Statement of

Geoffrey H. Fettus
Senior Attorney
Natural Resources Defense Council, Inc.

"Oversight Hearing on 40 CFR §192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, Proposed Rule, 80 Fed. Reg. 4156-4187 (Jan. 26, 2015), Docket ID No. EPA–HQ– OAR–2012–0788."

Before the

Congress of the United States
House of Representatives
Committee on Oversight & Government Reform
Subcommittee on Interior
Rayburn House Office Building, Room 2154

June 23, 2016, 10 a.m.

Natural Resources Defense Council, Inc.
1152 15th St. NW, Suite 300
Washington, D.C. 20005
Tele: 202-289-6868
gfettus@nrdc.org

I. Introduction

Madame Chairman Lummis, Ranking Member Lawrence, and members of the Subcommittee, thank you for providing the Natural Resources Defense Council, Inc. (NRDC) this opportunity to present our views on the Environmental Protection Agency's *Proposed Revisions to 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*, Proposed Rule, 80 Fed. Reg. 4156-4187 (Jan. 26, 2015), Docket ID No. EPA–HQ– OAR–2012–0788 (hereinafter, "EPA's Draft Rule")..

NRDC is a national, non-profit organization of scientists, lawyers, and environmental specialists, dedicated to protecting public health and the environment. Founded in 1970, NRDC serves more than one million members, supporters and environmental activists with offices in New York, Washington, Los Angeles, San Francisco, Chicago, Bozeman, Montana, and Beijing. We have worked on nuclear fuel cycle and associated regulatory issues since our founding, and we will continue to do so.

II. Summary of Testimony

The current regulatory regime for uranium recovery fails to protect public health and the environment and indeed, isn't even designed to address the in situ leaching (ISL), also known as solution mining or in situ recovery (ISR) method of uranium recovery/mining. The U.S. Environmental Protection Agency (EPA) original standard setting authority, granted in 1978, was incoherently superimposed on a U.S. Nuclear Regulatory Commission (NRC) uranium mine licensing process. The result is a complicated, dysfunctional and inadequate standards for protection of public health and the environment, assembled from differing regulatory areas. Nearly a decade ago, former NRC Commissioner Jeffrey S. Merrifield called for a rulemaking to solve the problems plaguing the regulation and protection of groundwater from ISL uranium mining facilities. Commissioner Merrifield stated:

> While the staff has done its best to regulate ISL licensees through the generally applicable requirements in Part 40 and imposition of license conditions, our failure to promulgate specific regulations for ISLs has resulted in an inconsistent and ineffective regulatory program. We have been attempting to force a square peg into a round hole for years, and I believe we should finally remedy this situation through notice and comment rulemaking.[1]

The statements of the former Commissioner include word choices such as "inconsistent" and "ineffective" – terms that accurately describe the splintered, incoherent licensing regime now in place for ISL uranium mining. Commissioner Merrifield was modestly observing that the existing regulatory framework was designed to address conventional uranium milling—not what was then an unconventional technique, such as ISL mining, which as EPA notes in the preamble to the Draft Rule, is likely to comprise the majority of new uranium recovery sites in the next

---

1 "*Regulation Of Groundwater Protection At In Situ Leach Uranium Extraction Facilities*," Memorandum From: Jeffrey S. Merrifield to Chairman Diaz, Commissioner McGaffigan, Commissioner Jaczko, Commissioner Lyons (COMJSM-06-0001), January 17, 2006.

decade and likely going forward into the future. Regulations promulgated in the late 1970s and 1980s did not contemplate ISL mining and its associated harms, and the legal framework that currently governs ISL mining is wholly inadequate to the task of protecting scarce western U.S. groundwater resources. This regulatory gap must be filled if the nation is to avoid future risks to this important public resource.

This testimony will briefly describe ISL uranium recovery (Section III). It will then address EPA's well-grounded authority to issue these revisions (Section IV). We then turn to the need for the revisions and the state of groundwater that has been harmed (Section V). Finally, we address the costs of the revisions and the significant long term environmental and social costs of EPA not acting (Section VI).

All of this should make it apparent that simply updating regulations for conventional milling would solve only part of the problem the nation faces going forward with domestic uranium mining and milling. We have urged both EPA and the NRC to move swiftly to update the relevant protections for uranium recovery. The sooner that improved standards can be put into effect, the sooner that public health and the scarce western groundwater will be protected. The EPA, to its credit, has commenced this revision of its standards. After EPA finalizes its rule, NRC should commence work on its own ISL rulemaking proceeding so it can conform its licensing process to EPA's standards. Until newly protective rules that create a coherent regulatory process are in place, NRDC supports a moratorium on the review and granting of any new ISL uranium mining licenses or, indeed, the expansion of any existing licenses.

And whether the current situation exists by intent or happenstance is beside the point. Even though the rule is years overdue, EPA has properly focused on curing these past deficiencies and developing a more protective regulatory framework for uranium recovery, before even more environmental damage is done. In the intermountain West, where much of this ISL uranium mining processing has taken place and where new or expanded mines could commence operations, population growth, prolonged dry weather conditions, and competing resource extraction technologies (such as coal bed methane drilling) have created severe competition for surface and underground freshwater resources. Permanent loss of freshwater aquifers due to contamination from ISL mining activities is a significant social and economic issue for the region both in the short and long term. More importantly, despite a clear legal mandate via its NEPA obligations, the NRC – along with its federal brethren such as the Department of the Interior's Bureau of Land Management – have failed to study the long-term cumulative impacts of sacrificing aquifers in the intermountain West to facilitate the extraction of mineral and energy resources. EPA's long overdue rulemaking on groundwater impacts will begin to rectify this situation.

Unless EPA establishes clear, protective rules for the ISL uranium mining industry, there will continue to be divisive, contentious groundwater contamination controversies similar to ongoing litigation in Wyoming, New Mexico, and South Dakota and similar to events in Goliad, Texas.

The benefits of issuing a final set of EPA standards are, for the first time, a set of meaningful protections and accountability for harm to billions of gallons of scarce underground aquifers and the communities that rely on that water across the arid American West, from Texas to Wyoming.

III. ISL Recovery Described

A uranium recovery process has emerged within the last 40 years that involves injecting an oxidizing solution into a groundwater aquifer containing naturally occurring uranium ore via pumps and wells arrayed in patterns across the mined area. The injected solution dissolves the uranium minerals from ore-bearing rock in the aquifer, and the 'pregnant' solution is pumped to the surface through a second array of wells, after which the uranium is subsequently processed and shipped offsite. The ISL process exploits the redox (oxidation-reduction) chemistry of uranium. In the ore body, uranium exists as a solid mineral formed by natural conditions over geologic time frames. The injection of a lixiviant solution oxidizes the naturally occurring uraninite ore, which is substantially more soluble and remains in the aquifer as a pollutant.

IV. EPA Has the Authority to Promulgate Revisions to 40 C.F.R. §192

We are pleased to offer our support today to EPA in its efforts to finalize the Draft Rule, as it is a well-grounded interpretation that the Uranium Mill Tailings Radiation Control Act (UMTRCA) is the controlling legal authority for protection of groundwater for ISL sites and, further, that the NRC or any agreement state is obligated to implement these standards. As we discuss in more detail in the pages that follow and in our extensive comments on the Draft Rule, EPA has ample authority under the Atomic Energy Act to issue these standards. And as the current state of regulatory system is not protective of western groundwater, it is past time for EPA to move forward.[2] The Committee should also be aware that while NRDC supports EPA's lawful promulgation of these revisions, there are areas where the rule either needs significant clarification or strengthening – issues such as ongoing industrial waste disposal for ISL operations, how excursions are monitored and upper control limits are established, and ensuring that the new standards apply to ISL uranium recovery operations that phase in and out of operation – are just a few items that needed substantially more precision. We addressed all of those matters and more in our attached comments.

The legal authority for EPA's rule is Section 275 of the Atomic Energy Act (AEA) of 1954, as amended by Section 206 of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. Health and environmental protection standards established by EPA under UMTRCA are implemented by NRC. *See* 42 U.S.C. § 2022(b) and (d). AEA section 275, 42 U.S.C. § 2022 (2012), allows EPA to issue "standards of general application for the protection of the public health, safety, and the environment" from certain "radiological and nonradiological hazards," including those "associated with the processing and with the possession, transfer, and disposal of byproduct material[3] . . . at sites at which ores are processed primarily for their source material content or which are used for the disposal of such byproduct material." *Id.* § 2022(b). EPA's

---

2 *See* Attachment A, *NRDC Comments on 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings,* Proposed Rule, 80 Fed. Reg. 4156-4187 (Jan. 26, 2015), Docket ID No. EPA–HQ– OAR–2012–0788, (hereinafter "NRDC Comm. at _."))

3 *See* 42 U.S.C. § 2014(e) (2012) (defining "byproduct material" broadly).

Draft Rule comfortably resides in this category because it protects public health and the environment against such hazards presented by "byproduct materials" generated by uranium in-situ leaching, a method by which "ores are processed . . . for their source material content."

The rulemaking satisfies the AEA's statutory requirements for new EPA regulations. In establishing standards under section 275, "the Administrator shall consider the risk to the public health, safety, and the environment, the environmental and economic costs of applying such standards, and such other factors as the Administrator determines to be appropriate." *Id.* EPA's proposal explicitly considered risks to the public health, safety, and the environment, Draft Rule at 4164–65, and environmental and economic impacts, *id.* at 4180–81. Additionally, standards issued under subsection (b) for non-radiological hazards "shall, to the maximum extent practicable, be consistent with the requirements of [the Resource Conservation and Recovery Act (RCRA)]." 42 U.S.C. § 2022(b)(2) (2012).

Thus, the Draft Rule ensures this consistency by adapting the RCRA groundwater monitoring framework to ISL sites and their attendant environmental concerns. Draft Rule at 4163–64. Last, the provision requires EPA to "consult with the Commission and the Secretary of Energy before promulgation" of a rule under subsection (b). 42 U.S.C. § 2022(c) (2012). And we understand that EPA has extensively consulted with both NRC and DOE over the last several years.

Furthermore, the Committee should be aware that prior rules have successfully relied on the same statutory authority to issue health and environmental standards for uranium ore byproducts. *See, e.g.*, Health and Environmental Standards for Uranium and Thorium Mill Tailings, 58 Fed. Reg. 60,340 (Nov. 15, 1993) (codified at 40 C.F.R. pt. 192); Environmental Standards for Uranium and Thorium Mill Tailings at Licensed Commercial Processing Sites, 48 Fed. Reg. 45,926 (Oct. 7, 1983) (codified at 40 C.F.R. pt. 192). The proposed rule is a fundamentally similar lawful agency action.

Next, EPA's promulgation of this rule does not supplant NRC's jurisdiction or impede its licensing authority. The AEA unambiguously assigns to EPA standard-setting authority, and to NRC implementation and enforcement authority. *See* 42 U.S.C. § 2022(b), (d) (2012). This division of jurisdiction does not shield preoperational, stability phase, or other monitoring from EPA regulation. Instead, EPA has correctly determined that this monitoring will help protect "the public health, safety, and the environment." *See id.* § 2022(b). Indeed, the proposed rule does not unlawfully direct NRC's implementation of EPA's health and environmental standards any more than the existing regulatory requirements under 40 C.F.R. § 192. For example, § 192.32(a)(4)(i) requires licensees to "conduct appropriate monitoring and analysis" of radon-222 releases using methods at least as effective as "the procedures described in 40 CFR part 61, Appendix B, Method 115." The proposed regulation similarly introduces explicit monitoring rules without imposing an impermissible compliance methodology on NRC. EPA has properly exercised its health and environmental standard-setting authority to require such monitoring, and NRC's role is only to implement and enforce compliance with this requirement.

To the extent that NRC's requirements for groundwater protection that it codified in 10 C.F.R. Part 40, Appendix A or elsewhere are inconsistent with EPA's standards, they are invalid. AEA section 275 explicitly requires: "Within three years after . . . revision of any [subsection (b) EPA] standard, the Commission . . . shall apply such revised standard in the case of any license for byproduct material . . . ." 42 U.S.C. § 2022(b)(2) (2012). NRC's regulations cannot overcome this statutory requirement to implement EPA's standards. Indeed, NRC's regulatory authority under AEA section 275 is limited to promulgating rules that "the Commission deems necessary to carry out its responsibilities in the conduct of its licensing activities under this chapter." *Id.* § 2022(b)(1). NRC's licensing "responsibilities" are defined by statute and by EPA's regulations. The AEA therefore subordinates NRC's rulemaking power to that of EPA.[4]

Last, nothing in the AEA or elsewhere bars EPA from issuing rules that interact with other federal regulatory programs. Simply by deciding to propose the present rule, EPA has determined that other regulatory schemes such as the Safe Drinking Water Act's Underground Injection Control program are inadequate "for the protection of the public health, safety, and the environment" from the hazards presented by ISL. The rule, therefore, is not duplicative, but is an important and proper exercise of EPA's statutory authority.

V. The Need for the New Regulations and the Status of Groundwater That Has Been Harmed.

a. How the ISL Regulations Currently Work.

The current regulatory scheme for ISL uranium mining works as follows. The NRC licenses and regulates ISL operations under standards written for conventional uranium mills. By statute, the NRC must also adopt EPA standards, also written for uranium mills, but then use those standards for ISL operations. The NRC issued a guidance document to present what the industry applicant must do to obtain an ISL license.[5] The site remediation program (SRP) guidance details how the agency will interpret its requirements for groundwater restoration under 10 CFR Part 40 (the NRC regulations for nuclear "materials" licenses).

First, the SRP provides that after an ISL mining and milling operation has concluded, the site must be cleaned up, or "decommissioned," and groundwater quality must be restored. The NRC guidance posits that even after receiving an aquifer exemption under the Safe Drinking Water Act (SDWA), an ISL uranium mining company is supposed to restore the contaminated groundwater aquifer to NRC-approved background values. Such a level of protection for the scarce resource is meant ensure that adjacent groundwater aquifers are safeguarded and that other potential future uses of the mined aquifer are not compromised. However, the NRC states that if the contaminated groundwater cannot be restored to the NRC-approved background level, then the aquifer may be restored to the less protective maximum concentration levels set in 10 C.F.R. § 40, Appendix A, Table 5C. And if even that standard is not achievable—as the NRC

---

4 For an extended discussion of industry's misplaced suggestion that EPA has somehow exceeded its authority, see Att. A at 27-32.

5 U.S. NRC, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications: Final Report*, NUREG-1569 (June 2003), *available at* http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf.

notes, "these two options may not be practically achievable at a specific site—then the licensee may propose an [even less protective] alternate concentration limit that it will argue presents no significant hazard."

As we described in detail our comments on EPA's Draft Rule (Att. A), in <u>every</u> instance, the industry has defaulted to this "alternative concentration limit" (ACL) for key parameters such as uranium or radium with little agency complaint. Agreement States such as Texas have adopted similar rules that allow the industry to be relieved of its burden to restore contaminated groundwater. Further, this relaxed and ad hoc regulatory scheme, lacking meaningful EPA standards, combines with how the NRC and industry use SDWA's "aquifer exemption" process to allow for significant contamination of the mined aquifer. Specifically, the Nuclear Regulatory Commission (NRC) and its NRC Agreement States rely on the requirements of the underground injection control program, authorized under separate legal authority (SDWA), to adequately address groundwater protection at ISL facilities. This reliance is misplaced, as the current NRC interpretation of the statutory regime and regulatory obligations directly allow for significant contamination of scarce sources of western groundwater. EPA clarified this issue in the Draft Rule and wrote:

> Aquifer exemptions have been a source of confusion regarding the applicability of our UMTRCA standards, which we hope to clarify today in this rule. There are limited UIC requirements relating to restoration of the exempted portion of the aquifer; furthermore, an aquifer exemption does not eliminate the need to comply with the requirements of UMTRCA. The aquifer exemption provides relief from certain UIC requirements under the SDWA, thereby allowing injection into aquifers that would otherwise meet the definition of a USDW. The part 192 standards, however, are promulgated under a different statute. Therefore, an aquifer exemption under the SDWA does not relieve the licensee of the obligation to remediate environmental contamination resulting from activities regulated under UMTRCA. <u>Today's proposal clarifies that EPA standards issued pursuant to UMTRCA do apply within the exempted portion of the aquifer</u>.

Draft Rule at 4168 (emphasis added).

In short, the current NRC interpretation of the rules permits aquifer exemptions to be parlayed into authorization for the exempted aquifer to become a toxic, hazardous disposal area and puts off to the future any examination of that result. EPA's revisions will move a significant distance in rectifying this situation. As a result, states such as Wyoming, New Mexico, Nebraska, Texas, or South Dakota could access the water in the aquifer where uranium mining took place for agricultural and possibly even drinking water uses, an option that would otherwise be foreclosed. The increasing scarcity of water in the American West is a crucial national issue, and all sources— be they surface water or groundwater—should receive the utmost protection.

b. The Contamination Caused by ISL Uranium Recovery

In its Draft Rule, EPA anticipated industry's objection that the presence of uranium deposits typically results in groundwater of poor quality, and not a pristine source of drinking water

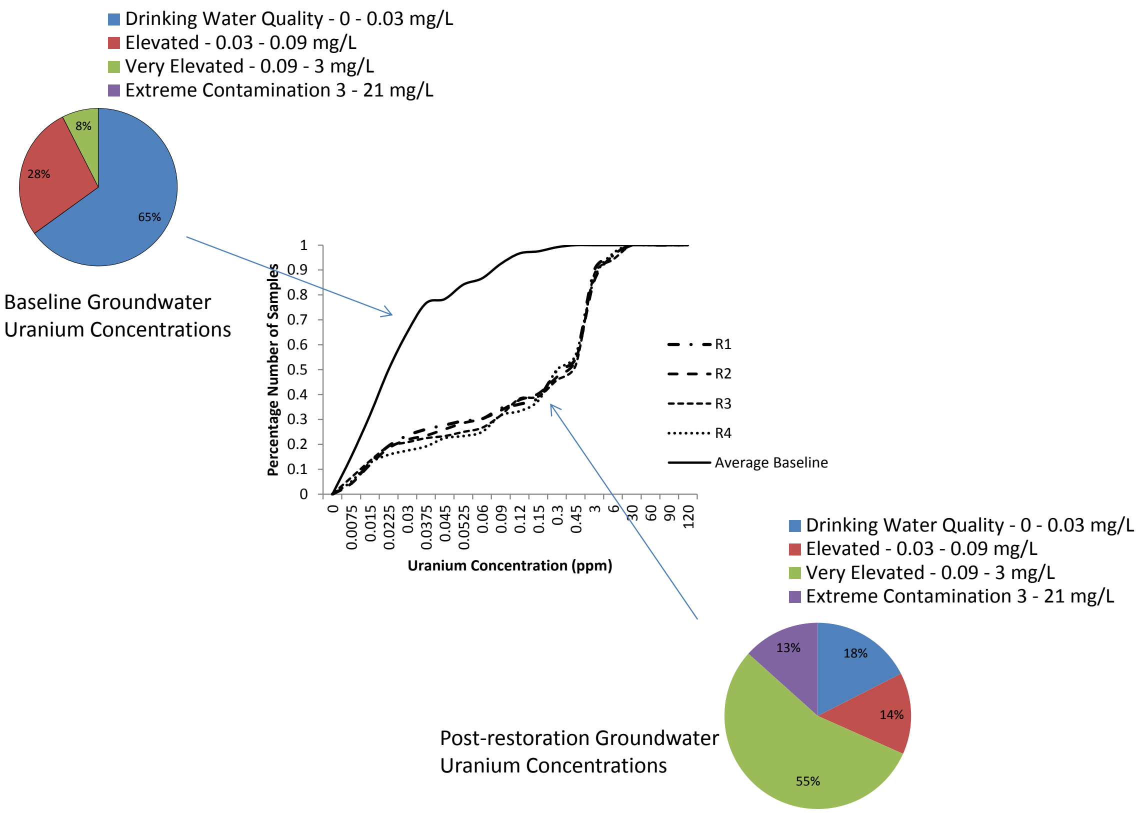
(Draft Rule at 4171). But EPA went on to note that "the increasing scarcity of groundwater is leading some communities to consider using sources of water that previously would have been considered non-potable, using advanced treatment to make it suitable for livestock or human consumption. Since such advanced treatment may not be economically feasible for some communities, it is all the more important to prevent, as much as reasonably possible, additional degradation of the groundwater." *Id*.

While we appreciate and support EPA's use of the precautionary principle in stating that it should not promulgate regulations that allow additional degradation of the groundwater, several things need to made precisely clear for this Committee's record: (1) it is not accurate to state that the presence of uranium necessarily equals poor groundwater quality; and (2) it is perfectly clear that ISL uranium recovery substantially degrades that groundwater quality in the mined aquifer, whatever its original state; (3) there has been a reported case of groundwater contamination in adjacent aquifers in an industry replete with excursions and failed efforts at restoration, and (4) because of the lack of meaningful long-term monitoring, there is a paucity of data on what the long term effects have been. Finalizing EPA's rule can rectify much of this and I will address each matter in turn.

(1) EPA's Draft Rule Would Improve Characterization of Original Water Quality.
Understanding what "baseline water quality" is and how it is assessed is a key matter in assessing impacts of ISL recovery and the need for EPA to finalize the Draft Rule. Baseline water quality is simply what it sounds like, making sure one understands the precise characteristics of the underground aquifer before any anthropogenic activity that might cause contamination takes place, allowing proper monitoring levels to be established to protect groundwater where ISL mining will occur. How the NRC allows baseline water quality to be established and whether the agency is in compliance with its National Environmental Policy Act (NEPA) obligation is currently in litigation and on appeal before the Commissioners of the NRC. Extensive discussions of the baseline matter can be found in Att. A at 12-16. Regardless of whether NRC has complied with NEPA(not a matter before EPA or this Committee), the ISL industry has long argued that the presence of uranium deposits typically results in groundwater of poor quality, and not a pristine source of drinking water. Even conceding that underground water chemistry is extraordinarily complex and varied, it's fully apparent from the evidence we have reviewed that industry substantially overstates the matter and indeed, it is not accurate to assert that the presence of uranium necessarily equals poor groundwater quality.

For our EPA comments, NRDC created a cumulative histogram for the ISL site Christensen Ranch Mine Units 2-6, showing the average baseline and each post restoration phase sampling round concentrations.

We include the histogram here:



Notably, the majority of the average baseline groundwater samples were below the Maximum Contaminant Limit (MCL) for uranium of 0.03 mg/L (~65%); 28 % had slightly elevated uranium concentrations (0.03-0.09 mg/L) and only 8% were very elevated (0.09 – 3.0 mg/L). Thus, using NRC's and industry's own data, we dispute that the presence of uranium deposits typically results in groundwater of poor quality, and not a source of drinking water. Until EPA and NRC have required substantially more transparent and rigorous background groundwater quality data, which EPA's Final Rule would require, all available evidence supports NRDC's assertion that industry is inaccurate in its assertion of poor quality groundwater.

(2) ISL Uranium Recovery Degrades Water Quality

It is undisputed that based upon the past history of ISL facilities, it is a virtual certainty that the industry will not be able to restore the affected and mined aquifers to primary or secondary limits. Even with ACLs approved by NRC, we have demonstrated that past ISL projects have resulted in significant impacts to aquifers and, to date, *no* ISL project has successfully restored every water quality constituent in an aquifer. As an example for the Committee, please examine the following web-based visual representations of NRC ISL uranium recovery data to illustrate the failure of restoration at ISL uranium recovery sites.

- Storymap #1, *A Visual Representation Of The Failure to Restore Contaminated Groundwater at a Selected Portion of the Willow Creek ISL Uranium Mining Site and Excursion Events* http://isl-uranium-recovery-impacts-nrdc.org/Willow-Creek/

- Storymap #2, *A Visual Representation Of The Failure to Restore Contaminated Groundwater & Demonstration of Near-Surface Contamination at a Selected Portion of the Smith Ranch ISL Uranium Mining Site;* http://isl-uranium-recovery-impacts-nrdc.org/Smith-Highland/.

Simply, these Storymaps are a visual, interactive spatial representation of the NRC and industry's own data coupled with detailed descriptions of the significance of the data. Shown a static map, without context or the ability to interact, it is much more difficult to assimilate the information. Our comments (and attachments thereto) explain in detail how we created the map, where we obtained the underlying data (from the NRC), how a user of the map can link to the data, and how our conclusions can be duplicated or reproduced. See Att. A at 16-23 for a full treatment of the matter. Importantly, just as EPA had the opportunity, the Committee can verify the accuracy of this data for itself.

What the data shows is the ISL process results in substantial degrading of the mined aquifer. The user can find examples, going well by well, where the observed post-restoration groundwater uranium concentrations can only be described as extreme (18.0, 20.7, 21.7, and 14.8 mg/L, which were 600 times, 690 times, 723 times, and 493 times average baseline and safe drinking water standards, respectively, (*Id*. at 18). We encourage committee members or staff to select various wells to observe specific impacts. Using NRC's own data, the Willow Creek Storymap provides a clear picture of substantial degradation of groundwater quality over the course of the ISL recovery process. As can be seen in the histogram above, we provided a summary of the data in the Storymap. Using the entire wellfield data set from Christensen Ranch Mine Units 2-6, we created a cumulative histogram for average baseline and each post restoration phase sampling round concentrations.

For the Willow Creek Storymap, as noted above, the majority of the average baseline (original) groundwater samples were below the MCL for uranium of 0.03 mg/L (~65%); 28 % had slightly elevated uranium concentrations (0.03-0.09 mg/L) and only 8% were very elevated (0.09 – 3.0 mg/L). However, after mining and restoration activities, the groundwater quality sample distribution shows significant changes to these observed percentages. Roughly 13% of the post restoration samples were extremely contaminated (greater than 3.0 mg/L, which is greater than 100 times the EPA's maximum contaminant limit for safe drinking water standards for uranium), and the 'very elevated' (range: 0.12 – 3.0) uranium concentrations increased from 8% (Baseline) to 54% (Post-restoration). And finally, the drinking water quality samples below maximum concentration limits for uranium decreased from approximately 66% of all samples, to roughly 18% of the observed samples. Even using the agency's own data, it is clear that any quantitative assessment demonstrates the severe water quality degradation which occurs as a result of ISL mining.

(3) Reported Case of Adjacent Aquifer Groundwater Contamination
Kingsville Dome observed the first known occurrence of private domestic well contamination as a result of ISL operations in the United States.[6] The Garcia wells (two wells 60 m apart) were located approximately 300 m downgradient of the Kingsville Dome mine. The Garcia wells uranium concentrations, in 1996, averaged roughly 180 µg/L. However, there is evidence to suggest groundwater quality from the Garcia wells met drinking water standards in 1988, as natural uranium measured 0.011 mg/L (11 µg/L).[7]

Public controversy erupted around 2005 when EPA well results indicated uranium concentrations above drinking water standards (0.181 mg/L), and prompted the Garcia family to discontinue the well and see a physician.[8] The uranium mining company involved in the ISL operations claimed natural uranium concentrations was elevated in the private wells and not caused by mining activities. Yet, samples in 2007 displayed uranium concentrations had increased again to 0.979 mg/L, or roughly 5.4 times higher than the 'natural' values reported in 2005 and 89 times higher than the values measured in 1988.[9] Further, by researching the geochemical trends, geology, and hydrology, the independent hydrologist cited in n.6 concluded "[t]he available data indicate that the likely source of the increased uranium concentrations in the Garcia well is PA-3. To the author's knowledge, this is the first time that contaminants in an off-site domestic well have been linked to ISL uranium mining in the United States of America."[10] As EPA noted in its Draft Rule when it assessed exposure scenarios and exposure pathways, ISL uranium recovery has "[t]he potential to result in significant exposures to individuals outside the production areas." Draft Rule at 4165.

(4) EPA's Draft Rule Would Provide Sorely Needed Data on Long-Term Impacts
In its Draft Rule EPA rightly noted that "[m]uch remains unknown about the geochemical stability of restored wellfields once ISR operations have ceased. Long-term environmental impacts may result if restoration processes do not return aquifers to their preoperational state, or if restored levels do not persist over time and groundwater degrades through the slow release of residual contaminants. Most ISR sites historically have been unable to meet restoration goals for all constituents even after extensive effort. Because the past practice of monitoring after restoration has typically been for a very limited time period, we do not know if the goals that are

---

[6] *See*, *Excursions of Mining Solution at the Kingsville Dome In-situ Leach Uranium Mine*, George Rice, Hydrologist, Vol. 9, Austin Geological Society Bulletin, 2013, at 20-34; found online at http://static1.squarespace.com/static/56e481e827d4bdfdac7fbe0f/t/56f87e264c2f85720ce5e512/1459125809672/Rice%2C+2013%2C+Excursions+of+mine+solution+at+the+kingsville+dome+in-situ+leach+uranium+mine.pdf.

[7] *See* NRDC Att. A1, *Garcia Data Well Sheets*.

[8] *See* NRDC Att. A2, *Uranium-tinged well puts family at risk*, Associated Press, August 01, 2005, Lubbock Avalanche Journal.

[9] *See* NRDC Att. A1, *Garcia Data Well Sheets* at 6 of pdf, 2007 Groundwater Analysis.

[10] *See*, *Excursions of Mining Solution at the Kingsville Dome In-situ Leach Uranium Mine*, George Rice, Hydrologist, Vol. 9, Austin Geological Society Bulletin, 2013, at 31; full cite at n.6.

met for the short-term are maintained for a longer time." Draft Rule at 4165. EPA is right, thus far little or nothing in the way of long term monitoring of the contaminated sites after the close of restoration has been required. *See* Att. A at 59-61, 67-71, for an extensive discussion.

As demonstrated quantitatively above, the volume of water affected by ISL recovery is significant (in the tens of millions of gallons per unit) and there is no reason to allow this groundwater to be further degraded. The increasing scarcity of groundwater across the West has precipitated a host of efforts to develop and to use advanced treatment to make groundwater suitable for livestock or human consumption. We agree with EPA that since such advanced treatment may not be economically feasible for some communities, it is all the more important to prevent, as much as reasonably possible, additional degradation of the groundwater. This is a straightforward application of the precautionary principle and should not be controversial.

VI. The Costs of Revisions and the Significant Long Term Environmental and Social Costs of EPA Not Acting.

Industry's suggestion that the costs of compliance with these revisions to 40 C.F.R. 192 will be onerous is specious. We expect there will be at most, minimal cost impacts. Specifically, EPA found that "the estimated costs of complying with the proposed rule are 0.6% to 1.7% of estimated 2015 revenues for three small firms that own ISR operations. Because costs do not exceed 2% of estimated sales, and because EPA projects that fewer than 10 small businesses will be affected by the rule at any given time, EPA concluded that the proposed rule would not result in significant impacts for a substantial number of small entities. For information on how EPA estimated these costs, see Section 3 and Appendix D of the Economic Analysis." Draft Rule at 4157.

NRDC concurs with EPA's assessment of the likely impacts of costs of complying with the proposed rule. The minimal costs of compliance for industry balanced against the costs due to water scarcity in the inter-mountain west is an important issue for EPA to rethink, and not just for ISL recovery. Water scarcity issues alone should cause governments and communities to reconsider whether uranium development and other water-intensive natural resource extraction techniques (such as coal-bed methane recovery and fracking of shalegas deposits) represent a wise course of action. The tradeoff between energy resource extraction and groundwater protection is only one of several complicated issues that face state resource professionals. With respect to groundwater scarcity, the crucial point is that even if there is a period of significant growth in the market for uranium, ISL uranium mining will likely constitute only a minor fraction of the uranium resources used in the United States, much less the rest of the world. It makes no sense to contaminate scarce western groundwater and harm iconic western landscapes for uranium production that amounts to a small fraction of global uranium output and U.S. consumption, and that does not fundamentally alter U.S. dependence on foreign sources of uranium. Even if a much higher degree of U.S. uranium self-sufficiency were, in principle, achievable economically, one would still want to weigh the environmental costs, especially the critical alternative uses for all the groundwater resources that would be impaired by stepped-up ISL mining activity.

With respect to just ISL impacts, the volume of contaminated water within the ore zone is not trivial, and the impacted water volumes can be (depending on the site specific geology and aquifer properties) in the hundreds of millions of gallons groundwater per mine unit. Further, NRDC commissioned a study of economic perspective and recommendations for EPA's valuation of groundwater. *See* Attachment B, *Comments on EPA's Draft Economic Analysis of Groundwater and Uranium ISR Rule Revisions*, Hjerpe & Morton, May 27, 2015.

And more specifically to this point, EPA conducted a qualitative assessment of the benefits of the proposed rule and recognized that "groundwater is a valuable resource, and is becoming more valuable as groundwater use increases. While the aquifers in the vicinity of ISR operations are currently providing little extractive value (because of their locations and, for some areas, the fact that groundwater quality is low), in future years these resources may have increased value. A recent analysis (Poe et al, 2001)[11] estimated the value to today's households of protecting groundwater for future use ranged from $531 to $736 per household. For this reason, EPA believes it is necessary to take a longer view of groundwater protection than taken in the past." Draft Rule at 4157. Simply, the ISL process degrades groundwater and causes severe environmental impacts. We demonstrated – and even the NRC's Atomic Safety & Licensing Board agreed – that in every instance we can find the industry cannot restore groundwater to primary or secondary limits and ACLs are inevitable. With that in mind, it is of profound import that the scarce groundwater resources in the American West be protected.

Groundwater is and will be a significant source of drinking water supply for municipalities and also a source for agricultural irrigation in this part of the country. Groundwater is an attractive water source to meet these demands because it is accessible in areas without substantial surface water availability, requires relatively less treatment compared to surface water, and is less susceptible to drought conditions. According to the USGS, groundwater is the source of drinking water for half the United States. Furthermore, groundwater contributes the largest percentage of source water for agriculture irrigation.

It's also perfectly clear that water demands in the future will increase,[12] therefore groundwater resources will be increasingly relied upon as a consistent, reliable, source of fresh water. However due to overreliance on groundwater, significant groundwater depletion has been observed by the United States Geological Survey over the past decade. The Central Valley Aquifer of California and the High Plains Aquifer (Ogallala) have already observed substantial groundwater volume losses from 1960-2008.[13]

---

11 EPA's citation is to Bergstrom, John C., Kevin Boyle, and Gregory L. Poe. *The Economic Value of Water Quality*. Edward Elgar, 2001; linked online at http://www.e-elgar.com/shop/the-economic-value-of-water-quality.

12 Att. C, Blanc, E., K. Strzepek, A. Schlosser, H., Jacoby, A. Gueneau, C. Fant, S. Rausch, and J. Reilly (2014), *Modeling U.S. water resources under climate change, Earth's Future*, 2, doi:10.1002/2013EF000214, February 2014.

13 Konikow, L.F., 2013, *Groundwater depletion in the United States* (1900−2008): U.S. Geological Survey Scientific Investigations Report 2013−5079, 63 p., http://pubs.usgs.gov/sir/2013/5079.

But just focusing on why groundwater matters so much in precise areas where ISL recovery takes place demonstrates the wisdom of EPA taking a longer view of groundwater protection than taken in the past. For example, population increases over the last decade in northeastern Wyoming have put increasing stress on the available water supplies. The city of Gillette, Wyoming depends on drinking water from the Fort Union Aquifer and other local aquifers, to provide municipal water supplies. However, water availability in these aquifers is dwindling and the population is projected to substantially increase from 37,000 to 57,000 by 2030. To meet increasing water demands, the city is enacting the Gillette Madison Pipeline Project, a 217.6 million dollar project, which will route water from the Madison aquifer, north of Keyhole Reservoir to Gillette via pipeline. The project is intended to meet growing water demands for the next 20 years. This example demonstrates the specific vulnerability of just one region where ISL takes place. Put simply, there are increased water demands and scarce options to meet those demands.

Next, going to EPA's point that in some instances, there is limited or no access to the water where ISL is taking place, we note that if the groundwater which has contaminant levels above the US EPA's drinking water standards is used directly as a primary source of drinking water it carries a risk of detrimental health impacts. Groundwater that does not meet drinking water standards would require "at the end of the pipe" treatment to return water to acceptable drinking water standards, which is costly and carries numerous logistical issues (waste disposal, energy requirements, O&M costs, etc.).

In general, financial limitations prompt municipalities to utilize the highest quality source water which requires the least amount of treatment. When relatively high quality (low treatment) source water is unavailable, the next economically available source of water is used. This general trend explains why desalination of sea water is used as a last resort, due to significantly high treatment costs. Therefore, preventing water contamination in the first place is regarded by many water resources and environmental engineers as the 'best treatment option'.

In summary, NRDC strongly supports EPA's proposed rule, 40 CFR §192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, because the current regulatory regime for uranium recovery fails to protect public health and the environment from uranium ISL mining. The EPA proposed rule addresses: current deficiencies in characterizing baseline aquifer water quality; groundwater degradation from mining activities; the potential for ISR uranium mining to contaminate adjacent aquifers; and long-term groundwater impacts. Governing law and policy make clear that EPA has the authority to promulgate this rule, which careful analysis has shown to have small economic impacts on the mining industry relative to the rule's benefits. Now and in the future, groundwater represents a significant source of drinking water supply for municipalities and water for agricultural use in areas where uranium mining has and will occur –these aquifers and the U.S. citizens who depend on this water now and in a more arid future need the scientifically rigorous protections built into this rule.

Thank you again for this opportunity and I am happy to answer any questions.

Natural Resources Defense Council, Inc.

NRDC Comments on 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, Proposed Rule, 80 Fed. Reg. 4156-4187 (Jan. 26, 2015), Docket ID No. EPA–HQ–OAR–2012–0788.

May 27, 2015

Natural Resources Defense Council, Inc.
1152 15th St. NW, Suite 300
Washington, D.C. 20005
Tele: 202-289-6868
gfettus@nrdc.org
llarson@nrdc.org

Table of Contents

NRDC

May 27, 2015

Via Electronic Mail

Air and Radiation Docket,
Environmental Protection Agency,
1200 Pennsylvania Ave. NW, Mailcode: 2822T
Washington, DC 20460

RE: Docket ID No. EPA–HQ– OAR–2012–0788, *Natural Resources Defense Council Comments on 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, Proposed Rule.*

Dear Sir/Madam:

The Natural Resources Defense Council (NRDC) writes today to comment on the Environmental Protection Agency's (EPA) proposed rule for 40 CFR 192*, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*. 80 Fed. Reg. 4156-4187 (Jan. 26, 2015) (EPA–HQ– OAR–2012–0788) [hereinafter Proposed Rule]. We begin by congratulating EPA on the issuance of these long overdue draft standards and urge promulgation of final standards with appropriate haste. Communities and water resources across the American West, from South Texas to Wyoming and states in between, have been negatively affected by uranium recovery for decades. This set of standards, implemented with all dispatch, can finally start the industry and its direct regulators – the Nuclear Regulatory Commission (NRC) and its Agreement States – on a path to a full accounting of the environmental harms and costs of uranium recovery.

I. NRDC Statement of Interest

NRDC is a national non-profit environmental organization with over one million combined members and activists. NRDC's activities include maintaining and enhancing environmental quality and monitoring federal agency actions to ensure that federal statutes enacted to protect human health and the environment are fully and properly implemented. Since 1970, NRDC has sought to improve the environmental, health, and safety conditions at the civil nuclear facilities licensed by the NRC under standards set by EPA. We have called for an EPA rule to address in situ leach (ISL) uranium mining for nearly a decade and we are pleased at the opportunity to comment on these long overdue draft standards.

