2008). As a result, declining groundwater resources are a growing concern in many parts of the country. Continuing population growth and the additional threats to water resources posed by climate change only serve to reinforce these concerns.

Growing scarcity also means that existing groundwater stocks are becoming increasingly valuable. Therefore, even though the aquifers in the vicinity of ISR operations are currently providing relatively little extractive value (due to their locations in relatively sparsely populated areas), there are potentially significant longer term benefits to protecting these resources for future generations. The fact that ISR operations are mostly located in arid regions of the country where water scarcity is a chronic problem further underscores the significance of these benefits.

Empirical evidence regarding these "bequest" values for protecting groundwater resources is limited; however, the Poe et al. (2001) meta-analysis provides some insights into the magnitude of these nonuse values. In particular, valuation studies that focused broadly on aquifer protection, rather than more specifically on use values associated with drinking water protection, had average WTP estimates that were larger by $531-$736 per household.

4.2.3 Avoiding Potential Future Remediation Costs

Under current conditions, due to limited post-restoration monitoring by ISR operations, the potential exists for groundwater contamination to occur and go undetected over a long period of time. Such processes could occur if the initial injection of oxidizing agents into the deposit also destroyed the natural reducing capacity in the host rock that immobilized the uranium initially. Later injection of chemical reducing agents may then only produce a temporary reduction of uranium mobilized by the lixiviant injection. Over time the influx of oxidized groundwater from up gradient of the deposit may remobilize the uranium, radium, or other constituents, and result in contaminant migration down gradient.

If such contamination does occur and is only discovered after a long delay, extensive and costly remediation would most likely be required to remove the contaminants from the aquifer and reduce human health and environmental risks to acceptable levels. As the time period before detection increases, it is also likely that the spatial extent of contamination and the corresponding remediation costs would increase. A long delay before detection could also decrease the likelihood that the ISR owners/operators will be held responsible for the cleanup costs and instead the burden could be shifted to future taxpayers.

Consequently, one of the expected benefits of the proposed rule will be to increase the likelihood of detecting mobilized uranium, radium, or other constituents at an early stage and therefore avoiding costs associated with more extensive remediation activities. To analyze these avoided remediation costs, we used the model facility described in Section 3, and applied the parameters of this facility to develop cost estimates for alternative remediation scenarios. Appendix C provides a detailed description of the methods and assumptions used to construct these remediation cost estimates. Note that this is an illustration of potential costs and cost savings associated with the proposed rule for a model mine unit; because we have no idea of which (if any) wellfields would experience a remobilization after restoration, EPA is unable to estimate national cost savings from reduced remediation costs.

As described in Appendix C, EPA used different assumptions about groundwater flow to estimate distance from the location where the constituents are first mobilized to the nearest monitoring well, and hence how long it would take for contamination to be detected. In addition, a variety of K_d[12] values were used, to reflect a variety of assumptions about how readily constituents are transported in groundwater. For purposes of this discussion, we focus on calculations assuming that K_d = 6.0E-06 m^3/gm. The K_d variable is a site specific measurement and limited examples were found for actual ISR sites that were measured either as part of baseline or after restoration was completed. The value selected for modeling purposes was a referenced (F.J. Pearson Jr., C.J. Noronha, and R.W. Andrews, 1983) K_d measured at a roll front sandstone site and was used as a representative general condition.

To evaluate the potential magnitude of the benefits associated with avoided remediation cost, we compare two main scenarios. The first scenario represents conditions *without* the proposed rule. Under this scenario, contamination is detected after the site is decommissioned and the license is terminated.[13] Three situations are examined: a small plume that is approximately 10% of the wellfield, or a larger plume that fills the entire wellfield. Once contamination is detected, this scenario estimates that remediation activities would continue for a period of 30 years (small plume) or 60 to 75 years (larger plume), involving pumping and treatment of contaminated groundwater from approximately 70 wells. For the larger plume, costs and duration vary depending on assumed direction of groundwater flow; we examine two possible directions because the current direction appears to be different from historical direction, possibly because of other mining activities in the area. Estimated total annualized costs of this scenario range from $1.45 million (small plume) to $10.3 to $10.5 million (large plume).[14] Because the site has been decommissioned and the license terminated, remediation costs might be borne by the taxpayer. Total costs, as shown in Table 4-1, range from $35.3 million for a

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[12] Sorption partition coefficient that controls the degree of linear sorption represented by the model.

[13] The actual time of detection depends on when someone drills a well in this location and tests the water at the correct time to detect the plume. In fact, if the facility has been decommissioned, it could be a long time before someone drills a well into the contaminated aquifer.

[14] Note that these costs do not include costs of scoping efforts to identify the size of the plume and develop a remediation strategy.

small plume to $586 million for a large plume, where the groundwater flows along the length of the wellfield.

The second scenario represents conditions *with* the proposed rule. In this case, contamination is assumed to be detected during long-term stability monitoring. We use costs for the 30-year with no geochemical modeling alternative, and assume that monitoring within the wellfield detects an increased concentration of constituents ten years into the 30 year period. When the remobilized constituents are detected, the licensing agency would require the owner/operator to resume restoration activities, in an effort to achieve restored, stable conditions. To estimate the costs of this additional restoration, we use the estimated restoration costs for the original restoration phase. We assume that the second restoration would be successful and no further remobilization of constituents is detected. After this second restoration, the facility would monitor to ensure that constituent levels are stable at 95% confidence for 3 years, then continue to monitor to ensure that stability is maintained for 30 years. EPA estimates that the cost of these activities would total $27.1 million.

The resulting estimates of avoided remediation costs for the model facility are summarized in Table 4-1. The summary costs for each scenario are expressed as a lump sum value, computed by summing costs across time. The avoided remediation costs are calculated as the difference between the two scenarios. Therefore, for this example facility and post-restoration contamination profile, the estimated benefits from the proposed rule include a value of at least $8.2 million to nearly $560 million in avoided remediation costs, including both capital/well development costs and annual costs.

In addition, the proposed rule is expected to shift the burden of required groundwater cleanups from future taxpayers to the owners and operators of ISR facilities. By requiring ISR operations to conduct more extensive long-term stability monitoring, it is more likely that movement of contaminants will be detected in the short term while owners and operators are still responsible for the site. Conversely, it is less likely that contamination episodes will go undetected for years into the future and be detected only after the facility has been decommissioned, thus reducing the probability of larger and taxpayer funded remediation activities.

Table 4-1. Summary of Avoided Remediation Cost Estimates for Model Facility with Post-restoration Groundwater Contamination (million 2011 $)

	Sum of Costs Over Time		
Plume Size and Groundwater Flow Direction	**Without-regulation Scenario (A)**	**With-Regulation: Compliance and Additional Restoration (B)**	**Avoided Remediation Costs (A) − (B)**
Small Plume	$35.3	$27.1	$8.20
Large Plume, Transverse	$481.0	$27.1	$453.1
Large Plume, Along	$586.1	$27.1	$559.0

Further, the proposed rule, with its geochemical modeling and monitoring components, provides both the regulator and the public with evidence that restored wellfield conditions will remain stable into the future and that the operator can be released from a 30-year long-term stability monitoring requirement and the site decommissioned, with greater confidence in its long-term safety than could be achieved based on monitoring alone.

4.3 Setting Groundwater Protective Standards

The second component of the revised regulation aligns the groundwater standards to current regulatory criteria (i.e., primary and secondary maximum contaminant levels (MCLs) under the SDWA and/or maximum concentration of hazardous constituents for groundwater protection under RCRA). The primary benefit to households of revising the standards will be reduced risk of adverse human health and environmental impacts.

As proposed, the revisions will reduce the need for EPA to update the regulations each time a standard changes and avoid the rulemaking process for each update, thus reducing future regulatory burden on both EPA and the regulated community. Rather, EPA would take comment during the rulemaking process for the primary rule that is being changed. Currently the list of groundwater standards is out of date and not aligned to SDWA and RCRA. Aligning the standards will ensure that the standards stay current with other regulations and increase the probability that society will be protected from risks to human health and the environmental. The requirement requires that regulators and operators update their plans based on the latest standards, but it relieves EPA of the costs associated with updating the regulation each time a standard is changed and ensures that there are no lags in updating the standards, which would potentially expose the public to risks.

4.4 Comparison of Benefits and Costs of the Proposed Rule

Since EPA conducted a qualitative assessment of the benefits of the proposed rule, a direct quantitative comparison of total benefits and costs is not possible. However, the analysis described in this section does provide some limited insights into the relative magnitude of costs and benefits. In particular, for the model facility with a defined excursion of groundwater contamination, the estimated net present value of avoided remediation costs is at least $35.0 million, whereas the NPV of monitoring costs plus a second remediation has an estimated NPV of $11.0 million, based on average costs and using a 3% discount rate. Therefore, for this example, the cost avoidance benefits exceed the costs. Whether this relationship holds at an aggregate level, however, depends importantly on (1) the likelihood of groundwater contamination events across all sites and (2) the similarity of conditions at other sites to those at the model facility.

4.5 Caveats and Uncertainties

Although the proposed rule is expected to provide substantial benefits by helping to ensure that potential groundwater contamination occurrences from ISR operations are promptly detected and addressed, it is not possible to reliably quantify the total magnitude of these benefits. One of the main sources of uncertainty is a lack of adequate data and models for estimating a full probability distribution of all alternative groundwater contamination scenarios across all current and future ISR sites. Instead, to provide a general understanding of avoided remediation costs and avoided health risks, EPA has examined a limited number of groundwater contamination scenarios at a defined site to illustrate the magnitude of potential remediation costs. It should not be assumed that all restored ISR wellfields will fail in the long-term. A second important source of uncertainty is for estimating benefits is the very long term nature of potential groundwater contamination episodes. Although future generations will certainly benefit from avoided contamination, it is very difficult to reliably predict the size and locations of potentially affected future populations.

Section 5

ECONOMIC IMPACT ANALYSIS

EPA examined the economic impacts that may result from the proposed rule, using information about the industry and estimated incremental costs that would result from the proposed rule and from one additional regulatory alternative, and employing accepted economic analysis methods.

5.1 National Costs

EPA first estimated the total annualized national cost of the proposed rule, as a measure of the overall impact the proposed rule might have on the uranium industry and the national economy. As described in Section 3, EPA estimated the incremental annual costs of monitoring for ISR facilities; EPA first estimated the costs under current practice and under two regulatory alternatives for a conceptual mine unit (CMU) model facility. Incremental costs were computed by subtracting the estimated base case costs from estimated costs under the two regulatory alternatives. EPA then scaled up the estimated incremental costs for the CMU to costs that would be incurred by facilities such as the five ISR facilities expected to be operating in 2014, the effective date of the proposed rule, based on the ratio of the wellfield acreage at each facility to the wellfield acreage of the CMU. EPA illustrated the range of costs that may result from the proposed rule using average, low, and high costs of monitoring. This approach makes the conservative high-cost assumption that all wellfields at each facility would be in some stage of pre-operations, operations, restoration, stability, or long-term stability monitoring (and thus affected by the proposed rule) in 2015.

Estimated national total annualized costs based on average monitoring costs are shown in Table 3-9, above, and used in this analysis. National costs based on low and high monitoring costs are shown in Appendix D. Depending on the assumptions used to compute the national costs, EPA's cost estimates varied widely, ranging from $11.6 million to more than $17.9 million. EPA examined the potential costs of the provisions of the proposed rule (30-year stability monitoring with the potential to reduce the duration if geochemical modeling demonstrated that wellfield conditions would remain stable); EPA also examined the potential costs of one regulatory alternative that was considered and rejected: 30-year stability monitoring with no potential to reduce the monitoring duration.[15] EPA chose to propose 30-year long-term

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[15] EPA also considered another regulatory alternative: a narrative standard with no fixed monitoring period. Because the compliance requirements under this alternative would be determined by the licensing body and thus extremely site and case specific, EPA did not estimate costs or impacts for this alternative.

stability monitoring with geochemical modeling because this standard has the advantage of being less costly than the 30-year monitoring alternative, and it demonstrates that conditions will remain stable or that conditions down-gradient will trap any mobilized constituents, thus ensuring that groundwater quality is protected. The regulatory alternative of 30-year stability monitoring with no provision to reduce the duration was rejected because it is generally expected to be more costly and less protective than the proposed alternative; even monitoring for 30 years does not guarantee that wellfield conditions will not degrade in the future. The remainder of the economic impact analysis thus focuses on the impacts of EPA's proposed rule. Analytical results for the 30-year stability monitoring with no provision for shortening are found in Appendix D. In addition, Appendix D provides results of a simulation reflecting the possibility that geochemical monitoring will reveal geochemical conditions in and around the wellfield that would not guarantee long-term stability—a "worst case" cost scenario. If that occurred, we expect regulators to require 30 years of long-term stability monitoring. EPA analyzed the costs and economic impacts that would occur if all ISR facilities had this experience, although that is unlikely to occur in actuality. As noted in Section 3 above, this scenario would only be realized if pre-operational monitoring and geochemical modeling indicated the site was safe to develop, but post-operational sampling and modeling gave a different result. If pre-operational sampling and modeling indicated that conditions are not sufficiently reducing to ensure long-term stability, EPA expects that either the owner operator would choose not to develop, or the licensing authority would not issue a license. Thus, this worst case is unlikely to occur.

Based on the proposed 30-year long-term stability monitoring with geochemical modeling using average monitoring costs and assuming that all wellfields are affected, EPA estimated that national total annual costs of complying with the proposed rule would be approximately $13.5 million (see Appendix D for the range of national costs estimated for the geochemical modeling alternative). Compared with the U.S. economy as a whole, these total annual costs are not extremely large. However, the uranium industry is small, with relatively few firms. Compared with the industry sales (estimated to be $3.0 billion in 2015 based on a uranium price of $57 per pound), these estimated total annualized costs comprise about 0.4% of estimated 2015 sales. EPA thus conducted a more in-depth assessment of potential impacts on the market for uranium and on firms in the industry.