II. Summary of Comments

EPA has proposed these new standards and amendments under its Atomic Energy Act authority, as amended by Section 206 of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. NRDC supports EPA's action and this appropriate exercise of federal authority. We are pleased with this opportunity to offer extensive written comments to support, clarify, and strengthen each section of the proposed standards. These strengthened and clarified 40 CFR 192, Subpart F standards, when promulgated in final form, will finally start the industry and its direct regulators – the Nuclear Regulatory Commission (NRC) and its Agreement States – on a path to a full accounting of the environmental harms and costs of uranium recovery.

Our comments commence with a short description of ISL uranium recovery. We then describe the inadequate existing requirements, with a history of how uranium has been treated, the initial UMTRCA controls, how the system works in practice, and the reasons for the regulatory morass. We then turn to the evidentiary record of the Ross proceeding, litigated by NRDC and the Powder River Basin Resources Council from 2011 through this day. We describe the Ross ISL Project and our National Environmental Policy Act (NEPA) challenge to the Nuclear Regulatory Commission's materials license. After we set forth how we will cite to the substantial record, we describe the substantive concerns – the failure to set an accurate baseline; the failure to restore groundwater quality after mining; and the failure to account for fluid migration. We conclude the section on the Ross Project by discussing how it illustrates the need for EPA's newly issued ISL standards. We then turn to legal support for the rule and finally, our section by section comments on the rule.

In summary, we are pleased to offer our unequivocal support today to EPA's well-grounded interpretation that UMTRCA is the controlling legal authority for protection of groundwater for ISL sites and, further, that the NRC or any agreement state is obligated to implement the 40 CFR part 192 standards to implement these standards. As we demonstrate in the specific comments that follow, EPA has ample authority under the Atomic Energy Act to issue these standards and, importantly, the current state of affairs is not protective of human health or the environment. Specifically, NRC's and NRC Agreement State reliance on the requirements of the underground injection control program, authorized under separate legal authority, fail to adequately address groundwater protection at ISL facilities. Rather, current NRC interpretation of the statutory regime and regulatory obligations directly allow for significant contamination of scarce sources of western groundwater. As EPA notes in this draft, if the groundwater is not considered a Underground Source of Drinking Water (USDW), as is typically the case at ISL sites, it is not protected under the Safe

Drinking Water Act (SDWA) and the ISL mining area is, for all intents and purposes, used as a disposal site and left, in every instance, severely contaminated.

Next, we offer support for EPA's well-grounded position that UMTRCA requires the establishment of protections consistent with the requirements of the Resource Conservation and Recovery Act (RCRA). Pointedly, and contrary to industry's assertions that we discuss extensively in our comments, an aquifer exemption under the SDWA does *not* relieve the licensee of the obligation to remediate environmental contamination resulting from activities regulated under UMTRCA, regardless of the issuance of an aquifer exemption or pre-mining groundwater quality. EPA standards issued pursuant to UMTRCA clearly and plainly apply within the exempted portion of the aquifer and the imposition of RCRA consistent standards offer the opportunity to fully account for environmental harms and protect future generations.

We expect EPA's valid interpretation of the statutory obligations will meet with resistance on a number of crucial issues. As one example, both NRC and the ISL industry take the position that background water quality – the fundamental requirements of collecting and analyzing environmental data, impacts and alternatives of the area where the mining will take place – can be done long after licensing and approving the site and long after the aquifer has been affected. Indeed, restoration goals that are never met are set on an already fouled nest. This cannot continue and these standards, when finalized, will start the process of addressing such harms.

Another example of expected resistance is that NRC and industry have asserted that environmental impacts can be dismissed as "small" and "temporary" without any underlying quantitative analysis that demonstrates a corresponding minimal impact. Indeed, to the contrary, our comments filed this day will demonstrate impacts to ISL mined aquifers that are, in every instance, large and irreversible, such that the groundwater is substantially degraded and there will be long-term harm to crucial natural resources.

While there are several aspects of the rule that merit our support, there are areas where the rule either needs clarification or strengthening – issues such as ongoing industrial waste disposal for ISL operations, how excursions are monitored and upper control limits are established, and ensuring that the new standards apply to ISL uranium recovery operations that phase in and out of operation – are just a few items that need substantially more precision.

III. ISL Recovery Described

A uranium recovery process has emerged within the last 40 years, termed in-situ ("in place") leach (ISL) or in-situ recovery (ISR) uranium extraction. This process involves injecting an oxidizing solution into a groundwater aquifer containing naturally occurring uranium ore. The solution dissolves the uranium minerals and the 'pregnant' solution is pumped to the surface, where the uranium is subsequently processed and shipped offsite. The process exploits the redox (oxidation-reduction) characteristics of uranium. In the ore body, uranium exists as U^{4+} is a solid mineral formed by natural conditions over geologic time frames. The injection of a lixiviant solution oxidizes the naturally occurring uraninite ore, creating the U^{6+} oxidation state, which is substantially more soluble.

IV. Inadequate Existing Requirements

A. Introduction

Nearly a decade ago, former NRC Commissioner Merrifield called for a rulemaking to solve the problems plaguing the regulation and protection of groundwater from ISL uranium mining facilities. Commissioner Merrifield stated:

> While the staff has done its best to regulate ISL licensees through the generally applicable requirements in Part 40 and imposition of license conditions, our failure to promulgate specific regulations for ISLs has resulted in an inconsistent and ineffective regulatory program. We have been attempting to force a square peg into a round hole for years, and I believe we should finally remedy this situation through notice and comment rulemaking.[1]

The statements of the former Commissioner include word choices such as "inconsistent" and "ineffective" – terms that accurately describe the splintered, incoherent licensing regime now in place for ISL uranium mining. Indeed, by 2007 NRDC was actively and publicly calling for both EPA and NRC to address the matter of inadequate regulatory treatment of ISL uranium mining, and in 2011/12 we authored an extensive paper on the topic. *See, Nuclear Fuel's Dirty Beginnings: Environmental Damage and Public Health Risks From Uranium Mining in the American West*, Fettus, McKinzie, March 2012, found online at http://www.nrdc.org/nuclear/files/uranium-mining-report.pdf.

While the paper is more than a few years old, what we wrote about the failures of the regulatory system remains accurate. Simply, the existing regulatory framework was designed to address conventional uranium milling—not unconventional techniques, such as ISL mining, which as EPA notes is likely to comprise the majority of new uranium recovery sites in the next decade and likely going forward into the future. Regulations promulgated in the late 1970s and 1980s did not contemplate ISL mining and its associated harms, and the legal framework that currently governs ISL mining is

---

[1] Memorandum for Chairman Diaz, Commissioner McGaffigan, Commissioner Jaczko, and Commissioner Lyons from Commissioner Merrifield, Regulation of Groundwater Protection at In Situ Leach Uranium Extraction Facilities (Jan. 17, 2006) at 1.

wholly inadequate to the task of protecting scarce western groundwater resources. This regulatory negligence must be rectified if the nation is to avoid future risks to the public health and environment.

As we noted in our 2012 analysis, simply updating regulations for conventional milling would solve only part of the problem the nation faces going forward into a new round of domestic uranium mining and milling. We have urged both EPA and the NRC to move swiftly to update the relevant environmental protections for uranium recovery. The sooner improved standards can be put into effect, the sooner public health and the environment will be protected. The EPA, to its credit, has commenced this revision of its health and environmental protection standards with the draft rule we comment on this day. Apparently content with the status quo until the EPA issues new standards, the NRC has yet to start its process. Rather than continue to perpetrate this ongoing debacle, immediately after EPA receives these comments, NRC should commence work on its own ISL rulemaking proceeding so it can conform its licensing process to EPA's proposed, and ultimately final, standards. The NRC will have plenty of time in the draft comment period to adjust to any changes the EPA might make between receipt of public comments and the issuance of final standards. Until newly protective rules that create a coherent regulatory process, NRDC supports a moratorium on the review and granting of any new ISL uranium mining licenses or, indeed, the expansion of any existing licenses.

B. History of the Inadequate Regulatory Treatment

We have long been aware of industry complaints that under the current system, it must obtain multiple permits from different regulatory authorities—the NRC, the EPA, state environment departments, and state engineers—but on a practical level, the paper burden is not nearly as heavy as industry suggests. Examining documents in the ongoing Dewey Burdock ISL application in South Dakota, it is apparent that industry submitted many of the same documents to the state or the EPA for the operation's Underground Injection Control application as it did for its NRC materials license. More important than the question of the paperwork burden on the industry is whether the regulatory scheme is failing to protect human health and the environment and overdue for revision.

And on that front, the current regulatory system, which manages to be complicated and dysfunctional at the same time, presents a picture that appears restrictive but fundamentally is not. The system needs to be reformed before additional ISL mines are licensed.

1. The Initial Statutory Controls— 1978's Uranium Mill Tailings Radiation Control Act.

The first imposition of any environmental control on conventional uranium recovery came with the Uranium Mill Tailings Radiation Control Act (UMTRCA). UMTRCA is divided into two titles. Title I addresses mill sites that were abandoned by 1978. The EPA was directed to promulgate radiation and hazardous waste standards for remediation, and DOE was to perform the cleanup of abandoned tailings sites (25 former AEA sites) subject to NRC licensing. Title II focuses on uranium milling facilities operating after 1978. It established the framework for NRC and Agreement States to regulate mill tailings and other wastes at mills licensed by the NRC at the time of UMTRCA's passage, and to adopt the subsequent standards set by the EPA. To insure the long-term stabilization and maintenance of the mill sites and to pass on industry's costs, ownership of the tailings passes to an agency of the federal government—such as the DOE—or the state after a mill is decommissioned. To date, as far as NRDC is aware, no state has become a perpetual custodian of a uranium mill site. This law and the subsequent regulations issued by the NRC and the EPA have never specifically addressed ISL mining operations until the draft rule under discussion this day.

Under its AEA authority (Chapters 7 and 8 of the AEA, "Source Material" and "Byproduct Material," respectively), the NRC regulates uranium recovery when it involves conventional milling (concentration) of uranium ore or ISL mining under its regulations for Domestic Licensing of Source Material. Despite a growing use of the ISL technique over the past two decades (and the past few years in particular), the NRC has not altered its source material licensing regulations to account for the impacts of ISL mining.

Rather than promulgate new rules that would address ISL mining, the NRC has used its 10 CFR Part 40 rules (meant for mill tailings) and agency guidance and specific license conditions to regulate ISL mining in an ad hoc fashion.

2. In-Situ Leach Mining Regulation: EPA's Statutory Authority Under UMTRCA

EPA has the responsibility to establish standards for public exposure to radioactive materials originating from mill tailings, and cleanup and control standards for inactive uranium tailings sites and operating sites. The EPA's regulations in 40 CFR 192 apply to remediation of such properties and address emissions of radon, as well as allowable concentrations of radionuclides, metals, and other contaminants in surface water and groundwater.

Despite the ability to do so under 40 CFR 192, for decades EPA did not establish radiation protection or other standards specific to ISL mining. Fortunately, in 2009 EPA commenced work on this long delayed draft rule.

Currently, however, as UMTRCA regulations will address ISL mining once this rule is finalized, the EPA's chief involvement with ISL mining has been through its

SDWA authority and its Underground Injection Control (UIC) regulations. States can be the relevant permitting authority for this matter if the state has assumed the EPA's authority for implementing the SDWA. Here, the ISL uranium mining company must apply to the EPA or its delegated state for approval of underground injection of solutions that will contaminate the exempted aquifer. The EPA's UIC regulations are designed to protect underground sources of drinking water (USDWs) by prohibiting the direct injection or migration of foreign fluids into these aquifers. A USDW is defined as any aquifer or portion thereof that supplies a public water system or contains fewer than 10,000mg/l total dissolved solids (TDS). The EPA stated that "an aquifer may be exempted from UIC regulation if it is shown to be completely isolated with no possible future uses." EPA TENORM Report, p. A VI-3.[2]

The theory is that such an aquifer cannot and will not serve as a source of drinking water because it is situated at a depth or location that makes recovery of the water technically or economically impractical. For years the discovery of producible mineral deposits led to what amounted to an automatic exemption, even in the arid West. Unfortunately, as we will show in later in our comments, this process of exempting aquifers has allowed the ISL uranium industry to use the mined aquifers as contaminated disposal zones, with the explicit assistance of its ostensible regulator, the NRC.

3. How the Current & Inadequate Regulatory System Works In Practice

The current regulatory scheme for ISL uranium mining works as follows. The NRC licenses and regulates ISL operations under standards written for conventional uranium mills. By statute, the NRC must also adopt EPA standards, also written for uranium mills, but then use those standards for ISL operations. The NRC issues a guidance document to present what the industry applicant must do to obtain an ISL license. U.S. NRC, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications: Final Report*, NUREG-1569 (June 2003), *available at* http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf. The site remediation program (SRP) guidance details how the agency will interpret its requirements for groundwater restoration under 10 CFR Part 40 (the NRC regulations for nuclear "materials" licenses).

First, the SRP provides that after an ISL mining and milling operation has concluded, the site must be cleaned up, or "decommissioned," and groundwater quality must be restored. The NRC guidance posits that even after receiving an aquifer exemption under the SDWA, an ISL uranium mine should restore the contaminated groundwater aquifer to NRC-approved background values. Such a level of protection for

[2] EPA, "Technologically-Enhanced, Naturally-Occurring Radioactive Materials From Uranium Mining" (hereinafter "TENORM Report"), 2-1. April 2008. Volume 1 can be found at epa.gov/ rpdweb00/docs/tenorm/402-r-08-005-voli/402-r-08-005-v1.pdf and Volume 2 at epa.gov/radiation/docs/tenorm/402-r-08-005-volii/402- r-08-005-v2.pdf.

the scarce resource would ensure that adjacent groundwater aquifers are safeguarded and that other potential future uses of the mined aquifer are not compromised. The NRC states that if the contaminated groundwater cannot be restored to the NRC-approved background level, then the aquifer must be restored to the maximum concentration levels set in 10 C.F.R. § 40, Appendix A, Table 5C. And if that standard is not achievable—as the NRC notes, "these two options may not be practically achievable at a specific site—then the licensee may propose an alternate concentration limit that it will argue presents no significant hazard."

As we will describe in detail below, in every instance, the industry has defaulted to an alternative concentration limit (ACL) for key parameters such as uranium or radium with little agency complaint. Agreement States such as Texas have adopted similar rules that allow the industry to be relieved of its burden to restore contaminated groundwater. The combination of an aquifer exemption (making the licensee exempt from water quality standards) and a relaxed NRC regulatory scheme allowing alternative limits for key parameters results in aquifer contamination where the ore is mined.

If there ever were a need states such as Wyoming, New Mexico, Nebraska, Texas, or South Dakota to access the water in the aquifer where uranium mining took place for agricultural and possibly even drinking water uses, our 2012 survey and initial study, our experience with the Strata case, and our analysis for these comments suggest that such an option would be foreclosed. The increasing scarcity of water in the American West is a crucial national issue, and all sources—be they surface water or groundwater—should receive the utmost protection.

4. Reasons for the Regulatory Morass

NRDC has identified two straightforward reasons for the current regulatory morass. First, the weak regulatory regime exists because ISL uranium mining was not in widespread use when conventional uranium mining was first subjected to any oversight beyond that of promoting and guaranteeing the viability of a market. Laws to protect public health and the environment from uranium mining and milling impacts were not drafted and passed until several decades of harm had already been inflicted across the American West. Those laws that were passed have rarely been updated and have been haphazardly enforced, with little accountability for lax decisions and a decided unwillingness among regulators to enforce protective standards. The NRC, the EPA, the DOI, the DOE, and the Bureau of Indian Affairs (under its trust responsibility) all hold portions of accountability for the regulation of past, present, and future harm resulting from uranium recovery.

The second reason for the ongoing failure to address the impact of ISL mining is that the existing regulatory schemes are assembled from an archaic set of jurisdictional concerns. NRC jurisdiction over uranium milling (and eventually ISL mining)—and not over conventional uranium mining—is founded on the perceived national need for the federal government to have full authority over nuclear materials in order to ensure the smooth operation of our weapons and commercial nuclear industries. The EPA's authority, granted in 1978, has been superimposed on the NRC process, with at best grudging acceptance by the nuclear agency. The result is a complicated set of standards assembled from regulations intended for differing areas. Whether the current situation exists by intent or happenstance is almost beside the point. The focus must be on curing these archaic deficiencies and swiftly developing a more protective regulatory framework for uranium recovery of all types, before even more environmental damage is done.

C. The Evidentiary Record of ISL Uranium Mining's Environmental Harms – the Ross Proceeding

The archaic and deficient regulatory system can be viewed in stark relief via an examination of the evidentiary record of our ongoing challenge to a NRC materials license for an ISL uranium mining site in northeastern Wyoming.

We recently concluded this four year challenge and the matter is currently on appeal to the full Commission. *See, In the Matter of Strata Energy, Inc.* Docket No. 40-9091-MLA. The entire docket for the proceeding can be found online at NRC's electronic hearing docket (https://adams.nrc.gov/ehd/). We will reference the evidentiary record of that proceeding throughout our substantive comments and here provide a short roadmap to that demonstrates (1) the inadequacy of the current regulatory regime and (2) the necessity for EPA to issue strong, protective standards.

Also, as a preliminary matter before we detail the Strata evidentiary record and how it precisely demonstrates the inadequacy of the current regulatory system, we start with highlighting a fundamental component of how ISL uranium mining has been regulated up until the issuance of these draft rules. Unlike EPA and many other federal agencies with statutory mandates that include the public—via citizen suit provisions—as a partner in achieving compliance with an organic statute, the NRC's statutory authority does not assign a direct role to the public in enforcing its regulatory requirements, which by law must ensure adequate protection of the public health and safety against radiation hazards from the licensed civilian uses of nuclear energy. Instead, the role envisioned under the AEA is for members of the public, including representatives of state, local, and tribal governments, to bring their concerns regarding compliance with the NRC's statutory mandate and regulatory requirements into the Commission's licensing and rulemaking processes, where these concerns can be fairly adjudicated. Unfortunately, as demonstrated by the NRC Staff's near perfect alignment with industry in opposing citizen petitions to intervene in licensing proceedings, the Commission today seems to have strayed quite far from the intent of this statutory framework, which was designed to allow contending views of nuclear safety & environmental hazards to be fully explored and adjudicated in a quasi-judicial proceeding. Along with splintered and inapposite application of rules not meant for ISL recovery, it is this proclivity of NRC to entirely side with industry that drives the need for finalizing EPA's rules and adopting strong, clear protective standards for ISL recovery.

1. Description of the Ross Project & Challenge to the License

In January, 2011 Strata Energy, Inc. (SEI) applied for a Materials License for an in-situ leach (ISL or ISR) uranium mining project in Crook County, Wyoming (Ross Project). The Ross Project – just the first section of a much larger Lance District uranium recovery region in northeastern Wyoming, will use 1,400 to 2,200 injection/recovery wells, and a ring of separate monitoring wells "to provide warning if lixiviant is migrating outside the" ore zone. A basic premise of ISL mining is that it occurs within a "confined" aquifer – *i.e.*, an aquifer overlain by an impervious confining geological unit limiting vertical transmission of the water. In analyzing the Ross Project's impacts, NRC Staff purported to find the ore zone aquifer to be "confined." U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 3-35 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf.[3]

NRDC and PRBRC filed a timely hearing request regarding deficiencies in SEI's Environmental Report (SER), and the Board admitted several contentions, lodged under the National Environmental Policy Act (NEPA), 42 U.S.C. §4321, *et seq*. While some were later rejected (two of which we sought review before the Commission and we await a decision on those as well), three contentions proceeded to a hearing over the February 2014 FSEIS. The long and winding road to an evidentiary hearing on the substantive environmental impacts of ISL mining can be understood by examining the extraordinary hearing record, the entirety of which can be found on NRC's (difficult to navigate) ADAMS public website.

In short, NRDC demonstrated that: (1) adequately characterizing baseline groundwater quality is crucial to a sound, meaningful NEPA analysis and, just as important, can be performed in a technically defensible manner that will allow the public and decision-makers to understand the environmental impacts and risks posed by the uranium mining operations before the agency decision is taken; (2) the NRC staff did not adequately assess the impacts stemming from the high likelihood that the Lance District will remain contaminated at the conclusion of the restoration process and the

---

[3] Portions of the aquifer are exempt from protection under the Safe Drinking Water Act (SDWA) under a regulation exempting an aquifer not currently used as a drinking water source and containing "minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible." 40 C.F.R. § 146.4(b)(1). However, as EPA emphasized in this draft rule, the fact that an aquifer is "exempt" does not reflect the actual *quality* of the water, which should be left, post-remediation, "in no worse condition than pre-ISR operational status." *See* 80 Fed. Reg. 4156, 4171 (Jan. 26, 2015). *See also id.* at 4,168 ("[A]n aquifer exemption under the SDWA does not relieve the licensee of the obligation to remediate environmental contamination resulting from activities regulated under UMTRCA").

information added to the FSEIS on other sites did not and cannot fulfill Staff's NEPA obligation to disclose the likely outcome – including, at minimum, a bounding analysis of likely results – at this site; and (3) the FSEIS was technically inadequate because it (a) failed to disclose and assess the high risks of fluid migration from unplugged boreholes that fundamentally compromise the assumption of confined (and therefore non-contamination transporting aquifers, (b) was based on SEI's pump tests that were inadequate.

For reasons we discuss in the comments that follow, the Board, on January 23, 2015, resolved against NRDC the three contentions subject to an evidentiary hearing, *i.e.* the failure to: (1) collect and disclose adequate baseline water quality data; (2) evaluate and disclose the degradation of water quality likely to remain at the conclusion of the project; and (3) consider and disclose the likelihood that groundwater contamination will move beyond project boundaries. *See* ASLB's Initial Decision, (hereinafter "Init. Dec.").[4] The Board's decision speaks for itself. We appealed the matter to the full Commission and assert the Board erred in resolving these Contentions. Our appeal has been fully briefed and we await the Commission's ruling. Crucially, while the Board ruled for industry and NRC staff on the NEPA contentions, at no point in its ruling did it find any portion or item in NRDC's evidentiary presentation inaccurate. Rather, the Board's ruling stands as the current NRC interpretation of NEPA requirements of the ISL industry – as such, that fact alone demonstrates that a coherent, science based set of regulatory standards from EPA would dramatically improve the accountability of the industry for its environmental impacts and could hopefully obviate some of these contentious disputes before they happen in the first instance.

Instead of incorporating the entirety of the Ross evidentiary record in this proceeding and expecting EPA to sift through it, today we supply a short roadmap to what NRDC and PRBRC demonstrated and how that uncontroverted factual demonstration supports EPA issuance of a final version of this draft rule with all dispatch. For EPA's consideration, we appended and hand delivered to the agency this day disc with a substantial portion of our evidentiary presentation from the Ross Project proceeding. *See* Attachment 2, where we list, in order, the documents and their supporting attachments. We have not attempted to email these documents, as they are voluminous and would not be accepted via the agency's electronic mail system (thus, our hand delivered disc).

The disc provides a pdf of each and every one of those documents. Notably, when citing the documents from the Ross proceeding, we will use the basic citation form from the trial. For example, citations to Dr. Larson's Initial Direct Testimony are "JTI003 at _." Citations to Dr. Abitz's Direct Testimony are "JTI001 at __" and so forth. All the exhibits that supported their testimony are submitted this day as well and carry the JTI citation form, with the proper page number inserted. See Attachment 2 for the full listing of supporting documentation from the Ross proceeding.

---

[4] See Attachment 2 for the full citation information for files cited repeatedly in these Comments.

Finally, any other supporting document provided today that was *not* used in the Ross proceeding – generally, NRC or industry documents from the ADAMS website – will be hyperlinked with the page number noted, if appropriate.

2. The Substantive Concerns at Issue in the Ross Project Proceeding

A. The Failure To Set An Accurate Baseline Representative Of Pre-Mining Conditions

i. The NRC allows for groundwater baseline to be set long after the licensing and NEPA process have concluded.

In the Ross Project proceeding we argued that the FSEIS failed to comply with 10 C.F.R. §§ 51.90-95, 10 C.F.R. Part 40, Appendix A, and NEPA because it lacks an adequate description of the present baseline (i.e., original or pre-mining) groundwater quality and fails to demonstrate that groundwater samples were collected in a scientifically defensible manner, using proper sampling methodologies. The inadequacy of the current NRC regulatory process is clear and the record in the Strata proceeding illustrates it precisely.

We first presented what it means to have "baseline" water quality established in an underground aquifer and how the terms are commonly understood by industry and government regulators. JTI001 at ¶¶11-15. Fundamentally, the critical need for a precise knowledge of baseline groundwater quality is so that all may properly understand the environmental impacts at a site where natural resource extraction activities are going to take place so as to understand as best one can the condition of the aquifer before any anthropogenic activity that might cause contamination takes place so proper monitoring levels can be established to protect the groundwater. *Id.* at ¶15.

NRDC then presented that for hazardous waste sites, baseline values are established for the groundwater horizons by installing wells, under approved procedures and valid statistical sampling plans, upgradient of known or suspected contamination zones, with sampling occurring more than 8 times. *Id.* at ¶¶12-14 (citing EPA (2009) Unified Guidance (JTI 006, at 5-3). We then explained that the process for collecting baseline groundwater quality data for the Ross Project is not consistent with the standard, scientifically defensible approach to setting baseline water quality, as the FSEIS provides that two separate efforts to evaluate baseline water quality data will occur, one pre-license and another post-license, <u>with almost all the data collection and the actual setting of baselines only post-license, after the regulatory decision is made</u>. *Id.* at ¶16.

This arbitrary splitting of the baseline collection process until after the licensing and environmental evaluation of the facility is problematic, our expert, Dr. Abitz, explained, because (1) to collect samples that represent the true geochemical conditions in the aquifer, the baseline must be established using groundwater samples obtained from an aquifer that has not been contaminated by extensive exploration drilling; (2) allowing contamination of the aquifer prior to establishing baseline is contrary to the scientific definition of baseline and the noted criteria in 10 C.F.R. 40 Appendix A; and (3) failure to develop and present the actual baseline conditions on the site deprives the public and the decision-maker any meaningful evaluation of the project's likely environmental impacts. *Id.* at ¶¶17, 18.

Thus, we concluded that under the NRC's currently sanctioned approach for this project, baselines are not actually evaluated and established before the decision to go ahead with the project has been made. Allowing baseline data collection post-license is problematic because it means that the groundwater quality will not be characterized properly, resulting in the establishment of high excursion values and restoration standards that will preclude the use of the water for future domestic, livestock or agriculture needs. *Id.*

We explained in detail the specific flaws in how industry presented baseline –

- the statistical justification for the location of the six monitoring-well clusters is lacking because the wells were not randomly located,
- the ore zone was oxidized when the wells were installed, and a true baseline cannot be developed after hundreds to thousands of wells are drilled in the well fields. *Id.* at¶¶27-29,
- and the screen lengths for the existing monitor wells were inappropriate. *Id.* at ¶¶22-26.
- All of these factors have the effect of biasing groundwater samples to high values for uranium. *Id.*
- Finally, we presented extensive evidence of how the industry will collect baseline samples from the most disturbed and contaminated portion of the aquifer that has been oxidized by above described techniques, resulting in more misleading results. *Id.* at ¶¶18, 25-31. In his testimony, Dr. Abitz relates his experience with the Kingsville Dome site in Texas, which suffered from similar technical flaws. *Id.* at ¶¶30-31.

In contrast to what NRC found acceptable, NRDC's expert presented how baseline groundwater can be accurately portrayed via scientifically defensible methods. *Id.* at ¶¶33-36. This presentation generally comports with what EPA proposes to require in its draft rule, but certain clarifications are necessary to ensure a technically accurate assessment of baseline groundwater quality is set.

Fundamentally, the need for rules and trying to make sense of how NRC's interpretation of its regulatory responsibilities leads to dispute is found in the fact that while the Board found against us, neither SEI nor Staff disputed that the baseline water quality data relied on in the FSEIS was insufficient to meaningfully characterize the site. *E.g.*, Transcript of Proceedings at 354, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1427/ML14279A153.pdf (acknowledging only the ore zone is screened, thus providing inaccurate data); *id.* at 465 (acknowledging evaluation was not based on "unbiased group sampling"). They simply argued that accurate baseline characterization would occur post-license, when each monitoring well ring is constructed and the Commission Approved Background (CAB) is established for each constituent. *Id.* at 380 (Dr. Johnson); 326 (Mr. Knode). Unfortunately, the Board accepted this approach, concluding NEPA does not require "best practices," and framing the question as whether the "sampling protocols [relied on for the FSEIS were] so facially deficient as to require that they be redone in accord with Joint Intervenors' preferred methodology." Init. Dec. at ¶4.22.

Further, clear requirements to set a technically defensible and protective groundwater quality baseline – such as could be suggested by the draft rule at issue today – could avoid this controversy in the first place. We have no quarrel with the idea that additional "site-specific data to confirm proper baseline quality values" may be collected as part of the post-license process, but that has no bearing on whether legally sufficient baseline data must be collected for the NEPA process, before the licensing decision is made, and certainly is a dispute that could be avoided by EPA requiring baseline be set before the aquifer has been affected.

In short, based on the (wrongly held) legal premise that accurate baseline data may be collected long after the license is issued – we have argued that the Board never meaningfully considered our critique of the baseline water quality approach incorporated into the FSEIS, and our discussion of how this data must be collected to be of scientific value. Moreover, while paying lip service to the appropriate legal framework, whereby it was industry's and NRC Staff's burden to show compliance with NEPA by a preponderance of the evidence, Init. Dec. ¶3.8, the Board put that burden squarely on NRDC, functionally requiring us to demonstrate the data relied upon was "so facially deficient" that it must be supplemented. *Id.* ¶4.22. Under any approach to evidentiary burdens, however, it is evident that the number of wells and their locations, and the sampling methods used, fell far short of NEPA's dictates and it also falls far short of what would be required under any reasonable set of protective standards, such as those EPA might promulgate.[5] Again, we cannot imagine a better object lesson for an

---

5 A clear example of this is the dispute over the number and location of wells. The Board required NRDC demonstrate "evidence of actual bias." Init. Dec. ¶4.22. The Board did not explain how NRDC could meet such a burden, and, in fact, the Board also never explained how SEI and NRC Staff had met their burden to demonstrate that the number of wells and their locations complied with basic scientific principles. As NRDC's expert witness Dr. Abitz testified, EPA's "Unified Guidance" – entitled "Statistical

area where strong, protective standards that require establishment of a meaningful baseline can forestall disputes before they emerge.[6]

In sum, new, protective rules can obviate disputes on this matter by requiring groundwater sampling be done in such as manner as to locate wells and collect data representative of overall site conditions.

ii. The NRC allows for improper techniques in establishing baseline.

Next, we presented evidence the sampling wells are "screened only through the part of the aquifer containing the stacked ore horizon," Init. Dec. ¶4.30, and the Board, Staff and SEI did not dispute that this approach could bias results to high values. *Id.* ¶4.27-28; *see also, e.g.*, Transcript of Proceedings at 354, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1427/ML14279A153.pdf (SEI witness: "It is correct . . . that we do only screen the ore zone"); U.S. NRC, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications: Final Report*, NUREG-1569 at 5-43 (June 2003), *available at* http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf

---

Analysis of Groundwater Monitoring Data at RCRA Facilities" – sets forth specific, scientifically-based protocols for groundwater sampling to determine baseline water quality, independent samples drawn from randomly located wells. Dr. Abitz's presentation comports with EPA has proposed in this current draft. As Dr. Abitz explained and as EPA plainly understands, this type of approach is necessary to collect scientifically meaningful data, and the data relied on in the FSEIS, which complied with none of these protocols, is deficient. Abitz Test. (JTI001) at 7–8, 35–41; Abitz Rebuttal (JTI051) 2-3, 6-7; Transcript of Proceedings at 428, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1427/ML14279A153.pdf; *see also* EPA Unified Guidance (JTI006) at 5-3.
NRC Staff's interpretation directly contradicts the sound science presented by Dr. Abitz. A NRC Staff expert noted at the Ross Project evidentiary proceeding: "[t]he major criteria for doing the tiering is to determine and establish that this project fits within the overall characterization with the geology and the groundwater quality and so on that were evaluated in the GEIS, the generic environmental impact statement. So that's another purpose of this initial review of the prelicense site characterization, to establish that it is consistent or comparable with that evaluated in the generic impact statement. And for that purpose the type of statistical evaluation that EPA uses, for example, to come up with remediation goals is simply not necessary." Transcript of Proceedings at 469, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1427/ML14279A153.pdf.

[6] As yet another example, no witness or exhibit disputed Dr. Abitz's assessment that the wells relied on for groundwater sampling were "not located and distributed in a manner designed to collect data representative of overall site conditions," Abitz. Test. At A.22, and the Board acknowledged that requiring the use of such "best practices" is "not without some attraction." Init. Dec. ¶4.21; *see also* Dep't of Energy Char. of Background Water Quality for Streams and Groundwater (JTI014 at 923-995). In short, Dr. Abitz demonstrated – and no one disputed – that the non-systematic approach used by SEI was neither designed to, nor did, collect representative baseline water quality data.

(discussing need for "fully screened monitor wells"). Moreover, in the absence of any scientific protocol concerning the number and kind of monitoring wells necessary to collect meaningful baseline data (which the Board deemed unnecessary), it would be irrelevant even if these samples reflected that some data had been collected from outside the ore zone. Similarly, the accuracy of the excursion data that may be collected post-license is irrelevant to whether the license was issued based on a meaningful assessment of the baseline water quality – which, again, is an issue that can be obviated by strong, protective requirements.

B. Failure To Restore Groundwater Quality In Exempted Aquifers & Abuse Of The Alternative Concentration Limit Concept

The second issue that went to a full evidentiary hearing was that the FSEIS fails to meet the requirements of 10 C.F.R. §§ 51.90-95 and NEPA because it fails to evaluate the virtual certainty that the applicant will be unable to restore groundwater to primary or secondary limits in that the FSEIS does not provide and evaluate information regarding the reasonable range of hazardous constituent concentration values that are likely to be applicable if the applicant is required to implement an Alternative Concentration Limit (ACL) in accordance with 10 C.F.R. Part 40, App. A, Criterion 5B(5)(c).

We presented the uncontroverted evidence that based upon the past history of ISL facilities, it is a virtual certainty that the industry will not be able to restore the impacted aquifers to primary or secondary limits. Even with ACLs approved by NRC, NRDC showed that past ISL projects have resulted in significant impacts to aquifers and to date, no ISL project has successfully restored an aquifer. After reviewing extensive restoration data from other ISL projects, we demonstrated that the likelihood of similar impacts occurring at the Ross Project (and, for the purposes of the NEPA hearing before the NRC, that these impacts have not been adequately assessed in the FSEIS).

First, NRDC's expert analyzed the FSEIS's discussion of aquifer restoration, addressing each example provided by Staff in turn: Nubeth (JTI003 at ¶¶12-15), Crow Butte (*Id.* at ¶16), Smith Ranch/Highlands Wellfield A (*Id.* at ¶¶17) and Irigaray Mine Units 1-9 (*Id.* at ¶¶18-19). Dr. Larson concludes that based on the examples the NRC cites in the FSEIS as well as the Christensen Ranch restoration results, and examples he provides later in the testimony, it was his professional opinion that it is inconceivable that the Ross Project will have a "SMALL and Temporary" impact on groundwater quality, as the NRC's FSEIS concludes. *See* U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 4-36 to -37 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf.

To the contrary, if the NRC had considered the actual baseline conditions on the site and compare those values to the reasonably anticipated conditions post-restoration, it would disclose that the Ross Project will have significant environmental impacts. We will now describe the uncontroverted proof of that significant environmental impact.

Dr. Larson introduced visual representations of NRC ISL uranium recovery data to illustrate the failure of restoration at ISL uranium recovery sites. Specifically, Dr. Larson presents

- Storymap #1, *A Visual Representation Of The Failure to Restore Contaminated Groundwater at a Selected Portion of the Willow Creek ISL Uranium Mining Site* and Excursion Events

- Storymap #2, *A Visual Representation Of The Failure to Restore Contaminated Groundwater & Demonstration of Near-Surface Contamination at a Selected Portion of the Smith Ranch ISL Uranium Mining Site*.

- The storymaps can be located here: http://isl-uranium-recovery-impacts-nrdc.org/Willow-Creek/; and http://isl-uranium-recovery-impacts-nrdc.org/Smith-Highland/

In short, Dr. Larson's Storymaps are a visual, interactive spatial representation of the NRC and industry's own data coupled with detailed descriptions of the significance of the data. In our presentation to the NRC, Dr. Larson explained that if a user is shown a static map or a spreadsheet, without context or the ability to interact, it is much more difficult to assimilate the information. JTI003 at ¶25. Dr. Larson then explains in detail how he created the Storymaps, where he obtained the underlying data (from the NRC), how a user can link to the data, and how his conclusions can be duplicated or reproduced. *Id.* at ¶¶26-40. Importantly, EPA can verify the accuracy of this data for itself.

In our testimony before the NRC, which EPA can find via Att. 2, JTI003, in demonstrating just a fragment of what the Willow Creek Storymap can show, Dr. Larson examines well 2AI30 in mine unit 2 where the baseline value presented is 0.02 mg/L. *Id.* at ¶¶52-54 where a pdf of what one would see on the screen. He then describes how the user can find the corresponding uranium concentrations post-restoration (Sampling Rounds 1-4 were 0.207, 0.113, 0.263, 0.25 mg/L). He states these values become apparent when you 'scroll' over the columns with the mouse cursor (he shows round 3 in his screen shot). *Id.* at ¶¶55-56. He then states that at this well after active restoration, the lowest observed uranium concentration (0.113 mg/L) was approximately 5x higher than the average baseline concentration (0.0223 mg/L) and approximately 3.8x higher than safe drinking water standards (0.03 mg/L). *Id.*

His testimony continue and he provides examples where the observed groundwater uranium concentrations can only be described as extreme (18.0, 20.7, 21.7, and 14.8 mg/L, which were 600 times, 690 times, 723 times, and 493 times average baseline and safe drinking water standards, respectively, (*Id.* at ¶57). Dr. Larson encourages the reader to select various wells to observe specific impacts and we suggest the same. Using NRC's own data, the Willow Creek Storymap provides a clear picture of substantial degradation of groundwater quality over the course of the ISL recovery process.

Next, Dr. Larson provided a summary of the data in the Storymap. Using the entire wellfield data set from Christensen Ranch Mine Units 2-6, he created a cumulative histogram for average baseline and each post restoration phase sampling round concentrations. *Id.* at ¶58. Ultimately for the Willow Creek Storymap, the majority of the average baseline groundwater samples were below the MCL for uranium of 0.03 mg/L (~65%); 28 % had slightly elevated uranium concentrations (0.03-0.09 mg/L) and only 8% were very elevated (0.09 – 3.0 mg/L).

Dr. Larson then showed that after mining and restoration activities, the groundwater quality sample distribution shows significant changes to these observed percentages. Roughly 13% of the post restoration samples were extremely contaminated (greater than 3.0 mg/L, which is greater than 100 times the EPA's maximum contaminant limit for safe drinking water standards for uranium), the 'very elevated' (range: 0.12 – 3.0) uranium concentrations increased from 8% (Baseline) to 54% (Post-restoration).

And finally, the drinking water quality samples for uranium <u>decreased</u> from approximately 2/3 of all samples, to roughly 18% of the observed samples. *Id.* Dr. Larson's analysis demonstrates, quantitatively, the severe water quality degradation which occurs as a result of ISL mining, which is not disclosed or discussed in the FSEIS *Id.* at ¶59.

Along with illustrating the potential impacts to the groundwater from the Ross project – the project in question for this testimony – these figures demonstrate the definitive need to evaluate information regarding the reasonable range of hazardous constituent concentration values likely to be applicable when an Alternative Concentration Limit (ACL) is sought. *Id.* ¶¶59, 66. Indeed, we've seen no evidence to contradict the fact that similar or worse groundwater degradation at the Ross Project or any other ISL site is virtually inevitable. *Id.* ¶60.

As another example, at well MP20, he found the average uranium baseline concentration was 0.04 mg/L, suggesting the last and lowest uranium concentration observed post-restoration was ten times higher than the baseline and roughly twelve times higher than safe drinking water standards (0.03 mg/L). *Id.* at ¶¶62-65.[7]

The NRC's response to all of this data, its own groundwater data, is that it is irrelevant. NRC Staff asserted throughout the course of the hearing that potential groundwater impacts from the Ross Project would be SMALL and temporary, notwithstanding the potential future need for an ACL at the site. *See* U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 4-26, 4-36 to -37 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf. Staff even went further in simply asserting that whatever might happen at Ross would be small and temporary, stating "the Staff's conclusion in the FSEIS regarding potential impacts to groundwater from the Ross Project assumes that a Commission-approved ACL *of any amount* would have only a SMALL impact on groundwater at the site." *Id.* at 32-33 (emphasis in original).

How these literal interpretations of environmental cleanup obligations have and will play out at actual ISL recovery sites can be seen in the following exchange that occurred at the evidentiary hearing:

> CHAIRMAN BOLLWERK: All right. Let's go back on the record, please. We have returned from a break for Board consideration of a question that was posed relative to Contention 2, to the staff panel, and we are going to ask the following question, and this is for, at least, initially for Dr. Johnson. You testified that, in evaluating the size and level of the environmental impacts on groundwater, the focus is on the nonexempt aquifer, and that, therefore, the impacts to the exempted aquifer, itself, are immaterial. Does this mean that if the NRC were to approve an ACL thousands of times above EPA Safe Drinking Water Act Standards for uranium, the impacts could still be small?
>
> DR. JOHNSON: Judge Bollwerk, the -- I certainly did not imply that the concentrations of any constituent – let's use uranium as an example -- inside the exempted aquifer is immaterial. The concentrations that are within the exempt aquifer at the -- at the time, let's say, a restoration is

---

7 To sum up the dispute under NEPA at the hearing, Dr. Larson concludes by stating that based on the examples the NRC cites in the FSEIS, the Christensen Ranch results discussed earlier in his testimony, and the clear visual representation that are the Storymaps, it is his professional opinion that it is inconceivable that the Ross Project will have a "SMALL and Temporary" impact on groundwater quality, as the FSEIS concludes. To the contrary, if the FSEIS were to consider the actual baseline conditions on the site and compare those values to the reasonably anticipated conditions post-restoration as evidenced by the Storymaps and the underlying NRC data, the FSEIS would disclose that the Ross Project will have significant environmental impacts. *Id.* ¶66.

> approved, first of all, there are for two reasons, I would say. One is because the way that the approved restorations were done that are discussed in the SEIS were average concentrations over all the wells within the -- the production area. So, that average, of course, would be -- would be higher if there were some wells that were, you know, very, very high concentrations. So, the overall average has to be to, you know, some level that would -- would be approved. And so, of course, those levels are important in any given well in terms of making sure that your average meets the -- the ACL that is ultimately approved. Now, the ACL can't just be any number. It has to be a number that – a value, a concentration, that, upon evaluation shows that, once you reach the boundary of the exempted aquifer, you are at drinking water standards for constituents, including uranium.
>
> So, if the ACL were, you know, let's say, you know, at a ridiculously large number then, in all likelihood, it would not -- you could not demonstrate that it would be protective of the human health and the environment at that boundary of the exempted aquifer. So, the -- you know, the ACL can't just be any number. It has to be a number that meets that, you know, very important criteria that is protective of -- at the -- at the boundary of the exempted aquifer.
>
> CHAIRMAN BOLLWERK: All right. Judge White, do you have any –
>
> JUDGE WHITE: So, you are -- am I correct that you are saying that -- that the that the aquifer outside the exempt aquifer, at that boundary of the exempt aquifer, is still the standard for deciding whether the impact is small, medium or large and that -- and that you are saying that this -- this example, this hypothetical here with some extremely high value would be reflected in the water quality outside the exempt aquifer, and that is what -- that is still what is -- is what is important? It isn't really what concentration in the exempt aquifer is, it is how the concentration in the exempt aquifer will affect water just outside the boundaries, is that correct, that you are saying that?
>
> DR. JOHNSON: Yes. That is correct.

Transcript of Proceedings at 559–61, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1428/ML14280A199.pdf

The issue continued on – in discussing whether impacts of an ACL could ever be large, NRC Staff testified at the Hearing that:

> A large impact means that the environmental impacts are clearly noticeable and are sufficient to destabilize important attributes of the resource considered. We have not found that an ACL, which would have no -- pose no current or potential hazard to human health would also destabilize important attributes of the resource considered.

Id. at 548.

In other words, according to Staff, impacts of an ACL within the mined and exempted aquifer could never be considered "large." In making this conclusion, NRC Staff relied on the fact that the aquifer is not currently used as a drinking water source and received an aquifer exemption from EPA. *Id*. at 549 (Testimony of Ms. Moore: "if the groundwater is exempted as a source of drinking water, then that is something that goes into our determination of what would destabilize that resource.").

Further, this disregard for the environmental effects of ISL recovery on the exempted and mined aquifer evolved over the course of the proceeding as NRDC and PRBRC continued to demonstrate the environmental degradation inflicted. For example, in the Draft Supplemental EIS, Staff stated that aquifer restoration will "return the ground-water quality *in the production zone* (i.e. the exempted ore zone) to ground-water protection standards specified at 10 CFR Part 40, Appendix A." U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Draft Report for Comment*, NUREG-1910 at 4-39 (2013), *available at* http://www.stratawyo.com/wp-content/uploads/2013/03/Ross-DSEIS-optimized-Complete.pdf (emphasis added).

Staff went on to state that the "purpose of aquifer restoration is to restore the respective aquifer to its baseline conditions, as defined by post-licensing, pre-operational constituent concentrations, so as to ensure public health and safety." *Id*. In particular the DSEIS explained that specific groundwater restoration techniques will "return total dissolved solids (TDS) (a water quality parameter), trace-metal concentrations, and aquifer pH to the preoperational baseline values that would have been determined during the Applicant's post-licensing, pre-operational sampling and analysis program; these concentrations would be required by the NRC license." *Id*. at 2-32 to 2-34 (citations omitted).

The FSEIS, by contrast, states:

> The purpose of aquifer restoration is to restore the ground-water quality in the wellfield to the ground-water-protection standards specified at 10 CFR Part 40, Appendix A, Criterion 5B(5), so as to ensure no hazard to human

> health or the environment. Water quality is measured at the *point of compliance that coincides with the established boundary of the exempted aquifer*. During uranium-recovery operation, the point-of-compliance wells would be those in the perimeter ring as well as those in the overlying-and underlying-aquifers, as required by the ground-water monitoring program. During aquifer restoration, however, *the group of point-of-compliance wells would be expanded to include the representative wells in the exempted aquifer*.

U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 2-34 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf (emphasis added) (citations omitted). Finally, the FSEIS further states:

> [S]hould Strata submit a request for application of an Alternate Concentration Limit (ACL) at a designated wellfield, the NRC staff will review the aquifer restoration activities to ensure that an appropriate level of effort has been performed. Based upon the NRC staff's review of the Applicant's commitments in the license application coupled with Condition No. 10.6 in the Draft Source and Byproduct Materials License pertaining to ground-water restoration, the NRC staff is reasonably assured that the Applicant would restore ground water to the ground-water-protection standards of 10 CFR Part 40, Appendix A, Criterion 5B(5) and would provide the information for the NRC's determination required per 10 CFR Part 40, Appendix A, Criterion 5D.
>
> *Id*. at 2-35.

To sum up for EPA's consideration, the Board agreed that, "based on the historical record, ACLs are a foreseeable consequence of ISR mining," Init. Dec. ¶4.81, and that the FSEIS failed to include information necessary to evaluate those impacts. However, the Board "supplemented" the FSEIS with data included in Staff's prefiled testimony, and calculations included in the Initial Decision, and deemed the FSEIS adequate, as supplemented. *Id.* ¶4.89-4.96. The Board further deemed the FSEIS "one-page discussion" of results at other ISL sites to be all that NEPA requires. *Id.* ¶4.72. Again, this matter is currently being appealed.

The inadequacy of the current regulatory regime is apparent in Staff's plain disregard for the environmental harms of ISL recovery. The Board even went so far as to suggest staff do a bit more analysis next time. *See* Init. Dec. ¶4.101 n.58 (stating that although "staff apparently considers this analysis to be a 'one and done' effort, i.e., the bounding analysis apparently was included in the Ross FSEIS only to address EC 2 as admitted by the Board and will not be replicated for any other ISR facility"). The Board went on to point out the failure to do such an analysis "raises unnecessary questions about agency compliance with the dictates of NEPA," because "an ACL is a foreseeable consequence of ISR mining, the environmental impacts of which seemingly should be addressed at the earliest realistic opportunity using relevant historical information." *Id.*

Finally, regardless of the post hoc contamination measurements the Board construed to be an appropriate NEPA bounding analysis of reasonably foreseeable ISL impacts, the NRC, put simply, *relies on the existence of an aquifer exemption for the mined aquifer as an allowance to profoundly contaminate that aquifer*. *See* Init. Dec. ¶4.106. The Board attempted to justify Staff's clear position that, because an ACL will require future approval, the impacts of an ACL could never be considered "large" under NEPA. Init. Dec. ¶4.107 n.62. Indeed, the Board even went so far to acknowledge that the Staff's position "does, at least on its face, suggest a 'resolution by definition' approach." *Id.* Rather than grapple with the implications of Staff's position (that an aquifer exemption allows for substantial contamination – and that such contamination only matters at the edge of the mined aquifer) the Board stated that "validation of this staff approach lies in the fact that the ACL process requires another, separate agency judgment about what is an appropriate concentration level for the various hazardous constituents that will remain post-operation in the production aquifer and that this agency assessment is subject to an adjudicatory challenge." *Id.*

This position, upheld by the Board, that the "ACL can't just be any number – it can't be ridiculous," permits EPA's aquifer exemption to be parlayed into authorization for the exempted aquifer to become a toxic, hazardous disposal area and puts off to the future any examination of that result. EPA rules are needed to rectify this situation. Finally, as NRC only requires ~12 months of stability monitoring of these disposal sites, the harms to adjacent USDWs beyond that time period is largely unknown. From excursion examples and data provided throughout this document, it's likely that severe environmental contamination has and will occurred to surrounding, non-exempt USDWs.

C. Failure to Account for Fluid Migration and Uranium Geochemistry

The third contention litigated in the Ross Project proceeding was whether there was adequate hydrological information to demonstrate SEI's ability to contain groundwater fluid migration. Both Dr. Abitz and Dr. Larson served as expert witnesses for this portion of the proceeding.

i. Fluid migration from boreholes; inadequate pump tests, and excursion indicators.

Dr. Abitz detailed three main flaws in the NRC Staff's analysis in the FSEIS in regard to fluid migration. First, the FSEIS discounts the risk of fluid migration from thousands of unplugged and improperly abandoned exploration boreholes. Second, by relying upon pump tests that were inadequate to demonstrate aquifer containment, the FSEIS did not properly assess the risk of fluid migration. Third, the FSEIS's impacts analysis is inaccurate in concluding that other contaminants will serve as more accurate excursion indicators than uranium itself.

As to the first point, NRDC put forth evidence showing that the FSEIS did not fully assess the risk of fluid migration from improperly plugged and abandoned boreholes because the NRC relied upon data supplied by SEI without doing independent analysis of the likelihood of more wells. JTI001 at ¶¶41-42. [8] As to the second point, Dr. Abitz explained that "neither the number of wells tested for hydrological parameters nor the short duration of the pump tests run to date establish adequate hydrological information to demonstrate control of groundwater." *Id.* at ¶¶43-46. As to the third point, Dr. Abitz details that uranium should be included as an excursion parameter and that by not including it, the NRC fails to properly mitigate the risk of excursions during the project's operations. In his pre-filed testimony, Dr. Larson states that "the FSEIS has failed to sufficiently analyze the potential for and impacts associated with vertical fluid migration, and unidentified or unsealed drillholes between aquifer units." JTI003 at ¶67.

Next, Dr. Larson reviews the information in the FSEIS demonstrating that at the time of this filing, SEI failed to locate over 1,000 wells, let alone properly plug them, and therefore the risk of fluid migration during the Ross Project is extremely high. *Id.* at ¶¶69-75. Dr. Larson also expresses a fundamental disagreement with the NRC over how it interprets basic geochemical interactions that will take place in the subsurface when efforts to establish baseline are commenced and, more important, when mining commences. *Id.* ¶¶67-68.

Dr. Larson also reviewed excursion problems at other ISL facilities, which have regularly occurred, and explains that it is "difficult to assess whether an aquifer is truly confined." *Id.* at ¶¶69-70. Dr. Larson then presented a Storymap related to the excursion history of the Willow Creek facility. *Id.* at ¶¶76-85. He noted that one facility has suffered from both vertical and horizontal excursions, with vertical excursions being particularly difficult to correct. According to the data Dr. Larson reviews, some wells remained on "excursion status" for months and even years. *Id.* at ¶81. Dr. Larson also reviews excursion data at the Smith Highland Ranch facility. *Id.* at ¶¶82-85.

Finally, concluding our presentation of evidence at the hearing, Dr. Larson provided a brief explanation why extensive groundwater degradation matters so much both regionally and specifically for eastern Wyoming. *Id.* at ¶¶86-88. Dr. Larson finally

---

[8] Dr. Abitz also explained that the data supplied by SEI is conflicting and relies upon the unfounded assumption that SEI will locate and plug *all* wells prior to wellfield development. *Id.* We illustrated this point with evidence that license conditions requiring boreholes be properly plugged have not necessarily led to satisfactory environmental results. *Id.* at ¶41.

asserts that the NRC underestimated the risk of fluid migration by improperly determining that the aquifer is confined. He states that "[i]n the FSEIS and license for the Ross ISL project the NRC Staff has approved the same groundwater restoration methods which have failed to meet baseline and/or safe drinking water standards at every previous ISL site, and for technical and scientific reasons, will not result in groundwater quality meeting primary or secondary standards." *Id.* at ¶89.

Despite the fact the Board rejected Staff's argument that excursions will be detected by the monitoring well ring and that filling the boreholes is not relevant to the conclusion that the impacts of excursions will be SMALL, finding "staff has overly discounted the importance of the license condition requirement that SEI act to locate and properly abandon all historic drill holes . . . ." Init. Dec. ¶4.127. However, while recognizing that these boreholes "presents a daunting challenge," and that the license only requires an "attempt" to fill them all, *id.* ¶4.127, the Board concluded both SEI and Staff have an adequate "incentive" to fill these holes, to both keep the project operating and to support the "predictive" finding of small impacts. Init. Dec. ¶4.128 and n.66.

The Board also rejected evidence that the pump tests conducted to support the FSEIS show vertical groundwater communication between aquifers, *id.* ¶4.132-4.141, and documenting that uranium may travel faster than planned excursion parameters. *Id.* ¶4.142-4.145. Finally, the Board deemed irrelevant the risk of excursions within the exempt aquifer. *Id.* ¶4.146-147. Again, all of this is currently on appeal to the Commission.

Rather than belabor where we disagree with the NRC, we simply point out one specific point here where protective EPA requirements can solve issues before they emerge as disputes in the first instance. In response to Drs. Abitz's and Larson's demonstration, based on controlled experiments and scientific literature, that uranium may move through the aquifer more quickly than chloride and the other excursion indicator constituents, the Board found that Staff had shown that the aspects of ISR mining that make uranium mobile "can break down when groundwater moves out of the OZ," that the controlled experiments "may not be applicable" to the Ross site, and that "the behavior of uranium during transport in groundwater is not yet well understood . . . ." Init. Dec. ¶4.144 (emphasis added). On that basis, the Board found NRDC failed to demonstrate a "compelling" case, based on "convincing site-specific evidence," for "using uranium as an excursion indicator for the Ross Project . . . ." *Id.* ¶4.145.

As a legal matter, we don't believe this conclusion can be sustained, for it once again puts the burden on NRDC, when in fact Staff has the burden to demonstrate why it refuses to monitor for migration of the very element that the ISL mining process is expressly designed to release into the groundwater. *See* Init. Dec. ¶3.8. To be sure, if the Board had concluded that, in fact, Staff had demonstrated that uranium will move more slowly than these other constituents, the finding could be sustained. But where, as here, the Board found uncertainty regarding uranium transport rates, it was error for the

Board to conclude that the Staff had appropriately found the impacts from excursions will be small based on excursion parameters that will not include monitoring for uranium.

And finally, NRDC also submitted data from other ISL sites demonstrating substantial horizontal and vertical uranium excursions, despite the same kind of protective measures being relied on for the Ross project. Such a showing further demonstrates the NRC's conclusion of SMALL impacts is erroneous. Init. Dec. ¶4.146-4.148; *see* JTI003 at 51–54, 55–64. The Board further discounted data on lateral excursions as irrelevant as long as they remain in the exempt aquifer. Init. Dec. ¶4.147.

As it did a number of times, the Board erred in relying on the exempt aquifer to uphold the Staff's conclusion that impacts from excursions that remain in the aquifer will be SMALL. As regards horizontal excursions, which NRDC demonstrated occurred elsewhere, the Board speculated excursions elsewhere might be due to "an engineering failure, i.e., a casing leak," Init. Dec. ¶4.147, without either relying on any evidence supporting that speculation, or explaining why SEI's project will not be prone to the same kind of problems that have plagued other ISR mining operations. Indeed, the FSEIS description of an excursion includes "poor well integrity,"[9] precisely what the Board assumes occurred at these other sites.

D. Conclusion of Ross Proceeding Evidence and Need for Rules

Unless EPA (and then in its turn, NRC) establish clear, protective rules for the ISL uranium mining industry, groundwater contamination controversies similar to the Strata and Dewey Burdock proceedings are sure to follow, and with those controversies will come degraded sources of scarce groundwater, negative national attention, additional state reactions such as Colorado's 2008 statutory and regulatory changes (which NRDC views as an improvement over the existing debacle that is the NRC regime), and vigorous litigation in multiple venues. This draft rule provides EPA and NRC Commission an overdue opportunity to repair what has been an ongoing regulatory morass, clarify the responsibilities of the industry, NRC Staff, and the interested public, and provide needed protections for scarce groundwater resources that have been negatively affected by ISL uranium milling, before additional harms and unnecessary litigation results.

This is an issue of significant legal, environmental, economic and social importance. In the intermountain West, where much of this ISL uranium mining processing has taken place and where several new or expanded mines are slated to commence operations in the next several years, population growth, prolonged dry

[9] U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 2-30 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf.

weather conditions, and competing resource extraction technologies (such as coal bed methane drilling) have created severe competition for freshwater resources. Permanent loss or impairment of freshwater aquifers due to contamination from ISL mining activities – even if those resources are not currently accessed by large populations or are of more marginal quality – is a significant issue for the region both in the short and long term. More importantly, despite a clear legal mandate via its NEPA obligations, the NRC – along with its federal brethren such as the Department of the Interior's Bureau of Land Management – have failed to study the long-term cumulative impacts of sacrificing aquifers in the intermountain West to facilitate the extraction of mineral and energy resources. This long overdue rulemaking on groundwater impacts can begin to rectify this situation.

V. Legal Support for the Draft Rule

The legal authority for this action is in Section 275 of the Atomic Energy Act (AEA) of 1954, as amended by Section 206 of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. Health and environmental protection standards established by EPA under UMTRCA are implemented by NRC. *See* 42 U.S.C. 2022(b) and (d).

A. AEA Section 275 Provides Ample Authority for EPA's Proposed Rule.

AEA section 275, 42 U.S.C. § 2022 (2012), allows EPA to issue "standards of general application for the protection of the public health, safety, and the environment" from certain "radiological and nonradiological hazards," including those "associated with the processing and with the possession, transfer, and disposal of byproduct material[10] . . . at sites at which ores are processed primarily for their source material content or which are used for the disposal of such byproduct material." *Id.* § 2022(b). EPA's proposed rule clearly in this category because it protects public health and the environment against such hazards presented by "byproduct materials" generated by uranium in-situ leaching, a method by which "ores are processed . . . for their source material content."

The rulemaking satisfies the AEA's statutory requirements for new EPA regulations. In establishing standards under section 275, "the Administrator shall consider the risk to the public health, safety, and the environment, the environmental and economic costs of applying such standards, and such other factors as the Administrator determines to be appropriate." *Id.* EPA's proposal explicitly considered risks to the public health, safety, and the environment, Proposed Rule at 4164–65, and environmental and economic impacts, *id.* at 4180–81. Additionally, standards issued under subsection (b) for non-radiological hazards "shall, to the maximum extent practicable, be consistent with the requirements of [the Resource Conservation and Recovery Act (RCRA)]." 42 U.S.C. § 2022(b)(2) (2012). The proposal ensures this

[10] *See* 42 U.S.C. 2014(e) (2012) (defining "byproduct material" broadly).

consistency by adapting the RCRA groundwater monitoring framework to ISL sites and their attendant environmental concerns. Proposed Rule at 4163–64. Last, the provision requires EPA to "consult with the Commission and the Secretary of Energy before promulgation" of a rule under subsection (b). 42 U.S.C. § 2022(c) (2012). Although not noted in the proposal, we understand that EPA has extensively consulted with both NRC and DOE over the last several years.

Prior rules have successfully relied on the same statutory authority to issue health and environmental standards for uranium ore byproducts. *See, e.g.*, Health and Environmental Standards for Uranium and Thorium Mill Tailings, 58 Fed. Reg. 60,340 (Nov. 15, 1993) (codified at 40 C.F.R. pt. 192); Environmental Standards for Uranium and Thorium Mill Tailings at Licensed Commercial Processing Sites, 48 Fed. Reg. 45,926 (Oct. 7, 1983) (codified at 40 C.F.R. pt. 192). The proposed rule is a fundamentally similar lawful agency action.

B. EPA Does Not Stray Beyond its Statutory Authority in Issuing the Rule.

First, EPA's promulgation of this rule does not supplant NRC's jurisdiction or impede its licensing authority. The AEA unambiguously assigns to EPA standard-setting authority and to NRC implementation and enforcement authority. *See* 42 U.S.C. § 2022(b), (d) (2012).

This division of jurisdiction does not shield preoperational, stability phase, or other monitoring from EPA regulation. Instead, EPA has correctly determined that this monitoring will help protect "the public health, safety, and the environment." *See id.* § 2022(b).

Indeed, the proposed rule does not unlawfully direct NRC's implementation of EPA's health and environmental standards any more than the existing regulatory requirements under 40 C.F.R. § 192. For example, § 192.32(a)(4)(i) requires licensees to "conduct appropriate monitoring and analysis" of radon-222 releases using methods at least as effective as "the procedures described in 40 CFR part 61, Appendix B, Method 115." The proposed regulation similarly introduces explicit monitoring rules without imposing an impermissible compliance methodology on NRC. EPA has properly exercised its health and environmental standard-setting authority to require such monitoring, and NRC's role is only to implement and enforce compliance with this requirement.

To the extent that NRC's requirements for groundwater protection that it codified in 10 C.F.R. Part 40, Appendix A or elsewhere are inconsistent with EPA's standards, they are invalid. AEA section 275 explicitly requires: "Within three years after . . . revision of any [subsection (b) EPA] standard, the Commission . . . shall apply such revised standard in the case of any license for byproduct material . . . ." 42 U.S.C. §

2022(b)(2) (2012). NRC's regulations cannot overcome this statutory requirement to implement EPA's standards. Indeed, NRC's regulatory authority under AEA section 275 is limited to promulgating rules that "the Commission deems necessary to carry out its responsibilities in the conduct of its licensing activities under this chapter." *Id.* § 2022(b)(1). NRC's licensing "responsibilities" are defined by statute and by EPA's regulations. The AEA therefore subordinates NRC's rulemaking power to that of EPA.

Second, other commenters have suggested that two cases require EPA to quantify risks before issuing the proposed standard: *Industrial Union Department, AFL-CIO v. American Petroleum Institute* (*Benzene*), 448 U.S. 607 (1980), and *Natural Resources Defense Council, Inc. v. EPA* (*Vinyl Chloride*), 824 F.2d 1146.[11] This interpretation misreads those cases.

The *Benzene* case involved an industry challenge to a major Occupational Safety and Health Administration (OSHA) rulemaking. The rule at issue sought to lower the exposure limit of airborne benzene in workplaces to 1 part per million, imposing costs of up to $82,000 per protected employee in some industries. *Benzene*, 448 U.S. at 613, 629. The Court of Appeals for the Fifth Circuit vacated the rule, and the Supreme Court affirmed. *Id.* at 614–15. However, the Supreme Court divided three-one-one-four on whether the decision should be grounded in statutory construction, constitutional requirements, or cost-benefit analysis principles.

---

[11] For example, at a public hearing on March 10, 2015, Anthony Thompson said:

> The Benzene decision by the Supreme Court, Industrial Union case, was a leading case wherein the Supreme Court found that before an agency can promulgate any permanent health or safety standard, the Secretary, in this case, of OSHA, is required to make a threshold finding that a place of employment is unsafe, in the sense that significant risks are present and can be eliminated or lessened by a change in practices.
>
> The Benzene decision's core findings were further endorsed in NRDC v. EPA, the so-called Vinyl Chloride decision. First the Court endorsed risk assessment based on realistic assumptions in light of the best available scientific information. EPA's task, the Courts concluded, is to determine what inferences should be drawn from available scientific data and decide what risks are acceptable in the world in which we live.
>
> Second, the Court noted that determination of acceptable risk will always be marked by scientific uncertainty. The Court further stated, as the Supreme Court has stated recently, safe does not mean risk-free. Instead, something is unsafe only when it threatens humans with a significant risk of harm. So the standard for promulgating health and safety standards in this country is that you are addressing a significant risk of harm.
>
> There is another case and I'm not going to go into that. I'm going to cut it out. But read together, the Benzene and the Vinyl Chloride Decisions, disfavor agency reliance on simplistic, unnecessarily conservative approaches for making judgments of risk. In these decisions, the Courts acknowledged that the quantification of risk is a difficult task, but it must be undertaken to establish credible, reliable, and legally supportable judgments on what risks are present, what regulatory actions should be taken.

Transcript of Public Hearing for Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings at 91–93, EPA-HQ-OAR-2012-0788-0046 (March 10, 2015).

In his plurality opinion, Justice Stevens interpreted two provisions of the Occupational Safety and Health Act together to mean that OSHA must show that there was a "significant risk" before it could issue such a regulation. *Benzene*, 448 U.S. at 651. OSHA did not do so in this case, so its regulation was found invalid. *Id.* at 662. This interpretation relied in part on the nondelegation doctrine as a tool of statutory construction; if it were not for this threshold significant risk requirement limiting OSHA's discretion, the statute might have been an unconstitutional delegation of legislative power to an executive agency. *Id.* at 646. Chief Justice Rehnquist's concurring opinion instead would have struck down the relevant portion of the Act as unconstitutional without reading in a threshold test to save it. *Id.* at 684 (Rehnquist, C.J., concurring in the judgment). Justice Powell would have decided the case on a cost-benefit basis because he believed the expected costs from the rule did not bear a "reasonable relationship" to the expected benefits. *Id.* at 667 (Powell, J., concurring in part and concurring in the judgment).

As a result, the *Benzene* case patently did *not* create a general rule requiring agencies to find that "significant risks" exist before they may issue a health or safety standard. In fact, Justice Scalia wrote shortly before he joined the Court that this three-one-one-four split "literally provides no conclusive answer to any legal question more general than whether the benzene exposure regulation promulgated by [OSHA] on February 10, 1978, is valid." Antonin Scalia, *A Note on the Benzene Case*, 4. Reg., July/Aug. 1980, at 25.

Even if the *Benzene* case did create such a general rule, it would not apply here. *Benzene* involved a grant of rulemaking authority to OSHA for rules that were "reasonably necessary or appropriate *to provide* safe or healthful employment." 29 U.S.C. § 652(8) (1976) (emphasis added). Justice Stevens's plurality opinion read this provision to require a finding that a workplace was "unsafe" before OSHA could issue rules that would "provide" a safe place of employment. *Benzene*, 448 U.S. at 642. In contrast, AEA section 275 authorizes EPA to promulgate rules "*for the protection* of the public health, safety, and the environment." 42 U.S.C. § 2022(b) (emphasis added).

These provisions are materially distinct: "provide" means "to make (something) available," Merriam-Webster, *Merriam-Webster.com* (2015), *available at* http://www.merriam-webster.com/dictionary/provide, while "protection" means "the state of being kept from harm, loss, etc.," *id.*, *available at* http://www.merriam-webster.com/dictionary/protection. Justice Stevens's view that OSHA must first make a threshold finding that a workplace is unsafe arose from OSHA's statute authorizing rules to provide safe workplaces where they did not exist previously. But such an inquiry makes little sense for EPA's rulemaking power under AEA section 275 to protect the *original* state of the public health and environment. OSHA's statute affirmatively sought to improve the public health relative to the status quo, while the AEA seeks merely to preserve the natural baseline.

The *Vinyl Chloride* case is similarly inapposite. In that case, the Court of Appeals for the D.C. Circuit reviewed EPA's emissions standards for vinyl chloride, a hazardous air pollutant. *Vinyl Chloride*, 824 F.2d at 1148. EPA promulgated the regulation under section 112 of the Clean Air Act, which required the Administrator of the EPA to set emissions standards "at the level which in his judgment provides an ample margin of safety to protect the public health." 42 U.S.C. § 7412(b)(1)(B) (1982). The court held that EPA first must determine the concentration level at which there is an "acceptable risk to health." *Vinyl Chloride*, 824 F.2d at 1165. Second, EPA may set emissions levels stricter than this "safe" concentration level to provide "an ample margin of safety." *Id*.

The D.C. Circuit's holding did not create a general principle of administrative law, and its reasoning does not apply to EPA's proposed ISL rule. The court did not say that the Administrative Procedure Act or common law principles of administrative law require all health or safety rules to evaluate and address a significant risk of harm. Instead, the D.C. Circuit explicitly grounded its analysis in the Clean Air Act, writing: "We find that the congressional mandate to provide 'an ample margin of safety' 'to protect the public health' requires the Administrator to make an initial determination of what is 'safe.'" *Vinyl Chloride*, 824 F.2d at 1164. The AEA does not require EPA's regulations to "provide[] an ample margin of safety." *See* 42 U.S.C. § 2022 (2012). Rather, as described above, EPA's broad authority under AEA section 275 "for the protection of" the public health and environment does not entail identifying and providing a specific degree of safety, but simply maintaining preexisting conditions. *Vinyl Chloride* is irrelevant.

Furthermore, AEA section 275 plainly is not a "residual risk" provision that would be subject to a threshold risk requirement like that in *Benzene* or *Vinyl Chloride*. *Cf*. 42 U.S.C. § 7412(f) (2012) (giving EPA authority to regulate residual risks from hazardous air pollution); *see also Sierra Club v. EPA*, 353 F.3d 976, 979–80 (D.C. Cir. 2004). Such a provision focuses on whether to reduce the public health risks posed by the pollution that remains *after* implementation of control requirements. For example, EPA's regulation of hazardous air pollution under the Clean Air Act began with technology-based standards. Then, in a second stage, EPA was required to study the health risks that had not been eliminated before it could attempt to regulate them using the "risk-based" residual risk provision. *Natural Res. Def. Council v. EPA*, 529 F.3d 1077, 1079–80 (D.C. Cir. 2008); *see also* 42 U.S.C. 7412(f) (2006). The AEA contains no comparable "first round of regulation." *See Natural Res. Def. Council*, 529 F.3d at 1080. Instead, EPA's authority under AEA section 275 is not limited to risk-based regulation, but may include technology-based standards and monitoring rules to protect against unquantifiable hazards.

Last, nothing in the AEA or elsewhere bars EPA from issuing rules that interact with other federal regulatory programs. Simply by deciding to propose the present rule, EPA has determined that other regulatory schemes such as the Safe Drinking Water Act's Underground Injection Control program are inadequate "for the protection of the public health, safety, and the environment" from the hazards presented by ISL. The rule, therefore, is not duplicative, but is an important and proper exercise of EPA's statutory authority.

VI. Specific Comments by Section

A. EPA's "Summary"

As at the outset, we congratulate EPA for the issuance of this draft rule and urge speedy promulgation of a final iteration. Our specific comments, section by section, follow.

1. "The proposed standards will regulate byproduct materials produced by uranium in-situ recovery (ISR), including both surface and subsurface standards, with a primary focus on groundwater protection, restoration and stability. ISR has a greater potential to directly affect groundwater than does conventional milling. Therefore, by explicitly addressing the most significant hazards represented by ISR activities, these proposed standards are intended to address the shift toward ISR as the dominant form of uranium recovery that has occurred since the standards for uranium and thorium mill tailings were initially promulgated in 1983. The general standards proposed today, when final, will be implemented by the Nuclear Regulatory Commission (NRC)." Proposed Rule at 4156.

NRDC Comment

NRDC concurs with EPA's statement of fact that ISR has a greater potential to directly affect groundwater than does conventional milling. Indeed, NRC's own data, as presented by in the storymaps[12]) plainly illustrate that ISR has had a significant and degrading effect on groundwater wherever it has been done. By explicitly addressing the most significant hazards, ISR, which has remained regulated by the NRC in an ad hoc, fashion, EPA can commence the process whereby the public can assess the harms of this extractive, polluting industry.

2. "The legal authority for this action is in Section 275 of the Atomic Energy Act (AEA) of 1954, as amended by Section 206 of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. Health and environmental protection standards established by EPA under UMTRCA are implemented by NRC. See 42 U.S.C. 2022(b) and (d)." Proposed Rule at 4156.

NRDC Comment

[12] http://isl-uranium-recovery-impacts-nrdc.org/Willow-Creek/;
http://isl-uranium-recovery-impacts-nrdc.org/Smith_Highland/

As indicated in our comments above in section V above, EPA has legal authority for issuance of these standards under Section 275 of the AEA, as amended by Section 206 of UMTRCA. We also concur that NRC must now implement these new health and environmental protection standards and that agency must commence its own rulemaking to alter its regulatory regime to reflect these newly issued standards.

3. "A section—§ 192.52 Standards—in which EPA proposes to specify the minimum 13 constituents for which groundwater protection standards must be met. The list includes the following: 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)." Proposed Rule at 4157.

NRDC Comment

NRDC concurs with this list and stresses that samples must be analyzed with the latest and best scientific sampling methods, analytical techniques, and quality control and quality assurance (QC/QA). Language should be inserted in the rule that requires as much. Later comments will demonstrate how the weak sampling requirements of NRC and agreement states allow for contamination of underground aquifers and mask environmental harms.

4. "Costs quantified in Table 2 address costs of the rule that reflect appropriate characterization of the background data, and then ensuring that: (1) The post-operational groundwater is restored to that of the initial groundwater conditions and (2) the post-restoration groundwater conditions will remain stable." Proposed Rule at 4157.

NRDC Comment

NRDC concurs with the reasonable nature of EPA's quantification of the costs of this rule, but notes that ISL industry proposed and intact decommissioning bonds have almost always been insufficient to finance the necessary reclamation and restoration activities: since the industry financial assurance estimates are made by the companies themselves — entities with a financial interest in the result of those calculations—they are not likely to be an accurate representation of restoration and reclamation costs. The calculations have also been repeatedly flawed because they do not consider the difficulty in restoring aquifers to pre-mining conditions and the actual restoration and reclamation costs incurred. Put in the larger context, in their comments on NRC's Draft Generic EIS for ISL uranium mining, EPA stated:

> Section 2.115 of the draft GEIS provides several examples of uranium mining facilities where the number of pore volumes needed for aquifer restoration were significantly underestimated during the planning or operations phases. Aquifer restoration efforts commonly take much more time and many more pore volumes than initially estimated.

EPA Comments on Draft GEIS for ISL Uranium Milling Facilities (Nov. 6, 2008), at 5.

5. "The proposed rule requires affected facilities to monitor groundwater for a longer period of time compared to current practice (estimated to be 9.5 additional years if geochemical modeling indicates that conditions will remain stable, and estimated 32.5 additional years if long-term stability monitoring continues for 30 years. The major costs associated with the proposed rule are the costs of these monitoring activities. National total annualized incremental costs of the proposed rule, based on likely implementation represented by the average cost of 30-year long-term stability monitoring with geochemical modeling to shorten the duration, is $13.5 million (in 2011 dollars), as shown in Table 2 below." Proposed Rule at 4157.

NRDC Comment

NRDC concurs with EPA's proposed requirement of significant long term monitoring and additional geochemical modeling. We discuss in detail later in our comments (see Comment #24) the failure of NRC to require long term stability monitoring data, but we expand on the discussion when addressing in specific comments addressing the geochemical stability of restored wellfields once ISR operations have ceased. *See infra*, Comment #8.

6. "EPA found that the estimated costs of complying with the proposed rule are 0.6% to 1.7% of estimated 2015 revenues for three small firms that own ISR operations. Because costs do not exceed 2% of estimated sales, and because EPA projects that fewer than 10 small businesses will be affected by the rule at any given time, EPA concluded that the proposed rule would not result in significant impacts for a substantial number of small entities. For information on how EPA estimated these costs, see Section 3 and Appendix D of the Economic Analysis." Proposed Rule at 4157.

NRDC Comment

NRDC concurs with EPA's assessment of the likely impacts of costs of complying with the proposed rule. The minimal costs of compliance for industry balanced against water scarcity in the inter-mountain west is an important issue for EPA to rethink, and not just for ISL recovery. Water scarcity issues alone should cause governments and communities to rethink whether uranium development and other water-intensive natural resource extraction techniques (such as coal-bed methane recovery and fracking of shalegas deposits) represent a wise course of action. The tradeoff between resource extraction and groundwater protection is only one of several complicated issues that face state resource professionals. With respect to groundwater scarcity, the crucial point is that even if there is a period of significant growth in the market for uranium, ISL uranium mining will constitute only a minor fraction of the uranium resources used in the United States, much less the rest of the world. It makes no sense to contaminate scarce western groundwater and harm iconic western landscapes for uranium production that amounts to a small fraction of global uranium output and U.S. consumption, and that does not fundamentally alter U.S. dependence on foreign sources of uranium. Even if a much higher degree of U.S. uranium self-sufficiency were, in principle, achievable economically, one would still want to weigh the environmental costs, especially the critical alternative uses for all the groundwater resources that would be impaired by stepped-up ISL mining activity.

7. "EPA conducted a qualitative assessment of the benefits of the proposed rule. EPA recognizes that groundwater is a valuable resource, and is becoming more valuable as groundwater use increases. While the aquifers in the vicinity of ISR operations are currently providing little extractive value (because of their locations and, for some areas, the fact that groundwater quality is low), in future years these resources may have increased value. A recent analysis (Poe et al, 2001) estimated the value to today's households of protecting groundwater for future use ranged from $531 to $736 per household. For this reason, EPA believes it is necessary to take a longer view of groundwater protection than taken in the past." Proposed Rule at 4157

NRDC Comment

In the Ross Project proceeding, we demonstrated how the ISL process degrades groundwater and causes severe environmental impacts. We demonstrated – and even the NRC's ASLB agreed – that in every instance we can find the industry cannot restore groundwater to primary or secondary limits and ACLs are inevitable. With that in mind, it is of profound import that the scarce groundwater resources in the American West be protected.