5.2 Market Impact Assessment

To illustrate likely impacts of the proposed rule on the market for uranium, EPA developed a simplified model of the U.S. market for uranium, using projected quantities of uranium purchased by COOs in 2015, the effective date of the proposed rule. The U.S. Energy

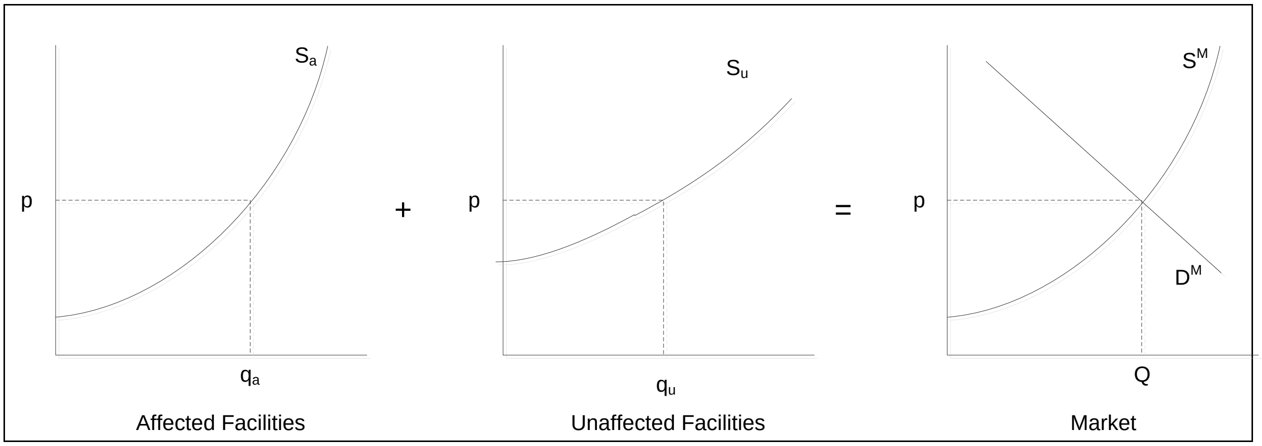
Information Administration projects that uranium purchases by U.S. COOs will increase between 2010 and 2040 at a rate of 0.2% per year. Using this rate of growth, EPA estimates that in 2015, COO purchases will have grown from 57.4 million pounds (2013) to 57.6 million pounds. Over the period 2000 to 2013, the share of COO purchases supplied by U.S.-origin uranium averaged 16.4% (EIA, 2014b). Assuming that the share of that quantity coming from domestic-origin uranium in 2015 reflects this historical pattern, EPA estimated that in 2015, COOs will purchase 9.45 million pounds of domestic-origin uranium. Using the projected market price and quantity, EPA applied the costs of complying with the proposed rule and simulated market responses, including changes in market price and quantity, and changes in the share of the market represented by domestic supply and imports. Table 5-1 shows projected 2015 conditions in the U.S. uranium market, which estimate quantities and prices without the proposed rule, and form the basis for the market impact simulations.

Table 5-1. Projected U.S. Uranium Market Conditions, 2015

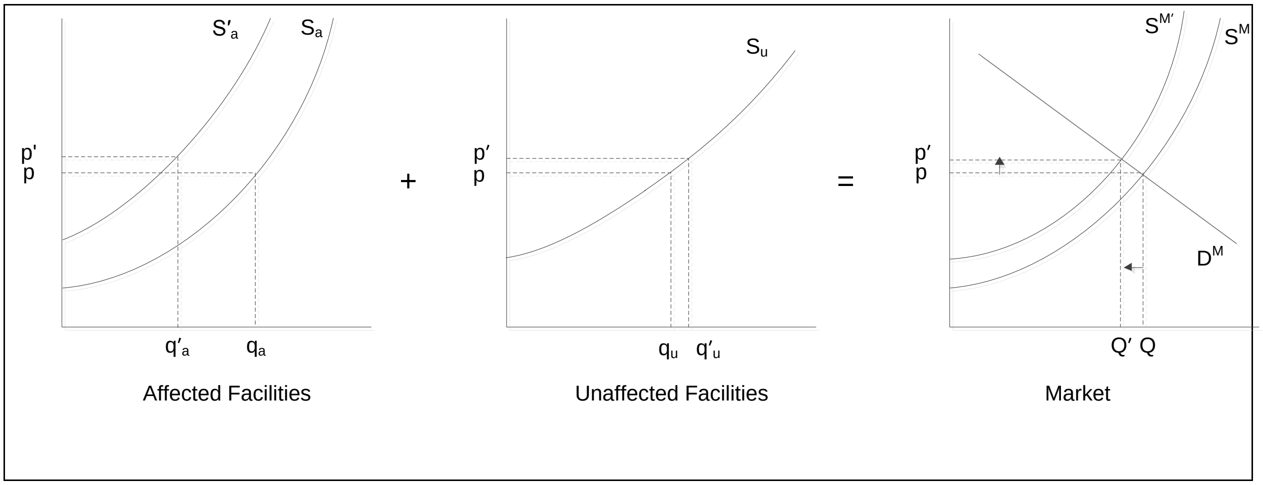
	Market Conditions
Supply (million pounds)	57.630
U.S. Origin Uranium	9.451
Foreign Origin Uranium	48.179
Price	$57.00

5.2.1 Market Simulation Model

EPA used a partial equilibrium model of the U.S. market for uranium to analyze the impacts of the proposed rule. Market supply is defined as the sum of domestic-origin uranium purchased and foreign-origin uranium. Domestic demand for uranium is a function of the demand for electricity and is represented by projected purchases of U.S. COOs. Figure 5-1 illustrates a market in which some suppliers of the product are affected by the proposed rule and others (such as foreign suppliers) are not. Promulgation of the proposed rule would increase the costs of supplying uranium for ISR facilities, thus shifting their supply curve upward, and the market supply curve upward by a lesser amount. As a result, the with-regulation equilibrium price is slightly higher, and the with-regulation equilibrium market quantity slightly lower. The unit cost of complying with the rule (the vertical shift in the supply curve for affected facilities) is greater than the increase in the market price. Because unaffected facilities respond to the increased market price by increasing the quantity of uranium they supply the market, affected facilities are unable to pass along much of their increased costs to their customers, and the



a) Without-Regulation Equilibrium



b) With Regulation Equilibrium

Figure 5-1. Market Equilibrium Without and With Regulations

profitability of their operations declines. Thus, the quantity of uranium supplied by U.S. ISR facilities declines, while the quantity of uranium supplied by unaffected suppliers increases. The partial equilibrium model used by EPA quantifies estimated market impacts, as described below.

5.2.2 Characteristics of Market Demand for Uranium

Uranium is an input into the production of electricity. Thus, the demand for uranium is derived from the demand for electricity. The responsiveness of the demand for uranium to changes in the price of uranium is measured by the elasticity of demand for uranium (computed as the percentage change in the quantity of uranium demanded divided by the percentage change in its price). Elasticity values are typically negative, because increases in price typically cause demanders to want to purchase less of a commodity, if all the other influences on uranium demand are held constant. Elasticity values greater than one in absolute value are termed elastic and indicate demand that is responsive to changes in price. Elasticity values below one in absolute value are termed inelastic. The closer the value is to zero, the less responsive demand is to changes in price. EPA's assessment indicates that the demand for uranium is very inelastic.

Economists compute the elasticity of demand for an input as a function of

- the elasticity of demand for the final product,
- the elasticity of substitution between the input and other inputs,
- the elasticity of supply of other inputs, and
- the cost share of the input as a share of the cost of the final product, in this case electricity.

The elasticity of demand for electricity is low, approximately −0.3. The elasticity of substitution between fuels in production of electricity is also low. The cost of uranium typically represents between 0.2% and 0.4% of the cost of electricity. Using these values, we estimated the elasticity of demand for uranium to be about −0.07%. This very low elasticity value indicates that changes in the price of uranium do not result in great changes in the quantity of uranium purchased. Another way of looking at this is to say that the demand for uranium responds less to changes in its price than to other factors affecting demand, such as the share of electricity produced using nuclear power, the price of alternative energy sources for electricity generation, and operating status of U.S. nuclear power plants, for example.

5.2.3 Characteristics of Market Supply

The responsiveness of supply to changes in price is similarly measured by an elasticity of supply, computed as the percentage change in quantity supplied divided by a percentage change in price. When price increases, uranium firms will respond by increasing uranium production, because at higher prices, more uranium sources will be profitable to operate. Currently, several ISR facilities are not operating because the market price has been too low to make operation profitable. Further, several ISR facilities are licensed and permitted but have not been constructed. If price rises as projected, some of these sources may be brought online. EPA uses a supply elasticity of two to measure the price-responsiveness of both domestic supply and import supply. Historically, because of the presence of large stockpiles of uranium, supply has been quite responsive to price. However, there is evidence that this is changing, because stockpiles are being drawn down. Thus, in the future, uranium supplied will generally be from recent production, which is expected to be less responsive to price changes than are supplies drawn from inventories or stockpiles. A supply elasticity of two is consistent with values from the literature (University of Chicago, 2004; Ux Weekly, 2004).

5.2.4 Impacts of the Proposed Rule

Based on average monitoring costs and assuming 100% of each facility's wellfields are affected simultaneously, implementation of the proposed rule would increase the cost of producing uranium at ISR facilities by $1.50 per pound of uranium. Neither the cost of production using conventional technologies nor the cost of uranium from foreign sources would be affected. Incremental costs of complying with the proposed rule are estimated to be approximately 2.6% of baseline market price.

The increased costs incurred by ISR facilities would increase the cost of domestic production overall. Given the characteristics of demand and supply described above, economic theory would predict that the market price of uranium would increase, and the quantity of uranium purchased would fall somewhat. Because imports are a large share of total supply and their costs would not be affected by the rule, domestic suppliers of uranium would have a limited ability to pass the costs of compliance to their customers through price increases. EPA thus estimates that the market price of uranium would increase by only a fraction of the rule's cost per pound, the share of uranium purchased from domestic sources would decline, and the share of foreign-origin uranium imports would increase, if all market conditions other than the proposed rule are held constant.

5.3 Summary of Economic Impact Results

Table 5-2 shows EPA's market impact analysis results. These results should be interpreted as an illustration of the relative impacts on the U.S. uranium market as a whole and on domestic suppliers, demanders, and foreign trade, rather than a specific prediction of market outcomes.

Using a 2015 projected baseline, initial market quantity is approximately 57.6 million pounds of U_3O_8, of which an estimated 9.45 million pounds are of domestic origin and 48.2 million pounds are imported. Baseline price is assumed to be $57 per pound. After the market adjusts to costs of compliance with the proposed rule in effect, increasing the costs of ISR production by $1.50 per pound, the overall quantity of uranium demanded by U.S. COOs is projected to decline by about 15.9 thousand pounds (0.03%), and the price of uranium is estimated to increase by approximately $0.24 (0.4%). The quantity of domestic-origin uranium purchased is projected to decline to 9.03 million pounds, a decline of approximately 4.4%, while COO purchases of foreign-origin uranium are estimated to increase by 0.8%.

Table 5-2. Market Impacts of Proposed Rule based on Average Costs, 2014

	Baseline	30 Years, Geochemical Modeling to Shorten	30 Years
Supply (million pounds)	57,630	57,614	57,612
U.S. origin	9,451	9,032	8,982
Foreign origin	48,179	48,582	48,631
Price ($/pound)	$57.00	$57.24	$57.27
Change in price	$0.24	$ 0.27	
Percentage changes			
Market quantity		−0.03%	−0.03%
U.S. origin		−4.4%	−5.0%
Foreign origin		0.8%	0.9%
Price		0.4%	0.5%
Incremental cost per pound of uranium		$1.50	$1.68

5.4 Employment Impacts of the Proposed Rule

According to the U.S. Census Bureau's Statistics of U.S. Business (Census, 2013), in 2011 the uranium and vanadium mining industry had 670 employees. Assuming that employment in the uranium and vanadium industry increases at the same rate as production, employment in 2015 is projected to be 682.[16]

Assessing the impact of the proposed rule on employment requires consideration of factors that tend to decrease employment and factors that tend to increase it. Assuming production employment in the U.S. uranium industry declines by approximately the same percentage as output is estimated to decline, EPA estimates that production employment in the U.S. uranium industry would fall by approximately 30 full-time equivalent employees. However, EPA's assessment is that this computation overestimates the decline in employment. First, although ISR is the dominant form of uranium production in the United States, it is less labor intensive than conventional mines and mills. Not all the industry's employees work at ISR facilities, so the actual reduction in ISR facility employment would be smaller than estimated. Further, because of the labor needed to implement the provisions of the proposed rule, EPA expects a countervailing increase in employment in the industry. To comply with the proposed

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[16] Note that the companies owning operating ISR facilities have more than 1,400 employees; however, not all of these employees work in the United States.

rule, ISR operations may increase their environmental compliance staff to conduct the additional monitoring. To the extent that facilities install more monitoring wells than they would have at baseline, well-drilling employment may also increase. In addition, outside the uranium and vanadium industry, laboratories that analyze groundwater samples may also increase their employment somewhat, in response to an increased demand for analysis. Thus, it is difficult to estimate either the direction or the magnitude of overall employment impacts that would result from the proposed rule.