As discussed in Dr. Larson's testimony (JTI003) groundwater is a significant source of drinking water supply for municipalities and also a source for agricultural irrigation in this part of the country. Groundwater is an attractive water source to meet these demands because it is accessible in areas without substantial surface water availability, requires relatively less treatment compared to surface water, and is less susceptible to drought conditions. According to the USGS, groundwater is the source of drinking water for half the United States. Furthermore, groundwater contributes the largest percentage of source water for agriculture irrigation (JTI047).

It's also perfectly clear that water demands in the future will increase (JTI048), therefore groundwater resources will be increasingly relied upon as a consistent, reliable, source of fresh water. However due to overreliance on groundwater, significant groundwater depletion has been observed by the United States Geological Survey over the past decade. The Central Valley Aquifer of California and the High Plains Aquifer (Ogallala) have already observed shocking groundwater volume losses from 1960-2008 (JTI027).

The current drought crises in these regions are causing many communities to scrounge and save for water. For example, a community in Texas (Wichita Falls) recently began using treated, recycled wastewater (sewage water), for municipal drinking water, as few available options for water sources could be used to meet demands.[13]

And then there is California. We understand that ISL recovery is not currently conducted in California, but across the West the limited sources of water are being depleted at an alarming rate and transfers of water across vast distances are not unlikely. California communities are currently enacting strict water usage fines for community members to deal with a record drought. Future water issues will be compounded significantly, suggesting water supplies will be increasingly scarce and using fresh water sources wastefully, for any means, is shortsighted.

But just focusing on why groundwater matters so much in precise areas where ISL recovery takes place demonstrates the wisdom of EPA taking a longer view of groundwater protection than taken in the past. For example, in population increases over the last decade in northeastern Wyoming have put increasing stress on the available water supplies. The city of Gillette, Wyoming depends on drinking water from the Fort Union Aquifer and other local aquifers, to provide municipal water supplies. However, water availability in these aquifers are dwindling and the population is projected to substantially increase from 37,000 to 57,000 by 2030. To meet increasing water demands, the city is enacting the Gillette Madison Pipeline Project, a 217.6 million dollar project, which will route water from the Madison aquifer, north of Keyhole Reservoir to Gillette via pipeline[14]. The project is intended to meet growing water demands for the next 20 years. This example demonstrates the specific vulnerability of just one region where ISL takes place. Put simply, there are increased water demands and scarce options to meet those demands.

Next, going to EPA's point that in some instances, there is limited or no access to the water where ISL is taking place, we note that if the groundwater which has

[13] http://www.npr.org/2014/05/06/309101579/drought-stricken-texas-town-turns-to-toilets-for-water
[14] http://www.gillettewy.gov/index.aspx?page=902

contaminant levels above the US EPA's drinking water standards is used directly as a primary source of drinking water it carries a risk of detrimental health impacts. Groundwater that does not meet drinking water standards would require "at the end of the pipe" treatment to return water to acceptable drinking water standards, which is costly and carries numerous logistical issues (waste disposal, energy requirements, O&M costs, etc.).

In general, financial limitations prompt municipalities to utilize the highest quality source water which requires the least amount of treatment. When relatively high quality (low treatment) source water is unavailable, the next economically available source of water is used. This general trend explains why desalination of sea water is used as a last resort, due to significantly high economical treatment costs. Therefore, preventing water contamination in the first place is regarded by many water resources and environmental engineers as the 'best treatment option'. And as an example of how this could play out, in the Ross Project NRDC recently litigated, the NRC Staff has approved the same groundwater restoration methods which have failed to meet baseline and/or safe drinking water standards at every previous ISL site, and for technical and scientific reasons, will not result in groundwater quality meeting primary or secondary standards. Further, we demonstrated it's common for 'restored' post-mining groundwater at ISL operations to exceed that value, and in some wells by an order of magnitude or more.

The volume of contaminated water within the ore zone is not trivial, and the impacted water volumes can be (depending on the site specific geology and aquifer properties) in the hundreds of millions of gallons groundwater per mine unit (JTI038). Further, NRDC commissioned a study of economic perspective and recommendations for EPA's valuation of groundwater. *See Comments on EPA's Draft Economic Analysis of Groundwater and Uranium ISR Rule Revisions,* Hjerpe & Morton, May 27, 2015, Attachment 1 (cited hereinafter as *Economic Analysis of Groundwater).*

8. "Currently, monitoring groundwater conditions after restoration is typically conducted for a short period of time (EPA assumes 6 months for cost estimate purposes), which may not be long enough to detect instability in groundwater conditions. EPA's proposed rule requires a 30 year long-term stability monitoring period, which may be shortened if geochemical modeling demonstrates that conditions in the restored wellfield will remain stable over time." Proposed Rule at 4157.

NRDC Comment

NRDC concurs with EPA's statement that monitoring groundwater conditions after restoration is typically conducted for a short period of time. Based on the following examples of other ISL sites degradation groundwater long after restoration ended, EPA's proposed 30 year time frame, at a minimum, is warranted. Industry and NRC's assumptions that natural conditions will return are convenient interpretations not grounded in the latest science.

For example, samples from the production authorization area 1 (PAA-1) at Kingsville Dome ISL in Texas were taken in 2011, roughly a decade after active mining and restoration ended in 1999.[15] The uranium concentration data suggests that reducing conditions have not reestablished in the production zone. We go on to describe other variations on this same theme.
Production zone wells have observed violent increases in uranium concentrations years after the end of active groundwater restoration. At Wyoming's Willow Creek, Christensen Ranch site, monitor well 5AV46-1 was located in the production zone of the previously 'restored' mine unit 5. Production zone wells at Christensen Ranch mine unit 5 ended stability monitoring on 8/1/2004.[16] Well 5AV46-1 was installed as a monitor well for mining activities which restarted within Christensen mine unit 5-2 after restoration was denied by NRC. Well 5AV46-1 observed startling increases in all excursion parameter values, and observed dissolved uranium concentrations increases from 5.4 mg/L to 31.2 mg/L in less than one year.[17] The final sample (31.2 mg/L) was collected on 7/2/2012, almost eight years after stability monitoring ended within mine unit 5, when the average was 2.26 mg/L.[18]

Long term groundwater sampling at Smith Highland Ranch mine unit A demonstrates similar water quality degradation over time. Groundwater concentrations for uranium in the production well approved by the NRC Staff in 2004[19] for well MP4 were 10.50 mg/L[20], or roughly 350x EPA's MCL (the NRC Staff approved the restoration report for Smith Highland mine unit A as the wellfield average uranium concentration was 4.32 mg/L, 144x EPA's MCL). According to Cameco's long term monitoring program, uranium concentrations in well MP4 peaked in 2012 at 17.3 mg/L, [21] or roughly 577x EPA's MCL, indicating that the concentrations were increasing in the production zone over time.

Thus, NRDC fully supports a minimum of 30 years monitoring requirement. Of note, Smith Highland Ranch, mine unit A began stability monitoring on

---

15 http://www.nmlegis.gov/lcs/handouts/IAC%20110111%20George%20Rice%20Presentation%20on%20Kingsville%20Dome.pdf
16 http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/willow-creek/isr-wellfield-ground-water-quality-data.html
17 https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14282A364
18 See table 1 under comment 29.
19 http://pbadupws.nrc.gov/docs/ML0418/ML041840470.pdf
20 http://pbadupws.nrc.gov/docs/ML0403/ML040300369.pdf (Page 150)
21 http://pbadupws.nrc.gov/docs/ML1223/ML12230A015.pdf (Page 52 and 53)

2/1/1999,[22] while the last known sample in the production zone at well MP4 (17.3 mg/L) was taken in 2012. Under EPA's proposed 30 year regulatory time frame, this example indicates Cameco is approximately half way through stability monitoring (~13 years), while the production zone well MP4 has observed it's highest uranium concentrations. Well MP-5 observed a similar trend, where uranium concentrations range from 5.9 – 11.00 mg/L, where 11.00 mg/L was the last sample available suggesting an progressively increasing trend. With this evidentiary record, EPA will be well justified in finalizing its 30 year time frame for monitoring ISL sites.

9. "The proposed rule will reduce the risk of undetected excursions of pollutants into adjacent aquifers. This in turn will reduce the human health risks that could result from exposures to radionuclides in well water used for drinking or agriculture in areas located down-gradient from an ISR. Because radionuclides are human carcinogens, the main health risk averted would be cancer. There is a benefit (estimated to be at least $8 million per premature death avoided) of reducing cancer deaths, but because we were unable to estimate how many cancer deaths would be averted, or when they would occur, EPA is unable to quantify this benefit." Proposed Rule at 4157.

NRDC Comment

NRDC concurs that the proposed rule, when finalized, and if implemented vigorously, can substantially reduce the risk of undetected excursions of pollutants into adjacent aquifers. This in turn will reduce the human health risks that could result from exposures to radionuclides in well water used for drinking or agriculture in areas located down-gradient from an ISR. As we have already demonstrated, the weak regulatory regime exists because ISL uranium mining was not in widespread use when conventional uranium mining was first subjected to any oversight beyond that of promoting and guaranteeing the viability of a market. Laws to protect public health and the environment from uranium mining and milling impacts were not drafted and passed until several decades of harm had already been inflicted across the American West. Those laws that were passed have rarely been updated and have been haphazardly enforced, with little accountability for lax decisions and a decided unwillingness among regulators to enforce protective standards.

Implementation of strong requirements for assessing pre-mining water quality, increased clarity on what should be strict requirements to attempt to restore damaged and polluted aquifers and vigorous monitoring requirements after restoration attempts will dramatically improve the accountability of the industry

---

[22] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-ground-water-quality-data.html

for its environmental impacts and could hopefully obviate some of these contentious disputes before they happen in the first instance.

10. Table 1: Characterization of the Costs and Benefits of 40 CFR Part 192, Subpart F. Proposed Rule at 4157.

NRDC Comment

NRDC has no objection to EPA's cost benefit analysis. We recommend EPA incorporate the observations of Att. 1, the Economic Value of Protecting Groundwater.

B. EPA's "Background Information"

11. EPA provides a discussion conventional mining and milling, heap leaching, and ISR recovery. Proposed Rule at 4161-62.

NRDC Comment

EPA's short background history of uranium recovery is accurate as far it goes, but it lacks substantial information and context on the lengthy record of environmental harms of the industry. For a more full treatment, see *Nuclear Fuel's Dirty Beginnings: Environmental Damage and Public Health Risks From Uranium Mining in the American West*, March 2012, G. Fettus and Dr. M. McKinzie, http://www.nrdc.org/nuclear/files/uranium-mining-report.pdf

12. "Once the groundwater at the site has gone through restoration and sufficient time has passed such that the licensees can demonstrate that chemical conditions are stable, the injection and extraction wells are properly plugged and abandoned, the wellfield infrastructure (pipes, header houses, etc.) is removed, and surface operations equipment (impoundment liners, buildings, etc.) is dismantled and shipped offsite for appropriate reuse or disposal." Proposed Rule at 4162-63

NRDC Comment

NRDC urges EPA to consider that any assumption that groundwater at ISL sites that have gone through restoration and presumably sufficient time has passed such that there is a demonstration that chemical conditions are stable may not be fully protective of USDWs outside of the production zone. For example, the NRC's approved decommissioning at Crow Butte ISL mine unit 1 in Nebraska serves an example of contaminated groundwater being 'stable', albeit high concentrations relative to baseline.

On March 29, 2002, the NRC Staff denied the Crow Butte's proposed restoration report referenced and discussed in the FSEIS as being not protective of human health and the environment. (JTI053; p. 99). In that document, Staff concluded

> *the data in your Restoration Report, submitted by letter dated January 14, 2000, and the additional information submitted by letter dated August 24, 2001, <u>do not demonstrate that the restoration activities in Unit 1, have resulted in constituent levels that will remain below levels protective of human health and the environment, in accordance with 10 CFR 40.31(h) and Criterion 5F, 10 CFR Part 40, Appendix A.</u>*

Further, upon collection of additional groundwater samples between June and September 2002, the groundwater samples observed uranium concentrations of similar magnitudes (1.6 – 1.8 mg/L) (JTI053: p. 125 – 126), thus, precisely the same as what was described above as below levels deemed to be protective of human health and the environment. However, while there was no decrease in the uranium, but seemingly not approaching an arbitrarily set secondary standard of 5 mg/L, after this second round of stability sampling, NRC approved the restoration.

To reiterate, despite roughly equivalent uranium concentrations observed previously which were deemed not protective, the NRC approved restoration as adequately protective. The basis for finding similar concentrations protective in one instance and not in another is not discussed at all in the FSEIS. Indeed, approval of the Crow Butte mine unit 1 concentration levels -- 1.73 mg/L, or 18 times background levels -- as "protective of human health and the environmental" was determined by an arbitrary standard chosen out of expedience for that site. It also demonstrates NRC's subjective statement "protective of human health and the environment" is only condition dependent, and lacks scientific or empirical basis for assessing restoration performance.

13. "Title II of the Act covers operating uranium processing or disposal sites licensed by the NRC or Agreement States. EPA was directed to promulgate generally applicable standards to protect public health, safety, and the environment from hazards associated with processing, possession, transfer and disposal of byproduct material. Such standards were to address both radiological and non-radiological hazards; further, standards applicable to non-radiological hazards were to be consistent with the standards required under Subtitle C of the Solid Waste Disposal Act (i.e., RCRA). NRC was required to implement these standards at Title II sites. See 42 U.S.C. 2022(b), (d)." Proposed Rule at 4163.

NRDC Comment
See discussion *supra*, at Part V of these comments, "Legal Support for the Draft Rule."

14. "To fulfill the statutory mandate described in section II.C of this preamble, we derived these provisions from the RCRA groundwater monitoring framework applicable to hazardous waste disposal sites. Today's proposal further adapts that framework to better address the specific situation presented by ISR technology."
Proposed Rule at 4163-64 (notes and citations omitted).

NRDC Comment

NRDC concurs and supports the use of the RCRA groundwater monitoring framework to address the specific situations presented by the ISL. First, establishing baseline, pre-mining groundwater quality is crucial in establishing both the current state of the environment where the extractive process will take place as well as accurate restoration goals.

As NRDC's expert witness Dr. Abitz testified, EPA's "Unified Guidance" – entitled "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities" – sets forth specific, scientifically-based protocols for groundwater sampling to determine baseline water quality, including independent samples drawn from spatially random located wells. As Dr. Abitz explained, this type of approach is necessary to collect scientifically meaningful data, and the data relied on in the FSEIS, which complied with none of these protocols, is deficient. Abitz Test. (JTI001) at 7–8, 35–41; Abitz Rebuttal (JTI051) 2-3, 6-7; Transcript of Proceedings at 428, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1427/ML14279A153.pdf; *see also* EPA Unified Guidance (JTI006) at 5-3.

Dr. Abitz summed up the matter succinctly at the hearing when he stated:

> I believe this gets back to the fundamental professional opinion problem we've been having here today. Baseline and background are baseline and background. CERCLA, RCRA, or ISL, it does not matter. CERCLA or RCRA was just given as an example where robust scientific and statistical methods are used and proven to establish what the natural, undisturbed conditions in an aquifer are. I read Appendix A criteria in 7 and 5(b). There is no discussion of two different backgrounds or baselines there. They say complete baseline information. To me that's a full-blown quantitative analysis

> with proper scientific and statistical protocols. So I believe we're getting wrapped around the axle on something that doesn't need to be this complicated. Baseline is baseline and it should be done properly at any site. It doesn't matter what regulations govern it.

Transcript of Proceedings at 469-80, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1427/ML14279A153.pdf.

15. "Though standards at subpart D apply to ISR facilities, ISR was not the predominant uranium extraction method at the time the standards were promulgated. Subpart D addresses contamination of aquifers resulting from releases of contaminants from uranium mill tailings impoundments, which are surface structures (engineered units) designed to contain uranium byproduct material (e.g., conventional tailings impoundments, evaporation or holding ponds). The RCRA hazardous waste framework, which is intended to prevent, detect, and mitigate contamination of groundwater resulting from releases of hazardous waste being held in an engineered unit, is directly applicable to this situation." Proposed Rule at 4164 (note omitted).

NRDC Comment

NRDC concurs with EPA's assessment that ISL was not the predominant uranium extraction method at the time the standards were promulgated. The current inadequate regulatory framework was designed to address conventional uranium milling—not unconventional techniques, such as ISL mining, likely to comprise the majority of new uranium recovery sites in the next decade. Regulations promulgated in the late 1970s and 1980s did not contemplate ISL mining and its associated harms, and the legal framework that currently governs ISL mining is wholly inadequate to the task of protecting scarce western groundwater resources. This regulatory negligence must be rectified if the nation is to avoid future risks to the public health and environment. Simply updating regulations for conventional milling would solve only part of the problem the nation faces going forward into a new round of domestic uranium mining and milling.

16. "At ISR sites, however, the groundwater has already been influenced by the natural mineralization associated with the uranium roll front deposits. In essence, the 'management unit' that is the potential source of contamination is the natural setting itself, though extraction of the uranium from the deposit alters the geochemistry of the ore-bearing formation and may increase the concentration of radionuclides and other metals in the water." Proposed Rule at 4164.

NRDC Comment

NRDC asks EPA to reconsider and quantify what actual water quality concentrations are present in the aquifer prior to chemical and mechanical disturbances from well installation and exploratory activities. Dr. Abitz demonstrated that the thermodynamics of uraninite dictate the amount of uranium that can be in solution. In Dr. Abitz's initial testimony in the Ross Project proceeding, he describes these disturbances to the ore zone aquifer. Dr. Abitz writes (and we quote from the testimony extensively in the pages that follow), from JTI001:

> The well installation and development methods oxidized the ore zone by introducing oxygen-rich fluids (relative to the depleted oxygen levels in the aquifer) during drilling and atmospheric air (20% oxygen) during well development and these improper actions contaminated the aquifer prior to collecting baseline water quality samples. Instead, for the oxygen-depleted conditions associated with uranium ore deposits, baseline water quality data should be collected using wells that have not been installed and developed with oxygen-rich fluids and air-purging techniques. This is in accordance with professional standards for well installation recommended by the U.S. Geological Survey (1997; http://water.usgs.gov/owq/pubs/wri/wri964233/wri964233.pdf) (JTI011).
>
> Professional standards for well design, installation and development are discussed in detail by the USGS (1997) (JTI011), with the following highlights and recommendations:
>
> "The primary consideration for selecting well-installation methods and materials is to minimize the effects on the chemical and physical properties of the ground-water sample." (JT1011 at 18). "The goal for water quality studies is to have the well design compatible with requirements to obtain samples that accurately represent the chemical constituents of concern in groundwater. " (JTI011 at 20). "Additional considerations that influence selection of the well-construction method include:
>
> - Requirements inherent in the chemical constituents targeted for sampling, their anticipated concentrations, and the accuracy needed to meet study objectives." (JTI011 at 45)
>
> In particular, the bulleted portion of the above quote highlights three important criteria we have repeatedly stressed. First, "requirements inherent in the chemical constituents targeted for

sampling" explicitly implies that if you are going to measure uranium concentrations in groundwater in contact with a uranium ore body, you cannot use a well-construction method that introduces oxygen into the ore zone. An appropriate method would be to use air-rotary drilling (JTI011 at 57) with recirculated nitrogen gas instead of air and a foam surfactant that contains organic constituents to eliminate oxygen.

The second part of the above bullet, "their anticipated concentrations", refers to the concentration of uranium in the ore zone. NRC Staff wrote in the Ross ISL FSEIS (SEI009A, p. 3-16)[23]: "The presence of pyrite confirms the geochemical conditions necessary for formation of the roll front." This is consistent with the common occurrence of pyrite with uranium ore deposits at extremely low oxygen levels in groundwater (JTI012, Brookins, 1988; p. 153). The levels of oxygen in groundwater contacting pyrite and uranium ore (uraninite) are easily calculated using commercial software, such as the Geochemist's Workbench (http://www.gwb.com/). I calculated the stability field for pyrite (below figure) using the Geochemist's Workbench and the approximate highest groundwater concentrations for iron (0.57 milligrams/liter), carbonate (610 milligrams/liter) and sulfate (920 milligrams/liter), as reported for the ore zone (Appendix C of FSEIS). The thermodynamic calculations indicate that pyrite is stable over the pH range of 6 to 10 only when oxygen levels are below $1x10^{-65}$moles/liter. Next, the uranium concentration in groundwater can be estimated by constraining the uraninite stability field to oxygen levels less than about $1x10^{-65}$moles/liter. I constructed this figure (below) using the same water quality data noted above and when the uraninite stability field is below oxygen levels of $1x10^{-65}$moles/liter, uranium concentrations in groundwater are less than $1x10^{-10}$moles/liter (2.38E-08 grams/liter or 2.38E-14 micrograms liter, which is over 13 orders of magnitude lower than the EPA uranium MCL of 30 micrograms/liter). This analysis shows that the true uranium concentration in groundwater contacting uraninite and pyrite is so low that it cannot be detected with present laboratory methods.

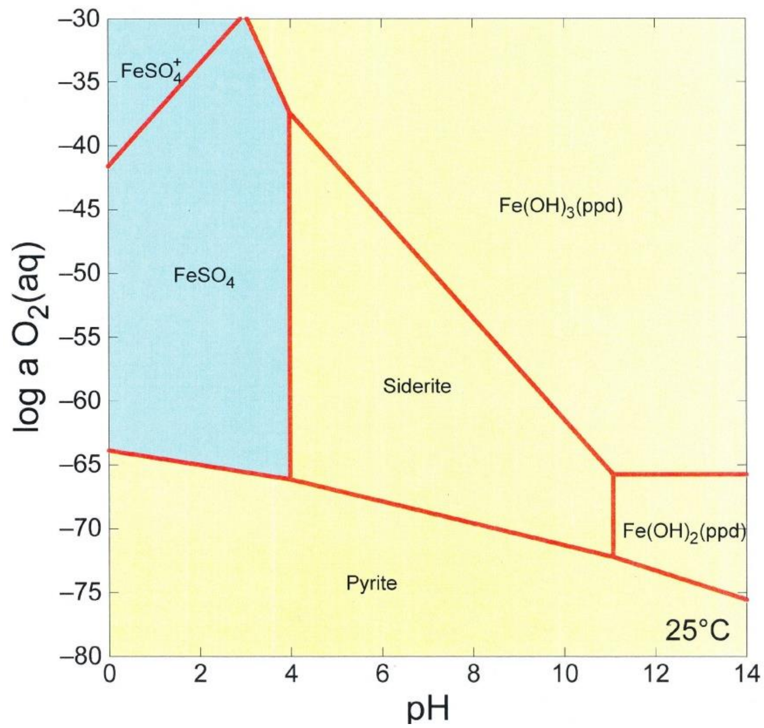
The last criterion in the quoted text under the above bullet states "the accuracy needed to meet study objectives." Given that oxygen levels are extremely low in uranium ore deposits, the well-

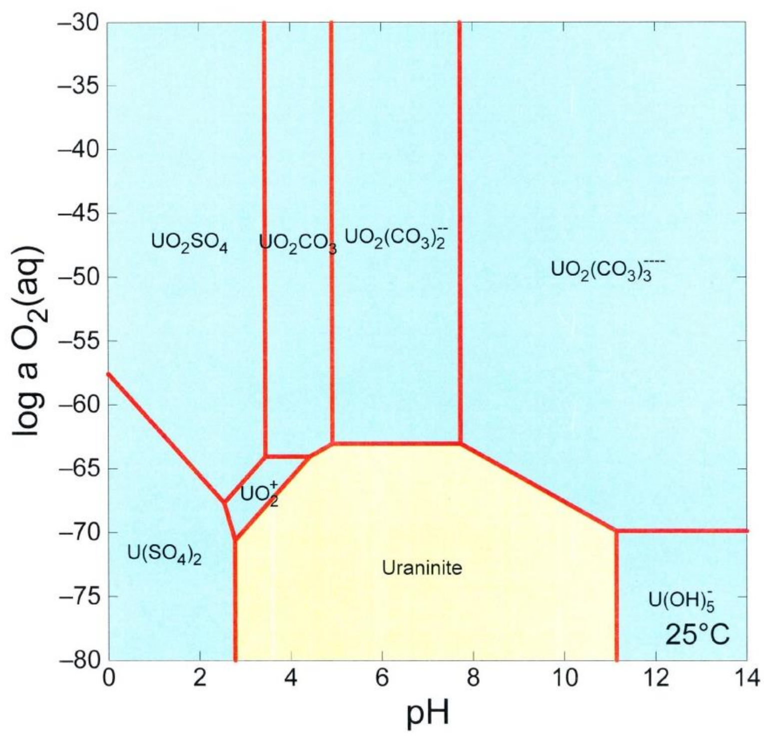
---

[23] U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 3-16 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf.

construction methods must provide the accuracy needed to ensure no oxygen is introduced to the ore zone via drilling fluids and compressed atmospheric air."

Below are Pourbaix diagrams displaying relevant geochemical conditions from Geochemist Workbench®. The top figure shows Iron and bottom figure shows the uranium stability fields.





The addition of a lixiviant and complexing agent to a reduced uranium ore creates a violent oxidation process which significantly alters the geochemistry and hence the solubility of uraninite in solution. These two conditions are signifying the incredible change in chemistry due to addition of lixiviant. The figure below, first produced today for these comments, demonstrates the theoretical change in uraninite solubity when no oxygen is present (solid red line) and when oxygen and carbonate is added to the model (dashed red line). The gray region approximates the geochemical conditions present when ore is extracted from the production zone. This significant change in geochemistry should make it apparent to EPA that there are substantial differences between pre-mining, original conditions and post-restoration conditions that have much less to do with the natural mineralized state of the water.

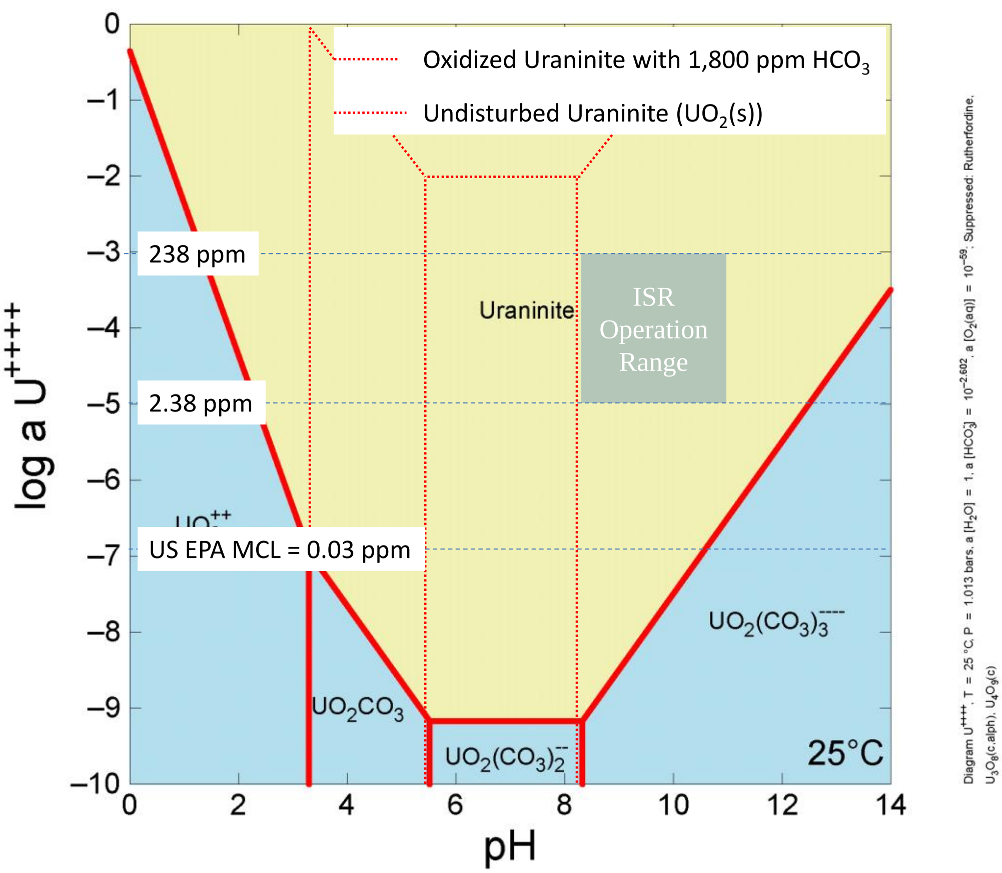


FIGURE 1:

17. “We believe that ISR-specific standards are necessary because uranium ISR operations are very different from conventional uranium mills and the existing standards do not adequately address their unique aspects. In particular, we believe it is necessary to take a longer view of groundwater protection than has been typical of current ISR industry practices.” Proposed Rule at 4164.

NRDC Comment

NRDC concurs with EPA’s assessment that ISL standards are necessary as the environmental impacts from ISL recovery are so different from the impacts from conventional mining. The deficient regulatory system can be viewed in stark relief via an examination of the evidentiary record of our ongoing Ross Project challenge. The evidentiary record of that proceeding, discussed *infra*, IV-, demonstrates (1) the inadequacy of the current regulatory regime and (2) the necessity for EPA to issue strong, protective standards.

Also, see examples provided in Comment #8, demonstrating long term groundwater impacts from ISL mining.

18. “Although the presence of significant uranium deposits typically diminishes groundwater quality, current industry practices for restoration and monitoring of the affected aquifer may not be adequate to prevent either the further degradation of water quality or the more widespread contamination of groundwater that is suitable for human consumption.” Proposed Rule at 4164.

NRDC Comment

First, NRDC questions the basis of EPA’s conclusory statement that the presence of significant uranium deposits typically diminishes groundwater quality. We don’t believe the evidence supports that this is necessarily the case. Further, we urge EPA drop the qualified, caveated language inherent in the statement “current industry practices for restoration and monitoring of the affected aquifer may not be adequate to prevent either the further degradation of water quality or the more widespread contamination of groundwater that is suitable for human consumption.” To the contrary, it is well established that current industry practices are not adequate to prevent degradation of water quality or widespread contamination.

Examination of the Story maps and histogram evidence from the Ross Project proceeding illustrates that (1) it is not accurate to state that the presence of uranium necessarily equals poor groundwater quality; and (2) it is perfectly clear that ISL activity degrades that groundwater quality, whatever its original state.

> Using NRC and industry data, Dr. Larson provides a meaningful summary of the data using the entire wellfield data set from Christensen Ranch MU2-6. He created a cumulative histogram for average baseline and each post restoration phase sampling round concentrations. JTI003 at ¶58. Ultimately for the Willow Creek Storymap, the majority of the average baseline groundwater samples were below the MCL for uranium of 0.03 mg/L (~65%); 28 % had slightly elevated uranium concentrations (0.03-0.09 mg/L) and only 8% were very elevated (0.09 – 3.0 mg/L), thus our immediate questioning of EPA's basis in asserting that as a general matter, the presence of significant uranium deposits typically diminishes groundwater quality.
>
> Next, Dr. Larson then showed that after mining and restoration activities, the groundwater quality sample distribution shows significant changes to these observed percentages. Roughly 13% of the post restoration samples were extremely contaminated (greater than 3.0 mg/L, which is greater than 100 times the EPA's maximum contaminant limit for safe drinking water standards for uranium), the 'very elevated' uranium concentrations increased from 8% (Baseline) to 54% (Post-restoration). And finally, the drinking water quality samples decreased from approximately 2/3 of all samples, to roughly 18% of the observed samples. *Id.* Dr. Larson's analysis demonstrates, quantitatively, the severe water quality degradation which occurs as a result of ISL mining
>
> This straightforward presentation of data from a set of ISL mine units needs to be put into a larger scientific context. NRDC is quite aware that groundwater hydrology is astonishingly complex and overall conclusory statements, long foisted on the public by an industry loathe to be regulated, assert that the original water quality in the entirety of mined aquifers is poor. Our evidence, in contrast, conclusively demonstrates that this is not the case and, in fact, if meaningful baseline assessments were required (which is not the case now), substantial amounts of water could be of high quality (but at this point, we simply don't know as NRC has not required adequate characterization of ISL sites).

19. "Because monitoring after restoration is typically conducted for only a short period, we find it difficult to characterize the probability or magnitude of future contamination problems, or the costs involved in remediating such future contamination. Such costs are not now borne by ISR licensees, nor is there any guarantee that they could be held responsible if contamination were detected by new monitoring implemented years, decades or even longer after the end of site activities once the facility is officially decommissioned and the license is terminated by the NRC or Agreement State. It is likely, however, that the costs of such future remediation would far exceed the costs of the more extensive monitoring (in all phases of site activity) that we are proposing today, together with the costs of any additional restoration or prompt corrective action that may be required to address any issues identified as a result of the more extensive monitoring. In this sense, perhaps a generalized future cost of groundwater remediation

can be viewed as a proxy for the value of groundwater and its protection." Proposed Rule at 4164.

NRDC Comment

NRDC concurs with EPA's assessments that restoration is typically conducted for only a short period, there any guarantee that they could be held responsible if contamination were detected by new monitoring implemented years, decades or even longer after the end of site activities once the facility is officially decommissioned and the license is terminated, and that the costs of such future remediation would far exceed the costs of the more extensive monitoring EPA has proposed (together with the costs of any additional restoration).

Indeed, we demonstrated in the Ross proceeding that there was both substantial degradation of the mined/exempted aquifer and that there was a paucity of any subsequent data delineating either the stability or the potential migration of that contamination. *See supra*, Part IV.

For specific examples of long term groundwater trends, see Comment #8.

20. "Similarly, because ISR activities often take place in areas that are sparsely populated, and any subsequent contamination may take years, decades or even longer to reach groundwater being consumed by humans, it is difficult to characterize the benefits of our proposal by applying typical Agency metrics, such as the number of cancers averted. We also recognize, however, that our efforts to protect groundwater must consider the use, value, and vulnerability of the resource, as well as social and economic values. We believe it is important to protect groundwater to ensure the preservation of the nation's currently used and potential underground sources of drinking water (USDWs) for present and future generations. Also, we believe it is important to protect groundwater to ensure that where it interacts with surface water it does not interfere with the attainment of surface-water-quality standards; these standards are also necessary to protect human health and the integrity of ecosystems." Proposed Rule at 4164.

NRDC Comment

NRDC concurs that ISR activities often take place in areas that are sparsely populated, and any subsequent contamination may take years, decades or even longer to reach groundwater being consumed by humans. As noted above, it makes no sense to contaminate scarce western groundwater and harm iconic western landscapes for uranium production that amounts to a small fraction of global uranium output and U.S. consumption, and that does not fundamentally alter U.S. dependence on foreign sources of uranium. Indeed, we don't believe such a sacrifice of western water would be wise even if there were some small alteration in U.S. dependence on foreign sources of uranium, especially in a carbon constrained world. But in any event, the likely trade-offs inherent in the continuation of a failed ISL regulatory system and its assured sacrifice of scarce aquifers is not balanced in the least.

21. "In many areas of the country, particularly in western states where ISR activities are most likely to take place, groundwater is a scarce and valuable resource that is being rapidly depleted to support increased demands. There is evidence that some communities are making efforts to utilize groundwater that is not of "good" quality, and in our view this trend will only increase." Proposed Rule at 4164.

NRDC Comment

EPA is accurate when it states that there is evidence that some communities are making efforts to utilize groundwater of lesser quality. We discussed one such community in Comment #7. There, the city of Gillette, Wyoming depends on drinking water from the Fort Union Aquifer and other local aquifers, to provide municipal water supplies. However, water availability in these aquifers are dwindling and the population is projected to substantially increase from 37,000 to 57,000 by 2030. To meet increasing water demands, the city is enacting the Gillette Madison Pipeline Project, a 217.6 million dollar project, which will route water from the Madison aquifer, north of Keyhole Reservoir to Gillette via pipeline[24]. The project is intended to meet growing water demands for the next 20 years.

Along these lines, the USGS states that brackish water: "is considered by many investigators to have dissolved-solids concentration between 1,000 and 10,000 milligrams per liter (mg/L)."[25] In its National Brackish Groundwater Assessment, USGS documented the expected increasing demand for groundwater demand that has led to an increased need to protect brackish groundwater that in the past may have been deemed unsuitable for drinking water. USGS writes:

> *In many parts of the country, groundwater withdrawals exceed recharge rates and have caused groundwater-level declines, reductions to the volume of groundwater in storage, lower streamflow and lake levels, or land subsidence. It is expected that the demand for groundwater will continue to increase because of population growth, especially in the arid West. Further, surface-water resources are fully appropriated in many parts of the*

[24] http://www.gillettewy.gov/index.aspx?page=902
[25] http://water.usgs.gov/ogw/gwrp/brackishgw/brackish.html

> *country, creating additional groundwater demand. Development of brackish groundwater as an alternative water source can help address concerns about the future availability of water and contribute to the water security of the Nation.* [26]
>
> - *United States Geological Survey*

Brackish water is already being treated for use as drinking water. The state of Texas, overwhelmed by historic droughts over the last decade,[27] is planning to partially meet current and future water demands with the treatment of brackish groundwater.[28] It's estimated that roughly 100 brackish groundwater plants are currently being used in Texas and it has been estimated that roughly 13% of the total water supply for the Lower Rio Grande Valley could be met with brackish groundwater by 2060.[29] According to the director of the Texas Desalination Association: "Until recently, brackish water was not considered usable. But with chronic drought conditions, it is suddenly becoming more and more useful."[30] In communities across the West, brackish water is being used and there is strong evidence that it will be increasing relied upon in the future.

22. "Another critical issue in groundwater protection is that groundwater generally is not directly accessible. Thus, it is much more difficult to monitor and/or decontaminate groundwater than is the case with other environmental media. Because of the expenses and difficulties associated with remediation of contaminated groundwater, we believe it is prudent and cost-effective to prevent the occurrence of such contamination rather than rely on the cleanup of preventable pollution. Thus, the Agency believes that it is in the national interest to preserve the quality of groundwater resources to the extent practicable, and that the best way to do so is to prevent contamination by addressing its source. We believe today's proposal, which focuses on the source of potential contamination at ISR sites by stricter application of groundwater standards and more extensive monitoring to ensure that groundwater restoration will endure, is a reasonable and responsible approach to achieving this goal." Proposed Rule at 4164.

NRDC Comment

NRDC concurs with EPA here and notes that there is significant evidence -- from a variety of environmental media and scenarios – that supports the essential

---

[26] http://water.usgs.gov/ogw/gwrp/brackishgw/study.html
[27] http://www.npr.org/2014/05/06/309101579/drought-stricken-texas-town-turns-to-toilets-for-water
[28] Nicot, J.-P. & Scanlon, B. R. Water use for Shale-gas production in Texas, U.S. Environ. Sci. Technol. 46, 3580–6 (2012).
[29] http://www.twdb.texas.gov/innovativewater/bracs/doc/TWDB_Report_383_LRGV_GulfCoast.pdf
[30] http://www.sanluisobispo.com/welcome_page/?shf=/2014/11/08/3339786_cambria-csd-water-treatment-plant.html

conclusion that the expenses and difficulties associated with remediation of contamination (in air, land, groundwater, surface water) far outstrip prudent and cost-effective measures to prevent the occurrence of such contamination in the first instance. *See, e.g.*, *Nuclear Energy Inst., Inc. v. EPA*, 373 F.3d 1251, 1284 (D.C. Cir. 2004) ("EPA adequately explained its reasons for adopting the ground-water standard: Not only did the agency conclude (unremarkably) that an ounce of prevention is worth a pound of cure, but it explained that adding a ground-water standard would produce other salutary effects . . ."); *Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst.*, 448 U.S. 607, 656 (1980) (Stevens, J., plurality opinion) ("the Agency is free to . . . risk[] error on the side of overprotection rather than underprotection").