5.5 Impacts on Small Entities

Under the RFA, as amended by SBREFA, EPA is required to evaluate the impacts on small entities affected by its rulemakings. Small entities include small businesses, small governments, and small nonprofits. Small governments and small nonprofits are not expected to be affected by the proposed rule; however, two of the firms owning currently operating ISR facilities, and five additional firms owning planned or standby facilities are small businesses, based on the SBA's criterion for NAICS 212291: 500 or fewer employees. It is important to note that the size determination is made at the owner-company level. Uranium companies frequently have complicated ownership structures, with several layers of ownership. To accurately assess the vulnerability of the firms owning ISR operations, it is the ultimate parent company's size that should be considered. If a small company is actually a subsidiary of a larger company, the impact on the larger company is examined. However, where a larger company is a shareholder in a small company but the small company is nevertheless an independent entity, EPA evaluated the impacts on the small company.

EPA assessed the potential for adverse impacts on small businesses by estimating the costs that would be incurred by the firms that own existing facilities, then comparing those estimated costs to the firms' revenues. EPA's guidance on complying with the RFA and SBREFA (2006) establishes criteria for significant impacts: if the proposed rule's costs are less than 1% of sales, impacts are deemed insignificant. If costs exceed 3% of sales, significant impacts are likely. Between 1% and 3% of sales, impacts may or may not be significant. EPA adopted these criteria in determining whether the proposed rule's impacts on small businesses are significant.

In Table 5-3, EPA compares the estimated costs for firms owning existing ISR facilities to their sales. Of the four firms owning existing ISR facilities, three are small according to the SBA's definition for NAICS 212291, because they have fewer than 500 employees.

Table 5-3. Estimated Impacts of the Proposed Rule on Small Entities

Parent Company (ISR Facilities)	Small Business	Annual Sales (millions USD)	Estimated Cost to Sales Ratio		
			Low	Average	High
30 Years with Geochemical Modeling to Shorten					
Cameco Corporation (Crow Butte, Smith Ranch-Highland-Reynolds)	No	$2,400.0	0.4%	0.5%	0.6%
Mestena Uranium[a] (Alta Mesa)	Yes	$28.5	1.4%	1.7%	1.9%
Uranium One, Inc. (Willow Creek)	No	$530.4	0.1%	0.1%	0.1%
Uranium Energy Corp.[a] (Hobson-La Palangana)	Yes	$28.5	0.9%	1.1%	1.2%
Ur-Energy (Lost Creek)	Yes	$57.0	0.6%	0.6%	0.7%
30 Years, No Option to Shorten					
Cameco Corporation (Crow Butte, Smith Ranch-Highland-Reynolds)	No	$2,400.0	0.5%	0.5%	0.6%
Mestena Uranium[a] (Alta Mesa)	Yes	$28.5	1.6%	1.9%	2.2%
Uranium One, Inc. (Willow Creek)	No	$530.4	0.1%	0.1%	0.1%
Uranium Energy Corp.[a] (Hobson-La Palangana)	Yes	$28.5	1.0%	1.2%	1.4%
Ur-Energy (Lost Creek)	Yes	$57.0	0.6%	0.7%	0.9%

[a] To assess impacts on the small firms companies based on typical operations, EPA estimated sales revenues based on the facility's estimated production and market price. For the two large firms, 2013 reported sales were used.

small firm, Mestena Uranium, no data on sales are available. EPA estimated Mestena's 2015 sales revenues by first estimating their production, then multiplying estimated production times the projected 2015 price of uranium. For Mestena's Alta Mesa ISR operation, EPA estimated 2015 production to be 500,000 pounds. At $57 per pound, which is the projected price of U_3O_8 in 2015, Mestena's estimated revenue from uranium sales would be $28.5 million. Another small firm, Uranium Energy Corporation (UEC), reported that it had sold 220,000 pounds of uranium in 2013 for $9.0 million. Based on projections that the market for uranium will have recovered somewhat by 2015, EPA estimates that UEC also will sell 500,000 pounds of U_3O_8 in 2015, with estimated revenues of $28.5 million. The third small business, Ur-Energy, stated in its 2013 Annual Report that it planned to sell 1,000,000 pounds of U_3O_8 from its Lost Creek operation in 2014. EPA thus assumed that 2015 production at Lost Creek would again be 1,000,000 pounds and that Ur-Energy's revenues for the year would be $57 million. For the two large firms, Cameco and Uranium One, EPA used 2013 reported sales as the estimate for 2015 sales.

EPA's analysis estimates that average estimated costs of complying with the proposed rule represent between 0.6% and 1.9% of estimated revenues for the three small businesses, and between 0.1% and 0.6% of revenues for the two businesses that are not small. Even using the high estimated costs and making the unrealistic assumption that 100% of facilities' acreage would be involved in operations regulated under the proposed rule at a given time, the maximum cost-to-sales ratio is 1.9%. For none of the firms analyzed does EPA's analysis indicate that costs of the proposed rule would exceed 2% of company sales revenues. EPA has chosen to analyze the possible impacts on companies owning ISR facilities using information about the companies that own existing ISR operations because they are believed to be representative of companies that may own ISR facilities in the future. EPA examined financial information for some firms that own planned facilities. However, it is unclear when and indeed whether these ISR facilities may begin producing uranium. Without this information about planned production, EPA was unable to include them in the analysis. Thus, the results in Table 5-3 include only firms that own existing ISR facilities.

Using these companies as representative of companies that may own ISR facilities affected by the proposed rule and estimating revenue for the small firms based on estimated production in 2015, EPA found that their costs would be between 0.6% and 1.9% of firm revenue, based on average compliance costs, and at most 2.2% based on high-cost estimates. Further, EPA estimates that fewer than 10 small businesses would be affected by the proposed rule at any time in the future. Thus, EPA thus does not expect the costs of complying with the proposed rule to result in significant impacts to a substantial number of small firms.[17]

5.6 Uncertainties

For a given ISR operation, the costs of complying with the proposed rule are a function of the characteristics of the wellfields at that operation. Unfortunately, EPA does not have detailed descriptions of the mine units at existing ISR operations and thus cannot directly estimate the costs that would be incurred for individual wellfields. Instead, EPA estimated the costs of complying with the proposed rule for a CMU and scaled the costs up, proportional to

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[17] Cost-to-sales ratios for firms owning ISR operations under different regulatory alternatives are shown in Table D-3. Even for the highest cost assumptions and the most costly regulatory alternative, costs represent at most 2.7% of estimated firm sales. These estimates support EPA's findings that there would not be a significant economic impact to a substantial number of small entities.

total acreage, to estimate the costs for each ISR facility. This approach implies that costs are a function of wellfield size and does not take into account the other facility-specific factors that would affect costs. For example, in the case of a site composed of more than one distinct ore zone within its footprint, costs would be underestimated because more monitoring and sampling would be conducted than assumed in the scaling calculations reported here. Unfortunately, in the absence of wellfield-specific data, EPA is unable to assess whether costs for a particular ISR facility are overestimated or underestimated.

EPA estimated the costs of undertaking additional monitoring at the pre-operational, operational, restoration, stability, and long-term stability monitoring stages. Incremental costs were computed by subtracting estimated costs of current compliance practices from the estimated costs of compliance under the proposed rule. EPA recognizes that many of the provisions of the proposed rule are embodied in existing permits and licenses. Therefore, the incremental costs of the proposed rule are somewhat overstated. However, EPA is unable to determine the exact magnitude of this effect.

EPA has analyzed the potential economic impacts of the proposed rule and possible impacts on both small and large owner companies using information about the projected 2015 conditions in the market for uranium and companies owning existing ISR facilities. The proposed rule will take effect in 2015 and affect ISR facilities that operate from that time, going forward. Conditions in the uranium market are volatile; the price of uranium and the market share of U.S. producers have historically been variable. The market price of uranium is projected to increase to about $57 per pound of U_3O_8 equivalent, from a 2013 price of about $52 per pound. If that occurs, several of the facilities that are currently idle or that are in the process of being licensed may begin production. Revenues for firms owning ISR uranium facilities would certainly increase, if both production and price rises. However, EPA is unable to estimate how those changes would affect estimated market impacts and impacts on small entities and has made conservative assumptions about the quantities of U_3O_8 that would be produced by these facilities. Also, although the EIA projects that both purchases of uranium and its price will increase by 2015, the price of uranium has recently been declining, because of the combined influences of the Fukushima earthquake and tsunami and the global economic downturn. If the market for uranium does not recover as projected, 2015 conditions could reflect lower purchases and prices than are estimated in this study. EPA used publicly available sales revenue data for two large firms owning ISR facilities. For the small entities, EPA first estimated 2015 production by estimating 2015 production levels based on their capacity and recently reported production levels, adjusted to reflect somewhat higher prices and production in 2015. EPA then estimated revenues for these firms by multiplying the estimated production times the projected 2015 price of $57 per pound. These estimates are thus based on EPA’s projections of 2015 conditions in the uranium market; both production and the price of uranium in 2015 are uncertain.

Section 6

STATUTORY AND EXECUTIVE ORDER REVIEWS

6.1 Synopsis

This section summarizes the statutory and Executive Order (EO) impact analyses relevant for Proposed Revisions to 40 CFR Part 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings. For each EO and statutory requirement, we describe both the requirements and the way in which our analysis addresses these requirements.

EPA has concluded that ISR uranium facilities, if not adequately monitored during and after operations, have the potential to pollute adjacent groundwater aquifers if geochemical conditions in the wellfield change after restoration so that uranium is once again mobilized. Such pollution would potentially impose costs on people who are neither buyers nor sellers of uranium (thus, external to the market) who may be exposed to pollutants in down-gradient aquifers. Externalities such as pollution are one type of market failure, which requires regulatory intervention to ensure that social benefits of uranium production exceed social costs of its production.

6.2 Executive Order 12866: Regulatory Planning and Review and Executive Order 13563: Improving Regulation and Regulatory Review

Under EO 12866 (58 FR 51735, October 4, 1993), this action is a "significant regulatory action." The EO defines "significant regulatory action" as one that is likely to result in a rule that may "raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Executive Order."

White House Office of Management and Budget Circular A-4, *Regulatory Analysis*, requires government agencies to consider market failure "to the extent permitted by law and where applicable." In market transactions where information is equally available to buyers and sellers, all costs and benefits are borne by either buyers or sellers and there are enough buyers and sellers to ensure competition, markets will efficiently allocate resources so that, from society's point of view, the net benefits of the market transactions are maximized. However, in situations where production of a commodity such as uranium produces pollution, people who are external to the market (neither buyers nor sellers in the market) for uranium may be exposed to uranium and thus bear costs. These external costs or negative externalities are one example of market failure and are the underlying justification for government regulatory intervention in such markets. Based on its examination of hydrogeology and geochemistry at ISR sites and its review of publicly available information about ISR mining operations, EPA believes that ISR operations pose a risk of contaminating groundwater and having the contamination remain undetected for years, if sufficient post-restoration monitoring is not done. Because ISR uranium mining poses the potential for external costs and is thus affected by market failure, EPA is required by EO 12866 to develop this proposed rule and to examine its economic impacts, costs, and benefits to ensure that its benefits to society exceed its costs.

Thus, EPA has conducted this economic analysis to examine the costs, benefits, and estimated impacts of the proposed rule. EPA's study estimates that affected ISR operators would incur costs to comply with the proposed rule, which would require comprehensive pre-operational characterization of the site (including characterization of geochemical conditions down-gradient of the production zone), careful monitoring during the operation, restoration of groundwater quality, at least 3 years of stability monitoring, and 30 years of long-term stability monitoring, with the potential to shorten the duration based on modeling and monitoring of down-gradient geochemical conditions. Using existing ISR operations as models for ISR operations that would be affected by the rule, projecting that 2015 ISR uranium production will be 8.95 million pounds, and using average estimated costs of complying with the proposed rule, EPA estimates that the proposed rule would increase the average cost of uranium production at ISR facilities by approximately $1.50 per pound of uranium and that annual costs incurred by individual ISR facilities would vary from $303,000 to $9.5 million, depending on the scale of the ISR. Nationally, EPA estimates that the incremental total annual cost of the proposed rule would be approximately $13.5 million. Discounted at 7%, the estimated present value of the stream of national costs would be approximately $181 million. Discounted at 3%, the estimated present value of national costs would be approximately $290 million. EPA also examined the costs that would be incurred under a regulatory option that would require 30 years of long-term stability monitoring with no option for shortening the duration using geochemical modeling. National total annualized cost under this alternative is slightly higher, an estimated $15.1 million. The estimated discounted present value of costs (discounted at 7%) would be approximately $203 million; discounted at 3%, the estimated present value of costs under this alternative would be approximately $420 million. Please see Appendix D for a sensitivity analysis of estimated costs and impacts of the proposed rule and the 30-year long-term stabilization monitoring alternative.

EPA conducted a qualitative assessment of the benefits of the proposed rule. The rule would require thorough characterization of baseline conditions within the ore zone and surrounding aquifers and would put in place an automatic updating feature so that the requirements affecting ISR operations are always consistent with requirements of SDWA and RCRA. Further, EPA's proposed rule would require a longer period of monitoring, 30 years, to ensure that conditions in the exempted aquifer had been restored, had achieved steady state, and were stable. Further, EPA allows facilities to use geochemical modeling to demonstrate that groundwater conditions will remain stable and thereby reduce the duration of stability monitoring to less than 30 years. These provisions help ensure that, after the ISR operation's license is terminated and the site is closed, groundwater conditions do not deteriorate. Groundwater is a valuable resource, particularly in the western United States where ISR uranium mining is most common. Although EPA is unable to quantify the value of the groundwater resources that would be protected by the proposed rule, EPA nevertheless believes that the groundwater resources are likely to become more valuable over time. Reducing the risk of contamination of groundwater also protects surface water bodies to which it discharges. If groundwater near an ISR facility were to become contaminated due to remobilization of uranium and other constituents, it might be many years before the contamination was discovered, especially under current practice where stability monitoring typically lasts only a year or two.

One way to illustrate the potential benefits of the proposed rule is to estimate the costs of corrective action that would be required if contamination occurred. If the proposed rule prevents the contamination (or causes it to be discovered sooner), it would reduce the corrective action costs incurred to remediate the contamination. EPA estimated potential contamination and associated corrective action costs for the CMU under various assumptions. The costs of remediation far exceed the costs of complying with the proposed rule, both on an annualized basis and as a present value. Using a hydrological model, EPA estimated that cleaning up the plume of contamination could require 100 years of pump and treat remediation. In addition, if contamination were detected after decommissioning of a site, the costs of remediation could be borne by the taxpayer or by the owner of the property, rather than the uranium company responsible, if the former owner company were no longer in existence. Because we cannot anticipate how many ISR operations might experience deteriorating groundwater conditions after decommissioning or how long it would be before the contamination would be detected, EPA is unable to estimate what the national cost savings resulting from avoided remediation costs might be. However, EPA believes they could be substantial.

In addition to cost savings, the proposed rule has the potential to protect human and ecosystem health. Since a closed ISR facility has no regulatory oversight, this provision would reduce the risks of unintended exposure of human and ecological receptors to chemical and radiological constituents. To the extent that such exposures are reduced, associated human health risks such as cancer may also be reduced.

6.3 Paperwork Reduction Act

EPA has determined that this action does not impose an information collection burden under the provisions of the Paperwork Reduction Act, 44 U.S.S. 3501 et seq. Burden is defined at 5 CFR 1320.3(b).

6.4 Regulatory Flexibility Act

The RFA generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For purposes of assessing the impacts of the proposed rule on small entities, small entity is defined as (1) a small business whose company has fewer than 500 employees and is primarily engaged in leaching or beneficiation of uranium, radium, or vanadium ores as defined by NAICS code 212291; (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field. Of these three categories, only small businesses are potentially affected by the proposed rule; no small organizations or small governmental entities have been identified that would be impacted by the proposed revisions to Part 192.

This proposed rule is estimated to impact approximately 19 ISR uranium recovery facilities that are currently operating or may operate in the future. The 19 uranium recovery facilities are owned by 10 firms, of which eight are believed to be small.

To evaluate the significance of the economic impacts of the proposed revisions to Part 192, EPA estimated the costs that would be incurred by existing facilities, based on their estimated production and EPA's estimated cost per pound of U_3O_8. According to EPA's *Final Guidance for EPA Rule Writers: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act* (EPA, 2006), firms for which estimated costs of complying with a rulemaking are less than 1% of firm sales are presumed not to incur significant impacts. Firms for which costs exceed 3% of firm's baseline sales are believed to incur significant impacts. If costs of compliance are between 1% and 3% of the firm's revenue, it is not certain whether impacts would be significant.

To analyze the proposed revisions to Part 192, EPA assessed potential impacts to six currently operating ISRs, believing that they are good proxies for firms that would own affected ISR facilities subject to the proposed rule. The operating ISRs are Crow Butte and Smith Ranch-Highland-Reynolds owned by Cameco Resources, Alta Mesa owned by Mestena Uranium, LLC, Willow Creek owned by Uranium One, Inc., Hobson-La Palangana owned by Uranium Energy Corp, and Lost Creek owned by Ur-Energy Corporation. Using the fewer than 500 employees' criterion, Mestena Uranium, LLC, Ur-Energy Corporation, and Uranium Energy Corporation are small businesses, while Cameco Resources and Uranium One, Inc. are both large businesses.

In addition to the six operating ISRs, 12 ISRs have are at some stage of planning or licensing, or are undergoing restoration:

- Dewey-Burdock owned by Powertech Uranium Corp.;
- Nichols Ranch owned by Uranez Uranium Corp.;
- Moore Ranch and Antelope-Jab, owned by Uranium One, Inc.;
- Crownpoint, Kingsville Dome, Rosita, Church Rock, and Vasquez all owned by Uranium Resources;
- Ross, owned by Strata Energy/Peninsula Energy Ltd;
- Goliad, owned by Uranium Energy Corp; and
- Reno Creek, owned by Bayswater E&P.

All of these companies, except Uranium One, Inc., are small businesses.

Of the facilities identified above, 11 are owned by eight small businesses. EPA's economic impact analysis estimated that for the small firms currently operating ISR facilities, costs of the proposed rule would be at most 0.7% of estimated 2015 operating revenues for Ur-Energy, at most 1.2% of estimated 2015 operating revenues for Uranium Energy, and at most 1.9% of estimated 2015 operating revenues for Mestena, if the highest-cost assumptions were used. Based on EPA's criteria for significance, impacts for these firms are not believed to be significant. In addition, the number of firms potentially incurring costs to comply with the rule is not a substantial number. Thus, EPA concludes that the proposed rule would not result in a significant impact to a substantial number of small entities. (See Section 5.5 above for additional details.)

6.5 Unfunded Mandates Reform Act (UMRA)

This rule does not contain a federal mandate that may result in expenditures of $100 million or more for state, local, and tribal governments, in the aggregate, or the private sector in any 1 year. Using the five existing ISR operations as examples of typical ISR facilities, EPA estimates that total annual costs of complying with the rule for five such ISR facilities would range from $11.6 million to $15.2 million, averaging $13.5 million, assuming geochemical modeling to shorten the duration, and between $12.9 and $17.9, averaging $15.1 for required 30-year duration of long term stability monitoring. The proposed rule imposes no enforceable duties on any state, local, or Tribal governments or the private sector. Thus, this rule is not subject to the requirements of sections 202 or 205 of UMRA.

This rule is also not subject to the requirements of section 203 of UMRA because it contains no regulatory requirements that might significantly or uniquely affect small governments because it contains no requirements that apply to such governments nor does it impose obligations upon them.

6.6 Executive Order 13132: Federalism

This proposed rule does not have federalism implications. It will not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government, as specified in EO 13132. None of the facilities subject to this action are owned and operated by state governments, and, nothing in the proposed rule will supersede state regulations. Thus, EO 13132 does not apply to this proposed rule.

6.7 Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

This action does not have tribal implications, as specified in EO 13175 (65 FR 67249, November 9, 2000). The action imposes requirements on owners and operators of ISR facilities and not tribal governments. Although EO 13175 does not apply to this action, EPA sought opportunities to provide information to tribes and tribal representatives during the review of 40 CFR Part 192. EPA specifically solicits additional comment on this proposed action from tribal officials.

6.8 Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks

EPA interprets EO 13045 (62 FR 19885, April 23, 1997) as applying to those regulatory actions that concern health or safety risks, such that the analysis required under section 5-501 of the Order has the potential to influence the regulation. Because this action addresses environmental standards intended to mitigate health or safety risks, it is subject to EO 13045. We evaluated several regulatory strategies for ensuring groundwater restoration and stability at ISR facilities and selected the option providing most assurance that groundwater systems will remain in a chemically reduced state, thereby limiting contamination of groundwater. The proposed rule is expected to reduce children's risk of exposure to contaminated groundwater by improving monitoring to detect and correct contamination.

6.9 Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution or Use

This action is not a "significant energy action" as defined in EO 13211 (66 FR 28355, May 22, 2001), because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. This proposed rule will not adversely directly affect productivity, competition, or prices in the energy sector. EPA projects that the proposed rule would reduce the quantity of uranium used in this country to produce electricity by less than 0.1%. The price of uranium is projected to increase by only $0.24 (0.4%) per pound, and this is projected to increase the cost of producing electricity by less than 0.1%.

6.10 National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) of 1995 ("NTTAA"), Public Law No. 104-113, 12(d) (15 U.S.C. 272 note) directs EPA to use voluntary consensus standards in its regulatory activities unless to do so would be inconsistent with applicable law or otherwise impractical. Voluntary consensus standards are technical standards (e.g., materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standards bodies. NTTAA directs EPA to provide Congress, through OMB, explanations when the Agency decides not to use available and applicable voluntary consensus standards.

This proposed rulemaking does not involve technical standards of the type indicated in NTTAA. Therefore, EPA is not considering the use of any voluntary consensus standards.

We request public comment on this aspect of the proposed rulemaking, and specifically, ask you to identify potentially applicable voluntary consensus standards and to explain why such standards could be used in this regulation.

6.11 Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

EO 12898 (59 FR 7629, Feb. 16, 1994) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States.

EPA has determined that this proposed rule will not have disproportionately high and adverse human health or environmental effects on minority or low-income populations because it increases the level of environmental protection for all affected populations without having any disproportionately high and adverse human health or environmental effects on any population, including any minority or low-income population**.** This proposed rule addresses groundwater restoration, monitoring, and protection of surrounding aquifers and thus decreases the potential groundwater contamination to which all affected populations are exposed. Thus, the proposed rule is projected to have positive, not adverse, impacts on human health and the environment.

Section 7

CONCLUSIONS

EPA is proposing revised groundwater monitoring program for ISR facilities that produce uranium by injecting and extracting a solution that dissolves the uranium from the porous minerals in which it is found. ISR uranium production represents an increasing share of uranium production, and poses special groundwater protection challenges, compared to conventional uranium production. Currently, facilities are required to monitor groundwater conditions for only a short time (generally less than 2 years) after restoration. Case studies of post-restoration monitoring conducted by the U.S. Geological Survey (USGS, 2009) have shown that conditions may not remain stable within restored wellfields, with concentrations of some constituents increasing again. Thus, there is a potential for uranium and other constituents to remobilize over time, with the potential for groundwater contamination. Accordingly, EPA is proposing to add a new subpart to 40 CFR Part 192, establishing additional monitoring requirements during all phases of an ISR facility:

- Pre-operational monitoring: measuring background groundwater concentrations
- Operational monitoring: monitoring, to detect any excursions of contaminated groundwater to adjacent aquifers, either beside, above, or below the exempted aquifer
- Restoration monitoring: monitoring to document the progress of restoration through groundwater sampling
- Post-restoration monitoring, which has two parts:
  - Stability monitoring: monitoring, conducted after restoration efforts have ended, to establish that wellfield groundwater characteristics are stable and meet restoration goals (at least 3 years)
  - Long-term stability monitoring: monitoring and statistical analyses to show that the concentration of each monitored constituent is not increasing with time and that the concentration is not statistically different from the restoration goal

Using a model facility approach, EPA estimated the costs that facilities may incur to comply with the proposed rule; costs were estimated for each phase of ISR operation under two regulatory options, and a range of costing assumptions. Cost data were compiled for each stage over the duration of the stage’s monitoring activities for the CMU, then scaled up based on relative total wellfield acreage to estimate the costs that would be incurred by existing facilities. EPA estimated the acreage of the CMU and scaled estimated CMU costs up to actual facility costs using the ratio of total wellfield acreage at existing facilities to acreage of the CMU. These estimated facility costs were used to assess impacts on the market for uranium and on firms owning ISR facilities.

The market for uranium is an international market, with suppliers and demanders in many countries. The United States has historically been the largest user of uranium for electricity production but has generally produced only a small share of what it consumes, and foreign suppliers have provided the remaining 80% to 90%. The uranium market has historically been volatile, exhibiting considerable year-to-year variation in both price and domestic production. Going forward, the worldwide demand for uranium is projected to grow substantially over the next 20 years, due largely to increased demand from China and India; prices are also projected to increase to $64 per pound by 2018. The U.S. EIA projects that uranium purchased by COOs of nuclear power plants will grow by approximately 0.2% annually. Using this rate of growth, EPA projected baseline market conditions in the U.S. uranium market in 2015, the effective date of the proposed rule.

EPA estimated the impact of the proposed rule on the market for uranium and found that, overall, the market quantity of uranium purchased for use in electric generation would decline by less than 0.1% and the market price would increase by approximately 0.4%. Domestic ISR facilities would decrease their production by approximately 4.1%, and imports of uranium would increase by less than 1%. Because the cost of uranium is a very small share of the cost of electricity, EPA estimates that the cost of generating electricity would increase by less than 0.1%.

Although the national total annual costs of the proposed rule (approximately $13.5 million, based on average costs) is well below the $100 million threshold that is one of the criteria used to identify a significant regulatory action, the industry has only a small number of companies operating a small number of ISR operations. EPA used existing ISR operations and the companies that own them as models for the types of facilities and companies that would likely be affected by the proposed rule. EPA thus estimated the ISR facilities would incur annual costs of compliance between $262,000 and $12.7 million depending on the characteristics of the ISR facility and the alternative and costing assumptions used; for small firms owning ISR facilities, EPA's analysis estimates cost-to-sales ratios of 0.6% to 2.2%, depending on the size of the operation and the costing assumptions used. Because EPA does not estimate costs to exceed 2.2% of small company sales, and because fewer than 10 small companies would be affected, EPA has determined that the proposed rule would not have a significant impact on a substantial number of small entities.

EPA's qualitative benefits assessment presents a discussion of the expected effects of the proposed rule on human and environmental health. EPA expects that the improved monitoring program proposed will reduce the risk of contaminating groundwater resources, thus also reducing potential exposures to radiological and nonradiological contaminants in groundwater and potentially in surface water to which affected aquifers discharge. Because the major risk of exposure to radiological constituents is cancer, the proposed rule has the potential to reduce cancer risks.