23. "The alteration of large subsurface areas through injection of chemical solutions also has the potential to cause changes in groundwater at significant distances downgradient. The migration of constituents liberated from the subsurface is controlled during the operational phase through the use of extraction wells." Proposed Rule at 4164-65.

NRDC Comment

NRDC concurs that there is substantial alteration of large subsurface areas via the ISL process. This is indisputable. We also concur that there is significant potential for migration of constituents, both during the operational phase, the restoration phase and after monitoring ceases and the site has been decommissioned. We stress again that NRDC reviewed excursion problems at other ISL facilities, which have regularly occurred, and explains that it is "difficult to assess whether an aquifer is truly confined." JTI003, *Id.* at ¶¶69-70. Dr. Larson then presented a Storymap related to the excursion history of the Willow Creek facility. *Id.* at ¶¶76-85. He noted that one facility has suffered from both vertical and horizontal excursions, with vertical excursions being particularly difficult to correct. According to the data Dr. Larson reviews, some wells remained on "excursion status" for months and even years. *Id.* at ¶81.

More to the technical point at the foundation of EPA's recognition that there is alteration of large subsurface areas through injection of chemical solutions, NRDC agrees that uranium geochemistry is extraordinarily complex and the up to date scientific understanding must be considered in this rulemaking and applied ISL sites. Simply, without a thorough understanding of subsurface hydro-biogeochemical mechanisms, it is impossible to adequately address the risks to adjacent USDW aquifers and private well locations by uranium migration.

The following paragraphs, technical in nature, address the updated scientific literature concerning uranium transport through groundwater, which has greatly improved our understanding of uranium transport mechanisms through an aquifer, especially concerning geochemical conditions which arise due to ISL operations.

As EPA knows, *in situ* recovery mining exploits intrinsic geochemical properties of uranium. Uranium was deposited in fluvial roll-front where oxidizing water meets a reducing zone: the oxidized, soluble U(VI) was reduced and precipitated as insoluble U(IV), typically as the mineral uraninite. Ideally for industry, ISL operations occur in highly permeable, confined sandstone formations, with low permeability vertical overlying and underlying confining units. Injection and recovery wells pumping rates are optimized to balance and control the hydraulic head of the wellfield to maintain a net inward hydraulic gradient. The injection solution, termed lixiviant, contains an oxidant (usually hydrogen peroxide) and complexing ligands (inorganic carbon), which solubilize U(IV) to U(VI). Lixiviants, such as ammonium carbonate or sodium carbonate, are used for 'targeted' alkaline leaching of uranium.

Acid lixiviants have been used for pilot-scale studies in the United States and currently in international ISL projects, such as the Beverley Mine, Australia.[31] Acid lixiviant ISL mines in Eastern Europe are largely unreclaimed and have resulted in "extreme" environmental impacts to groundwater[32]. ISR operations in the United States have primarily used a sodium carbonate lixiviant since the mid-1980s. The use of an alkaline lixiviant, opposed to acid lixiviant, minimizes the unintended proton-promoted dissolution of other hazardous constituents.

The relative composition of aqueous U(VI) speciation, which are dependent on localized geochemical conditions, largely dictate uranium subsurface mobility.[33] In natural environments, uranium forms complexes with various anions, termed ligands, in solution. Complexes are species which form when the central atom

---

[31] Mudd, G. (2001a). Critical review of acid in situ leach uranium mining: 1. USA and Australia. Environmental

[32] Mudd, G. (2001b). Critical review of acid in situ leach uranium mining: 2. Soviet Block and Asia. Environmental Geology, 41(3-4), 404–416. doi:10.1007/s002540100405

[33] Curtis, G. P.; Davis, J. a.; Naftz, D. L. Simulation of reactive transport of uranium(VI) in groundwater with variable chemical conditions. *Water Resour. Res.* 2006, *42*.

Bond, D.; Davis, J.; Zachara, J. Uranium (VI) release from contaminated vadose zone sediments: Estimation of potential contributions from dissolution and desorption. *Dev. Earth …* 2007, *9197*.

Stewart, B. D.; Mayes, M. a; Fendorf, S. Impact of uranyl-calcium-carbonato complexes on uranium(VI) adsorption to synthetic and natural sediments. *Environ. Sci. Technol.* 2010, *44*, 928–934.

Waite, T. D.; Davis, J. a.; Payne, T. E.; Waychunas, G. a.; Xu, N. Uranium(VI) adsorption to ferrihydrite: Application of a surface complexation model. *Geochim. Cosmochim. Acta* 1994, *58*, 5465–5478.

interacts with a ligand. Uranium can conceivably exist as several species given the specific conditions of the solution (See figure below).

Fox et al. (JTI058 at p. 8) demonstrated that the presence of calcium and carbonates have significant impact on uranium adsorption to reactive mineral surfaces. This is due to the formation of calcium-uranyl-carbonate complexes (Ca-UO2-CO3) which are thermodynamically stable under those conditions. Kelly et al. (JTI059) observed evidence of the existence of these species with spectroscopy and thermodynamic speciation calculations predicted geochemical stability ranges. These measurements provide direct evidence for the existence of these complexes and consistency was established with thermodynamic speciation calculation predictions, which were used in my geochemical model below.

We've created the figure below using a geochemical modeling software (PHREEQC v.3.1.2) using an updated thermodynamic database which includes the formation of the Ca-UO2-CO3 complexes and representative average stability data from Christensen Ranch ISL mine unit 5. The pH was the master independent variable and average post-restoration constituent concentrations were held constant. The shaded grey region shows the range of measured pH values from the stability samples at Christensen Ranch. The table below the figure shows the input data into the thermodynamic database and model. This figure shows, unequivocally, that the representative geochemical conditions in the aquifer post-restoration are largely dominated by Ca-UO2-CO3 complexes predicted by the updated thermodynamic database. This evidence demonstrates that NRC and industry are using outdated assumptions about uranium geochemistry and transport, and EPA should, at a minimum, incorporate the updated science into its reasons for the rule. .

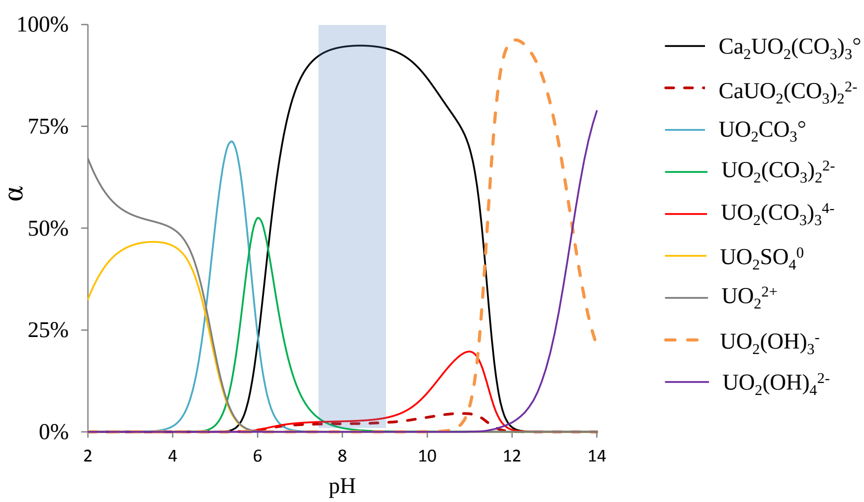


FIGURE 2

We further discuss uranium adsorption and reductive precipitation in the paragraphs that follow.

Adsorption describes the phenomenon where certain ions attract to a reactive surface. The relative abundance of various U(VI) aqueous complexes is associated to uranium adsorption capacity to various mineral surfaces. Specifically, uranyl-ions (UO_2^{2+}) strongly adsorb to ferrihydrite at circumneutral pH values and adsorption was largely dependent on the pH, pCO_2, and [U(VI)][34]. U(VI)-carbonate complexes observed relatively poor interactions with Fe oxide surfaces, compared to U(VI)-hydroxide complexes.[35] Furthermore, the formation of Ca-U(VI)-CO_3 aqueous complexes occur with greater availability of calcium.[36]

These complexes ($Ca(UO_2(CO_3)_2^{2-}$ and $Ca_2UO_2(CO_3)_3^{\circ}$) have observed substantially decreased uranium adsorption to ferrihydrite and quartz surfaces.[37] In other words, Ca-U(VI)-CO_3 complexes are relatively unaffected by surface interactions and hence, mobile compared to U(VI)-hydroxide species.

In plain terms, U(VI) is sticky like chewed gum, but calcium and carbonate ions act like sand grains covering the chewed gum. These decrease the ability of U(VI) to stick to various mineral surfaces, thus the uranium stays in the groundwater and is able to move unrestricted through the aquifer (i.e., highly mobile).

Our understanding of the science is consistent with sorption experiments, which observed decreasing partitioning coefficients (K_d) values with increasing alkalinity.[38] Furthermore, a single K_d value modeling approach is too simplistic of an approach to adequately predict U(VI) mobility in groundwater; consequently

---

[34] Waite, T. D., Davis, J. a., Payne, T. E., Waychunas, G. a., & Xu, N. (1994). Uranium(VI) adsorption to ferrihydrite: Application of a surface complexation model. Geochimica et Cosmochimica Acta, 58(24), 5465–5478. doi:10.1016/0016-7037(94)90243-7.

[35] Wazne, M., Korfiatis, G. P., & Meng, X. (2003). Carbonate effects on hexavalent uranium adsorption by iron oxyhydroxide. Environmental Science & Technology, 37(16), 3619–24. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12953874.

[36] Kelly, S. D., Kemner, K. M., & Brooks, S. C. (2007). X-ray absorption spectroscopy identifies calcium-uranyl-carbonate complexes at environmental concentrations. Geochimica et Cosmochimica Acta, 71(4), 821–834.

[37] Fox, P. M., Davis, J. a., & Zachara, J. M. (2006). The effect of calcium on aqueous uranium(VI) speciation and adsorption to ferrihydrite and quartz. Geochimica et Cosmochimica Acta, 70(6), 1379–1387. doi:10.1016/j.gca.2005.11.027

[38] Bond, Deborah L., James A. Davis, and John M. Zachara. "Uranium (VI) release from contaminated vadose zone sediments: Estimation of potential contributions from dissolution and desorption." *Developments in Earth and Environmental Sciences* 7 (2007): 375-416.

surface complexation models (SCM) are more appropriate to predict U(VI) mobility.[39]

If EPA relies on geochemical transport models to justify site decommissioning, the agency should rely on the most current thermodynamic databases and site specific geochemical data collected for model calibration. Understanding the predominant aqueous U(VI) speciation is also important concerning the effectiveness of groundwater treatments using chemical reductants. Chemical injection restoration techniques have used hydrogen sulfide gas or NaS to reduce uranium through reductive precipitation. In laboratory experiments, hydrogen sulfide was found to reduce only the uranyl-hydroxide complexes and was unable to reduce uranyl-carbonate complexes. It was observed that the rate of uranium reduction from hydrogen sulfide decreased with increasing pH (6.89 – 9.06) and increasing total carbonate concentrations, due to the formation of uranyl-carbonate complexes under those geochemical conditions.[40] Further, the injection of a chemical reductant, such as hydrogen sulfide, will preferentially donate electrons to relatively higher thermodynamically favored electron acceptors, such as Fe(III). Accordingly at one ISR restoration site, uranium concentrations observed increases after chemical sulfide injection, presumably due to the reductive dissolution of U-bearing Fe(III) oxides.[41]

In situ bioremediation is another potential treatment option for aquifers contaminated with of U(VI). Briefly, electron donors are injected into a uranium contaminated aquifer, inducing reducing conditions by stimulating microbial activity, thus precipitating U(VI) as immobile U(IV). However, considerable technical, logistical, and scientific uncertainties remain with in situ bioremediation efficacy as a long-term ISR groundwater restoration option.

Upon introduction of acetate into shallow uranium impacted aquifers, both iron reductive and sulfate reductive metabolisms have been observed[42]. Under Fe(III) reducing conditions, evidence suggests *Geobacter*-like strains of dissimilatory

---

[39] Curtis, G. P., Davis, J. a., & Naftz, D. L. (2006). Simulation of reactive transport of uranium(VI) in groundwater with variable chemical conditions. Water Resources Research, 42(4). doi:10.1029/2005WR00397.

[40] Hua, B.; Xu, H.; Terry, J.; Deng, B. Kinetics of uranium(VI) reduction by hydrogen sulfide in anoxic aqueous systems. *Environ. Sci. Technol.* 2006, *40*, 4666–4671.

[41] Hall, S. Groundwater restoration at uranium in-situ recovery mines, South Texas coastal plain. USGS Open File Report. 2009.

[42] Williams, K. H.; Long, P. E.; Davis, J. a.; Wilkins, M. J.; N'Guessan, a. L.; Steefel, C. I.; Yang, L.; Newcomer, D.; Spane, F. a.; Kerkhof, L. J.; et al. Acetate Availability and its Influence on Sustainable Bioremediation of Uranium-Contaminated Groundwater. *Geomicrobiol. J.* 2011, *28*, 519–539.

Fe(III) reducing bacteria (DIRB) are capable of enzymatic reductive precipitation of U(VI)[43]. As bioavailable Fe(III) becomes exhausted (or is unavailable), subsurface redox conditions favor sulfate reducing bacteria (SRB). Under sulfate reducing conditions, relative increases in uranium concentrations have been observed, presumably due to SRBs relatively lower capacity to respire U(VI)[44]. Other authors have suggested models with co-amendments of Fe(III) with acetate to prevent or limit sulfate reducing conditions[45]. Yet, SRB activity is important in the formation of mackinawite (FeS), which may be vital to abiotic uranium redox transition pathways or stabilizing biogenic uranitite.[46] Other research observed under reducing conditions, U(VI) was removed from solution, not by reductive precipitation to U(IV), but rather, through the precipitation of U(VI)-phosphate minerals and U(VI) sorption.[47]

Research has shown the relatively high percentage of the $Ca_2UO_2(CO_3)_3°$ specie post ISR restoration are relatively less bioreducible compared to other uranyl complexes, such as $UO_2(CO_3)_3^{4-}$ and $UO_2\ (CO_3)_2^{2-}$.[48] Additionally, reaction kinetics substantially complicate predictions of uranium reduction, as the products at the iron- and sulfur- redox 'fence' are extremely complex and inherently interconnected through biogeochemical feedbacks.[49] Abiotic and

---

[43] Mkandawire, M. Biogeochemical behaviour and bioremediation of uranium in waters of abandoned mines. *Environ. Sci. Pollut. Res. Int.* 2013, *20*, 7740–7767.

[44] Williams, K. H.; Long, P. E.; Davis, J. a.; Wilkins, M. J.; N'Guessan, a. L.; Steefel, C. I.; Yang, L.; Newcomer, D.; Spane, F. a.; Kerkhof, L. J.; et al. Acetate Availability and its Influence on Sustainable Bioremediation of Uranium-Contaminated Groundwater. *Geomicrobiol. J.* 2011, *28*, 519–539.
[45] Zhuang, K.; Ma, E.; Lovley, D. R.; Mahadevan, R. The design of long-term effective uranium bioremediation strategy using a community metabolic model. *Biotechnol. Bioeng.* 2012, *109*, 2475–2483.

[46] Bargar, J. R.; Williams, K. H.; Campbell, K. M.; Long, P. E.; Stubbs, J. E.; Suvorova, E. I.; Lezama-Pacheco, J. S.; Alessi, D. S.; Stylo, M.; Webb, S. M.; et al. Uranium redox transition pathways in acetate-amended sediments. *Proc. Natl. Acad. Sci.* 2013, *110* , 4506–4511.

[47] Salome, K. R.; Green, S. J.; Beazley, M. J.; Webb, S. M.; Kostka, J. E.; Taillefert, M. The role of anaerobic respiration in the immobilization of uranium through
[48] Williams, K. H.; Long, P. E.; Davis, J. a.; Wilkins, M. J.; N'Guessan, a. L.; Steefel, C. I.; Yang, L.; Newcomer, D.; Spane, F. a.; Kerkhof, L. J.; et al. Acetate Availability and its Influence on Sustainable Bioremediation of Uranium-Contaminated Groundwater. *Geomicrobiol. J.* 2011, *28*, 519–539. Mkandawire, M. Biogeochemical behaviour and bioremediation of uranium in waters of abandoned mines. *Environ. Sci. Pollut. Res. Int.* 2013, *20*, 7740–7767. Stewart, B. D.; Amos, R. T.; Nico, P. S.; Fendorf, S. Influence of Uranyl Speciation and Iron Oxides on Uranium Biogeochemical Redox Reactions. *Geomicrobiol. J.* 2011, *28*, 444–456.

[49] Spycher, N. F.; Issarangkun, M.; Stewart, B. D.; Sevinç Şengör, S.; Belding, E.; Ginn, T. R.; Peyton, B. M.; Sani, R. K. Biogenic uraninite precipitation and its reoxidation by iron(III) (hydr)oxides: A reaction modeling approach. *Geochim. Cosmochim. Acta* **2011**, *75*, 4426–4440.

biotic kinetic rate constants varied with availability and structure of Fe(III) minerals and decreased with increasing dissolved Ca^{2+}.[50]

Other scientific or logistical issues for successful *in situ* bioremediation are associated with balancing donor injection rates, vertical and horizontal aquifer anisotropy, biomass accumulation in pores and wells (resulting in a loss of hydraulic conductivity), and re-oxidation of biogenic uraninite.[43,45,49], [51] Logistical operational issues, such as unbalanced wellfield injection rates, can create localized high hydraulic head gradients, further destabilizing or creating a net flux of contaminants away from the ore zone.[52] The fore mentioned factors complicate the potential effectiveness, both short and long term, of successful ISR restoration via amended donor injections. However, consideration of cumulative, site specific hydro-biogeochemical factors are essential to developing scientifically defensible restoration strategies.

24. "Much remains unknown about the geochemical stability of restored wellfields once ISR operations have ceased. Long-term environmental impacts may result if restoration processes do not return aquifers to their preoperational state, or if restored levels do not persist over time and groundwater degrades through the slow release of residual contaminants. Most ISR sites historically have been unable to meet restoration goals for all constituents even after extensive effort. Because the past practice of monitoring after restoration has typically been for a very limited time period, we do not know if the goals that are met for the short-term are maintained for a longer time." Proposed Rule at 4165.

NRDC Comment

NRDC concurs with EPA's statement that much remains unknown about the geochemical stability of restored wellfields once ISR operations have ceased as there exists little or no data on their states. Indeed, NRC has required little or nothing in the way of long term monitoring of the contaminated sites after the close of restoration.

---

[50] Stewart, B. D.; Amos, R. T.; Nico, P. S.; Fendorf, S. Influence of Uranyl Speciation and Iron Oxides on Uranium Biogeochemical Redox Reactions. *Geomicrobiol. J.* **2011**, *28*, 444–456.

[51] Zhuang, K.; Ma, E.; Lovley, D. R.; Mahadevan, R. The design of long-term effective uranium bioremediation strategy using a community metabolic model. *Biotechnol. Bioeng.* **2012**, *109*, 2475–2483.

[52] Long, P. E.; Yabusaki, S. B.; Meyer, P. D.; Murray, C. J.; N'Guessan, A. L. Technical Basis for Assessing Uranium Bioremediation Performance; Richland, WA (United States), **2008**.

With respect to EPA's statement that "most ISR sites historically have been unable to meet restoration goals for all constituents even after extensive effort," we urge the agency to lose the qualifying word "most." As demonstrated previously, the likelihood of meeting either the original baseline or the EPA Maximum Contamination Limit for uranium is non-existent and the environmental impacts are large and long-term. Specifically, we presented the uncontroverted evidence that based upon the past history of ISL facilities, it is a virtual certainty that the industry will not be able to restore the impacted aquifers to primary or secondary limits. Even with ACLs approved by NRC, NRDC showed that past ISL projects have resulted in significant impacts to aquifers and to date, no ISL project has successfully restored an aquifer. As the ASLB court stated in its final opinion, "[w]hile the Board agrees with Joint Intervenors that, based on the historical record, ACLs are a foreseeable consequence of ISR mining …" Init. Dec. at ¶4.81 (emphasis added).

Finally, to make this point even more clear, consider this stilted exchange at the hearing where it's finally made clear that no applicant has ever restored to pre-mining water quality, but there have been instances where the industry did not have to seek a license amendment because it was allowed to simply claim restoration had been completed to a prior class of use designation.

> CHAIRMAN BOLLWERK: All right. So, it sounds like, in terms of license amendments, all roads lead to ACL's?
> MR. SAXON: That is correct.
> CHAIRMAN BOLLWERK: All right. And so, I guess -- well, the question would be relative to number one and number two, have any applicant -- I am sorry. Have any licensees ever come and requested approval under one or two?
> MR. SAXON: No, Your Honor.
> CHAIRMAN BOLLWERK: So, everyone has been under number three, up to this point, anyway?
> MR. SAXON: Number -- it would be under -- at the time it wasn't an ACL because we were instructed to use the class of use standard. So, in order to -- but it is confusing, but that is called the secondary standard or -- it is not an alternate concentration of an ACL. It was an alternate standard, if you will, but it doesn't meet our ACL standard.
> CHAIRMAN BOLLWERK: Right.
> MR. SAXON: So if they came in and requested that the approved restoration to the class of use over the -- say, Wyoming, UIC standards.
> CHAIRMAN BOLLWERK: And that did require a license amendment?
> MR. SAXON: No, it didn't.

> CHAIRMAN BOLLWERK: It did not?
> MR. SAXON: Did not.
> CHAIRMAN BOLLWERK: So, that is the only instance where you -- where someone has come in and asked for an approval for restoration plan or restoration standard that did not involve a license amendment?
> MR. SAXON: No, it didn't. No, Your Honor.
> CHAIRMAN BOLLWERK: Great.

Transcript of Proceedings at 552–54, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1428/ML14280A199.pdf.

25. "The restoration process likewise cannot be assumed to fully restore the porosity and permeability characteristics of the host rock to the exact conditions that existed before the ISR operations began. These changes in hydrologic properties in the host rock during extraction and restoration processes can have the net effect of altering flow paths within the deposit on a local level. Such largely unavoidable, incomplete restoration efforts may result in pockets of slowly leaching contaminants that may migrate out of the production zone over time." Proposed Rule at 4165.

NRDC Comment
NRDC largely concurs, but EPA needs to review the updated state of geochemistry science and its clear implications for fluid migration and uranium (and other metals and radionuclides) transport out of the production zone.

Specifically, the high abundance of Ca-U(VI)-CO_3 aqueous complexes in post-restoration ISL impacted aquifers alters conventional assumptions of uranium solution removal mechanisms. The occurrence of these species enhances uranium mobility in groundwater through the combination of decreased adsorption and relatively decreased abiotic and biotic reduction potential. Under such geochemical conditions, the ability for natural attenuation of uranium in ISL impacted ore zones remains largely unclear. Horizontal and vertical uranium fluid migrations from the ore zone at ISL sites have been documented during operations and post-restoration. Therefore, understanding the predominant aquifer hydro-biogeochemistry is crucial to developing strategies which will result in successful groundwater restoration minimizing the potential for off-site fluid migration.

Recently, a one dimensional transport model using an updated thermodynamic database including Ca-U(VI)-CO_3 complexes, observed uranium transport from an ISL ore zone was largely dependent on the availability of Fe(III) oxides and geochemical conditions in the aquifer.[53] Under certain model scenarios with relatively lower availability of Fe(III) oxides, the uranium 'plume' modeled closely to non-reactive transport, that is, adsorption had limited attenuating influence on dissolved uranium. The extent of changes in aquifer mineralogy between baseline and post-restoration conditions is unclear, as natural conditions are extremely complex with organics and other ions competing for surface sites.

Regardless, the aqueous speciation from mining and restoration activities suggests localized geochemistry post-restoration alters the potential uranium removal from solution mechanism by adsorption. The USGS used an updated geochemical model to simulate uranium transport from conditions similar to the proposed Dewey-Burdock ISL operation in South Dakota.[54] The authors demonstrated the recently updated thermodynamic database, based on the addition of Ca-UO2-CO3 and U(VI)-CO3 complexes, display the nonreactive transport of uranium in confined aquifers. The red line indicates the modeled uranium concentration using outdated thermodynamic database (WATEQ4F) without considering CA-UO2-CO3 complexes. The uranium concentrations predicted by the red line are substantially lower due to the assumption that Ca-UO2-CO3 complexes are not present in solution and adsorptive processes are removing uranium from solution.

The blue line shows the modeled uranium concentration using (WATEQ4F) which includes Ca-UO2-CO3 complexes. The uranium concentrations predicted by the blue line are substantially higher, because of the stability of Ca-UO2-CO3 complexes and their inability to react with iron oxides. Thus, under these geochemical conditions, uranium is highly mobile and does not adhere to conventional adsorptive mechanisms. The green line displays the concentration of uranium when adsorption was removed from the model (nonreactive transport).

[53] https://www.imwa.info/docs/imwa_2013/IMWA2013_Johnson_417.pdf
[54] https://www.imwa.info/docs/imwa_2013/IMWA2013_Johnson_417.pdf

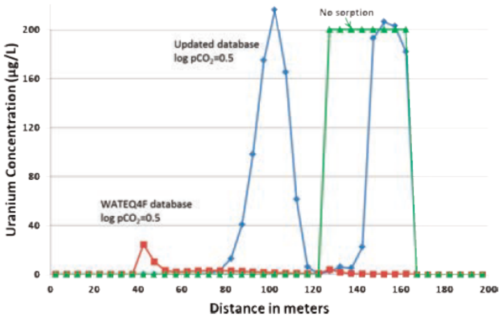


***Fig. 9** Uranium concentrations in groundwater at 25 years with 500 ppm Fe and CO2 in recovery zone of log pCO2 equal to 0.5 and downgradient calcite equal to 0.15 weight percent. Green line is with no sorption, blue line is with updated database and red line is with WATEQ4F database.*

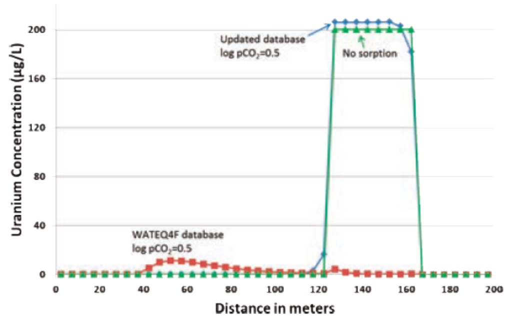


***Fig. 10** Uranium concentrations in groundwater at 25 years with 500 ppm Fe and CO2 in recovery zone of log pCO2 equal to 0.5 and infinite calcite. Green line is with no sorption, blue line is with updated database and red line is with WATEQ4F database.*

FIGURE 3: THEORETICAL REACTIVE TRANSPORT MODEL FROM AN ISR SITE DISPLAYING THE

These older models are problematic for accurately predicting the rate at which uranium moves through the groundwater. According to the USGS and the geochemical conditions modeled, within 25 years the front edge of the uranium plume was predicted to migrate roughly 165 m (See figure above). More importantly is the vast difference between model results for the updated thermodynamic database (Blue) and the outdated thermodynamic database (Red) suggesting that uranium transport from ISL sites is grossly underestimated and transport of high levels of uranium concentrations beyond the well field could reasonably occur within the span of a human life time or a matter of decades once hydraulic control is lost or absent.

This paper also serves as scientific evidence to support EPA's proposed 30 year monitoring requirement. This paper indicates that groundwater transport can take substantial time for contamination to migrate out of the production zone into non-exempt USDWs.

26. "In the absence of explicit regulatory language addressing ISR facilities, NRC and its Agreement States have used guidance and license conditions to implement many aspects of groundwater protection programs, including the selection of restoration goals and post-restoration monitoring. Based upon the information that we have reviewed, we believe an even more rigorous approach is warranted for (a) determining background groundwater concentrations, which are necessary to establish appropriate restoration goals, (b) establishing restoration goals, and (c) demonstrating the continued stability of groundwater after restoration. In addition, prolonged stability

monitoring is needed to provide the necessary level of confidence that groundwater quality will not degrade over time or promote contaminant migration in the future." Proposed Rule at 4165.

NRDC Comment

NRDC concurs with EPA's suggested rigorous approach for the reasons described above. The current regulatory regime does not require a meaningful determination of background groundwater concentrations, either prior to licensing or as part of the NEPA process, and what is required for background is as likely as not to "foul the nest" and ensure that inaccurate, less protective restoration goals are established. Next, the restoration goals that are set under the current regime– via an inadequate establishing of background groundwater concentrations, are essentially, under the NRC interpretation of its obligations, essentially a process whereby an ACL is the end result every time. *See* Comment #24. More rigorous standards requiring detailed restoration efforts are long overdue. And finally, requirements demonstrating stability of the groundwater after restoration are also long overdue. This approach on all of these matters, if rigorously applied, can bring some long needed coherency and accountability to ISL recovery.

27. "We recognize that it is difficult to reach a definitive conclusion regarding the frequency and extent to which longterm contamination has been or is likely to be a problem at ISR sites, because post-restoration stability monitoring typically occurs for a relatively short timeframe, a few years at most; nevertheless, we believe the available information supports our concerns in this matter. Because the lixiviant used during operations oxidizes not just the uranium but the entire production zone, the effect from adding reducing agents to restore the wellfield may just be temporary. If these reducing agents migrate out of the production zone, reoxidation of the uranium in the "restored" wellfield may occur. This is especially likely if the natural reducing agents originally present in the production zone (i.e., organic materials and iron sulfide minerals) were sufficiently depleted during ISR operations. To determine if remobilization of constituents precipitated by the restoration process will occur, longer-term monitoring of the site is warranted." Proposed Rule at 4165.

NRDC Comment

NRDC concurs that longer-term monitoring is warranted because of the paucity of information regarding the state of the numerous ISL fields that dot Wyoming, south Texas, and other locations. But to the extent we do have information on the state of the contaminated ISL sites, we know that water quality has been substantially degraded from pre-mining conditions. *See* JTI003.

28. "We are aware of the potential for geochemical conditions in the restored wellfield to alter over time. The ISR process can cause a loss of the chemically reducing potential in the ore zone. Over time, as oxidizing groundwater makes its way into the abandoned wellfield, re-oxidation could occur. Given the slow groundwater travel times in these deposits, it would take even longer time for the degraded water to make its way to water supply wells downgradient of the production zone aquifer and be detected there. Therefore, when we speak of long-term alteration of the groundwater, we imply timeframes of decades (or longer) rather than a few years." Proposed Rule at 4165.

NRDC Comment

NRDC has already provided a substantial amount of information and analysis in our previous comments on the need for long term monitoring and adequate excursion monitoring to protect USDWs due to significantly altered groundwater geochemistry from ISL mining. But we now turn the legacy uranium recovery sites to demonstrate that EPA should be concerned over the long term.

From research conducted on uranium contaminated water at Cold War era legacy UMTRCA sites, the scientific community has gained detailed information regarding the various site specific factors which influence uranium mobility. Once liberated into the groundwater, uranium stubbornly remains in the groundwater at concentrations that are well above the EPA's drinking water standards and hazardous to human health. The result has prompted a 40+ years of research and millions of dollars[55] to answer the question, why?

While this research has advanced our understanding of uranium geochemistry, especially in techniques for predicting the key environmental factors which impact uranium mobility in groundwater, much of the research suggests: 1) uranium is very difficult to remove through various restoration techniques groundwater and 2) it will remain elevated in the groundwater for a very long time. Researchers from Stanford studying uranium in shallow groundwater at Rifle, Co were quoted: "*However, studies have shown that groundwater contamination is unexpectantly long lived*" and the article states that site specific conditions predicted uranium will remain elevated in groundwater for "*at least another 100 years at several sites.*"[56]

Another quote from DOE: *"For years the attitude was science can fix anything," said April Gil, environmental team lead for the Department of Energy's Legacy Management. "You can just wait long enough, someone will come up with an*

[55] http://doesbr.org/PImeetings/2014/DLesmes-SBROverview5-6-14.pdf
[56] https://www6.slac.stanford.edu/news/2015-01-22-slac-scientists-search-new-ways-uranium-ore-processing-legacy.aspx

idea and we'll be able to put Mother Nature back to the natural state. And we've not been able to do that with uranium."[57]

Heavy reliance on geochemical transport models in the past has been largely unable to predict natural process which could remove uranium from groundwater. This is exemplified by a recent Uranium Mill Tailings Remedial Action (UMTRA) report by the Colorado Department of Public Health and Environment to the Colorado Legislature on September 2, 2014,[58] where the State noted:

> *For most of the sites, the groundwater modeling projects were conducted in the late 1990's so 10 -20 years of monitoring data is now available for comparison to modeling predictions. As expected, the modeling is somewhat imprecise; at most of the sites the degree of correlation between the actual concentrations and the model predictions is low. In most cases, natural flushing is not occurring at the rates predicted by the models. The department continues to work with DOE to determine if the models should be refined, if additional, more active strategies could be employed to enhance or increase natural flushing rates, or if more time is needed before new decisions are made. During fiscal year 2013-2014, the department reviewed documents submitted by DOE including: annual Verification Monitoring Reports, groundwater monitoring plans/data, and revised Groundwater Compliance Action Plans. The department continues to work with DOE to refine the methods used to monitor the institutional controls that are in place to preclude exposure to contaminated groundwater.*

Results from ISL mining and groundwater restoration attempts in the United States have confirmed much of what we have learned from legacy UMTRCA sites about stubbornly high uranium concentrations in groundwater. The troubling aspect about ISL mining, as opposed to legacy UMTRCA sites, is that the UMTRCA sites can remediate the source uranium ore at the surface to mitigate any further source of uranium from dissolving into the groundwater. This is not the case with ISL mining, as source ore remains in the aquifer long after groundwater restoration is complete. According to an ISL industry presentation,

---

57 http://www.fronterasdesk.org/content/9979/feds-try-clean-uranium-found-navajo-water

58 https://www.colorado.gov/pacific/sites/default/files/HM_umilltail-2013-2014-Uranium-Mill-Tailings-Management-Annual-Report.pdf at 6.

approximately 20-40% of uranium in a roll-front deposit is not recoverable.[59] However, the amount of this material which could contribute to elevated groundwater contamination is unknown, yet the EPA's proposed regulations would help identify and mitigate any unforeseen groundwater impacts through adequate, dynamic, and responsive long term groundwater monitoring.

Finally, in a paper published by NRC, the authors acknowledge that the ISL process does not occur under regulatory time frames for the bulk of the leached zone. *"This reversal of the ISR process does not naturally occur under regulatory time frames for the bulk of the leached ore zone. In fact, the persistence of uranium and other contaminants elevated during ISR operations, in spite of years of restoration effort, is a strong motivation for investigating more efficient and effective restoration approaches."*[60]

29. "There is only very limited information in the open literature (note 24) on the stability of a restored wellfield after ISR operations have ended. Typically, post-restoration monitoring concludes and license termination proceeds within a matter of several years after the restoration phase ends. The behavior of the restored wellfield in the long-term, i.e., decades or longer after the ISR operations end, has not been examined." Proposed Rule at 4165.

NRDC Comment

NRDC concurs with EPA's statement that behavior of the restored wellfield in longer term has not been examined. In fact, the paucity of data regarding the state of "restored" wellfields is remarkable considering the number of ISL sites that could be made available for examination, should either the licensing agency (the NRC) or the standard setting agency (EPA) require it. Our review is also consistent with one done by the USGS. In 2008 the agency conducted a study of groundwater restoration at ISL mines in Texas, which has a history of not requiring restoration of contaminated groundwater to premining conditions.[61] Additionally, Texas's recordkeeping is poor. The state's ISL restoration data are, according to USGS, "poorly organized and difficult to search," and much of the information is simply missing.[62] Where records were available to the USGS, they paint a bleak picture. Of 36 uranium mining sites authorized by Texas, 27 were

---

[59] http://csu-cvmbs.colostate.edu/Documents/erhs-hp-uranium-symposium-handouts-2008.pdf (Page: 34)
[60] (JTI060; p.44)
[61] Susan Hall, "Groundwater Restoration at Uranium In-Situ Recovery Mines, South Texas Coastal Plain," USGS, 2009, 6, pubs.usgs.gov/of/2009/1143/pdf/OF09-1143.pdf.
[62] USGS report at 7; *see also*, Southwest Groundwater Consulting LLC, "Report on Findings Related to the Restoration of Groundwater at In-Situ Uranium Mines in South Texas," September 28, 2008, 1 (stating data are "unorganized and difficult to navigate"), uraniuminfo.org/files/BK_Darling%20 Report_Complete_Sept_30.pdf.

actually developed, resulting in the construction of 77 well fields.[63] Baseline and amended restoration values are available for all 27 developed ISL sites. However, "final value" records are available for only 22 of the 77 well fields (representing just 13 of the 36 mines). *Id* at 21. And of those mines for which records were available, "no well field… returned every element to baseline." *Id*. at 21.

A typical example occurred at the Zamzow well field, where the baseline for uranium was set at 0.171 mg/L. *Id*. at 8. As we established earlier in our comments, we note that the term "baseline" here is a misnomer in that we do not necessarily trust that it reflects what we suspect is the real pre-mining baseline concentration of constituents in groundwater over the entirety of the aquifer. This suspicion is based on the USGS's reporting. As the USGS describes the process, "restoration values are initially set as baseline, with operators selecting the highest average concentration from either the production or mine area as their restoration goal." *Id*. at 7. This is also consistent with what NRC has asserted is lawful in the Ross Project, currently on appeal. As we noted when we wrote our review of ISL uranium recovery in 2012, we presume this means that instead of having to establish a baseline water quality for the whole project area and inclusive of a wide swath of the affected aquifer, the applicant can select a baseline from the immediate production area of the ore bearing portion of the aquifer, allowing for an inflated standard. And under this standard, the Texas Commission on Environmental Quality Underground Injection Control program later granted Zamzow an amended limit of 3.00 mg/L., 17.5 times as high as the pre-mining "baseline" value. *Id*. at 9. This is consistent with our experience of the nearly meaningless restoration requirements. And finally, to the point of EPA's original assertion that the behavior of the restored wellfield in the long-term, *i.e.*, decades or longer after the ISR operations end, has not been examined, NRDC has no data on the final value achieved at Zamzow and as far as we know, the only entity that might is the company that mined the site.

Restoration of uranium concentrations in groundwater to pre-mining baseline conditions at commercial ISR sites in the United States has been overwhelmingly unsuccessful (NRDC Table 1, Comment #29), and this history, as EPA notes, has not been examined.

We invite the EPA to examine the NRC's underlying datasets for these ISL operations.[64],[65],[66] Much of the data presented throughout this document for data

[63] Susan Hall, USGS, *Groundwater Restoration at Uranium In-Situ Recovery Mines, South Texas Coastal Plain*, Open-File Report 2009–1143 at 30 (2009), *available at* http://pubs.usgs.gov/of/2009/1143/pdf/OF09-1143.pdf.

[64] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/willow-creek/isr-wellfield-ground-water-quality-data.html

[65] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-ground-water-quality-data.html

analysis are found within these spreadsheets. We would also encourage EPA to explore these spreadsheets to examine the data that is not required by NRC. Specifically, the stability data for overlying, underlying, and perimeter wells is largely unknown. This must change. We've created a table below which compares basic statistics for baseline and stability groundwater uranium concentrations within the production zone.

Of the sites in table 1, Smith-Highland Ranch mine unit A, Crow Butte mine unit 1, and Irigaray mine units 1-9 have all been approved by the NRC for decommissioning, largely based on the implementation of an alternative concentration limits (ACLs) or comparison to a State UIC standard. Groundwater restoration results for Christensen Ranch mine units 2N-6 were approved by WDEQ, however the restoration approval package was denied by the NRC in 2012 JTI035. No further active restoration on any of the NRC denied Christensen Ranch mine units has been performed since 2005.[67]

Of note, Uranium One acquired the Christensen Ranch license from Cogema in 2009 and has restarted ISL operations in mine unit 5, and began operations in several new mine units without prior approval of the restoration report for mine units 2-6 (JTI055). It's unclear from EPA's rule, how the agency would proceed to handle a pending groundwater restoration approval of several mine units (MU2-MU6), while concurrent ISL operations are occurring at adjacent (MU7, MU8, MU9, MU10-A, MU10-B: JTI055) and within former mine units (MU 5-2: JTI056; p.2), and the potential environmental impacts to groundwater which would ensue in such a process. We address the timing and applicability of this rule *infra* at Comment #46, but to be clear at this juncture, we think EPA's final standards should have application at all ISL sites.

---

[66] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/crow-butte/isr-wellfield-ground-water-quality-data.html
[67] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML15105A138 (Page 6)

TABLE 1: COMPARISON OF BASELINE AND STABILITY URANIUM CONCENTRATIONS FOR WYOMING ISL SITES

		Baseline					Post Restoration Stability Monitoring					Percent Difference : Mean Stability and Mean Baseline
ISR Project	Mine Unit	Mean	St.Dev.	Min	Max	n	Mean	St.Dev.	Min	Max	n	
Smith Highland Ranch	A	0.041	0.023	0.01	0.0893	25	3.83	4.36	<0.1	11.5	45	9388%
Smith Highland Ranch	B	0.056	0.030	0.004	0.62	54	2.38	1.71	0.18	7.97	103	4248%
Crow Butte	1	0.065	0.081	0.0044	0.441	103	1.68	1.52	0.103	9.35	99	2079%
Irigaray	1	3.04	4.96	<0.0003	18.6	25	0.988	0.529	0.317	1.94	7	32%
Irigaray	2	0.130	0.124	0.02	0.464	16	3.78	1.61	0.972	6.87	12	2909%
Irigaray	3	0.020	0.017	<0.01	0.057	13	2.88	1.59	0.183	5.07	12	14462%
Irigaray	4	0.044	0.058	<0.01	0.232	26	2.42	1.78	4.19	0.726	8	5475%
Irigaray	5	0.016	0.019	<0.01	0.06	12	1.49	0.256	1.08	1.97	12	9451%
Irigaray	6	0.109	0.229	<0.01	1.0176	41	1.85	1.23	0.64	6.03	20	1698%
Irigaray	7	0.128	0.250	<0.01	1.577	89	1.46	0.935	0.064	3.03	24	1136%
Irigaray	8	0.041	0.046	<0.0003	0.178	29	1.59	0.159	1.41	1.9	8	3919%
Irigaray	9	0.065	0.066	<0.0003	0.254	32	1.83	0.835	0.84	3.5	22	2817%
Christensen Ranch	2N	0.041	0.034	<0.0003	0.164	32	0.693	0.966	0.013	4.46	32	1687%
Christensen Ranch	2	0.028	0.024	<0.0003	0.111	64	0.117	0.136	<0.0001	0.554	64	421%
Christensen Ranch	3	0.078	0.091	0.0013	0.557	88	0.142	0.321	0.0049	2.58	76	183%
Christensen Ranch	4	0.044	0.065	0.005	0.373	49	3.74	3.78	0.009	17.1	60	8565%
Christensen Ranch	5	0.026	0.025	0.006	0.22	100	2.26	3.74	0.0069	21.7	100	8718%
Christensen Ranch	6	0.013	0.015	<0.001	0.102	180	0.985	1.60	0.0015	9.28	188	7876%
Christensen Ranch	7	0.025	0.084	<0.0003	0.957	178	NA	NA	NA	NA	NA	

Uranium Concentrations in mg/L

Close examination of this history is merited. Groundwater restorations to baseline concentrations for certain water quality parameters, such as TDS, alkalinity, conductivity, and certain trace metals are occasionally achieved. Distinct from those water quality parameters, uranium is particularly of concern due to detrimental human health impacts. In the United States, the US EPA maximum concentration limit (MCL) for uranium in drinking water is 0.03 mg/L.[68] The world health organization (WHO) recommends uranium in drinking water less than 0.015 mg/L.[69] It is common for post-restoration stability concentrations to observe elevated levels of other trace metals, specifically arsenic and selenium[21], which have not been returned to baseline conditions and

---

[68] http://water.epa.gov/drink/contaminants/
[69] http://www.who.int/water_sanitation_health/publications/2012/background_uranium.pdf

exceed respective drinking water standards. Uranium exposure in drinking water has been found to damage kidney functions and is potentially carcinogenic.[70]

30. "We have assessed exposure scenarios and exposure pathways for potentially hazardous constituents (mainly radionuclides) and found that migration of contaminants within the ore-bearing aquifer and slow movement of contaminants into upper aquifers through discontinuities or disruptions (e.g., abandoned boreholes) and other possible failure scenarios (leaks, spills, etc.) have the potential to result in significant exposures to individuals outside the production areas." Proposed Rule at 4165.

NRDC Comment

NRDC concurs with EPA's statement that ISL recovery is can cause migration of contaminants within the ore-bearing aquifer and slow movement of contaminants into upper aquifers through discontinuities or disruptions (e.g., abandoned boreholes) and other possible failure scenarios (leaks, spills, etc.) have the potential to result in significant exposures to individuals outside the production areas. This is consistent with our work in the Ross Project where we found that the NRC failed to account for the potential for contaminant excursions in light of an inadequate assessment of aquifer confinement. Specifically, the NRC failed to sufficiently analyze the potential for and impacts associated with vertical fluid migration, and unidentified or unsealed drillholes between aquifer units. *See* JTI003 at 50.

This is directly relevant to the NRC's failure under its current interpretation of its regulatory responsibilities to analyze sufficiently the potential for and impacts associated with fluid migration associated with unplugged exploratory boreholes, including the adequacy of applicant's plans to mitigate possible borehole-related migration impacts by monitoring wellfields surrounding the boreholes and/or plugging the boreholes. Further, the early detection systems will be inadequate to capture potential for fluid migration and there is a failure to understand the aquifer geochemistry.

And to direct this comment to explicit concerns, there are several examples of vertical excursions in aquifers that were allegedly confined. The NRC staff has

[70] http://water.epa.gov/drink/contaminants/; http://www.who.int/water_sanitation_health/publications/2012/background_uranium.pdf; Kurttio, P., Auvinen, A., Salonen, L., Saha, H., Pekkanen, J., Mäkeläinen, I., ... & Komulainen, H. (2002). Renal effects of uranium in drinking water.*Environmental health perspectives*, *110*(4), 337.

determined previous ISL sites were confined aquifers and therefore would not allow for vertical fluid excursions. For example, the NRC stated in 1988, in the Environmental Assessment (EA) for Malapai Resources, Christensen Ranch In Situ Leach Satellite operation:

> *This data [aquifer testing characterizations] would theoretically indicate that ground-water flow would be contained by the aquitards and concentrated within the production zone. Further evidence of the confining characteristics associated with the units bounding the production zone has been evidence by the successful operation of the Christensen Ranch Research and Development operation.*

JTI044 at 26.

However analysis of the Christensen Ranch Restoration Technical Evaluation Report (TER), in 2008, shows that vertical excursions were an environmental issue. To quote,

> *First, excursions in the shallow aquifer in the vicinity of the southern area of MU-2 and the northern area of MU-3 indicate an impact greater than a single well.*

JTI035 at 11.

At this same site, NRC Staff included a comment about how the groundwater monitoring parameter values, called upper control limits (UCLs), in an overlying aquifer were set extremely high, not allowing them to detect a fluid migration:

> *The staff evaluated the setting and found spatial nexus between the wells that were, or have been reported, on excursion. The relations are: (1) well 2MW-89 is located between MU-2 South and MU-3, (2) three (2MW-68S, 3MW-46S, and 3MW-48S) of five wells in the shallow aquifer overlying the southernmost portion of MU-2 South and northernmost of MU-3 have been on excursion either during operations (3MW-48S and 3MW-46S), or during or subsequent to restoration (2MW-68S and 3MW-48S); and (3), established UCLs for two other wells in the shallow aquifer in that area (2MW-70S and 2MW-72S) are extremely high, limiting their potential to detect an excursion.*

JTI035 at 22.

Like many reported excursion events, the precise source of the vertical excursions was unclear. The NRC confirmed this uncertainty with the following statement:

> *Furthermore, the staff notes that the documentation by the licensee on the source of the excursions for wells in the overlying aquifer is*

> *inconclusive. For example, for the 1991 excursion at well 3MW-48S, the licensee noted that the excursion in the overlying aquifer could be through well completions, exploration boreholes or hydraulic communication between aquifers.*

JTI035 at 23.

NRC staff or other regulators have made the same erroneous assumption about confined aquifers at other sites. Indeed, "*aquifer testing procedures have had more limited success in determining the potential for vertical excursions*".[71] And Dr. Staub further supported this statement with an analysis of vertical excursions at Irigaray in the late 1970s:

> *WMC investigated possible reasons for the excursions in wells SM-1, SM-6, and SM-7 beginning in April, 1979. Geologic and hydrologic data were studied, including geophysical logs, core data, geologic cross sections, and pump test data. WMC (1980) [original document] could find no evidence of natural hydraulic connection between the Upper Irigaray Sandstone and the Coal Unit [72]." As a result of these diagnostic tests, WMC (1980) concluded that the most likely pathways for lixiviant migration to the Coal Unit in Production Units 4 and 5 during 1980 were unplugged exploration boreholes.*[73]

In other words, the standard methods for proving aquifer confinement could not predict nor explain vertical excursions.

And unidentified, unsealed abandoned boreholes could definitely affect aquifer confinement. The consensus for vertical excursions appears to be directly related to the number of abandoned, unidentified exploration drillholes, or failed well casings.[74] In other words, "*vertical excursions are directly related to the intensity of drilling activity*"[75] . Even where an aquifer was naturally confined, a drillhole or abandoned well creates preferential vertical flow paths. And many such drillholes create many pathways for those contaminants. *See* JTI003 at 53-55.

The last example of vertical contamination is from Smith Ranch Highland ISL operation, which has the largest financial assurance surety bond associated with groundwater restoration and site decommissioning. As of March 26, 2015, the surety for SRH was $212,252,900 or approximately a quarter of a billion dollars.

---

[71] http://pbadupws.nrc.gov/docs/ML1423/ML14237A635.pdf; (Page 32)
[72] http://pbadupws.nrc.gov/docs/ML1423/ML14237A635.pdf; Page A-28, 2nd paragraph
[73] http://pbadupws.nrc.gov/docs/ML1423/ML14237A635.pdf
[74] http://pbadupws.nrc.gov/docs/ML1423/ML14237A635.pdf; Page 30
[75] http://pbadupws.nrc.gov/docs/ML1423/ML14237A635.pdf; Page 48 in pdf, 1st paragraph

On top of the costs of groundwater restoration and site decommissioning, the NRC has incorporated the estimated costs to remediate shallow groundwater in non-exempt aquifers associated with ISL well casing failures into the surety bond. NRC's language, "*initial estimate*", suggests that the extent of contamination, and more importantly, the amount of money required to remediate the shallow groundwater is largely unknown.

"*The financial assurance update seeks to increase the financial assurance amount for Smith Ranch Highland to a total of $212,252,900 from the currently approved amount of $211,051,700. This update reflects changes in: operating status of mine units, plugging and abandonment costs for exploration and delineation borings; ground water restoration costs; adjustment of the timeframe to complete ground water restoration, and an initial estimate of the effort necessary to complete cleanup activities associated with the casing leak investigation.*"[76]

Finally, NRC's vertical excursion wells were unable to identify these issues as vertical excursion wells were installed in the sandstone unit directly above the ore zone aquifer. According to NRC's data spreadsheet from Smith Ranch Highland ISL, overlying vertical wells were installed at ~ 450 – 500 feet deep.[77] Recall however that much of the shallow groundwater contamination occurred <200 feet deep, limiting overlying excursion wells ability to adequately monitor for near surface groundwater contamination.

31. "We have assessed exposure scenarios and exposure pathways … have the potential to result in significant exposures to individuals outside the production areas." Proposed Rule at 4165.

NRDC Comment

Kingsville Dome observed the first known occurrence of private domestic well contamination as a result of ISL operations in the United States of America.[78] The Garcia wells (two wells 60 m apart) were located approximately 300 m downgradient of the Kingsville Dome mine. The Garcia wells uranium concentrations, in 1996, averaged roughly 180 µg/L. However, there is evidence

---

[76] See http://pbadupws.nrc.gov/docs/ML1502/ML15028A303.pdf and http://pbadupws.nrc.gov/docs/ML1502/ML15028A303.pdf.
See tabs 3 and 4: http://isl-uranium-recovery-impacts-nrdc.org/Smith_Highland/; Underlying report at ML13109A315; Underlying data report here: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14237A676
[77] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-ground-water-quality-data.html
[78] http://www.austingeosoc.org/AGS%20Bulletin%202012-13_Final.pdf (See Technical Paper: Pages 20 - 34)

to suggest groundwater quality from the Garcia wells met drinking water standards in 1988, as natural uranium measured 0.011 mg/L (11 µg/L)[79].

Public controversy erupted around 2005 when EPA well results indicated uranium concentrations above drinking water standards (0.181 mg/L), and prompted the Garcia family to discontinue the well and see a physician.[80] The uranium mining company involved in the ISR operations claimed natural uranium concentrations was elevated in the private wells and not caused by mining activities. Yet, samples in 2007 displayed uranium concentrations had increased again to 0.979 mg/L, or roughly 5.4x higher than the 'natural' values reported in 2005 and 89x higher than the values measured in 1988.[81] Further, by researching the geochemical trends, geology, and hydrology, an independent hydrologist concluded "The available data indicate that the likely source of the increased uranium concentrations in the Garcia well is PA-3. To the author's knowledge, this is the first time that contaminants in an off-site domestic well have been linked to ISL uranium mining in the United States of America."[82]

32. "These assessments suggest that a robust regulatory approach is advisable in order to prevent various failure scenarios that may occur during and after ISR operations, and to mitigate the potential adverse effects of any such failures. At 4165/66.

NRDC Comment

NRDC concurs that a robust regulatory approach is called for in terms of establishing background aquifer quality, setting restoration standards and requiring RCRA consistent 30 years of post-closure monitoring.

33. "In examining the technical literature pertaining to ISR operations, we have found that some modeling studies indicate that the uranium recovery operations can result in the development of relatively slower groundwater pathways through the wellfield, as well as the persistence of injected lixiviant within the production zone." Proposed Rule at 4166.

NRDC Comment

We refer to EPA to our discussion of uranium geochemistry in Comment #23. Further, EPA fails to reference studies supporting its point.

---

[79] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14237A649
[80] See *Uranium-tinged well puts family at risk*, August 01, 2005, Lubbock Avalanche Journal, , http://lubbockonline.com/stories/080105/nat_080105032.shtml#.VWZNovPD9Mt.
[81] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14237A649
[82] http://www.austingeosoc.org/AGS%20Bulletin%202012-13_Final.pdf

34. "Statistical analyses of well water chemistry data over a relatively short time (a year or two) alone does not in itself demonstrate that slow pathways are absent or that the groundwater will remain in a chemically reduced state over the long term. We believe that only a combination of longer stability monitoring and geochemical modeling using site-specific data can provide confidence that the ISR site poses no long-term hazards, and we are proposing such provisions today." Proposed Rule at 4166.

NRDC Comment

NRDC concurs with EPA's statement that a combination of longer stability monitoring and geochemical modeling using site-specific data are appropriate here, but we do not share EPA's confidence that the long term monitoring and modeling can necessarily instill confidence that the ISR process poses no long-term hazards. We think the first several years of monitoring and data collection after the implementation of the final rule will be illuminating as to the environmental effects and challenges from ISL recovery.

35. "The EPA document, ''Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities— Unified Guidance'' (2009), offers appropriate guidance on the level of confidence to be attained for demonstrating stability before regulatory decisions are made to terminate the operating license and release the wellfield for other uses. For RCRA monitoring results, where the intent is to ensure contaminants do not migrate out of the unit and into the uppermost aquifer, a confidence level of 95 percent is expected to support a regulatory action to terminate the permit. We believe an equivalent degree of confidence in the long-term stability of a restored ISR wellfield is appropriate." Proposed Rule at 4166.

NRDC Comment

NRDC concurs that a confidence level of 95 percent should be required to support a regulatory action to terminate the permit after 30 years. Such reliance on long established and protective RCRA standards is both appropriate and consistent with EPA's UMTRCA obligations.

36. EPA discusses the SAB, Proposed Rule at 4166-67.

NRDC Comment

The SAB was a useful stage in the promulgation of these draft standards. The findings of the ASLB Board speak for themselves, but beyond what was produced for the agency several years ago, the evidentiary material in these comments and in the Ross proceeding submitted by NRDC this day provide EPA ample support to finalize these standards with the clarifications and strengthening proposed by NRDC.

37. "EPA disagreed with the approach recommended by the Commission. EPA has always held the position that UMTRCA is the controlling legal authority for protection of groundwater and NRC is obligated to implement the 40 CFR part 192 standards to carry out that function at ISR sites. Reliance on the requirements of the UIC program alone would not adequately address groundwater protection at ISR facilities, given that the purpose of the UIC program is to prevent endangerment of underground sources of drinking water (USDWs), not to address restoration of groundwater. Moreover, if the groundwater is not considered a USDW, as is typically the case at ISR sites, it is not protected under the Safe Drinking Water Act (SDWA). Reliance on the UIC program alone would also likely lead to inconsistent levels of protection since states can implement more stringent requirements than the national UIC requirements and, as NRC discovered, states with authority to implement the UIC program may not have groundwater protection requirements consistent with those that have been applied to conventional mills. EPA decided to address groundwater protection at ISR facilities by amending its UMTRCA standards, as we are proposing to do today. The Commission subsequently decided that the NRC rulemaking should be deferred until EPA's revised standards are final." Proposed Rule at 4167.

NRDC Comment

NRDC concurs that the law is clear and EPA has strong foundation in law and fact that UMTRCA is the controlling legal authority for protection of groundwater and NRC is obligated to implement the 40 CFR part 192 standards to carry out that function at ISL sites. NRDC, in the Ross Project proceeding, unequivocally demonstrated that reliance on UIC programs alone fails to adequately address groundwater protection at ISR facilities. Specifically, the manner in which NRC has interpreted its restoration obligations consign the mined aquifer to a permanently polluted and degraded state. See our discussion at IV, where it is clear that NRC literally allows industry to treat the mined portion of the aquifer as a contaminated disposal area rather than as a place that must receive serious restoration effort.

Specifically, NRC *relies on the existence of an aquifer exemption for the mined aquifer as an allowance to profoundly contaminate that aquifer*. *See* Init. Dec. ¶4.106. As discussed previously, the Board attempted to justify Staff's clear position that, because an ACL will require future approval, the impacts of an ACL could never be considered "large" under NEPA. Init. Dec. ¶4.107 n.62. Indeed, the Board even went so far to acknowledge that the Staff's position "does, at least on its face, suggest a 'resolution by definition' approach." *Id*.

This position, upheld by the Board, that the "ACL can't just be any number – it can't be ridiculous," permits EPA's aquifer exemption to be parlayed into authorization for the exempted aquifer to become a toxic, hazardous disposal area and puts off to the future any examination of that result. EPA rules are needed to rectify this situation.

38. "It should be noted that UMTRCA requires us to establish protections consistent with the requirements of the Resource Conservation and Recovery Act." Proposed Rule at 4167.

NRDC Comment

See discussion in part V of these comments. NRDC concurs with EPA's plain reading of the law. *See, e.g.*, *Chevron, U.S.A., Inc. v. Natural Res. Def. Council, Inc.*, 467 U.S. 837, 842¬–43 (1984) ("If the intent of Congress is clear, that is the end of the matter; for the court, as well as the agency, must give effect to the unambiguously expressed intent of Congress.").

39. "Aquifer exemptions have been a source of confusion regarding the applicability of our UMTRCA standards, which we hope to clarify today in this rule. There are limited UIC requirements relating to restoration of the exempted portion of the aquifer; furthermore, an aquifer exemption does not eliminate the need to comply with the requirements of UMTRCA. The aquifer exemption provides relief from certain UIC requirements under the SDWA, thereby allowing injection into aquifers that would otherwise meet the definition of a USDW. The part 192 standards, however, are promulgated under a different statute. Therefore, an aquifer exemption under the SDWA does not relieve the licensee of the obligation to remediate environmental contamination resulting from activities regulated under UMTRCA. Today's proposal clarifies that EPA standards issued pursuant to UMTRCA do apply within the exempted portion of the aquifer." Proposed Rule at 4168.

NRDC Comment

NRDC agrees with EPA that there has been confusion regarding the application of aquifer exemptions and the necessary cleanup and restoration obligations that apply in that exempted aquifer. Specifically, industry has used the aquifer exemption process (and the NRC has allowed it) to disregard the environmental effects of ISL recovery on the exempted and mined aquifer.

And going to the confusion that EPA describes above, the restoration obligations, or lack thereof, have devolved over time. In the Draft Supplemental EIS for the Ross Project, Staff stated that aquifer restoration will "return the ground-water quality *in the production zone* (i.e. the exempted ore zone) to ground-water protection standards specified at 10

CFR Part 40, Appendix A."[83] (emphasis added). Staff went on to state that the "purpose of aquifer restoration is to restore the respective aquifer to its baseline conditions, as defined by post-licensing, pre-operational constituent concentrations, so as to ensure public health and safety." *Id.* In particular the DSEIS explained that specific groundwater restoration techniques will "return total dissolved solids (TDS) (a water quality parameter), trace-metal concentrations, and aquifer pH to the preoperational baseline values that would have been determined during the Applicant's post-licensing, pre-operational sampling and analysis program; these concentrations would be required by the NRC license (NRC, 2009)." *Id.* at 2-32 to 2-34.

Under pressure of litigation and scrutiny from NRDC and PRBRC, the NRC moved the goalposts and, by contrast, states:

> The purpose of aquifer restoration is to restore the ground-water quality in the wellfield to the ground-water-protection standards specified at 10 CFR Part 40, Appendix A, Criterion 5B(5), so as to ensure no hazard to human health or the environment. Water quality is measured at the *point of compliance that coincides with the established boundary of the exempted aquifer*. During uranium-recovery operation, the point-of-compliance wells would be those in the perimeter ring as well as those in the overlying-and underlying-aquifers, as required by the ground-water monitoring program. During aquifer restoration, however, *the group of point-of-compliance wells would be expanded to include the representative wells in the exempted aquifer*.

U.S. NRC, *Environmental Impact Statement for the Ross ISR Project in Crook County, Wyoming Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities: Final Report*, NUREG-1910 at 2-34 (April 2014), *available at* http://pbadupws.nrc.gov/docs/ML1405/ML14056A096.pdf (emphasis added) (citations omitted). Finally, the FSEIS further states:

> [S]hould Strata submit a request for application of an Alternate Concentration Limit (ACL) at a designated wellfield, the NRC staff will review the aquifer restoration activities to ensure that an appropriate level of effort has been performed. Based upon the NRC staff's review of the Applicant's commitments in the license application coupled with Condition No. 10.6 in the Draft Source and Byproduct Materials License pertaining to ground-water

[83] http://www.stratawyo.com/wp-content/uploads/2013/03/Ross-DSEIS-optimized-Complete.pdf; Page: 4-39

> restoration, the NRC staff is reasonably assured that the Applicant would restore ground water to the ground-water-protection standards of 10 CFR Part 40, Appendix A, Criterion 5B(5) and would provide the information for the NRC's determination required per 10 CFR Part 40, Appendix A, Criterion 5D.

Id. at 2-35 (citations omitted).

To sum up, the NRC, in the course of the Ross proceeding, went from requiring restoration to the relevant standards in the mined aquifer in the Draft EIS to requiring such restoration that water quality measured at the *point of compliance that coincides with the established boundary of the exempted aquifer*. Rather than grapple with the implications of Staff's position (that an aquifer exemption allows for substantial contamination – and that such contamination only matters at the edge of the mined aquifer) the Board stated that "validation of this staff approach lies in the fact that the ACL process requires another, separate agency judgment about what is an appropriate concentration level for the various hazardous constituents that will remain post-operation in the production aquifer and that this agency assessment is subject to an adjudicatory challenge." *Id.*

The current NRC interpretation of the rules permits aquifer exemptions to be parlayed into authorization for the exempted aquifer to become a toxic, hazardous disposal area and puts off to the future any examination of that result. EPA rules are needed to rectify this situation. Today's proposal clarifies that EPA standards issued pursuant to UMTRCA do apply within the exempted portion of the aquifer are both overdue and well-grounded in law.

C. EPA's "Summary of Today's Proposal"

40. "After groundwater restoration, the concentration of each listed constituent within the exempted aquifer of an ISR wellfield must remain at or below the most protective standards under the SDWA (40 CFR 141.61, 141.62, 141.66, 141.80 and 143.3), values from RCRA standards (40 CFR 264.94), or Table 1 to subpart A of part 192, except in cases where the measured preoperational background concentration 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 groundwater protection standards for additional constituents as necessary, consistent with site conditions. The new subpart also describes the process for requesting and approving alternate concentration limits (ACLs) after restoration has taken place." Proposed Rule at 4170

NRDC Comment

NRDC concurs with the proposed requirement that the values concentration of each listed constituent within the exempted aquifer of an ISR wellfield must remain at or below the most protective standards under the SDWA (40 CFR 141.61, 141.62, 141.66, 141.80 and 143.3), values from RCRA standards (40 CFR 264.94), or Table 1 to subpart A of part 192, except in cases where the measured preoperational background concentration is higher than the most stringent value in the applicable regulations. If thorough and transparent background assessments of groundwater quality are required, areas where water quality is greater or less optimal water quality can be readily identified and substantial future disputes could be avoided. As UMTRCA requires EPA to establish protections consistent with the requirements of the Resource Conservation and Recovery Act, requiring less would be an impermissible agency action. *See, e.g.*, *Chevron, U.S.A., Inc. v. Natural Res. Def. Council, Inc.*, 467 U.S. 837, 843 n.9 (1984) ("The judiciary is the final authority on issues of statutory construction and must reject administrative constructions which are contrary to clear congressional intent.").

D. EPA's "Rationale for Today's Proposal"

41. "Groundwater is one of our nation's most precious resources … Groundwater is also a valuable and dwindling resource, particularly in western states where most ISR activities are anticipated. EPA views protecting groundwater as a fundamental part of its mission. Particularly in cases where groundwater is directly threatened by an activity, as it is by the ISR technology, EPA believes it has a special duty to ensure that the authority of all applicable federal statutes (e.g., UMTRCA and the SDWA) are used to help protect the groundwater and that appropriate standards to protect public health, safety and the environment are developed and implemented." Proposed Rule at 4171.

NRDC Comment

NRDC concurs with EPA that groundwater is a valuable and dwindling resource, particularly in western states where ISL recovery will take place. *See also*, Att. 1, Economic Analysis of Groundwater.

42. "We anticipate the objection that the presence of uranium deposits typically results in groundwater of poor quality, and not a pristine source of drinking water. We recognize that this is often the case, and that the volume of water affected by the mineralized zone may be significant. We do not, however, see this as a reason to allow this groundwater to be further degraded. The increasing scarcity of groundwater is leading some communities to consider using sources of water that previously would have been considered non-potable, using advanced treatment to make it suitable for livestock or human consumption. Since such advanced treatment may not be economically feasible for some communities, it is all the more important to prevent, as

much as reasonably possible, additional degradation of the groundwater." Proposed Rule at 4171.

NRDC Comment

First, as we discussed extensively in comment #18, examination of the Story maps and histogram evidence from the Ross Project proceeding illustrates that (1) it is not accurate to state that the presence of uranium necessarily equals poor groundwater quality; and (2) it is perfectly clear that ISL activity degrades that groundwater quality, whatever its original state. As we noted *infra* at comment58, using NRC and industry data, Dr. Larson created a cumulative histogram for Christensen Ranch MU2-6, showing the average baseline and each post restoration phase sampling round concentrations. JTI003. at ¶58.

The majority of the average baseline groundwater samples were below the MCL for uranium of 0.03 mg/L (~65%); 28 % had slightly elevated uranium concentrations (0.03-0.09 mg/L) and only 8% were very elevated (0.09 – 3.0 mg/L), thus, we question EPA's basis for countenancing seriously the objection that the presence of uranium deposits typically results in groundwater of poor quality, and not a pristine source of drinking water. Until EPA and NRC have required substantially more transparent and rigorous background groundwater quality data, all available evidence supports NRDC's assertion that industry is simply wrong in its assertion of poor quality groundwater.

It also indisputable that Dr. Larson showed that after mining and restoration activities, the groundwater quality sample distribution at Willow Creek shows significant changes to these observed percentages. Roughly 13% of the post restoration samples were extremely contaminated (greater than 3.0 mg/L, which is greater than 100 times the EPA's maximum contaminant limit for safe drinking water standards for uranium), the 'very elevated' uranium concentrations increased from 8% (Baseline) to 54% (Post-restoration). And finally, the drinking water quality samples decreased from approximately 2/3 of all samples, to roughly 18% of the observed samples. *Id.* at ¶59.

Thus, as Dr. Larson demonstrated, the volume of water affected by the mineralized zone is significant (not "may be") and there is no reason to allow this groundwater to be further degraded. The increasing scarcity of groundwater, also well established and of enormous concern across the West, has precipitated a host of efforts to use advanced treatment to make groundwater suitable for livestock or human consumption. We agree with EPA that since such advanced treatment may not be economically feasible for some communities, it is all the more important to prevent, as much as reasonably possible, additional degradation of the groundwater. This is a straightforward application of the precautionary principle and should not be controversial. *See infra*, Comment #58.

43. "A guiding philosophy in radioactive waste management, as well as waste disposal in general, has been to avoid imposing burdens on future generations for clean-up efforts as a result of management approaches that are reasonably anticipated to result in pollution in the future. Adhering to the concept of sustainability, we should not knowingly impose undue burdens on future generations. Imposing performance requirements that avoid polluting resources that reasonably could be used in the future, therefore, is a more appropriate choice than imposing clean-up burdens on future generations. ISR facilities use significant volumes of water during both operations and restoration. We believe it is reasonable to make every effort to ensure that ISR activities leave groundwater in no worse condition than pre-ISR operational status." Proposed Rule at 4171.

NRDC Comment
NRDC concurs with EPA's philosophy that we must, if at all possible, avoid imposing burdens on future generations for clean-up efforts as a result of management approaches that are reasonably anticipated to result in pollution in the future. For all the reasons cited throughout our comments, we know for a fact that the ISL process degrades and contaminates scarce sources of groundwater in the West. The imposition of performance requirements such as thorough baseline water quality assessments, rigorous restoration standards, and long-term monitoring, we can avoid many of the contentious disputes of the last several years and it's a more appropriate choice than imposing clean-up burdens on future generations.[84]

The confusion regarding the use of aquifer exemptions has affected the issuance of decommissioning and the granting of ACLs. The situation ongoing between NRC Staff and Cameco provides a potential example of future situations which may arise when ISL mine operators apply for ACL's.

Smith Ranch Highland is located in Converse County, Wyoming and is the largest uranium ISR facility in the United States. The average baseline concentration of uranium in the groundwater in 1987 was ~0.056 mg/L and the average post-restoration concentration was 2.18 mg/L, demonstrating a 39x increase and uranium levels that are 73 times higher than the EPA's MCL for uranium (0.03

---

[84] *See, e.g.*, *Nuclear Energy Inst., Inc. v. EPA*, 373 F.3d 1251, 1284 (D.C. Cir. 2004) ("EPA adequately explained its reasons for adopting the ground-water standard: Not only did the agency conclude (unremarkably) that an ounce of prevention is worth a pound of cure, but it explained that adding a ground-water standard would produce other salutary effects . . ."); *Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst.*, 448 U.S. 607, 656 (1980) (Stevens, J., plurality opinion) ("the Agency is free to . . . risk[] error on the side of overprotection rather than underprotection").

mg/L).[85] Despite years of active restoration, groundwater restoration throughout the entire mine unit failed to restore the uranium concentrations to baseline conditions and groundwater in the area remains severely contaminated.[86],[87]

Despite severe ground water contamination, it appears that private water well drillers have continued to drill new water wells in the area. Documents submitted by the operator to the NRC in 2013 identify private domestic wells within 2 km that were not identified in the initial ACL application, likely due to an incomplete well database and difficulty assessing where private drinking water wells are located. The following discussion by NRC Staff demonstrates the agencies concern that these elevated concentrations could pose a risk to adjacent private well owners.

NRC Staff State:

> *The number, current condition, and use of all water wells within 2 kilometers (km) of MUB have not been satisfactorily established. In Section 1.2.5.4 of the application, surrounding land and water use, no description was provided of the current condition or use of water wells within 2 km of MUB. In an independent search of Wyoming State Engineer's Office (WSEO) records, NRC staff found numerous water wells within 2 km of MUB located in sections 29, 28, 21, 20, 16 and 17. Many were not identified in the application.*[88]

Further, regulatory confusion exists regarding what constitutes 'future use' through the SDWA and the state's groundwater use classification authority.

NRC Staff State:

> *Hazard assessment incorrectly states that aquifer exemption prohibits ground water use by humans now or in the future. NRC staff observes that the aquifer exemption only precludes use as public water supply under the Safe Drinking Water Act. NRC staff's understanding is that state classification of ground water as Class IV is not enforced to prevent future human ingestion.*" [89]

---

[85] Data taken from NRC spreadsheet: http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-ground-water-quality-data.html
[86] http://isl-uranium-recovery-impacts-nrdc.org/Smith_Highland/
[87] http://pbadupws.nrc.gov/docs/ML1401/ML14010A162.pdf
[88] http://pbadupws.nrc.gov/docs/ML1401/ML14010A162.pdf

[89] http://pbadupws.nrc.gov/docs/ML1401/ML14010A162.pdf

Finally, the NRC goes on to note the neither they, nor the WDEQ or WSEO (Wyoming State Engineers Office), notifies or informs any potential private well driller of an aquifer exemption, class of use, or change in class of use. Further, no authority exists to stop a private well owner to drill in or around an exempted aquifer, which is severely contaminated with uranium, other metals, and radionucleotides. Therefore, once an exempted aquifer has been contaminated, there are little or no options for regulatory agencies to stopping individuals from unknowingly drinking from the contaminated aquifer. Further, the language "in or around MUB (mine unit B)" suggests uncertainty with the spatial extent of contamination in the aquifer. In sum, NRC staff states:

> *No method to identify or protect the site from ground water use was offered to prevent private well use or installation in the ore zone aquifer or other aquifers in or around MUB. The NRC staff understands that neither WDEQ or WSEO monitors or notifies a potential well applicant of the aquifer exemption, current water quality or class of use of water at any time. Additionally, the NRC staff understands that WDEQ and WSEO also do not have any regulatory authority to stop a potential well applicant or user from accessing water in the aquifer exemption zone for any purpose. The NRC staff is aware of WDEQ's requirement of a deed notice for individual wellfields once all wells are plugged and abandoned, but the intent of this notification is unknown. NRC staff is unclear if the "deed notice" required by the State confers any protection such as identification of the exempted aquifer.*

It's important to note that Smith Ranch Highland mine unit B has not been approved for an ACL by the NRC staff. However, Smith Ranch Highland mine unit A has been approved for site decommissioning by the NRC staff, with similar groundwater quality concentrations that are currently being proposed for mine unit B. This is problematic because Smith Ranch MU-A and MU-B are vertically stacked in the same monitor well ring (i.e., at different depths within the aquifer).[90]

---

[90] *See* http://isl-uranium-recovery-impacts-nrdc.org/Smith_Highland/: Note, Wells MP1-MP5 were production wells for Smith Ranch Highland Mine Unit A used to approve an ACL (In 2004, uranium concentrations averaged ~ 4.32 mg/L). The remaining 'MP' wells comprise Smith Ranch Highland mine unit B, currently under consideration by NRC Staff for a proposed ACL of ~6.30 mg/L for uranium – or 210x times EPA's MCL. (http://pbadupws.nrc.gov/docs/ML1316/ML13168A522.pdf (Page 36 in pdf).

This discussion reflects the unfortunate situation where state and federal regulators have lost any meaningful measures to mitigate groundwater use once an aquifer has become contaminated by ISL operations. The situation at Smith Highland B is all too familiar, and parallels the issues with dealing with uranium contaminated groundwater from UMTRCA legacy sites.

Another example is the Western Nuclear – Split Rock Uranium Recovery Facility, a former uranium acid heap leach facility (not ISL), which operated in Wyoming from 1957 – 1981. During that time, seepage and infiltration of waste products in unlined tailings ponds caused significant uranium groundwater contamination.[91] The NRC allowed for the establishment of ACLs and institutional controls, "*purchasing land or establishing durable and enforceable restrictions on domestic groundwater use within the long-term surveillance boundary*."[92] In other words, once groundwater restorations fail and an ACLs are approved, institutional options are limited to buying adjacent land to prevent groundwater drillers to use the water source. To be clear, this is the definition of water sacrifice.

This degree to which the situation at Western Nuclear – Split Rock Uranium Recovery Facility has become a regulatory morass is illustrated in a recent NRC technical meeting summary on March 17, 2015 (~30 years after site decommissioning ended in ~1988):

> *WNI discussed the three types of property at the Split Rock site: property that is owned in fee simple by WNI that will transfer to the U.S Department of Energy (DOE); property owned by the Bureau of Land Management (BLM) to be withdrawn from public use and transferred to DOE; and, property for which WNI purchased the subsurface estate (Claytor property) or established restrictive covenants or easements (McIntosh and Walker/Petersen properties) as institutional controls to prevent access to the site and ground water. The McIntosh and Walker/Peterson properties will not transfer to DOE, however, these institutional controls run with the land can be enforced by WNI and its successor licensee, for example, DOE. WNI provided copies of all land ownership documents for the site. These documents are included in Enclosure 2.*
> *WNI also discussed the manner in which the institutional controls were enforceable by DOE. For the Claytor property, the subsurface estate (i.e., land deeper than 7 feet*

[91] http://www.nrc.gov/info-finder/decommissioning/uranium/is-western-nuclear-inc.pdf
[92] http://www.nrc.gov/info-finder/decommissioning/uranium/is-western-nuclear-inc.pdf

> *below the surface) will transfer to DOE, which will prevent persons from accessing ground water. DOE will own land adjacent to the Walker/Petersen property. DOE's ownership of the adjacent land, in combination with the restrictive covenant in the Walker/Peterson deed, provides DOE with greater ability to restrict access to the ground water on these properties. WNI also explained that the institutional controls extended beyond the long-term care boundary because the institutional controls were established before the final long-term care boundary was established.*[93]

While the situation at Split Rock deals with historical groundwater uranium impacts from non-ISL uranium milling operations, the institutional options parallel the current situation proposed at Smith Highland Ranch mine unit B, and likely many future ISL operations where production zone aquifers remain contaminated.