If uranium and other constituents remobilize in groundwater over time and if monitoring ends too soon and sites are prematurely decommissioned, it is possible that groundwater in surrounding aquifers could be contaminated, and it might be many years before the contamination is detected. EPA simulated groundwater contamination using its CMU model facility under varying assumptions and estimated the costs of corrective action to remediate the groundwater contamination. Based on these simulations, the cost of remediation would far exceed the costs of complying with the proposed rule, both on an annual and total basis. For the model facility simulation, this subset of benefits (avoided remediation costs) exceeded the costs of complying with the proposed rule. See Table 7-1 for this comparison. Further, if contamination were detected after decommissioning, the costs of remediation could be borne by the taxpayer or the land owner, not the uranium company owner/operator (if, for example, the former owner company were no longer in existence or if sufficient time had passed that the connection between the contamination and the decommissioned mining operation was not identified). EPA was unable, however, to estimate potential avoided costs of remediation on a national scale and thus was unable to quantify the rule's net benefits nationwide.

Table 7-1. Comparison of Costs of Complying with the Proposed Rule and Costs of Remediating Contaminated Groundwater (Million 2011$)

	Sum of Costs Over Time		
Plume Size and Groundwater Flow Direction	**Without-Regulation Scenario (A)**	**With-Regulation: Compliance and Additional Restoration (B)**	**Avoided Costs (A) − (B)**
Small plume	$35.3	$27.1	$8.2
Large plume, transverse	$481.0	$27.1	$453.9
Large plume, along	$586.1	$27.1	$559.0
		Annualized Costs	
Small plume		$1.45 million	
Large plume, transverse		$10.3 million	
Large plume, along		$10.5 million	
Compliance with proposed rule plus additional restoration		$345,000	

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APPENDIX A:
UNIT COSTS FOR WELLS AND BORINGS

Unit costs were compiled for both wells and geotechnical borings. The number of wells and borings varied between the groundwater monitoring scenarios. The following is a summary of the unit costs used in the cost analysis.

A.1 Mine Unit Wells

The well types considered in the conceptual mine unit (CMU) models developed for the groundwater monitoring scenarios evaluated include:

- Injection wells
- Extraction wells
- Perimeter monitoring wells,
- Excursion monitoring wells in the overlying and underlying aquifers

Additional well types considered for some scenarios included:

- Down-gradient ore zone monitoring wells,
- Remediation wells

The total depths of these wells were based on the hydrogeology of the example mine unit from the Highland site in Wyoming. Table A-1 below summarizes the well depths of overlying and underlying monitoring wells and also the production wells (Michel and Hoffman, 1991). The average depth for each well zone (i.e., ore zone, overlying aquifer, and underlying aquifer) was used to calculate the unit costs.

EPA (2012b) previously estimated the cost per foot (ft) for well construction. This was assumed to include costs for well materials (casing, well screen, caps, etc.), mobilization of drill rig and support trucks, drilling time, and surface completion (materials and labor). Range of costs for well construction was from $9 to $32 per foot. Higher costs per foot were typically for shallower wells. Based on documentation provided by EPA a cost of $30 per foot was assumed for any well 500-ft or deeper. Since the wells at the Highland site, on which the CMU model was based, are in the 500-foot depth range, the unit cost of $30 per foot was chosen all well types considered in the groundwater monitoring and remediation scenarios. Costs of production wells were also used for other ore zone wells (i.e., ore zone monitoring wells and remediation wells).

Table A-1. Depth of Selected Wells and Average Unit Cost

Overlying Wells		Underlying Wells		Injection/Extraction Wells	
Total Depth	**Well Cost**	**Total Depth**	**Well Cost**	**Total Depth**	**Well Cost**
410.4	$12,312	620.5	$18,615	635	$19,050
519.1	$15,573	658	$19,740	624	$18,720
534	$16,020	669	$20,070	559.3	$16,779
435	$13,050	681.3	$20,439	562	$16,860
484	$14,520	689.45	$20,684	597	$17,910
426	$12,780	682	$20,460	602	$18,060
510	$15,300	670	$20,100	618	$18,540
550	$16,500	650	$19,500	596	$17,880
424.5	$12,735	651	$19,530	589	$17,670
540	$16,200	676.8	$20,304	600.5	$18,015
520	$15,600	664.1	$19,923	600	$18,000
545	$16,350	669.6	$20,088	610.5	$18,315
450	$13,500	660	$19,800	602.5	$18,075
		668	$20,040	584	$17,520
		690	$20,700	596.5	$17,895
				594	$17,820
				600.4	$18,012
				589.9	$17,697
				592	$17,760
				595	$17,850
				600	$18,000
				597.1	$17,913
				602.5	$18,075
				592	$17,760
				597	$17,910
				612	$18,360
				614.6	$18,438
				621.3	$18,639
				618	$18,540

(continued)

Table A-1. Depth of Selected Wells and Average Unit Cost (continued)

	Overlying Wells		Underlying Wells		Injection/Extraction Wells	
	Total Depth	Well Cost	Total Depth	Well Cost	Total Depth	Well Cost
					614	$18,420
					625	$18,750
					604	$18,120
					650	$19,500
					645	$19,350
					600	$18,000
					601	$18,030
					571.5	$17,145
					588	$17,640
					629.6	$18,888
					595	$17,850
					607	$18,210
					586	$17,580
					593	$17,790
					599.3	$17,979
					581.7	$17,451
					537	$16,110
					585.4	$17,562
					592.4	$17,772
					612.8	$18,384
					631.8	$18,954
					602.55	$18,077
					591.6	$17,748
					591	$17,730
					592.5	$17,775
					557	$16,710
MAX=	550	$16,500	690	$20,700	650	$19,500
MIN=	410	$12,312	621	$18,615	537	$16,110
MEDIAN=	510	$15,300	669	$20,070	599.3	$17,979
AVERAGE=	**488**	**$14,649**	**660**	**$19,795**	**600**	**$17,993**

A.2 Geotechnical Borings

Costing information available from the U.S. DOE (2013) for geotechnical boring drilled for characterizing the geochemistry for geothermal energy development in the western United States was used as a guide for estimating corehole costs. However, due to the way the DOE costs were presented and limited time, the estimated costs for geotechnical borings was also based on experience and best professional judgment. The costs of a geotechnical boring is related to the corehole depth, penetration rate expected, drilling method and technology requirements, the number of samples, type of samples taken and the sample method; and there are also regional factors that control costs for drilling and construction services (e.g., variation in licensing and permitting requirements). Boring costs were only assumed applicable for geochemical modeling. Drilling time was assumed to be one day per corehole with a maximum drilling depth of 650-feet which is the total average depth assumed for the underlying non-exempt aquifer in the CMU. Composite sampling of selective zones in each corehole was assumed resulting in 2 samples per corehole, on average, sent to the laboratory for analysis. Costs for core analysis and logging were also included. A summary of the boring costs assumptions and the total costs for the boreholes is provided in Table A-2.

Table A-2. Summary of Well and Borehole Costs Assumed for Modeled Scenarios

Well Types	Unit Cost ($/well; $/core; $/day)	CMU Well Totals and Costs					
		CP	2011$	30-yr	2011$	30-yr with Geochem	2011$
OZ-PW	$17,993	26	$467,805	26	$467,805	26	$467,805
OZ-IW	$17,993	166	$2,986,755	166	$2,986,755	166	$2,986,755
OZ-EW	$17,993	77	$1,385,423	77	$1,385,423	77	$1,385,423
OZ-MW	$17,993	0	$0	0	$0	10	$179,925
OW	$14,649	5	$73,246	10	$146,492	10	$146,492
UW	$19,795	10	$197,950	20	$395,900	20	$395,900
	Well Totals:	284	$5,111,179	299	$5,382,375	309	$5,562,300
Core Hole	$11,316.50	0	$0.00	0	$0.00	8*650ft	$90,532.00
Core Analysis	$400.00	0	$0.00	0	$0.00	8	$3,200.00
Lab Analysis	$400.00	0	$0.00	0	$0.00	8	$3,200.00
	Core Totals:	0	$0.00	0	$0.00		$96,932.00

CP = current practice

A.3 References

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APPENDIX B:
SUMMARY OF UNIT COSTS FOR SAMPLING AND ANALYSIS

Unit costs were determined for the collection and analysis of a groundwater sample. These unit costs were then used for estimating total sampling and analysis costs for each of the groundwater monitoring scenarios evaluated. Groundwater sampling and analysis costs are summarized for each scenario in Section 3 of the report.

B.1 Analysis Costs

The total laboratory costs are dependent upon the number of parameters that are analyzed. EPA recognizes that analytical costs are site specific since the list of parameters required for monitoring are a function of the geochemistry of the aquifer units being sampled, as well as operational and regulatory requirements. In general, analytes may be required for analysis based on EPA or state regulation, to identify excursions, to monitor the condition of the lixiviant, and to characterize and model the pre and post-mining geochemistry (U.S. EPA, 2012a). The groundwater monitoring scenario cost models have assumed full lists of applicable analytes, and no assumptions were made that would serve to reduce a list of parameters and analytes (e.g., based on the Highlands site geochemistry and CMU model) that might be sampled due to an assumed monitoring requirement (i.e., state, EPA NRC, etc.).

The lists of parameters and analytes were originally compiled from 4 different sources—including EPA, NRC, TCEQ, and WDEQ—as seen in Table B-1. A unit cost was developed to estimate the cost of analyzing the full suite of 56 parameters, as well as for various subsets, including the EPA specified 33 parameters, the 35 parameters from the NRC's ISL Standard Review Plan, and the state specified parameters. EPA collected costs to perform the specific analyses required from 12 actual analytical laboratories (TDSHS, 2007; Pace, 2009; BVNA, 2010; NDHHS, 2010; ELI, 2011; CCAL, 2012; ML, 2013; ELI, 2013; SARA, 2012; ACTI, 2005; EPA, 2012b). The average, low, median, and high analytical costs for each analyte are shown in Table B-1. Average costs were only used in the analysis of the groundwater monitoring scenarios; however, the other costs are provided for comparison.

Table B-1. Analysis Costs for Analytes Generally Required in ISR Groundwater Monitoring Programs (2011$)

	Requirements by Analyte Group						Analysis Cost (sample^{-1})			
Species	**EPA**	**NRC**	**TCEQ**	**WDEQ**	**UCL[j]**	**Geochem**	**Average**	**Low**	**Median**	**High**
Trace and Minor Elements										
Aluminum	Yes					Yes	$13.63	$8.00	$14.40	$19.00
Antimony	Yes						$13.63	$8.00	$14.40	$19.00
Arsenic	Yes	Yes	Yes	Yes			$13.63	$8.00	$14.40	$19.00
Barium	Yes	Yes					$13.63	$8.00	$14.40	$19.00
Beryllium	Yes						$13.63	$8.00	$14.40	$19.00
Boron		Yes		Yes			$13.63	$8.00	$14.40	$19.00
Cadmium	Yes	Yes	Yes	Yes			$13.63	$8.00	$14.40	$19.00
Chromium	Yes	Yes		Yes			$13.63	$8.00	$14.40	$19.00
Cobalt	Yes						$11.83	$8.00	$10.00	$19.00
Copper	Yes	Yes					$13.63	$8.00	$14.40	$19.00
Fluoride	Yes	Yes	Yes	Yes		Yes	$16.50	$12.00	$15.50	$21.00
Iron[i]	Yes	Yes	Yes	Yes		Yes (Total and Fe2+)	$13.97	$8.00	$14.40	$19.00
Lead	Yes	Yes	Yes				$13.63	$8.00	$14.40	$19.00
Manganese	Yes	Yes	Yes	Yes		Yes	$13.97	$8.00	$14.40	$19.00
Mercury	Yes	Yes	Yes				$17.13	$8.00	$14.40	$37.00
Molybdenum	Yes	Yes	Yes	Yes			$13.63	$8.00	$14.40	$19.00
Nickel	Yes	Yes					$13.63	$8.00	$14.40	$19.00
Selenium	Yes	Yes	Yes	Yes			$13.63	$8.00	$14.40	$19.00
Silver	Yes	Yes					$13.63	$8.00	$14.40	$19.00
Thallium	Yes						$13.63	$8.00	$14.40	$19.00
Tin	Yes						$11.00	$8.00	$10.00	$19.00
Uranium	Yes	Yes	Yes	Yes		Yes	$16.13	$8.00	$16.00	$25.00
Vanadium	Yes & V_2O_5	Yes		Yes			$11.33	$8.00	$10.00	$16.00
Zinc	Yes	Yes					$13.63	$8.00	$14.40	$19.00

(continued)

Table B-1. Analysis Costs for Analytes Generally Required in ISR Groundwater Monitoring Programs (2011$) (continued)

Species	Requirements by Analyte Group						Analysis Cost (sample^{-1})			
	EPA	NRC	TCEQ	WDEQ	UCL[j]	Geochem	Average	Low	Median	High
Common Constituents										
Alkalinity		Yes			Yes	Yes	$16.33	$10.00	$16.00	$23.00
Ammonia			Yes	Yes		Yes (NH4+)	$23.75	$15.00	$22.50	$35.00
Bicarbonate		Yes	Yes	Yes		Yes	$13.00	$13.00	$13.00	$13.00
Calcium		Yes	Yes	Yes		Yes	$12.17	$8.00	$10.00	$19.00
Carbonate		Yes	Yes	Yes		Yes	$13.00	$13.00	$13.00	$13.00
Chloride	Yes	Yes	Yes	Yes	Yes	Yes	$16.17	$10.00	$17.00	$21.00
Magnesium		Yes	Yes	Yes		Yes	$14.00	$8.00	$10.00	$29.00
Nitrate	Yes	Yes	Yes	Yes		Yes	$20.60	$12.00	$20.00	$30.00
Nitrite	Yes			Yes			$19.83	$12.00	$20.00	$26.00
Phosphate[e]						Yes	$23.33	$20.00	$25.00	$25.00
Potassium		Yes	Yes	Yes		Yes	$14.00	$8.00	$10.00	$29.00
Silica			Yes			Yes	$23.50	$10.00	$26.00	$32.00
Sodium		Yes	Yes	Yes		Yes	$14.00	$10.00	$14.00	$18.00
Sulfate	Yes	Yes	Yes	Yes		Yes	$16.17	$10.00	$17.00	$21.00
Sulfide	Yes			Yes		Yes	$38.00	$35.00	$39.00	$40.00
Chemical and Physical Indicators										
Anion/Cation Balance						Yes	$10.00	$10.00	$10.00	$10.00
Specific Conductivity		Yes[a]	Yes		Yes	Yes	$13.67	$10.00	$12.00	$19.00
pH	Yes	Yes[a]	Yes			Yes	$11.00	$8.00	$10.00	$17.00
Redox Potential						Yes	$45.00	$45.00	$45.00	$45.00
Total Dissolved Solids	Yes	Yes[b]	Yes	Yes	Yes	Yes	$19.33	$12.00	$18.00	$31.00
Temperature						Yes	NA	NA	NA	NA
Turbidity[f]						Yes	$15.00	$15.00	$15.00	$15.00
Dissolved Oxygen[g]						Yes	$18.67	$10.00	$11.00	$35.00