While EPA's proposed standards would substantially improve the situation, EPA should require and disclose that institutional controls will be required adjacent to the operations and likely required at the termination of licensing. Much of this information could be supplied by requiring ALL groundwater wells used for establishing pre-licensing baseline values must be sampled during the 30 year stability monitoring. Requiring mandatory stability monitoring at all wells will improve decisions regarding institutional controls, hydrogeochemical modeling and calibration, and environmental and social accountability. This level of monitoring will ultimately shift the burden away from taxpayers and state and federal regulatory agencies who are tasked with dealing with, and paying for, these groundwater issues long after the ISL pumps are shut off.

44. "Specifically, we are proposing provisions that will result in long lasting protection of surrounding aquifers. The provisions specify how to determine preoperational background conditions that will be used to set appropriate restoration goals, applicable standards and alternate concentration limits. We are also proposing specifications for long-term groundwater stability monitoring and a corrective action program that is triggered if excursions/exceedances do occur. We view these as the key elements in ensuring that ISR sites do not become a source of continuing or widespread contamination after the ISR operation is terminated. Sufficient data must be collected to characterize the conditions existing within and outside the proposed production zone to set appropriate groundwater protection standards (i.e., restoration goals) that account for the variability in geochemistry frequently encountered in mineralized regions. Subsequent to the end of uranium production, the regulator must ensure that alternate

---

[93] http://pbadupws.nrc.gov/docs/ML1509/ML15091A527.pdf

standards are approved only after restoration has been attempted and it is clearly demonstrated that the initial groundwater protection standard(s) cannot be achieved, or once achieved, cannot be maintained. Such approval should take place only after the operator has made reasonable and satisfactory efforts to achieve and maintain the initial standard(s) and fully considered a number of factors. Whether the initial goals are met or alternate concentration limits are approved, conditions must be shown to be stable and groundwater quality must not degrade over time.…" Proposed Rule at 4171-72.

NRDC Comment
NRDC concurs with EPA's general outline for the reach of the standards. Specifying how to determine preoperational background conditions that will be used to set protective restoration goals is key after years of contentious disputes over the characterization of baseline water quality and the accuracy and success of efforts in restoring contaminated ISL mining sites. Specifying strict, protective restoration goals as well as more protective processes for arriving at alternate concentration limits will be welcome after decades of simply allowing industry to essentially set the terms of its restoration results. Further, EPA's proposal to set specifications for long-term groundwater stability monitoring and a corrective action program when excursions/exceedances do occur is necessary and overdue. Consistent with the agency, we view these as the key elements in ensuring that ISR sites will not become (even more than they already are) a source of continuing or widespread contamination after the ISR operation is terminated. We partition on comments on this section to address each item in turn.

a. Determining preoperational background conditions.
Use of the word baseline is typically applied to describe water quality parameters at a site prior to the start of any activity that might disturb or contaminate the aquifer. It should also be noted that baseline and background are interchangeable terms when describing water quality in an aquifer that has not been disturbed by human actions. EPA (2009), in Part I, Section 5.1, p. 5-1 of their Unified Guidance (http://www.epa.gov/wastes/hazard/correctiveaction/resources/guidance/sitechar/gwstats/) notes that:

> "The most important quality of background is that it reflects the historical conditions unaffected by the activities it is designed to be compared to." JTI006 at 5-1.

Generally, it is important to have a precise knowledge of the baseline water quality for two purposes. First, for remediation efforts aimed at restoring a contaminated aquifer – for example, at a hazardous waste site undergoing cleanup under the Resource Conservation & Recovery Act (RCRA) or the Comprehensive Environmental Compensation and Liabilities Act (CERCLA) – one wants to know the baseline as a guide for appropriate restoration. In other words, the aim is to restore to baseline in order to completely remediate or remove the contamination from the aquifer. Second, one needs a precise knowledge of baseline groundwater quality to understand the environmental impacts at a site where natural resource extraction activities are going to take place, such as will transpire with an ISL uranium facility. In either case, it's important for basic environmental decision making and assessment to understand as best one can the condition of the aquifer before any anthropogenic activity that might cause contamination takes place; so proper monitoring levels can be established to protect the groundwater.

Again, as noted by EPA (2009) in Part I, Section 5.1, p. 5-1 of the Unified Guidance:

> "High quality background data is the single most important key to a successful statistical groundwater monitoring program, especially for detection monitoring." JTI006 at 5-1.

And as Dr. Abitz wrote for NRDC in the Ross Project proceeding, for RCRA and CERCLA sites, baseline or background values (as stated above, the terms are used interchangeably) are established for the groundwater horizons by installing wells, under approved procedures and valid statistical sampling plans, *upgradient* of known or suspected contamination zones.

Further, the EPA (2009) Unified Guidance (JTI006 at Part I, Section 5.2.1, p. 5-3) recommends a minimum of 8 to 10 independent samples be collected before running statistical tests. Independent samples are defined as representative samples drawn from randomly located wells in the study area that have been properly installed and developed; and the submission of the samples to a certified and licensed laboratory for analysis of water quality parameters. After receipt and validation of the analytical results, proper scientific and statistical methods are used to establish valid baseline values. The appropriate protocols are outlined in the EPA (2009) Unified Guidance (JTI006) and references therein.

Precisely the same rigorous and statistically valid protocols for the collection of baseline water quality are appropriate and necessary for a site where the issue is not cleaning up existing contamination, but establishing the quality of the natural groundwater environment prior to the execution of a project that risks degrading water quality. *In summary, it is necessary to collect data from a sufficient number of wells, over a sufficient time period, under conditions that ensure representative samples are collected to produce valid data to establish the baseline values that will be used to monitor the change in groundwater conditions.*

There are fundamental scientific reasons why the baseline water quality effort must occur. First, to collect samples that represent the true geochemical conditions in the aquifer, the baseline must be established using groundwater samples obtained from an aquifer that has not been contaminated by extensive exploration drilling; with monitoring wells randomly located and installed and developed through the entire sand thickness with non-oxidizing drilling fluids and gases to ensure that the uranium ore zone remains under reducing conditions. Second, the concept of developing post-license baseline for each wellfield prior to its construction allows contamination of the aquifer prior to establishing baseline and this is completely contrary to the scientific definition of baseline and the noted criteria in 10 C.F.R. 40 Appendix A. In addition, because the groundwater quality data necessary to establish baselines were not collected, nor were baselines established, prior to completing the NEPA process and issuing the license, the FSEIS fails to disclose to the agency and the public the actual baseline conditions on the site, a critical element to any meaningful evaluation of the project's likely environmental impacts. Thus, for example, engaging in these activities in pristine groundwater may understandably raise more concerns than if the groundwater is already highly degraded.

Importantly, as noted under the NRC's approved approach in Ross Project, baselines are not actually evaluated and established before the decision to go ahead. But in addition, under the approach approved by the NRC, groundwater quality in the proposed mining area will be characterized improperly, resulting in the establishment of very high excursion values and restoration standards that will preclude the use of the water for future domestic, livestock or agriculture needs. Thus, under the NRC process, industry will be allowed to contaminate the aquifer prior to baseline development through extensive exploration programs that use oxidizing fluids during drilling operations and the installation of hundreds of wells with rotary-drill techniques that use oxidizing fluids and air-lifting techniques during well development - processes which oxidize the uranium ore and alter true baseline water quality values ((JTI009) Abitz, 2010 https://gsa.confex.com/gsa/2010AM/finalprogram/abstract_174957.htm; (JTI010) Laaksoharju et al., 2008). Moreover, industry will be allowed to screen the wells used for the collection of baseline samples only through the narrow ore zone within the aquifer. This ISL industry practice is scientifically and statistically invalid because it allows a company to collect baseline samples from the most disturbed and contaminated portion of the aquifer by screening only through the ore zone that has been oxidized by improper drilling and development techniques.

The rest of our concerns, especially with specific instances where baseline was improperly or inadequately characterized, how baseline could be accurately portrayed and other matters, are detailed in Dr. Abitz's testimony, JTI001. In short, the NRC's current process fails to identify proper statistical analysis and methods to establish valid baseline values and excursion limits and EPA's new provisions, if they require collection of baseline water quality samples from the delineated mining area prior to the completion of exploration activities as contamination can result from exploration drilling; collect samples throughout entire area and length of time the project operates; and identifies monitor-well ring as the proper location to collect samples for development of excursion parameters (and uranium should be one of the excursion indicators).

b. Allowing for alternate concentration limits.
NRDC has significant concerns with EPA's continued allowance for ACLs. EPA suggests that alternate standards could be approved only after restoration has been attempted and it is clearly demonstrated that the initial groundwater protection standard(s) cannot be achieved, or once achieved, cannot be maintained. While EPA's proposal strengthens restoration requirements, specifically with 13 constituents of concern, it leaves in place the option to forgo these restoration requirements if industry is having difficult restoring the aquifer. We call on EPA to disallow ACLs, or at the very least to tighten the requirements and conditions of approval to limit the circumstances in which they apply. To date, no aquifer has been completely restored to baseline conditions at an ISL facility and the industry has relied upon ACLs as a means to stop restoration activities premature of aquifer clean-up. We believe ACLs should be the exception to the rule – not the exception that proves that rule.

45. "This demonstration can include geochemical modeling to confirm the persistence of stability of the groundwater chemistry. Geochemical modeling can provide a defensible demonstration of an aquifer's natural capacity to maintain stability, which statistics alone cannot provide. Although the selection and application of geochemical models will be on a site specific basis, geochemical models that have been used to predict the fate and transport of uranium at ISR facilities include PHT3D, PHREEQC, and PHAST." Proposed Rule at 4171.

NRDC comment

NRDC agrees that geochemical models can be useful to evaluate groundwater transport. However, NRDC cautions EPA that models are not heavily relied upon, especially without confirmatory data to calibrate and confirm the model's accuracy. That is, requirements of groundwater samples taken at the perimeter wells would aid in the understanding of preferential flow paths. Updated thermodynamic databases and reactive transport models are recommended. Simplistic models are not appropriate for these highly complex systems.

NRDC also recommends EPA be cautions and not over-rely on the ISL operator's models ability to predict groundwater geochemical transport within a couple years when decades of experience at legacy sites have shown models accuracy to be low. While new models, supported by update scientific information and calibration data from monitoring wells, may provide better insight into these mechanisms and improve long term mitigation actions to safeguard USDWs, all of this data must be established with proper scientific protocols and quality controls.

Heavy reliance on geochemical transport models in the past has been largely unable to predict natural processes which assumed would remove uranium from groundwater. This is illustrated by a recent Uranium Mill Tailings Remedial Action (UMTRA) report by the Colorado Department of Public Health and Environment to the Colorado Legislature on September 2, 2014,[94] where the state notes:

> *For most of the sites, the groundwater modeling projects were conducted in the late 1990's so 10 -20 years of monitoring data is now available for comparison to modeling predictions. As expected, the modeling is somewhat imprecise; at most of the sites the <u>degree of correlation between the actual concentrations and the model predictions is low</u>. In most cases, natural flushing is not occurring at the rates predicted by the models. The department continues to work with DOE to determine if the models should be refined, if additional, more active strategies could be employed to enhance or increase natural flushing rates, or if more time is needed before new decisions are made. During fiscal year 2013-2014, the department reviewed documents submitted by DOE including: annual Verification Monitoring Reports, groundwater monitoring plans/data, and revised Groundwater Compliance Action Plans. The department continues to work with DOE to refine the methods used to monitor the institutional controls that are in place to preclude exposure to contaminated groundwater.*

46. "Upon promulgation, licensees currently in restoration, stability monitoring or longterm monitoring at a given wellfield at a licensed facility would continue to be held to the standard(s) in place at the time of licensing for those given wellfield(s), unless the regulatory agency determines otherwise. Operating wellfields, new wellfields and expansions of wellfields would be required to meet the newly promulgated standards. This option would make the groundwater protection standards under the proposed subpart consistent with all relevant current and future standards under SDWA and RCRA. We believe that this approach will more effectively keep the groundwater protection standards current with the Agency's policies while providing for regulatory

[94] https://www.colorado.gov/pacific/sites/default/files/HM_umilltail-2013-2014-Uranium-Mill-Tailings-Management-Annual-Report.pdf at 6.

certainty. The standards in the existing portion of 40 CFR part 192 are outdated for arsenic and uranium, both of which have had new MCLs established since the year 2000. Today's proposal would update the standards for arsenic and uranium as they apply to ISR facilities. Should the Agency propose to update its MCLs or RCRA standards at some point in the future, stakeholders will have the opportunity to comment on the potential impacts to ISR activities." Proposed Rule at 4172.

NRDC Comments

EPA's approach here that licensees currently in restoration, stability monitoring or longterm monitoring at a given wellfield at a licensed facility would continue to be held to the standard(s) in place at the time of licensing for those given wellfield(s), unless the regulatory agency determines otherwise, is lacking and potentially creates a loophole that allows for substantial non-compliance with the new regulations.

For instance, ISL sites have a long history of moving in and out of "restoration" or active mining, depending on market prices and a number of other factors. Online resources illustrate this phased manner of operation. See, for example, the WISE Uranium Site and its *Issues at Operating Uranium Mines and Mills - Wyoming, USA*:

> **COGEMA to restart Christensen Ranch in-situ leach uranium mine**
>
> With yellowcake cruising at $43 per pound on increased demand and dwindling worldwide stockpiles, COGEMA Mining Co. is now under strict orders from its international parent companies to get the Christensen Ranch in-situ leach uranium mine back on full production. "It's just a matter of a few -- six months -- before we're back in operation," said Mark Owens, who serves as manager of technical support for Mills-based COGEMA....
>
> "Due to an increase in the uranium market price, mining is anticipated to resume at Christensen Ranch during year 2007. The final decision to resume mining is still pending the Joint Participation's approval, hopefully by the end of 2006 (The Joint Participation includes COGEMA Mining, Inc. as the operator and 71% owner, Malapai Resources Company as 29% owner; decisions must be unanimous).
>
> Assuming that mining is resumed at Christensen Ranch, the first step will be continued well installation in the remainder of Mine Unit 7 (MU7). MU7 was about 50% installed when operations were shut down in year 2000. Drilling and well installation would resume in March 2007, followed by the initiation of surface construction (connection of wells to module buildings, connection to existing main trunkline to the plant). If

schedules are adhered to, and all necessary approvals obtained, lixiviant injection could resume in MU7 as early as September 2007." (COGEMA Mining, Inc., ANNUAL REPORT, PERMIT TO MINE NO. 478, August 19, 2005 through August 18, 2006)

On April 3, 2007, COGEMA Mining, Inc. requested an amendment of the license for its Irigaray/Christensen Ranch facilities to revert to an operating (uranium production) status from the current restoration and decommissioning status.

Christensen Ranch ISL project shut down

"Christensen Ranch Project

All chemical addition to the mining wellfields ceased during February, 2000. Uranium recovery was slowly phased out during the following months, with the last operating wellfield shut down on June 23, 2000. Groundwater restoration is ongoing with active restoration in two out of five Mine Units (#3 and 5). Residual uranium is removed at a rate of approximately 50 lbs. per day during the Christensen restoration process. Projected completion of groundwater restoration is in 2005, with final decommissioning and surface reclamation to follow."

Text and excerpts found online at http://www.wise-uranium.org/umopuswy.html (emphasis added) (accessed May 22, 2015).

We concur with EPA and see no reason why all operating mines, expansions of current operations, and newly proposed mines should have any objection to compliance with the newly promulgated rules. But EPA should make it precisely clear that wellfields that revert back to operating status from restoration/decommissioning status immediately enter the purview of the updated 40 CFR 192, Subpart F rules and prior restoration and monitoring requirements are no longer operable. Further, even though we think the mines currently undergoing restoration and decommissioning should have to comply with the new rules, especially those seeking an ACL or about to seek an ACL, EPA should explicitly apply the new monitoring requirements to the ISL sites undergoing restoration. It is our current understanding that there are a number of sites currently undergoing active restoration (Crow Butte and Smith Ranch-Highland), and failure to include a detailed analysis of the environmental impacts of such a significant amount of scarce western water would an oversight and would not be consistent with the rule.

47. "We are also considering the alternative approach of placing a static table of restoration goals in the new subpart F. The table would list the 13 required constituents for which groundwater protection standards must be met, and also provide the specific

numeric concentration value associated with each constituent. If this option is promulgated in the final rule, the standards would not automatically update with any future changes to standards under the SDWA or RCRA but would remain static." Proposed Rule at 4172.

NRDC Comment

NRDC urges EPA not follow this suggested alternative approach. Standard setting is an onerous and expensive process for the agency and can take years or even decades to accomplish. Indeed, these revisions to 40 CFR 192 have been in the works for years despite the pressing need of environmental harms at ISL sites. If the SDWA or RCRA are updated, it's to protect public health and the environment and there will inevitably be an opportunity to comment at the time. Moreover it provides certainty to industry and the public on the consistency of standards. Ensuring consistency between the statutes and the relative levels of protectiveness of the complementary regulatory schemes should be a high priority, especially after NRDC's demonstration of the evidence of the disparate and substantially relaxed treatment the ISL industry under the current regulatory regime. In short, please automatically update the 40 CFR 192 standards when other, relevant and related standards are updated.

48. "In order for an ISR operation to proceed, a UIC permit is required and typically, an aquifer exemption is needed as well. The exemption effectively removes from the protection of the SDWA, an aquifer or portion of an aquifer that would otherwise meet the definition of an underground source of drinking water. The wellfield used by the ISR operation to extract the uranium deposit may constitute only a portion of the overall exempted area. As noted in Section II.E.1 of this document, there is no similar exemption for the aquifer from the requirements of UMTRCA, nor does UMTRCA contemplate such a concept. We emphasize again that the SDWA-based aquifer exemption does not relieve the operator of an ISR facility of the obligation to remediate environmental contamination resulting from activities regulated under UMTRCA, both within and outside the exempted portion of the aquifer." Proposed Rule at 4173.

NRDC Comment

NRDC concurs with EPA's reading of the statutory obligations and and incorporates comment #39 to ensure that the confusion regarding the application of aquifer exemptions and the necessary cleanup and restoration obligations that apply in that exempted aquifer are clarified. Specifically, industry has used the aquifer exemption process (and the NRC has allowed it) to disregard the environmental effects of ISL recovery on the exempted and mined aquifer, and EPA is correct to emphasize again that the SDWA-based aquifer exemption does not relieve the operator of an ISR facility of the obligation to remediate environmental contamination resulting from activities regulated under UMTRCA, both within and outside the exempted portion of the aquifer.

49. "Today we propose to clarify the requirements for requesting and granting ACLs in the production zone, after restoration efforts have taken place … There is evidence that relaxed restoration standards have been granted in Agreement States, and some instances where ACLs have been identified and approved by the regulator before restoration efforts have been initiated and/or completed. We believe these situations can result in insufficient protection of groundwater; in particular, we believe it only is appropriate to establish restoration goals based on a thorough characterization of the preoperational environment and not to approve ACLs unless it has proven impracticable to achieve or maintain the initial restoration goals or return to background conditions after restoration." Proposed Rule at 4173.

NRDC Comment

NRDC remains concerned about the use of ACLs for restoration goals, as by their very nature the granting of an ACL is the acknowledgement of a failure to restore contaminated water to its original, pre-mining state. While EPA's proposal strengthens restoration requirements from their current dismal state, specifically with 13 constituents of concern, it leaves in place the option to forgo these restoration requirements if industry is having difficulty restoring the aquifer. If EPA sees fit to not simply disallow ACLs – as allowance for such is consistent with the stated mission to protect groundwater sources for the long term – then we urge tightening of the requirements and conditions of approval to limit the circumstances in which they apply. Specifically, along with the requirements suggested at 192(c)(2) and (3), EPA should include a requirement that license amendment applications for an ACL should not be considered until the applicant has attempted for at least 5 years of effort to restore the contaminated aquifer. As EPA is well aware through our conclusive demonstration, no aquifer has been restored to baseline conditions at an ISL facility and the industry has relied upon ACLs as a means to stop restoration activities premature of aquifer clean-up. We believe ACLs should be the exception to the rule – not the exception that proves that rule.

50. "These factors specify that, if ACLs are deemed necessary or appropriate after all best practicable restoration activities have been completed, they must not pose a substantial present or potential hazard to human health or the environment." Proposed Rule at 4173. The accompanying footnote states: "[A] licensee may propose alternatives to specific requirements adopted and enforced by the Commission under this chapter. Such alternative proposals may take into account local or regional conditions, including geology, topography, hydrology and meteorology. The Commission may treat such alternatives as satisfying Commission requirements if the Commission determines that such alternatives will achieve a level of stabilization and containment of the sites

concerned, and a level of protection for public health, safety, and the environment from radiological and nonradiological hazards associated with such sites, which is equivalent to, to the extent practicable, or more stringent than the level which would be achieved by standards and requirements adopted and enforced by the Commission for the same purpose and any final standards promulgated by the Administrator of the Environmental Protection Agency in accordance with section 2022 of this title. 42 U.S.C. 2114(c), emphasis added." *Id.*

NRDC Comment

Consistent with the preceding comment, NRDC remains concerned about the use of ACLs for restoration goals, as by their very nature the granting of an ACL is the acknowledgement of a failure to restore contaminated water to its original, pre-mining state. EPA has proposed to leave in place the option to forgo restoration to background requirements if industry is having difficulty restoring the aquifer and certain criteria are met. If EPA sees fit to not simply disallow ACLs – as allowance for such is consistent with the stated mission to protect groundwater sources for the long term – then we concur with EPA that any ACL must, after a license amendment, a NEPA process, and opportunity for a hearing, achieve a level of stabilization and containment, and a level of protection for public health, safety, and the environment from radiological and nonradiological hazards which is equivalent to or more stringent than the level which would be achieved by standards and requirements adopted and enforced by the Commission for the same purpose and any final standards promulgated by the Administrator of the Environmental Protection Agency in accordance with section 2022 of this title. The "to the extent practicable" language in EPA's text above should be deleted. The environmental protection should be at least as stringent as EPA's standards.

51. "ACLs should, where practicable, be established at concentration levels that represent a cumulative excess lifetime risk to an average individual at no greater than 10^-4 (one chance in ten thousand)." Proposed Rule at 4173.

NRDC Comment

We urge EPA to clarify the basis for why one chance in ten thousand is comparable with RCRA or SDWA standards.

52. "The regulatory agency may face situations in which the operator will request ACLs. If after extensive effort the operator determines that the initial restoration goals for one or more constituents cannot be achieved as required in the license, the operator may request and the regulatory agency may approve the levels that have been achieved as provisional ACLs and determine that restoration is complete (i.e., that there is no statistically significant trend in the concentrations of regulated species over time). Then,

the operator may request and the regulatory agency may approve final ACLs if post-restoration monitoring indicates three consecutive years of stability at the 95 percent confidence level. The approval of final ACLs, however, would not by itself satisfy the requirements for long-term stability monitoring." Proposed Rule at 4173.

NRDC Comment

NRDC concurs with the concept that approval of final ACLs would not by itself satisfy the requirements for long-term stability monitoring. And as we stated above, only after at least 5 years of restoration effort, a license amendment application, a NEPA process, and opportunity for a hearing, and after the agency has shown levels of stabilization, containment, protection of public health and the environment that are equivalent to or more stringent than any final standards promulgated by the Administrator of the Environmental Protection Agency in accordance with section 2022 of this title, then the agency may consider an ACL for a particular ISL mine.

53. "An additional consideration is the potential effect of ACLs on groundwater downgradient of the wellfield. The granting of ACLs could be viewed as inconsistent with the purpose of groundwater restoration, which is to prevent contamination of groundwater resources beyond the production zone. However, NRC has in recent years adopted an approach defining the "point of exposure" as the aquifer exemption boundary, where the initial restoration goal must be met. We propose to adopt a similar approach today." The accompanying footnote states that EPA guidance on application of ACLs under RCRA makes a similar distinction between the "point of compliance" and the "point of exposure," emphasizing that in granting ACLs, (1) groundwater plumes should not increase in size or concentration above allowable health or environmental exposure levels; (2) increased property holdings should not be used to allow a greater ACL; and (3) ACLs should not be established so as to contaminate off-site groundwater above allowable health or environmental exposure levels. See http://www.epa.gov/wastes/hazard/correctiveaction/resources/guidance/gw/acl.htm." Proposed Rule at 4173-74.

NRDC Comment

EPA contradicts its own rule in this statement when it writes "…the purpose of groundwater restoration, which is to prevent contamination of groundwater resources beyond the production zone." Earlier, EPA properly stated

> "[w]e anticipate the objection that the presence of uranium deposits typically results in groundwater of poor quality, and not a pristine source of drinking water. We recognize that this is often the case, and that the volume of water affected by the mineralized zone may be significant. *We do not, however, see this as a reason to allow this groundwater to be further degraded.* The increasing scarcity of groundwater is leading some communities to consider using sources of water that previously would

> have been considered non-potable, using advanced treatment to make it suitable for livestock or human consumption. Since such advanced treatment may not be economically feasible for some communities, it is all the more important to prevent, as much as reasonably possible, additional degradation of the groundwater." At 4171 (emphasis added) (see comment #42 where this is excerpt is discussed in detail).

Indeed, the granting of ACLs *is* inconsistent with the purpose of groundwater restoration as it an acknowledgement of restoration failure. And combined with the abuse of the aquifer exemption process, the granting of ACLs in exempted aquifers has allowed the ISL industry to avoid costly restoration efforts for decades and left a legacy of contaminated, permanently sacrificed western water. We have demonstrated as much in the attachments to our comments today. *See* JTI003.

EPA risks perpetuating this state of affairs if it allows the NRC to continue adopting the aquifer exemption boundary as the spot where initial restoration goals must be met. Rather, the point of compliance for any ACL should be, as DOE has done at its legacy UMTRCA sites, well by well.[95] Or at most, the ACL should not exceed the monitoring wells that ring each mine unit, not the entirety of an exempted aquifer. To allow such continues NRC's approach, which is plain in its disregard for the environmental harms of ISL recovery. As the Board in the Ross proceeding noted, "an ACL is a foreseeable consequence of ISR mining, the environmental impacts of which seemingly should be addressed at the earliest realistic opportunity using relevant historical information."

The NRC, put simply, relies on the existence of an aquifer exemption for the mined aquifer as an allowance to profoundly contaminate that aquifer. *See* Init. Dec. ¶4.106. Further, according to NRC, the impacts of an ACL within the mined and exempted aquifer could never be considered "large." In making this conclusion, NRC Staff relied on the fact that the aquifer is not currently used as a drinking water source and received an aquifer exemption from EPA. Transcript of Proceedings at 549, Strata Energy Inc. (Ross In Situ Recovery Uranium Project), No. 40-9091-MLA (2014) (ASLBP No. 12-915-01-MLA-BD01), *available at* http://pbadupws.nrc.gov/docs/ML1428/ML14280A199.pdf (Testimony of Ms. Moore: "if the groundwater is exempted as a source of drinking water, then that is something that goes into our determination of what would destabilize that resource.").

EPA should rethink this paragraph and ensure that the point of compliance for any ACL is well by well, or at most the monitoring ring, not the entire exempted aquifer.

[95] http://adamswebsearch2.nrc.gov/webSearch2/view?AccessionNumber=ML13241A105, at 1.

54 "For the ISR method, there are a number of "backgrounds" involved, the most important being the preoperational background within the portion of the ore zone where uranium production will take place (i.e., the production zone). Knowledge of this background is necessary to design the leaching process and set restoration goals—two very important steps in the ISR operation…. "Background" groundwater composition data are also needed in portions of the aquifer surrounding the wellfield and in overlying and underlying aquifers that may have communication with the uranium orebearing aquifer to determine whether excursions occur during operations, and to determine whether seasonal variations in groundwater chemistry are occurring in shallow aquifers….NRC requires establishment of background at uranium recovery sites in its regulations at 10 CFR part 40, Appendix A, Criterion 7." Proposed Rule at 4174.

NRDC Comment

As we explained earlier in our comments, the NRC's process for collecting baseline groundwater quality data (for the Ross Project and for all other sites) is not consistent with the standard, scientifically defensible approach to setting baseline water quality as EPA describes it ("The condition of groundwater, including the radiological and non-radiological constituent concentrations, in the exempted aquifer, adjacent aquifers, and in both overlying and underlying aquifers, prior to the beginning of ISR operations. The background groundwater constituent concentrations in the production zone prior to the beginning of ISR operations is commonly referred to by the industry and regulatory bodies as the 'baseline.'"). The NRC provides that two separate efforts to evaluate baseline water quality data will occur, one pre-license and another post-license, <u>with almost all the data collection and the actual setting of baselines only post-license, after the regulatory decision is made</u>.

This arbitrary splitting of the baseline collection process until after the licensing and environmental evaluation of the facility is problematic as it allows industry and agency to (1) collect samples that do not represent the true geochemical conditions in the aquifer as the aquifer has been contaminated by extensive exploration drilling; and (2) avoid following the scientific protocols for developing baseline; and (3) deprive the public and the decision-maker any meaningful evaluation of the project's likely environmental impacts.

Under NRC's currently sanctioned approach, baselines are not actually evaluated and established before the decision to go ahead with the any ISL project has been made. Allowing baseline data collection post-license is problematic because it means that the groundwater quality will not be characterized properly, resulting in the establishment of high excursion values and restoration standards that will preclude the use of the water for future domestic, livestock or agriculture needs. *Id.* Our presentations in the Ross Project explained in detail the specific flaws in how industry presented baseline. See Abitz Declaration, JTI001 for:

- the statistical justification for the location of the six monitoring-well clusters is lacking because the wells were not randomly located,
- the ore zone was oxidized when the wells were installed, and a true baseline cannot be developed after hundreds to thousands of wells are drilled in the well fields. *Id.* at¶¶27-29,
- and the screen lengths for the existing monitor wells were inappropriate. *Id.* at ¶¶22-26.
- biasing groundwater samples to high values for uranium. *Id.*
- extensive evidence of how the industry will collect baseline samples from the most disturbed and contaminated portion of the aquifer that has been oxidized by above described techniques, resulting in more misleading results. *Id.* at ¶¶18, 25-31. In his testimony, Dr. Abitz relates his experience with the Kingsville Dome site in Texas, which suffered from similar technical flaws. *Id.* at ¶¶30-31.

In contrast to what NRC found acceptable, NRDC's expert presented how baseline groundwater can be accurately portrayed via scientifically defensible methods. *Id.* at ¶¶33-36. This presentation generally comports with what EPA proposes to require in its draft rule, but certain clarifications are necessary to ensure a technically accurate assessment of baseline groundwater quality is set. *See* Abitz Declaration (JTI001).

55. "Today's proposal includes provisions to ensure that operators adequately characterize preoperational conditions inside and outside the wellfield. This characterization is necessary to establish appropriately protective restoration goals that are representative of the wellfield, accounting for natural variability. There is evidence that regulators and operators have at times used high-end values to represent the overall wellfield or have used a generalized "class-of-use" for the groundwater to set restoration goals." Proposed Rule at 4174.

NRDC Comment

Industry and regulators have used high, improperly established baseline groundwater concentrations to mask restoration contamination impacts. We explain the process at the Irigaray ISL site in Wyoming. There, at the Mine Unit (MU) MU1 operation, mean baseline uranium concentrations were reported as 3.09 mg/L and the maximum baseline uranium concentration was 18.6 mg/L. Post-restoration stability mean 0.988 mg/L, suggesting a 68% decrease due to restoration. Groundwater restoration at Irigaray was accepted by the NRC Staff on September 20, 2006.[96] The following discussion demonstrates how the decommissioning of the Irigaray site was based on inaccurate and biased baseline information.

[96] http://pbadupws.nrc.gov/docs/ML0625/ML062570175.pdf

Table 1 (Comment #29) shows the restoration results for average baseline and average stability uranium concentrations for Irigaray mine units 1-9. Note the high average baseline uranium concentration observed at Irigaray mine unit 1 of 3.04 mg/L. This concentration represents an example where ISR mine operators fail to set an accurate baseline and the problems that emerge from that failure.

The uranium concentrations for well AP-4 in Mine Unit 1 display clear evidence of extensive mechanical and chemical disturbance of the aquifer prior to establishing the baseline uranium value. The 'baseline' average was 13.57 mg/L at a particular well, while the post-mining (not post-restoration) uranium concentration was 4.95 mg/L.[97] The average uranium 'baseline' concentration at well AP-4 is thermodynamically unfeasible for natural groundwater in contact with uranium ore (uraninite) under reducing conditions,[98] and this conclusion is substantiated by the observation that the 'baseline' value is almost 2.5 times higher than the post-mining concentration.

Further investigation of operational history at Irigaray demonstrates how the invalid 'baseline' was affected by previous mining and exploratory activities. Research and development activities occurred at the Irigaray site in 1975. Specifically, the 517 site and Well Field A (now Mine Unit 1) began pilot operations in 1975.[99] Well Field A was ISR mined using an ammonium bicarbonate lixiviant from 1975 to mid-1976. *Id*. According to the 1978 draft environmental impact statement for commercial operations at Irigaray, baseline sample data for Well Field A were taken "from 11/9/76 to 2/24/77".[100] Therefore, the 'baseline' data used for Well Field A were collected immediately after pilot-scale research and development mining activities. The implications of approving high 'baseline' values in an ISR license are discussed in detail in the following paragraphs.

In the restoration summary report, the results are described as acceptable due to a best-effort approach: "*COGEMA has expended significant effort to restore the groundwater quality within the Irigaray wellfield to baseline conditions. At the completion of the Irigaray groundwater restoration program, the ore zone aquifer has been restored to standards consistent with Best Practicable Technology (BPT) and NRC's ALARA (As Low As Reasonably Achievable) principle. In this regard, over 840 million gallons of water were processed over*

---

[97] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/willow-creek/isr-wellfield-ground-water-quality-data.html.

[98] Langmuir, D., 1978. *Uranium solution-mineral equilibria at low temperatures with applications to sedimentary ore deposits*. *Geochimica et Cosmochimica Acta*, *42*(6), 547-569.
[99] Staub, W., Hinkle, N., Williams, R., Anastasi, F., Osiensky, J., & Rogness, D. (1986). An Analysis of Excursions at Selected In Situ Uranium Mines in Wyoming and Texas. Prepared for: Division of Waste Management. Office of Nuclear Material Safety and Safeguards., NUREGCR396. (**PAGE: A-6**)

[100] http://pbadupws.nrc.gov/docs/ML0910/ML091050582.pdf

an 11.5-year period, and an average of 13.7 pore volumes were treated for the entire wellfield. Treatment volumes exceeded the amounts included in the approved treatment plan."[101]

Furthermore, 'baseline' values from Irigaray (Mine Unit 1), which were elevated from research and development mining activities prior to 1976, were presented as the minimum, maximum, and average for wellfields 1-9. This was not coincidental; as industry and Wyoming state regulators agreed to present the entire Irigaray restoration results for all wellfields as a single combined wellfield.

"*In May 2003, COGEMA Mining, Inc. met with WDEQ personnel to discuss the restoration status of the Irigaray and Christensen Ranch projects. At that time, it was proposed and agreed that one restoration report package (this report [referring to the original document]) would be submitted for the Irigaray project. This would entail combining all baseline data from Units 1 through 9 together for a larger database. It was recognized that the data from Units 1 through 9 are more meaningful when combined as a whole than if presented as several individual packages. Thus, a combined baseline data set was compiled from the ore zone baseline wells located in Production Units 1 through 9 and is included in Table 4-2 [original document].*"[102]

Subsequently, the table of restoration data was presented to the NRC, which includes the elevated 'baseline' uranium concentrations that were determined after research and development activities.[103] All wellfields (1-9) were combined for a composite average 'baseline' and compared to restoration composite concentrations, as determined by COGEMA and WDEQ. However, 8 of the 9 wellfields (Wellfields 2 through 9) have significantly lower average 'baseline' uranium concentrations (range 0.020 – 0.130 mg/L) (table 1) relative to the composite average 'baseline' value of 0.52 mg/L. Thus, the elevated 'baseline' samples collected after research and development activities at Wellfield 1 skewed the composite wellfield average uranium concentration to a higher average value of 0.52 mg/L.

Consequently, the new restoration table gives the illusion that the overall post-restoration average uranium concentrations increased from only 0.52 to 1.83 mg/L (352% increase). However, when compared to the initial average 'baseline' uranium concentrations for each wellfield, the average post-restoration uranium increases for Wellfields 2 through 9 are substantially higher. This post-operations

---

[101] http://pbadupws.nrc.gov/docs/ML0532/ML053270037.pdf; Page 86 in pdf

[102] http://pbadupws.nrc.gov/docs/ML0532/ML053270037.pdf; Page 71

[103] http://pbadupws.nrc.gov/docs/ML0624/ML062400363.pdf

and post-restoration manipulation of data essentially masks the reality of the groundwater impacts of the mining operations.

The post-stabilization data were submitted and accepted by the WDEQ in 2005. Recall, this occurred after the 2003 meeting between COGEMA and WDEQ to discuss combining the restoration results for all wellfields. WDEQ approved a restoration and concluded further attenuation monitoring was not required and wells withing the wellfield may be abandoned.[104] The NRC Staff agreed with WDEQ's assessment, and approved groundwater restoration on September 20, 2006.[105]

Similarly, at ISL sites in Texas, documentation of "supplemental baseline" samples have been used to give the appearance that pre-mining groundwater quality is worse than reality. The following discussion demonstrates using very high 'supplemental baseline' groundwater samples which have been impacted by mining operations.

> *The initial samples collected from the baseline wells listed in table 7.1-1 were collected before mining began in the PAA. URI has also collected initial samples from 'supplementary baseline wells' after mining began in each PAA. URI defines supplementary baseline wells as: Every extraction well in a new wellfield that gets a pump and is sampled before injection begins152. URI claims that many of the samples from the supplementary wells represent baseline (pre-mining) conditions153. However, some supplementary baseline wells may have been affected by mining solutions from injection wells operating in the PAA. Therefore, the claim that the initial samples from the supplementary wells represent baseline conditions should be closely examined. Look, for example, at URI's claim regarding the initial sample from supplementary well 5525 in PAA-2. <u>According to URI this well had a baseline uranium concentration of 102 mg/L154. This is the highest pre-mining uranium concentration found in any KVD Mine well155. However, the initial sample was collected months after production began in PAA-2156. In addition there were five injection wells within a hundred feet of well 5525</u>. These wells began injecting between 11 and 40 days before well 5525 was sampled. The injection rates ranged from 1400 to 218,800 gallons per day.*[106]

---

104 http://pbadupws.nrc.gov/docs/ML0608/ML060830597.pdf.

105 http://pbadupws.nrc.gov/docs/ML0625/ML062570175.pdf.

106 http://www.uraniuminfo.org/files/RiceStudyJuly2006.pdf (at 52 pdf)

The examples from Irigaray and Texas ISL operations demonstrate that previous mining activities and operations have biased 'baseline' values to high concentrations. Based on the events which transpired between industry and state regulators during the Irigaray groundwater restoration approval process described above, it is our concern that the creation of artificially elevated uranium baseline concentrations can mask restoration failures and the actual groundwater impacts. This example further highlights why establishing a scientifically defense baseline is crucial to adequately determining groundwater impacts.