(continued)

Table B-1. Analysis Costs for Analytes Generally Required in ISR Groundwater Monitoring Programs (2011$) (continued)

Species	Requirements by Analyte Group						Analysis Cost (sample^{-1})			
	EPA	NRC	TCEQ	WDEQ	UCL[j]	Geochem	Average	Low	Median	High
Chemical and Physical Indicators (continued)										
Dissolved Organic and Inorganic Carbon[h]						Yes	$39.00	$32.00	$35.00	$50.00
Eh						Yes	NA	NA	NA	NA
Radiological Parameters										
Gross Alpha	Yes	Yes[c]		Yes		Yes	$48.33	$40.00	$50.00	$55.00
Gross Beta		Yes		Yes			$45.00	$40.00	$45.00	$50.00
Radium-226	Yes	Yes[d]	Yes	Yes		Yes	$77.25	$75.00	$75.50	$83.00
Radium-228	Yes	Yes[d]		Yes			$83.00	$70.00	$79.00	$104.00
Beta + Gamma	Yes						$75.00	$75.00	$75.00	$75.00
Totals:	33	35	25	28	4	29				

[a] Field and laboratory determination

[b] Laboratory only

[c] Excluding radon, radium, and uranium

[d] If site initial sampling indicates the presence of Th-232, then Ra-228 should be considered in the baseline sampling or an alternative may be proposed

[e] Phosphate costs from Cooperative Chemical Analytical Laboratory, Midwest Laboratories, Energy Laboratories Inc.

[f] Turbidity costs from Cooperative Chemical Analytical Laboratory (http://www.ccal.oregonstate.edu/fees.htm)

[g] Dissolved oxygen costs from Midwest Laboratories, San Antonio River Authority, and Aquatic & Consulting Testing Inc.

[h] Dissolved Organic and Inorganic Carbon from Cooperative Chemical Analytical Laboratory, two method (Combustion-Infrared and Sparge-Infrared) fees were combined for a total cost of analyzing both species (http://www.ccal.oregonstate.edu/fees.htm)

[i] Dissolved and total

[j] UCL—upper control limit/excursion parameters.

B.2 Groundwater Sampling Unit Costs

Included in the unit cost for groundwater sampling are the:

- laboratory analysis costs,
- labor cost of contractor personnel to collect the sample,
- expenses for contractor personnel to travel to the site,
- contractor fees (assumed 8%), and a
- contingency of 10% of all calculated costs.

These costs were calculated for each analyte group (i.e., EPA, NRC, etc.) and are summarized in Table B-2. The following items are not included or considered in the unit costs:

- materials (e.g., bottles, gloves, and reagents)
- sample transport to laboratory
- lodging
- record keeping,
- well maintenance during stability monitoring,
- sample disposal, as well as
- the impact of using on site personnel, rather than contractor personnel.

Table B-2. Unit Cost for Groundwater Sampling with Analysis Costs (2011$)

	Species Analyzed				
Component	**EPA**	**NRC**	**TCEQ**	**WDEQ**	**Geochem.**
Group Analysis (Average Costs)	$741	$700	$447	$665	$629
Direct Labor (hr^{-1})	$200	$200	$200	$200	$200
Indirect Labor (hr^{-1})	$46	$47	$47	$47	$47
Travel	$26	$26	$26	$26	$26
Fee (8%)	$25	$25	$25	$25	$25
Contingency (10%)	$34	$34	$34	$34	$34
Total	$1,073	$1,032	$779	$997	$961

These costs, individually and in total, were considered a small portion of the sum of analysis and labor costs.

B.3 Parameter References

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APPENDIX C:
SIMULATION OF REMOBILIZED URANIUM FROM A RESTORED ISR MINE

This appendix documents modeling simulations of a plume that could develop within an ore body after ISR mining and restoration have been completed. The scenario represents conditions that have destabilized the restored wellfield years after restoration of the production unit had been completed. The destabilization is due to a natural influx of oxidized groundwater from up-gradient of the mine unit that oxidizes the remaining uranium in the wellfield making it more mobile, thereby allowing a groundwater contamination plume to develop and allow the migration of the constituents down-gradient into the rest of the wellfield and potentially into the aquifer below the production zone. For this situation to develop, the mechanisms that were responsible for sequestering the uranium initially would have to be destroyed or dramatically weakened by the uranium recovery process so that the restoration process amounted to only a temporary re-establishment of chemically reducing conditions in the ore zone. For that situation, the movement of oxygenated groundwater into the production zone from up-gradient could, over time, re-oxidize the uranium and allow migration of the contaminants down-gradient.

The simulations illustrate the potential behavior of a remobilized contamination plume for the example mine site in Wyoming with the model setup generally based on actual conditions at the Highland site. It should be noted, however, that the model is for illustrative purposes only and the results do not suggest that the scenarios developed have or will occur at the example site.

Varying groundwater flow directions were considered for the conceptual mine unit (CMU) based on data from Wellfield-E documentation (Michel and Hoffman, 1991). A general groundwater flow direction, longitudinal with the linear extent of the ore zone, was assumed that could have been either induced from nearby pumping centers (e.g., other ISL production units) or preferential flow toward abandoned, idle, or active underground mine units that were nearby (see Fig. 3-1). A typical groundwater flow direction perpendicular to the length or face of the ore zone front was also considered for the remediation scenarios.

Even though a more eastward groundwater flow gradient is characteristic of the 50-sand unit due to the influence of other nearby pumping or groundwater drainage points, the modeled simulations of groundwater flow predict plume migration under ambient conditions that exist without any active pumping or extraction at the mine site. The simulations also predict plume migration under hypothetical pump and treat remediation scenarios, assuming the remobilized plume is discovered and actively remediated. The modeling results were used to support the estimation of remediation costs for a generally small and larger sized plume.

C.1 Background

The ISR mining process involves the injection of oxidizing agents and other chemicals (the lixiviants) into the ore zone to mobilize uranium for subsequent extraction. The oxidizing agents remove iron sulfides and reactive organic material in addition to uranium. Such naturally-occurring reducing agents were typically responsible for the original uranium sequestration that formed the ore deposit. The restoration process (following the ISR mining) is intended to return the aquifer to a chemically reducing environment similar to pre-mine conditions, thereby immobilizing uranium and other potential contaminants. However, the restoration process can have a limited potential to restore reducing conditions, particularly over long time periods. If levels of iron sulfides and organics have been reduced significantly by the mining process, attempts at restoration may only have a short term effect. The restoration may reduce uranium concentrations in groundwater, but unless a strongly chemically reducing environment is in place, concentrations may later increase. If more oxidizing groundwater enters the mine unit from up-gradient, it can re-oxidize the uranium, thereby increasing concentrations and creating an inorganic contaminant plume of uranium plus other metals (e.g., thorium) in groundwater. This plume could migrate out of the mine unit and impact down-gradient areas of the aquifer, particularly if there is not a strong reducing environment down-gradient, and potentially impacting beneficial groundwater uses.

Effects of uranium re-mobilization could be mitigated through natural attenuation processes that reduce down-gradient concentrations. The key attenuation mechanisms are dispersion along the flow path, sorption of uranium on the aquifer materials, and chemical reduction. The model simulations include mechanisms of dispersion and linear equilibrium sorption. Chemical reduction (and oxidation) processes require more information and more complex modeling than attempted for this evaluation.

C.2 Approach

The assessment uses the groundwater flow model MODFLOW (McDonald and Harbaugh, 1983) and the groundwater transport model MT3DMS (Zheng and Wang, 1999). These codes are well accepted in the technical community and widely used for groundwater and contamination fate and transport modeling. Table C-1 provides input parameter values developed to represent the case study site.

Table C-1. Input Parameter Values

Parameter	Value	Unit	Source
Hydraulic Conductivity (K)	2.20	m/day	Michel, Thomas G. and George Hoffman (July 1991).
Hydraulic gradient	0.0135	—	Michel, Thomas G. and George Hoffman (July 1991).
Porosity	0.20	—	Typical
Aquifer top elevation	1351	m	Michel, Thomas G. and George Hoffman (July 1991); Plate 2-1 and 2-1.
Aquifer bottom elevation	1341	m	Michel, Thomas G. and George Hoffman (July 1991); Plate 2-1 and 2-1.
Head at up-gradient plume boundary (ambient flow)	1570	m	Michel, Thomas G. and George Hoffman (July 1991); Plate 4-2, head near up-gradient ore body location
Pore velocity	0.15	m/day	Calculated (K*gradient/porosity)
Dispersivity	30	m^2/day	Estimated as 0.1*plume scale*pore velocity; plume scale=2000 m (http://www.iowadnr.gov/portals/idnr/uploads/ust/monohydrocarbonsguide.pdf)
Bulk density	2.00E+06	gm/m^3	McWorter, David B. and Daniel K. Sunada, 2010
Ore body length	1600	m	Based on length of northern ore body and configuration of Wellfield E
Ore body width	400	m	Based on width of northern ore body and configuration of Wellfield E
Initial dissolved concentration	0.10	mg/L=gm/m^3	Communication with EPA and data from Wellfield E annual reports
Target dissolved concentration	0.03	mg/L=gm/m^3	Communication with EPA
Kd minimum	1.00E-06	m^3/gm (0.03 mL/gm)	Pearson et al., 1983 and communication with EPA
Kd maximum	1.00E-05	m^3/gm (2200 mL/gm)	Pearson et al., 1983 and communication with EPA
Pumping rate (per well)	164	m^3/day	Michel, Thomas G. and George Hoffman (July 1991).

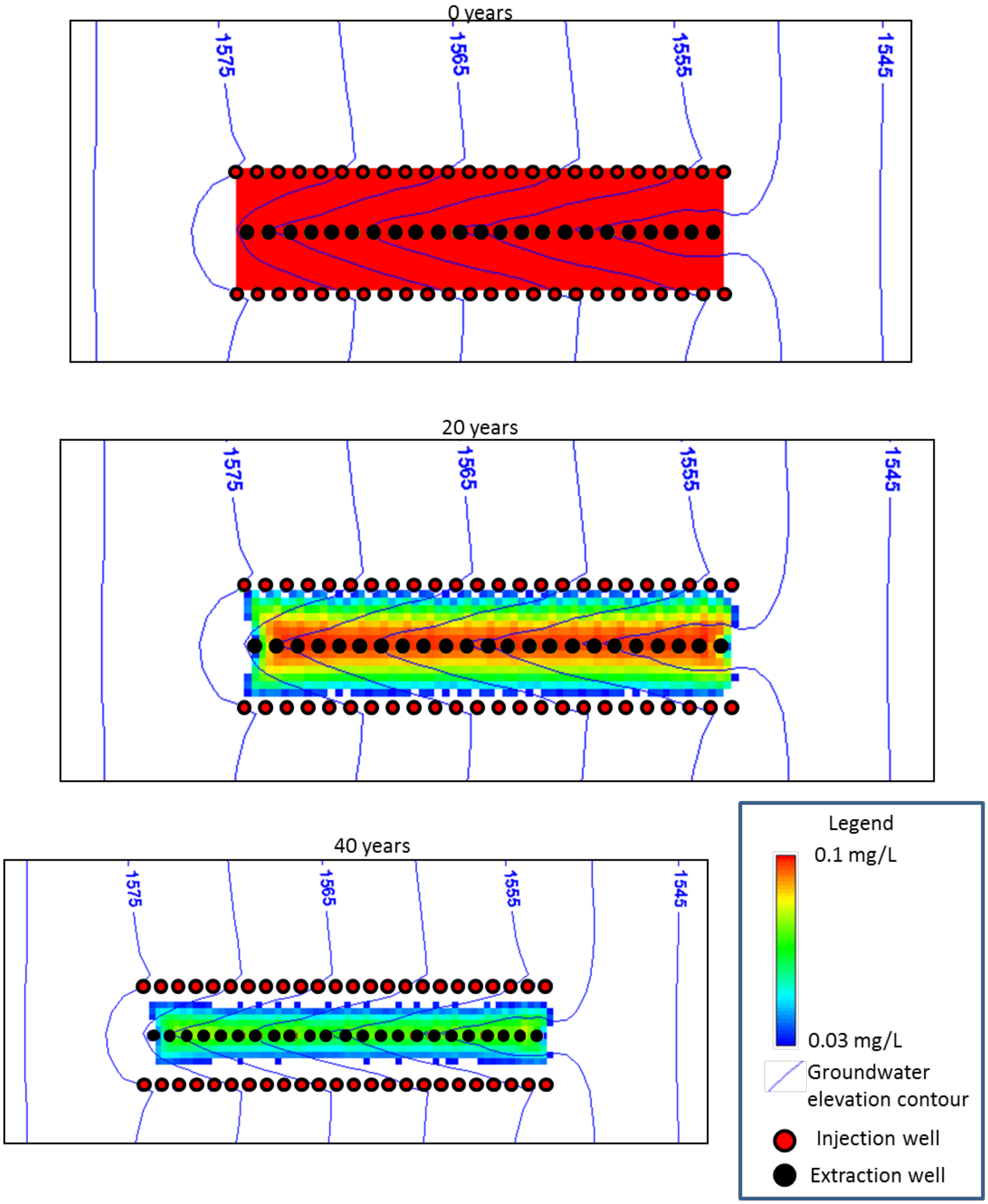
The model domain is rectangular and extends 10,000 m from the ore body in all directions. A line of constant head boundary cells along the up-gradient and down-gradient edges of the domain. The specified head values were set so that the ambient/background groundwater flow gradient matched the gradient at the example mine site. A rectangular plume with a similar geometry to the ore body (see Figures 3-1 and 3-2) was delineated in the middle of the model domain with a concentration of 0.1 mg/L. The simulations predict the time for the plume concentrations to decrease below 0.03 mg/L and any associated plume migration.

The sorption partition coefficient (K_d) controls the degree of linear sorption represented by the model. The K_d variable is site specific and limited examples were found for actual ISR sites that were measured either as part of baseline or after restoration was completed. The value selected for modeling purposes was a referenced (F.J. Pearson Jr., C.J. Noronha, and R.W. Andrews, 1983) K_d measured at a roll front sandstone site and was used as a representative general condition. This value was varied for the simulations between 1e-6 and 1e-5 m^3/gm to examine the sensitivity of the projections to the assigned value for this uncertain parameter.

The simulations predict plume migration under two flow-direction scenarios: 1) groundwater flow oriented parallel to the length of the original ore body; 2) groundwater flow oriented transverse to the length of the original ore body. The expected direction of groundwater flow would be perpendicular to the length of the ore body; however, a scenario was also considered with groundwater flow along the length of the ore body that would simulate geologic conditions where the modern flow regime was different than when the deposit was formed, and for cases where anthropogenic activities had altered the natural groundwater flow in the aquifer. The simulations predict plume migration under two flow field scenarios: 1) flow under ambient conditions with no groundwater pumping; 2) flow under hypothetical pump and treat scenarios that include groundwater injection as well as extraction wells. The pump and treat scenarios were selected to reduce plume concentrations below the target concentration (0.03 mg/L) in 100 years or less. More aggressive pump and treat designs could result in shorter remediation times. The selected scenarios were considered reasonable representations under the idealized model conditions. The scenario involving ambient flow rates without the pump and treat remediation is an assessment of the potential for natural attenuation mechanisms to contain the contamination plume.

With flow parallel to the length of the deposit, the pump and treat scenario includes a line of extraction wells through the center of the plume. The scenario also includes lines of extraction wells along the upper and lower plume boundaries (see Figure C-1). This configuration induces flow between the injection and extraction wells, removing contaminated groundwater and injecting treated water. In all scenarios, the total injection rate matches the extraction rate. At points of injection is the flow rate is 82 ft/day, and at extraction points the flow rate is 164 ft^3/day. As illustrated in Figure C-1, constituent concentrations are continually lowered over time while the plume is contained within the treatment area.

Figure C-1. Example Simulations with Flow Oriented Parallel to the Strike of the Ore Body; K_d=6e-6 m3/gm; Pump and Treat



With flow perpendicular to the length (or length) of the deposit, the pump and treat scenario includes a line of injection wells along the up-gradient plume edge. The scenario also includes a line of extraction wells along the down-gradient plume edge (see Figure C-2). This configuration induces flow between the injection and extraction wells, removing contaminated groundwater and injecting treated water. In all scenarios, the total injection rate matches the extraction rate. The flow at injection wells is at 164 ft^3/day, and flow from extraction wells is at 164 ft^3/day. As illustrated in Figure C-2, constituent concentrations are continually lowered over time while the plume is contained within the treatment area. Water is injected and flows down-gradient to the extraction wells, thereby flushing contamination to the extraction wells and reducing contaminant concentrations.

C.3 Simulation Results

Table C-2 summarizes the results of the modeling assessment for each scenario. The results are very sensitive to the K_d parameter that controls the degree of linear sorption represented by the model. Table C-2 includes the calculated retardation factor, which indicates how much slower the contaminant plume moves due to sorption when compared to groundwater flow.

The results illustrate that significant down-gradient migration of a remobilized plume is possible before natural attenuation mechanisms reduce concentrations below acceptable levels. For this situation, remediation intervention approaches are necessary to prevent large scale migration of the contamination. In addition, plume migration times are relatively slow under ambient flow conditions (the scenarios with no P&T component), further indicating that active remediation efforts would be needed to address the contamination potential. Consistently, pump and treat remediation times are relatively slow, requiring decades or longer to reduce concentrations to acceptable levels. In any particular field situation, the time frames for oxidizing waters to re-enter a well field that was not permanently returned to a strongly reducing chemical regime by the restoration process will vary based on site-specific conditions. Reliable prediction of when, and if, re-mobilization may take place is not possible without a thorough geochemical characterization of site conditions after the restoration process has been completed and continued monitoring of those conditions.

For developing the geochemical model, it is important to characterize conditions down-gradient from the ore body. As mentioned earlier, chemically reducing conditions in the sandstone host rock were responsible for originally sequestering the uranium and the presence of these conditions in the portion of the aquifer down-gradient of the ore zone would act as a barrier

Figure C-2. Example Simulations with Flow Oriented Perpendicular to the Strike of the Ore Body; K_d=6e-6; Pump and Treat

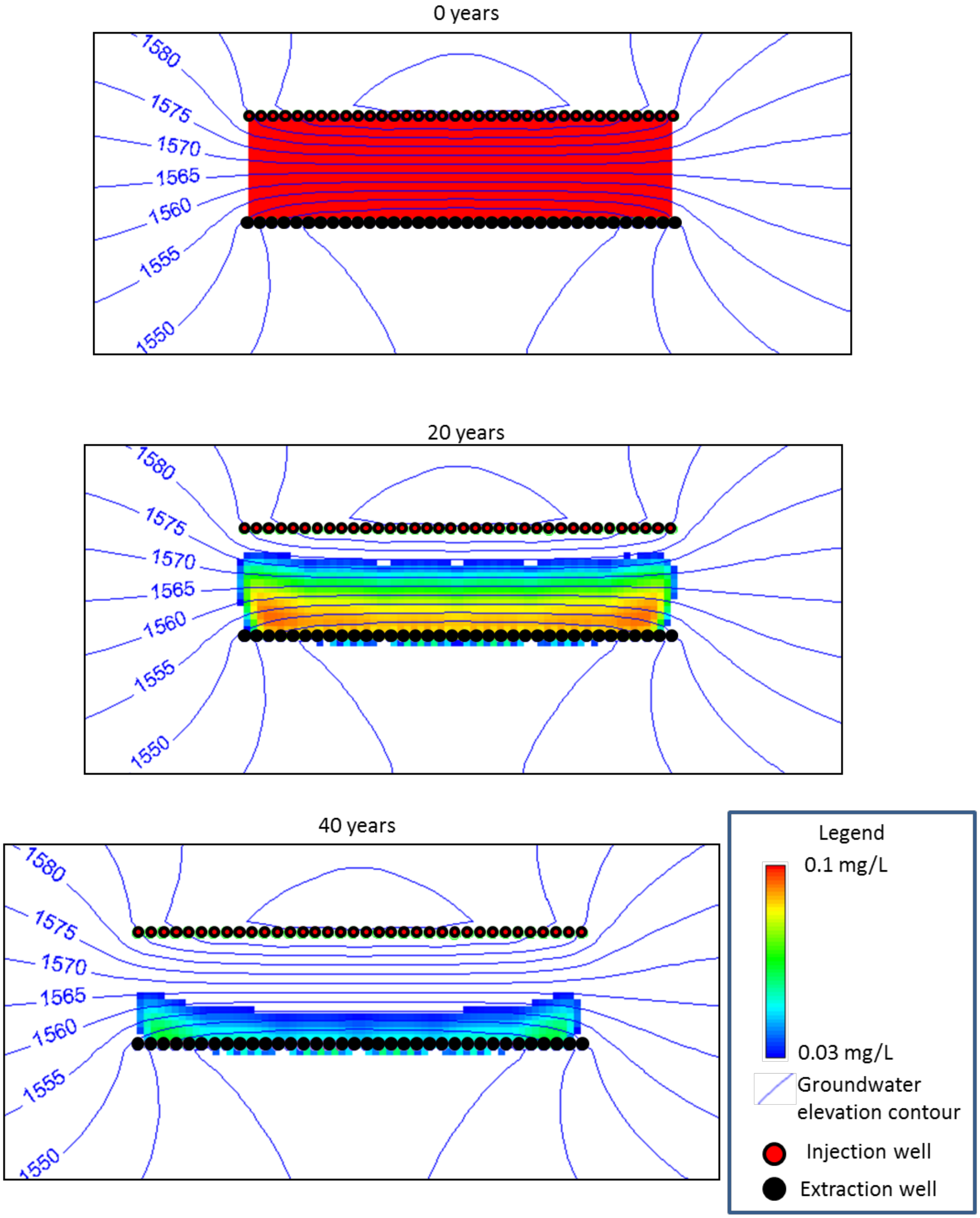


Table C-2. Simulation Results

Flow Direction	Flow Field	K_d (m3/gm)	Retardation Factor	Number of Injection Wells	Number of Pumping Wells	Time to Reach C<0.03 mg/L (yr)	Down gradient Travel Distance (m)
Parallel to length of deposit	Ambient Flow	1.0E-06	11	0	0	>2200[a]	>10000[a]
		6.0E-06	61	0	0	>5000[b]	>4800[b]
		1.0E-05	100	0	0	>5000[b]	>2800[b]
	Pump and Treat	1.0E-06	11	20	9	50	0
		6.0E-06	61	48	23	75	0
		1.0E-05	100	60	29	100	0
Transverse to length of deposit	Ambient Flow	1.0E-06	11	0	0	725	3300
		6.0E-06	61	0	0	4750	3800
		1.0E-05	100	0	0	>5000[b]	>2800
	Pump and Treat	1.0E-06	11	20	20	20	0
		6.0E-06	61	36	36	60	0
		1.0E-05	100	45	45	80	0

[a] Plume exits simulation domain before decreasing below 0.03.

[b] Simulation ends before plume decreases below 0.03.

to contaminant migration from the ore zone if re-mobilization occurs. In many cases, unmined down-gradient materials will maintain reducing conditions with sufficient capacity to immobilize a plume. The simulations in this appendix assume oxidizing conditions remain as the plume migrates down gradient.

The consequences of re-mobilization illustrated in the simulations supports the use of a reasonably long post-restoration long-term stability monitoring period to provide an opportunity to detect any re-mobilization and address it before the contamination becomes widespread through the wellfield. The 30 yr post-restoration stability monitoring period in the proposed rule is aimed at providing at least an opportunity to detect re-mobilization if it begins to occur. The benefit of developing a geochemical model of the production zone aquifer is also illustrated by these assessments. If the geochemical reducing capacity of the restored wellfield and down-gradient portions of the production aquifer can be shown to minimize the potential for post-restoration remobilization of uranium, the regulator can terminate the license with confidence that the full thirty year monitoring period would not be necessary. Conversely, if the geochemical model of the system does not indicate a strong chemically reducing environment exists at the site, the regulatory agency can consider additional monitoring periods as necessary to verify that contamination is not moving out of the restored production zone area and potentially beyond the border of the wellfield aquifer. Developing a defensible geochemical model of the system can provide significant cost savings for all the alternative situations. If a strongly reducing environmental is present, costs can be lowered by early termination of the ISR license since re-mobilization is unlikely and the full 30 year monitoring period may not be required. If a less effective geochemical situation exists at an ISR site, standard restoration activities can be augmented to limit the potential for re-mobilization and monitoring efforts can be focused on detecting re-mobilization before it spreads over a wider area, thereby reducing the potential for incurring significant remediation costs.

C.4 Estimated Costs of Remediation

The simulation results described above for the pump and treat scenarios were then used to estimate the costs of remediating a plume of contamination that might result if conditions within a restored mine unit did not remain stable over time. The costs of remediation include the costs of the wells (installation and 20% replacement after 20 years) and the costs of treatment. Not explicitly included are costs of disposing of treated water since during the pump and treat operations, it is assumed that much of this will be re-injected; in addition, treated water could be evaporated from holding ponds or used for irrigation in these generally rural areas. None of these options would add significant costs. Also omitted from the costs are scoping assessments to identify the location and characteristics of the plume. In reality, such scoping would likely be needed to determine how to structure the pump and treat remediation. Omitting these costs means that our estimated costs of remediation may underestimate actual costs.

This examination of the requirements and costs of remediating a plume of constituents at the CMU (under varying scenarios) is meant to illustrate the value of long-term stability monitoring. Clearly, the potential for remobilization, and creation of contaminant plumes, varies widely from site to site. EPA therefore did not attempt to generalize or extrapolate to estimate remediation requirements or costs that would be incurred at actual ISR sites. Instead, this is a CMU-specific example.

Table C-3 presents the estimated costs of remediation. Annual O&M costs are a function of the number of wells (and thus, the estimated wellfield yield); they are estimated based on a unit cost of $6.35 per 1000 gallons (EPA, 2001) treated. Capital costs are also a function of the number of wells (and the estimated wellfield yield), and are computed based on $30.48 per thousand gallons (EPA, 2001) treated. It is assumed that, after 20 years, 20% of the wells will need to be replaced. Capital costs are annualized over a period of 20 years at 7% rate of interest.

Total annualized costs are the sum of annual O&M costs and annualized capital costs for each scenario.

Because higher K_d means the constituents are more difficult to remove (due to the tendency for the constituents to adhere to aquifer matrix material), both the number of wells and the duration of treatment increase as K_d increases under each scenario (transverse to the length of the deposit and along the length of the deposit).

Also included in Table C-3 is a “short” remediation example, intended to represent the costs of using pump and treat methods to address increasing constituent concentrations detected in only a small area of the wellfield, approximately 20 acres. Fewer wells would be needed, and a shorter duration of treatment would be required to remediate the plume. This represents a lower-bound estimate of potential pump and treat remediation costs.

Table C-3. Estimated Costs of Remediation (Thousand $2011)

				Costs, $				
	K_d	**No. of Wells**	**Annual Wellfield Yield (1000 gal)**	**Annual O & M**	**Capital**	**Annualized Total Capital**	**Pumping Duration (years)**	**Total Annualized Remediation Costs**
Transverse to length of deposit	1.0E-06	40	630,720	4,005	19,224	1,815	20	5,820
	6.0E-06	72	1,135,296	7,209	34,604	3,266	60	10,475
	1.0E-05	90	1,419,120	9,011	43,258	4,083	80	13,094
Along length of deposit	1.0E-06	29	457,272	2,904	13,938	1,316	50	4,219
	6.0E-06	71	1,119,528	7,109	34,123	3,221	75	10,330
	1.0E-05	89	1,403,352	8,911	42,774	4,038	100	12,949
Short	6.0E-06	10	157,680	1,001	4,806	454	30	1,455

Table C-4 summarizes the overall cost estimates. EPA estimated that contamination moving transverse to the length of the deposit would be detected in 6 years after restoration is complete, and that contamination moving along the length of the deposit would be detected after the site is decommissioned and the license terminated. In fact, a plume of contamination would be detected only if and when someone wishing to use groundwater in the area had it tested; the longer the time before the plume is detected, the more extensive the area of contamination is likely to be, and the more costly it would be to remediate, and greater is the possibility that humans or ecological receptors could be exposed to the constituents. If contamination does occur, and is detected long after license termination, the costs of remediation could fall on the taxpayer, rather than the owner/operator.

Table C-4. Summary of Estimated Remediation Costs, by Scenario and K_d (Millions $2011)

K_d (m^3/gm):	**1.0E-06**	**6.0E-06**	**1.0E-05**
Scenario: Transverse to the length of the ore deposit			
Summed Costs	$99.3	$481.0	$790.1
Scenario: Along the length of the ore deposit			
Summed Costs	$163.3	$586.1	$968.1
Scenario: Short, assumes small area of contamination is detected during long-term stability monitoring		K_d=6.0E-06	
Summed Costs		$35.3	

The summary provided below, for each remediation scenario and assumed K_d, shows that costs (either summed across the duration of the pump and treat remediation operations without discounting, or present values discounted at 3% or discounted at 7%) increase depending on the size of the plume, the direction of groundwater flow, and the K_d. Comparing the estimated total summed costs of pump and treat remediation for K_d=6.0E-06 m^3/gm (under different scenarios) to the cost of complying with the proposed rule, including resuming restoration if contamination is discovered during long-term stability monitoring (see Table 4-1 for details) demonstrates the advantage of monitoring long enough to detect an upward trend in some constituents while the plume is still small so that re-mobilization can be detected and decisions made concerning treatment before the contamination becomes widespread and more expensive remedies are needed.

C.5 References

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APPENDIX D
SENSITIVITY ANALYSIS: ESTIMATED COSTS AND ECONOMIC IMPACTS

This Appendix presents results of a sensitivity analysis conducted to explore the uncertainty around costs of sampling. In Section 3, EPA presented the assumptions for each phase of ISR monitoring. These assumptions, shown in Tables 3-2 through 3-5, include a range of sampling and analysis costs. They also reflect estimated requirements under two regulatory alternatives and a "worst case" under which geochemical modeling does not provide assurance of future stability, and 30 years of long-term stability monitoring are required, in addition to geochemical modeling. As discussed in Section 3 above, EPA does not believe this "worst case" is likely to occur, because it would require that geochemical modeling conducted prior to the start of operations yields results that indicate that conditions would be stable long-term, but geochemical modeling conducted after operations have ended yields the opposite result. In reporting the results of the economic impact analysis in the main sections of this document, EPA focused on the proposed regulatory option; this appendix provides results for all the costing scenarios, under low, average, and high monitoring cost assumptions.

Table D-1 presents estimated costs under each alternative and cost scenario. In general, the costs are lowest for the proposed regulatory alternative, which includes 30 years of long term stability monitoring, with the potential to shorten the duration if geochemical modeling indicates that geochemical conditions in the wellfield and especially down-gradient from the field will ensure that restored conditions will remain stable over time. Costs for the other regulatory alternative, which requires 30 years of long-term stability monitoring with no potential for shortening the duration, are slightly higher. Table D-1 also presents the "worst case" scenario, which assumes that the geochemical modeling does not provide assurance of stability, so that 30 years of long term stability monitoring is then required. As ex[ected, these costs are the highest.

Table D-2 presents the results of a market model, which examines how the market for uranium (U_3O_8) would potentially be affected by the costs of complying with the regulation, under each alternative and costing scenario. The proposed regulatory alternative increases the cost of producing uranium by $1.30 to $1.70 per pound of U_3O_8. The 30-year long term stability monitoring with no potential to reduce duration causes the cost of uranium production to increase by an estimated $1.44 to $2.00 per pound. The "worst case" costing scenario causes the cost of uranium production to increase by $1.51 to $2.40 per pound. The lower the increase in the unit cost, the smaller the effect on the market. In all cases, the market price of U_3O_8 is projected to increase by less than the unit cost, domestic uranium production is projected to decline, and imports of uranium are projected to increase.

Table D-1. Estimated Facility and National Costs, by Costing Scenario (Thousand 2011$)

	Low	Average	High
Proposed Rule: 30-Year Long-term Stability Monitoring with Geochemical Modeling to Shorten Duration			
ISR Operation			
La Palangana	$262	$304	$343
Alta Mesa	$412	$477	$540
Willow Creek	$510	$591	$668
Crow Butte	$1,905	$2,205	$2,493
Smith Ranch-Highland-Reynolds	$8,224	$9,521	$10,766
Lost Creek	$317	$367	$415
Estimated Incremental National Costs			
Total Annualized Cost	$11,631	$13,465	$15,226
Total Cost, Summed across LOM	$379,564	$431,284	$490,514
Present Value, 3% discount rate	$253,378	$289,991	$329,385
Present Value, 7% discount rate	$156,468	$181,135	$204,822
Required 30-Year Long-Term Stability Monitoring			
ISR Operation			
La Palangana	$290	$340	$404
Alta Mesa	$456	$534	$635
Willow Creek	$565	$661	$786
Crow Butte	$2,107	$2,468	$2,931
Smith Ranch-Highland-Reynolds	$9,097	$10,657	$12,658
Lost Creek	$351	$411	$488
Estimated Incremental National Costs			
Total Annualized Cost	$12,865	$15,072	$17,901
Total Cost, Summed across LOM	$684,068	$814,903	$975,573
Present Value, 3% discount rate	$355,378	$419,826	$500,372
Present Value, 7% discount rate	$173,072	$202,754	$240,818

(continued)

Table D-1. Estimated Facility and National Costs, by Costing Scenario (Thousand 2011$) (continued)

	Low	Average	High
Geochemical Modeling with 30-Year Long-Term Stability Monitoring			
ISR Operation			
La Palangana	$305	$390	$484
Alta Mesa	$480	$613	$761
Willow Creek	$594	$759	$942
Crow Butte	$2,217	$2,832	$3,516
Smith Ranch-Highland-Reynolds	$9,571	$12,229	$15,182
Lost Creek	$369	$472	$586
Estimated Incremental National Costs			
Total Annualized Cost	$13,536	$17,296	$21,472
Total Cost, Summed across LOM	$15,145	$18,575	$22,642
Present Value, 3% discount rate	$7,999	$9,922	$12,157
Present Value, 7% discount rate	$3,960	$5,060	$6,281

Scaled up from CSM to national costs based on estimated total acreage.

Table D-3 examines the ratio of the estimated costs incurred by companies owning ISR facilities to their revenues, to assess the potential financial impacts of complying with the rule on firms in the industry, especially small firms. For the two large firms, reported 2013 sales are used to estimate 2015 sales. Revenues for two small firms owning currently-operating ISR facilities are not publicly available. They are estimated based on the projected 2015 price of uranium ($57.00 per pound) and their estimated facility production in 2015. A third small firm is publicly traded (Uranium Energy); its 2013 sales are depressed due to market conditions; because we are projecting improved market conditions by 2015, we also estimate sales for this firm, based on estimated 2015 facility production and estimated market price. The proposed regulatory alternative results in cost-to-sales ratios ranging from 0.1% to 1.9%, depending on the costing scenario. Even under the “worst case” costing scenario, costs are at most 2.7% of estimated company sales under the highest costing assumptions. Because costs are estimated to be less than 3.0% of company sales for the small businesses owning currently operating ISR facilities, and because EPA expects at most 10 small firms may be affected by the rule going forward, EPA concludes that the rule will not have a significant impact on a substantial number of small firms.

Table D-2. Estimated Market Impacts by Regulatory Alternative

		With Regulation in Effect		
	Baseline	Low	Average	High
Proposed Rule: 30-Year Long-Term Stability Monitoring with Geochemical Modeling to Shorten Duration				
Supply (1,000 pounds U_3O_8)	57,630	57,616	57,614	57,612
U.S. Origin (1,000 pounds U_3O_8)	9,451	9,089	9,032	8,977
ROW (1,000 pounds U_3O_8)	48,179	48,527	48,582	48,635
Demand (1,000 pounds U_3O_8)	57,630	57,616	57,614	57,612
Price ($/pound U_3O_8)	$57.00	$57.21	$57.24	$57.27
Change in Price		$0.21	$0.24	$0.27
Percentage Changes				
Market Quantity		−0.02%	−0.03%	−0.03%
U.S. Quantity		−3.8%	−4.4%	−5.0%
Imports		0.7%	0.8%	0.9%
Price		0.4%	0.4%	0.5%
Compliance Cost per Pound		$1.30	$1.50	$1.70
Required 30-Year Long-Term Stability Monitoring				
Supply (1,000 pounds U_3O_8)	57,630	57,615	57,612	57,609
U.S. Origin (1,000 pounds U_3O_8)	9,451	9,050	8,982	8,893
ROW (1,000 pounds U_3O_8)	48,179	48,564	48,631	48,715
Demand (1,000 pounds U_3O_8)	57,630	57,615	57,612	57,609
Price ($/pound U_3O_8)	$57.00	$57.23	$57.27	$57.32
Change in Price		$0.23	$0.27	$0.32
Percentage Changes				
Market Quantity		−0.03%	−0.03%	−0.04%
U.S. Quantity		−4.2%	−5.0%	−5.9%
Imports		0.8%	0.9%	1.1%
Price		0.4%	0.5%	0.6%
Compliance Cost per Pound		$1.44	$1.68	$2.00

(continued)

Table D-2. Estimated Market Impacts by Regulatory Alternative (continued)

		With Regulation in Effect		
	Baseline	Low	Average	High
Geochemical Modeling with 30-Year Long-Term Stability Monitoring				
Supply (1000 pounds U_3O_8)	57,630	57,614	57,610	57,605
U.S. Origin (1000 pounds U_3O_8)	9,451	9,029	8,912	8,782
ROW (1000 pounds U_3O_8)	48,179	48,585	48,697	48,823
Demand (1000 pounds U_3O_8)	57,630	57,614	57,610	57,605
Price ($/pound U_3O_8)	$57.00	$57.24	$57.31	$57.38
Change in Price		$0.24	$0.31	$0.38
Percentage changes				
Market Quantity		−0.03%	−0.04%	−0.04%
U.S. Quantity		−4.5%	−5.7%	−7.1%
Imports		0.8%	1.1%	1.3%
Price		0.4%	0.5%	0.7%
Compliance Cost per Pound		$1.51	$1.93	$2.40

Table D-3. Estimated Company Cost-to-Sales Ratios by Regulatory Alternative

	Estimated 2015 Sales (millions USD)	Low	Average	High
30 Year with Geochemical Modeling				
Parent Company				
Cameco	$2,400.0	0.4%	0.5%	0.6%
Mestena	$28.5	1.4%	1.7%	1.9%
Uranium One	$530.4	0.1%	0.1%	0.1%
Uranium Energy	$28.5	0.9%	1.1%	1.2%
Ur-Energy	$57.0	0.6%	0.6%	0.7%
30-Year Stability				
Parent Company				
Cameco	$2,400.0	0.5%	0.5%	0.6%
Mestena	$28.5	1.6%	1.9%	2.2%
Uranium One	$530.4	0.1%	0.1%	0.1%
Uranium Energy	$28.5	1.0%	1.2%	1.4%
Ur-Energy	$57.0	0.6%	0.7%	0.9%
Geochem with Required 30 Year				
Parent Company				
Cameco	$2,400.0	0.5%	0.6%	0.8%
Mestena	$28.5	1.7%	2.2%	2.7%
Uranium One	$530.4	0.1%	0.1%	0.2%
Uranium Energy	$28.5	1.1%	1.4%	1.7%
Ur-Energy	$57.0	0.6%	0.8%	1.0%