56. "The physical act of penetrating the aquifer to install the well can cause localized changes in constituent concentrations or chemical parameters, which can lead to a misleading picture of background conditions. This can, in turn, result in selection of artificially high restoration goals. It is important that the operator allow a sufficient interval of time between well installation and sampling to allow localized disturbances to dissipate and ensure that background conditions are accurately characterized." Proposed Rule at 4174.

NRDC Comment

NRDC concurs with EPA's statement. *See supra*, Comment #16.

57. "The successful protection of groundwater at ISR sites begins with the selection of rigorous and appropriate restoration goals. As described in Section III.B of this preamble, restoration goals will be established as the preoperational background concentration or as a specified regulatory level for that constituent, whichever is higher. This is more complicated than it might seem. ISR wellfields may cover areas of 10 acres or more, and the presence of mineralized zones often means that there is significant variability within the proposed production area. As a result, background concentrations in one area of the wellfield may diverge significantly from those measured elsewhere. The question, then, is whether it is possible to select a single level that is representative of the entire wellfield and, if not, how measurements should be evaluated." Proposed Rule at 4174-75.

NRDC Comment

NRDC states that after thorough characterization, restoration goals that are developed for the ISL site should be for either individual wells, or at most, groups of wells that shall not exceed 1 acre. The concept of a singular restoration goal for a wellfield that can comprise several acres and significant volumes of western water is inappropriate as it will almost certainly fail to account for the variability of the underground water. And with the certainty of ACLs being necessary, restoration of a wellfield to a singular goal would also consign significant portions of the aquifer to insufficient levels of restoration, thus permanently sacrificing them as potential future sources of water.

58. "Because of the site-specific nature of this variability, we are proposing today that operators utilize background measurements from across the wellfield, combined with appropriate statistical techniques, to determine restoration goals. As appropriate, goals may be developed for individual wells, groups of wells, or the entire wellfield. The point(s) of compliance for restoration will be determined by the operator and regulatory agency after a thorough technical evaluation of the operator's geophysical investigation." Proposed Rule at 4175.

NRDC Comment

After thorough characterization, restoration goals that are developed for the ISL site should be for either individual wells, or at most, groups of wells that shall not exceed 1 acre. Further, the point(s) of compliance for restoration will be determined by the operator and regulatory agency after a thorough technical evaluation of the operator's geophysical investigation should at the farthest be the monitoring wells for either individual wells or groups of wells that shall not exceed 1 acre.

The results from stability monitoring[107] trends in groundwater at Christensen Ranch suggest that uranium trends for any given well are highly localized. An unpredictable array of increasing, decreasing, or erratic trends in uranium concentrations were observed for any given well. Therefore, examining all baseline and post-restoration groundwater samples, cumulatively, provides an approach to understanding the change in sample distribution from the baseline conditions, as well as investigating the effectiveness of the groundwater restoration.

We provided a cumulative histogram for groundwater data from the Christensen Ranch ISL site (Figure 4; Comment #57). The results demonstrate that approximately 65% of all baseline samples (n = 433) were <0.03 mg/L, 31% were between 0.03 – 0.12 mg/L, and 4% were between 0.12 - 0.60 mg/L (Figure 4A). After ISL and groundwater operations at Christensen Ranch, the groundwater quality distribution observed substantially elevated uranium concentrations. Post-Restoration stability sampling round 4 results observed approximately 18% of the groundwater sample were <0.03 mg/L, 47% between 0.03-0.60 mg/L, and two new categories of elevated uranium concentrations were observed which

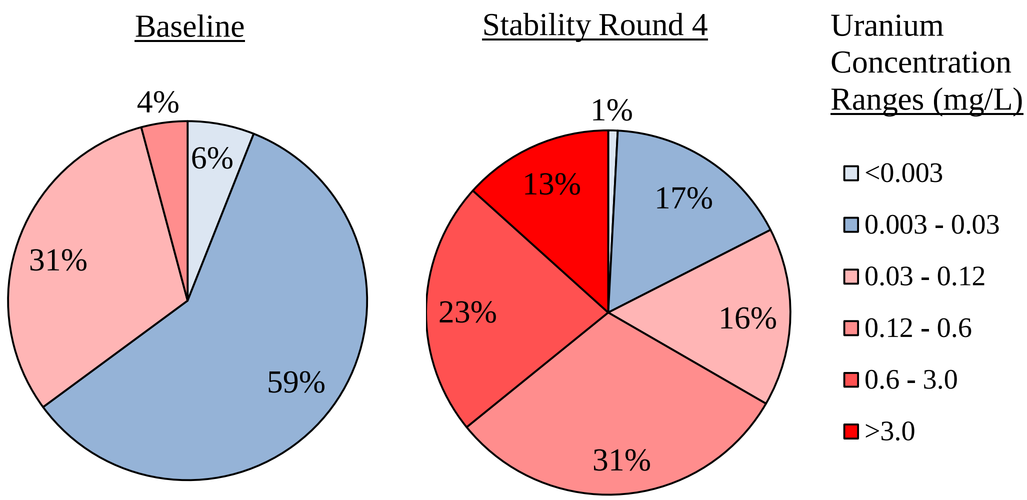
[107] Stability monitoring is the final restoration step and includes sampling of certain wells four times in a 12 month period to confirm that water quality concentrations are not statistically increasing (i.e. concentrations are 'stable').

observed 23% of samples were 0.6 - 3.0 mg/L, and 13% were >3.0 mg/L (Figure 4A).

Examining the groundwater quality distribution cumulatively for each post-restoration round circumvents issues with sporadic data trends for a given well (Figure 4B). The data suggests that the groundwater quality distribution across all mine unit samples display little appreciable temporal changes. If natural attenuation mechanisms were substantially decreasing the net uranium mass in groundwater, the post-restoration data distribution trends would progressively trend back to the baseline distribution. However, there's little difference between round 1-4 stability sampling distributions, suggesting the net groundwater uranium mass is staying relatively constant throughout the stability sampling period.

Further, this suggests that uranium trends observed at a given well may not be sufficient assessing uranium trends for an entire mine unit and a more holistic data analysis approach is required to adequately assess the restoration effectiveness. Further, this data supports EPA's proposed 30 year monitoring requirement, as the NRC's current 12 month shows little indication to how groundwater uranium concentrations are trending.

A



B

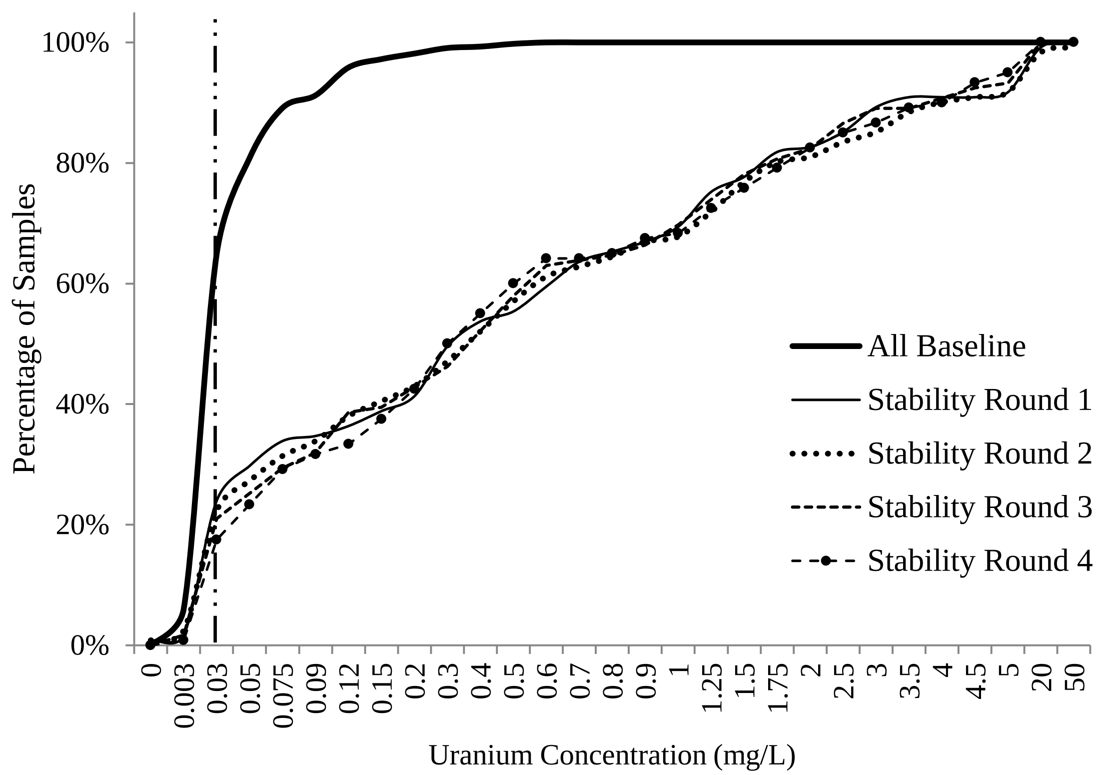


FIGURE 4: A) COMPARISON OF BASELINE AND STABILITY MONITORING FOR CHRISTENSEN RANCH MINE UNITS 2-6 AND B) CUMULATIVE HISTOGRAM OF GROUNDWATER URANIUM CONCENTRATIONS

59. "During the operational and restoration phases at an ISR wellfield, it is possible that lixiviant or byproduct fluids can escape the capture zones of the extraction wells and move toward the production zone. The placement of the injection and extraction wells, combined with their relative pumping rates, are designed to prevent such movement, but heterogeneities in the aquifer characteristics and difficulties in maintaining perfect performance of the wellfield can lead to lateral excursions as well as excursions into overlying and underlying aquifers (i.e., vertical excursions). Detecting these excursions is a prime focus of regulatory attention." Proposed Rule at 4175.

NRDC Comment

NRDC agrees that detecting excursions should be a prime focus of regulatory attention. In our Ross Project presentation, we demonstrated an extensive history of horizontal and vertical excursions at Willow Creek/Christensen Ranch ISL site. *See* JTI003 at 52, 53 and 56 (presenting several examples of vertical excursions in aquifers that were allegedly confined). And NRDC further notes that during the operational and restoration phases at an ISL site, it is a near certainty that lixiviant or byproduct fluids will escape the capture zones of the extraction wells and move toward the production zone. Lateral and vertical excursions are near certainties given experience at other sites and it is difficult to assess whether an aquifer is truly confined. The lack of well plugging endemic to the industry and the failure to identify hundreds of abandoned wells (*see* Abitz, JTI051), merits EPA's prime focus.

60. "Today we are proposing to adopt a definition of "excursion" consistent with that used by NRC in license conditions. Under this definition, an excursion is identified when two or more indicator parameters are measured at levels exceeding their upper control limits (essentially, background levels) at perimeter monitoring wells or in monitoring wells in overlying or underlying aquifers. Thus, an excursion can take place vertically between aquifers as well as horizontally within the aquifer from which uranium is being extracted.... We believe this approach to defining excursions (i.e., relying on two indicator parameters) is reasonable and has been shown to be workable in practice. We are also proposing to define "upper control limit" consistent with NRC's use of the term. The "upper control limit" defines the level of an indicator parameter that, when two of which are detected at excursion monitoring wells, would signal an excursion; as described above, indicator parameters will typically be identified in the facility license. It is important that the upper control limits be set appropriately to account for both background levels of indicator parameters and the characteristics of the lixiviant. We agree with NRC that "upper control limit concentrations of the chosen excursion indicators should be set high enough that false positives (false alarms from natural fluctuations in water chemistry) are not a frequent problem, but not so high that significant groundwater quality degradation could occur by the time an excursion is identified.... We have heard some concerns that upper control limits have in some cases been established at levels that would be unlikely to be exceeded under any conditions,

thereby eliminating the possibility of detecting an excursion altogether. Such a situation must be avoided." Proposed Rule at 4175-76.

NRDC Comment

The next several pages, from 110 to 126, comprise NRDC's Comment #60 on the current inadequacies of the excursion monitoring system accepted by EPA in this rule. We urge the agency to reject this incorporation of current practice as the current system is based on poor scientific assumptions that are inconsistent with the literature within the past decade and data collected at ISL sites. For example, the NRC largely bases its decision *not* to use uranium as an excursion indicator on one sentence, which does not carry any scientific citation:

> *Uranium is not considered a good excursion indicator because, although it is mobilized by in situ leaching, it may be retarded by reducing conditions in the aquifer.*

U.S. NRC, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications: Final Report*, NUREG-1569 at 5-41 (June 2003), *available at* http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf.

It's commonly asserted by NRC and industry that reducing conditions downgradient will 'precipitate' or 'retard' uranium transport offsite. This statement is an oversimplification of the current scientific understanding of uranium mobility in groundwater presented throughout these comments.

To quote from peer reviewed literature,[108] "*the development of a low redox potential is NOT a sufficient condition for the reduction of U(VI) and many other radionuclides*." In other words, much more geochemical data is required to predict uranium contaminant transport in the subsurface. Many times, regulatory agencies assume 'reducing conditions' will 'precipitate' uranium and therefore, uranium will not migrate off-site. These assumptions defy the current scientific understanding of contaminate fate and transport. Further, ample theoretical and analytical evidence which directly question the validity of these assumptions will be presented throughout this document.

The presence of high uranium concentrations remaining under reducing conditions is consistent with scientific literature, which has found decreased abiotic reduction of uranium due to the presence of bicarbonate[109] and the kinetics of sulfide promoted uranyl-carbonate complexes are substantially lower than uranyl-hydroxide complexes.[110] Moreover, biotic reduction of uranium in the presence of calcium has observed decreased uranium reduction rates

---

[108] Suzuki, Y., & Suko, T. (2006). Geomicrobiological factors that control uranium mobility in the environment: Update on recent advances in the bioremediation of uranium-contaminated sites. *Journal of Mineralogical and Petrological Sciences*, *101*(6), 299-307.
[109] http://www.sciencedirect.com/science/article/pii/S0016703705009439
[110] http://www.sciencedirect.com/science/article/pii/S0016703706021466

compared to conditions where no Ca was present.[111] This suggests that biotic reduction of uranium in the form of Ca-UO2-CO3 complexes is less bioavailable than other forms.

There is also empirical evidence that the presence of reducing conditions is a poor assumption that will impede uranium transport through spontaneous precipitation. This is supported by groundwater samples taken from Kingsville Dome in Texas which observed very elevated uranium concentrations under reducing conditions. In brief, all groundwater samples observed some indication of reducing conditions: low dissolved oxygen (<1 – 0.24 mg/L), occurrence of ferrous iron (Fe^{2+}) in solution, and the detection of sulfide (JTI060 at 60). All of these factors indicate evidence for reducing conditions present in the groundwater affected by ISL.

Indeed, the measured geochemical evidence from Kingsville Dome ISL groundwater samples strongly suggests ISL influenced uranium concentrations remain extremely elevated under reducing conditions. While all geochemical parameters mentioned previously indicate reducing conditions were present in the aquifer samples, uranium concentrations ranged between 4.7 – 12.5 mg/L (JTI060; p.59), which range 157x – 417x above safe drinking water standards and consistent with many of the elevated post-mining and post-restoration samples observed at Willow Creek and Smith Highland.

This observation (very high dissolved uranium concentrations under reducing conditions) is consistent with scientific literature which has found decreased abiotic reduction of uranium due to the presence of bicarbonate (JTI060 at 46) and the kinetics of sulfide promoted uranyl-carbonate complexes are substantially lower than uranyl-hydroxide complexes (JTI061). Simply put, the form of uranium which exists due to ISL mining is very difficult to reduce with sulfide.

Moreover, biotic reduction of uranium in the presence of calcium has observed decreased uranium reduction rates compared to conditions where no Ca was present (JTI043 at 2). This suggests that biotic reduction of uranium in the form of Ca-UO2-CO3 complexes is less bioavailable than other forms. In plain terms, certain microorganisms have difficulty 'eating' (reducing U(VI) to U(IV)) uranium when it's mixed with Calcium and carbonate, then they would without those ions present.

This geochemical discussion on the complexity of contaminant migration and sequestration mechanisms is supported by issues with horizontal fluid excursions observed at Kingsville Dome ISR operation in southern Texas. Recent data shows the increase in uranium concentrations at the monitor well ring, which surrounds the production authorization area by 400 feet (Table Below, from[112]). These high

[111] http://www.tandfonline.com/doi/abs/10.1080/01490451.2010.507646#.VLPw4CvF81I
[112] http://www.austingeosoc.org/AGS%20Bulletin%202012-13_Final.pdf

values of uranium observed at the monitor wells would <u>not</u> be considered excursions, as the TCEQ uses 6,540 ug/L as the upper control limit (UCL). Regardless of regulatory obligations, the significant increase in uranium concentrations in the monitor wells demonstrates that uranium has migrated substantial distances from the production area in a relatively short time frame (i.e. more or less, a decade).

This data is consistent with the technical scientific modeling and uranium geochemistry research described in depth in the previous paragraphs. That is, when uranium is oxidized and complexed with inorganic carbon (such is the case with ISR operations), conventional assumptions about adsorption and redox transformations may not be valid under certain environmental conditions. Further, this suggests sufficient sampling of proper excursions parameters, including uranium, is required at the monitoring well ring to incite corrective actions.

TABLE 2

Well ID	Background U concentration (µg/L)	U concentration during excursion (µg/L)	Date U detected
MW-74	21	3200	11/16/06
MW-89	22	1690	8/17/07
MW-90	24	1320	8/17/07
MW-90	24	1060	11/27/07
MW-91	31	2140	8/17/07
MW-91	31	1500	3/5/08
MW-92	36	1670	8/17/07
MW-92	36	1440	10/11/07
MW-92	36	1300	4/16/08
MW-93	37	2500	10/11/07
MW-98	59	1100	4/18/11
MW-100	30	3600	8/17/07
MW-101	53	2520	8/17/07
MW-102	20	1300	11/7/06
MW-102	20	5170	8/17/07
MW-103	16	2790	8/17/07
MW-104	36	2140	8/17/07
MW-105	31	2320	8/17/07
MW-106	32	3900	11/7/06
MW-106	32	1260	8/17/07
MW-118	101	1170	10/19/07

The uranium concentrations shown in table 5 would not be considered excursions by TCEQ. According to TCEQ, an excursion has not occurred unless uranium concentrations exceed 6540 µg/L (TCEQ 2006).

Kingsville Dome observed the first established occurrence of private domestic well contamination as a result of ISL operations in the United States.[113]

The Garcia wells (two wells 60 m apart) were located approximately 300 m downgradient of the Kingsville Dome mine. Prior to mining, the Garcia wells uranium concentrations, in 1996, averaged roughly 180 µg/L (Note: neither well is currently used as a drinking water source). However, there is evidence to suggest groundwater quality from the Garcia wells met drinking water standards in 1988, as natural uranium measured 0.011 mg/L (11 µg/L).[114]

The uranium mining company involved in the ISR operations claimed natural uranium concentrations was elevated in the private wells and not caused by mining activities. Yet, samples in 2007 displayed uranium concentrations had increased again to 0.979 mg/L, or roughly 5.4x higher than the 'natural' values reported in 2005 and 89x higher than the values measured in 1988.[115] Further, by researching the geochemical trends, geology, and hydrology, an independent hydrologist concluded "<u>The available data indicate that the likely source of the increased uranium concentrations in the Garcia well is PA-3. To the author's knowledge, this is the first time that contaminants in an off-site domestic well have been linked to ISL uranium mining in the United States of America</u>."[116]

The Crow Butte ISR mine unit operation in Nebraska offers similar insight into the inadequate excursion monitoring system and poor scientific assumptions used to justify it. Active ISR mining began on 4/1/1991 and operated until 3/1/1994. Active restoration began thereafter (4/1/1994) ending in 2/1/1999, while stability monitoring samples were collected until 8/1/1999. From the start of mining to stability monitoring sampling, the mine unit 1 operated ~8 years.[117] Over that time span, average uranium concentrations <u>in the monitoring wells</u> after restoration (stability monitoring) had increased from 0.11 mg/L to 1.21 mg/L or ~11x increased and 40x higher than EPA's drinking water standard for uranium (0.03 mg/L)[118]. However over the entire history of Crow Butte mine unit 1 (active mining, active restoration, and stability phases), the NRC reported <u>no excursions events at any monitoring wells.</u>[119] In other words, the monitor wells observed increases of average uranium concentrations of nearly 11x, while no excursions were detected.

---

[113] http://www.austingeosoc.org/AGS%20Bulletin%202012-13_Final.pdf (See Technical Paper: Pages 20 -34)
[114] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14237A649
[115] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14237A649

[116] http://www.austingeosoc.org/AGS%20Bulletin%202012-13_Final.pdf
[117] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/crow-butte/isr-wellfield-ground-water-quality-data.html (See Mine Unit 1 Spreadsheet)
[118] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14255A439 (p. 116)
[119] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/crow-butte/isr-wellfield-excursion-ground-water-quality-data.html (see Mine Unit 1 Spreadsheet)

Table 5. Summary of estimated maximum axial plume lengths and their site characteristics. The listed UMTRA sites are the only ones for which plume length data can be extracted.

Site	Type	Max. Axial Plume Length (km)	Min.Axial Plume Length* (km)	Sampled Depth (m)	Sources	Comments
Canonsburg, PA	UMTRA (Title I)	0.3-0.37	-	2-8	89	Groundwater table can be found at shallow depths in the fill. Humid continental climate.
Crow Butte Uranium Mine Unit 1, NB	In situ leaching	0.63	0.07	-	90	Pre-operational/baseline maximum plume length measured to ~ 20 ppb. Post-operational ISL mining caused [U] to be orders of magnitude larger in monitoring groundwater wells.
Falls City, TX	UMTRA (Title I)	4.95	3.94	-	39	Plume analysis comprises tailings pile areas 1, 2, 3, 4, 5, 6, and 7. Largest UMTRA plume.

FIGURE 5: PLUME ANALYSIS FROM CROW BUTTE MINE UNIT 1. NO EXCURSIONS WERE REPORTED DURING THE OPERATIONAL LIFETIME OF THIS OPERATION.

Also stated in the comments from NUREG/CR-6705 was "*Post-operational ISL mining caused [U] to be orders of magnitude larger in the monitoring groundwater wells.*" To reiterate, no excursions were reported over the entire operational history of Crow Butte Mine Unit 1,[120] yet uranium concentrations in monitor wells increased orders of magnitude and a uranium plume was established as roughly 2,000 feet long. It's important to note, that this reporting was ~15 years ago, and the extent of environmental impacts over that time period is largely unknown as NRC accepted the groundwater restoration and decommissioning of Crow Butte Mine Unit 1 based on groundwater comparisons with State UIC standards. EPA must require better groundwater monitoring, including reporting uranium, with proper quality controls and analytical sampling methods which use the most up to date techniques and detection limits.

This finding is inconsistent with many of the NRC's dated assumptions regarding uranium contaminant transport which largely influence the excursion monitoring program.

Clearly, the excursion monitoring systems needs to be updated to adequately understand contaminants potentially moving beyond the monitor well ring and the aquifer exemption boundary. The current scientific assumptions, if any, are dated and based on little more than arbitrary agency reports, with no scientific citation or documentation for such assumptions.[121]

---

[120] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/crow-butte/isr-wellfield-excursion-ground-water-quality-data.html

[121] *See* U.S. NRC, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications: Final Report*, NUREG-1569 at 5-41 (June 2003), *available at* http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1569/sr1569.pdf ("Uranium is not considered a good excursion indicator

Improper Sampling Methods Mask Groundwater Impacts.

It's largely unclear what analytical methods, quality controls, and standards are used to evaluate *any* excursion parameter. For example, modern analytical techniques, such as ICP-MS (Inductively coupled plasma – mass spectrometry) are capable of detecting uranium concentrations in water as low as 0.0003 mg/L. Therefore, using an analytical technique with a significantly higher detection limit (0.4 mg/L) may mask the reality of actual groundwater impacts from uranium in the groundwater.

If the analytical method used, which is unknown, has a detection limit of <0.4 mg/L, then an updated method must be implemented as the 0.4 mg/L threshold exceeds EPA drinking water standard (0.03 mg/L) by roughly 13.3x. However, the data from 7MW42 [122] suggests that the current method is capable of detecting uranium concentrations *below* 0.4 mg/L. Yet most values are reporting uranium <0.4 mg/L.

Industry's reporting of this data becomes even more puzzling, when subsequent sampling [123] shows that one sample measured uranium concentrations at 0.38 mg/L, which was below the 'detection limit' of 0.4 mg/L, indicating that the current technique had the capabilities of measuring below the 0.4 mg/L threshold. The question becomes, what is the actual detection limit of this unknown analytical technique?

The issue of analytical techniques for measuring uranium has been explored by an independent hydrologist concerning the downfalls of inaccurate measurement techniques. The following discussion from the July 2006 study, *Effects of URI's Kingsville Dome Mine on Groundwater Quality Final Report*, prepared for the Kleberg County URI Citizen Review Board by George Rice, reproduced in pertinent part, provides insight into the best available various analytical techniques and inconsistencies.[124]

---

because, although it is mobilized by in situ leaching, it may be retarded by reducing conditions in the aquifer.").

[122] http://pbadupws.nrc.gov/docs/ML1329/ML13298A741.pdf; Page 64

[123] http://pbadupws.nrc.gov/docs/ML1329/ML13298A741.pdf; Page 64

[124] http://www.uraniuminfo.org/files/RiceStudyJuly2006.pdf (Page 96)

The uranium samples collected by URI are analyzed by two laboratories. Most of the samples are analyzed by URI's in-house laboratory. Other samples are analyzed by Jordan Laboratories of Corpus Christi, Texas.

In general, pre-mining (background) uranium analyses were performed by Jordan Laboratories. Post-mining uranium analyses of samples from monitor wells (to detect excursions) and baseline wells (to monitor restoration progress) have been performed by URI's in-house laboratory. URI intends to use Jordan Laboratories for restoration verification analyses[304].

URI uses a Hach DR/4000 V spectrophotometer to analyze uranium samples. Although this machine is not specifically designed to analyze uranium, it is possible to do so if the user develops a 'user entered' program[305].

It is not clear what URI's uranium detection limit is. URI has stated that it has complete confidence in results greater than 1 mg/L, but less confidence in lower results[306]. At some point, uranium concentrations are so low that URI's analytical method is completely unreliable. That point has not been determined.

The uranium values reported by URI's in-house laboratory should be treated with caution. The lower the concentration, the less reliable the analysis.

Recent uranium analyses for well BL-547 point to other problems with URI's in-house uranium analyses. URI's in-house laboratory reported a value of 1.4 mg/L. This value was reported to the State[307] for a sample collected on 2/9/06. A few days later (2/13/06) the County and URI split samples from well BL-547. The uranium results reported by two outside laboratories were 35.2 mg/L and 33.0 mg/L[308]. Then, URI's in-house laboratory analyzed a sample collected on 5/31/06. The reported uranium concentration was 11.2 mg/L.

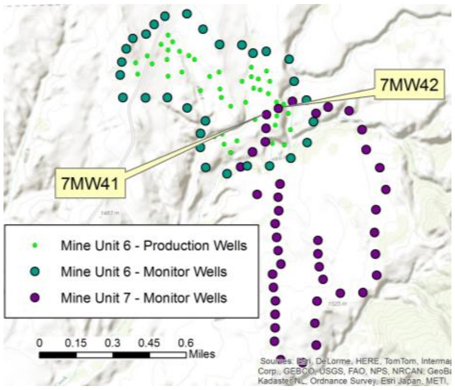
---

[304] Personal communication, Mark Pelizza of URI, December 2005.
[305] Personal communication, Scott Talbot of Hach Instruments, December 2005.
[306] Personal communication, Mike Hendrix of URI, December 2005.
[307] URI, 2006e.
[308] See appendix F.

Arbitrary Upper Control Limits (UCLs) and not using uranium as an excursion indicator

Further, the current use of UCLs masks potential impacts to surrounding and adjacent aquifers. As one example from the Willow Creek ISL site, baseline water quality samples were taken from well 7MW41 between 10/28/1997 and 12/4/1998.[125] Average concentrations of chloride, conductivity (reported as electrical conductivity or EC), alkalinity, and uranium were as follows, respectively: 7.2 mg/L, 855.5 umho/com, 91.7 mg/L as $CaCO_3$, and 0.0004 mg/L.

[125] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/willow-creek/isr-wellfield-ground-water-quality-data.html



URANIUM ONE
CHRISTENSEN RANCH
MINE UNIT 7
MONITOR WELL 7MW-41

SAMPLE DATE	CHLORIDE (UCL 38.4 mg/l)	CONDUCTIVITY (UCL 2775 µmhos/cm)	ALKALINITY (UCL 457 mg/l)	pH	WATER LEVEL	U_3O_8 ppm
5/22/2012	26.8	1418	347	7.6	4598.8	
6/5/2012	33.8	1800	356	7.6	4603.6	
6/19/2012	36.4	1899	335.6	7.4	4594.8	
7/3/2012	25.8	1386	328.8	7.6	4606.7	
7/19/2012	**39.8**	1927	377.8	7.6	4587.8	
7/31/2012	**43.2**	2041	395.6	7.5	4590.6	
8/13/2012	**43**	2084	405.8	7.4	4585.6	
8/27/2012	**44**	2117	414.6	7.6	4585.6	
9/11/2012	**45**	2182	418	7.7	4573	
9/26/2012	**57.6**	2369	425.4	7.5	4581.5	
10/12/2012	**49.8**	2181	**458.2**	7.3	4576.3	0.5
10/15/2012	**53.2**	2197	**466.4**	7.2	4584.9	0.9
10/22/2012	**50.2**	2216	**468.6**	7.5	4592.7	<0.4
10/29/2012	**49.6**	2207	**479**	7.2	4598.3	0.5
11/5/2012	**50**	2198	**469.6**	7.2	4583.6	<0.4
11/12/2012	**50.6**	2210	**473.6**	7.4	4596.2	0.7
11/19/2012	**50**	2208	**468.6**	7.3	4602.5	0.6
11/26/2012	**46.8**	2189	448.2	7.5	4602.5	0.6
12/3/2012	**47.6**	2208	453	7.4	4604.2	0.6
12/10/2012	**47**	2153	436.8	7.4	4603.2	0.6
12/17/2012	**47.6**	2125	450.2	7.4	4603.4	1.2
12/26/2012	**48**	2124	439	7.1	4604.1	0.5
12/31/2012	**44.8**	2146	430.2	6.9	4604.2	0.6
1/7/2013	**42.8**	2096	411	7.5	4603.4	0.5
1/14/2013	**42.2**	2133	400.8	7.3	4603.6	0.5
1/21/2013	**42.2**	2180	397.2	7.3	4605.2	0.6

FIGURE 6

The table was taken from when the excursion report specifically for well 7MW41 (ML13037A321) and the inset map shows the location of 7MW41 located within the production zone of MU6 and the spatial overlap of monitoring wells into production zones. Note that mine unit 6 had applied for restoration approval by the NRC but was denied (JTI035).

Due to ISL mining and restoration activities in MU6, the groundwater chemistry had been significantly altered (table 1). Therefore, the upper control limits (UCLs) for excursion detecting parameters were set at levels much higher than baseline (chloride 38.4 mg/L, conductivity 2775 umh/cm, and alkalinity 457 mg/L). Furthermore, the final uranium concentration measured was 0.6 mg/L, which was 1,500x higher than the average baseline and 20x higher than EPA's drinking water standard.

However, because the UCL's were set at much higher levels, the concentration of uranium was irrelevant because it is not an excursion monitoring parameter, but a parameter that was only required to be analyzed when a well went on excursion status. Therefore, since two of the three excursion parameters were below set UCLs, the well was removed from 'excursion status'.

In the excursion monitoring report, Uranium One stated[126]: "*In accordance with License Conditions 11.2 the criteria for termination of an excursion are when the concentrations of at least two of the three Excursion indicators remain below the established UCL's for three consecutive samples. This has been the case at Well 7MW-41 since December 10, 2012. Therefore, this letter additionally serves as notification that the excursion status for Monitor Well 7MW-41 has been terminated and this well will return to the routine bi-weekly monitoring frequency.*"

Uranium not used as an excursion indictor gives regulators and industry the opportunity to remove a monitoring well for excursion status, while uranium concentrations are orders of magnitude higher than baseline (production zone wells or monitoring wells). It is unacceptable for a groundwater monitoring system to detect very elevated concentrations of uranium and be removed from excursion status because "two of the three other parameters" were below arbitrarily set high UCL values. Further, EPA's SAB recommend using uranium as an excursion indicator was justifiable.[127]

Finally, UCLs were increased for well 7MW41 from the time spanning 4/1/2013 to 6/30/2013 as following: Chloride = 68.4 mg/L and alkalinity 562.7 mg/L as CaCO3[128] (conductivity remained 2775 umh/cm). Again, this example highlights both the arbitrary and convenient excursion monitoring structure that the NRC has currently in place, accepted by EPA in this rule. EPA must update its requirements for a proper, scientifically based excursion monitoring system.

The issue of overlapping and adjacent mine units poses serious issues to adequate excursion monitoring as fluid migration can impact water quality in adjacent mine units. The Wyoming Department of Environmental Quality (WDEQ) recognized the issue of overlapping mine units and the impacts to water quality at Christensen Ranch, in a letter to Uranium One on January 7th, 2013.[129] The WDEQ stated: "*The fact that Mine Unit 5 has since been partially returned to active mining status and that mining activities in Mine Unit 7 are clearly affecting the groundwater gradient across "restored" Mine Unit 6 are notable*

[126] http://pbadupws.nrc.gov/docs/ML1303/ML13037A321.pdf
[127] http://yosemite.epa.gov/sab/sabproduct.nsf/368203f97a15308a852574ba005bbd01/964968D9229863A0852579A7006EC71A/$File/EPA-SAB-12-005-unsigned.pdf **(Page B-3)**
[128] http://pbadupws.nrc.gov/docs/ML1329/ML13298A740.pdf (Page 73)
[129] http://pbadupws.nrc.gov/docs/ML1303/ML13036A169.pdf

> *issues. It is not unreasonable to assume similar issues could occur anywhere mining is actively occurring adjacent to previously "restored" areas.*"
>
> In other words, the succession of mine units adjacent to one another, undergoing various stages of mining, restoration, and monitoring needs to be clearly defined up front in order to circumvent issues associated with intermixing mine units. The establishment of scientifically defensible baseline, properly delineated mine units, and a site specific understanding of the hydr-biogeochemical are paramount for adequate groundwater protection to surrounding USDWs and scientifically defensible regulatory rules. Clearly the method in which NRC has approved the construction of monitoring wells in production zones of adjacent mine units is not adequate for identifying excursions or protecting groundwater quality beyond the exempted aquifer.
>
> Monitoring well 7MW42, located adjacent to 7MW41, demonstrates similar issues with setting arbitrarily high UCLs, and issues with improper sample analysis methods and detection limits.[130] No excursion parameters exceeded any respective UCLs, yet observed uranium concentrations were 0.5, <0.4, 0.4, <0.4, <0.4, <0.4, <0.4 mg/L between 1/1/2013 and 3/31/2013. Industry and NRC accepts <0.4 = 0 mg/L, which is likely an artifact of the analytical sampling technique detection limits.

[130] http://pbadupws.nrc.gov/docs/ML1329/ML13298A740.pdf (p.73)

Mine Unit 7 Well I.D. 7MW42		CHRISTENSEN RANCH PERIMETER ORE ZONE MONITOR WELL				For time period 1/1/2013 to 3/31/2013
Water Quality Parameters	Chloride	Specific Conductance	Total Alkalinity	pH	Uranium	Piezometric Elevation
Units	mg/l	μ mho/cm	mg/l as $CaCO_3$		ppm	msl
Upper Control Limit	48.4	2775	562.7			
Date						
01/02/2013	26.2	1698	362.2	7.6	0.5	4604.4
01/15/2013	27.2	1695	373.4	7.4	<0.4	4604.2
01/29/2013	23.8	1629	353.0	7.6	0.4	4603.1
02/11/2013	23.4	1668	328.2	7.4	<0.4	4609.9
02/25/2013	18.7	1722	277.4	7.5	<0.4	4613.1
03/12/2013	17.0	1642	271.6	7.9	<0.4	4613.9
03/26/2013	19.0	1539	316.0	7.6	<0.4	4611.0
*Values Exceed Upper Control Limit						

Mine Unit 7 Well I.D. 7MW42		CHRISTENSEN RANCH PERIMETER ORE ZONE MONITOR WELL				For time period 4/01/2013 to 6/30/2013
Water Quality Parameters	Chloride	Specific Conductance	Total Alkalinity	pH	Uranium	Piezometric Elevation
Units	mg/l	μ mho/cm	mg/l as $CaCO_3$		mg/l	msl
Upper Control Limit	48.4	2775	562.7			
Date						
04/11/2013	18.2	1516	316.4	7.6	<0.4	4616.2
04/24/2013	18.4	1518	302.0	7.4	<0.4	4618.7
05/07/2013	21.2	1580	318.0	7.7	0.38	4616.0
05/22/2013	22.4	1594	324.6	7.2	<0.4	4616.0
06/04/2013	19.0	1581	294.8	7.4	<0.4	4619.3
06/18/2013	18.5	1576	296.7	7.9	<0.4	4620.7
*Values Exceed Upper Control Limit Negative U308 Grades Indicate Less Than Detection Limit						

FIGURE 7: EXAMPLES OF EXCURSION WELLS AT WILLOW CREEK ISL DETECTING HIGH CONCENTRATIONS OF URANIUM AND NOT GOING ON EXCURSION STATUS DUE TO UCLS

Other situations have observed arbitrarily high UCLs, masking environmental impacts. At first, we believed this to be a reporting or documentation error, due to the sheer magnitude (For example, conductivity UCL was reported as 21,365 µmho/cm). However, upon inspection, total alkalinity had also significantly increased it's UCL to 5,861.3 mg/L as CaCO3 and these extraordinary high UCLs were reported for other wells.[131]

Another example of the inadequacy of the NRC's excursion monitoring detection system comes from well KM-031 at Smith Ranch Highland. Only alkalinity exceeded its respective UCL while uranium was documented as 1 mg/L or (33.3x EPA's MCL).[132] More interesting was the comment section which stated: "Uranium below .5" and "Uranium below detection limit" and "(blank)," demonstrating that it's largely unknown what the detection limit was, what

[131] http://pbadupws.nrc.gov/docs/ML1329/ML13298A741.pdf
[132] http://pbadupws.nrc.gov/docs/ML1128/ML11284A048.pdf; Page 12 in pdf.

methods were used what does "below .5" qualify as? The questions are abundant; however uranium concentrations were reported as 0 mg/L.

Smith Highland Ranch Well BM-42 (M-42) observed significant increases in uranium concentrations and was on excursion status for over approximately a decade.[133] Baseline uranium groundwater baseline concentrations were established in 1987 at 0.019 mg/L,[134] suggesting significant environmental impacts at and beyond the monitoring well ring.

Finally, other excursions show uranium concentrations near 2 mg/L, which have been on excursion status for years, and the source cannot be identified with the potentiometric surface.[135] EPA can view excursion events, terms and ultimately the lack of adequate data required for meaningful collection, at NRC's website.[136]

Natural attenuation capacity is largely unknown

Natural attenuation is lumped term which relies upon physical, chemical, and biological processes that naturally decrease concentration levels over time. The concept of natural attenuation is a black box for describing various contributions of sorption, redox (oxidation-reduction), and dispersion/dilution reactions which actively lower the concentrations observed at a given groundwater well. Broad assumptions about natural attenuating processes have been applied liberally, in the benefit of the ISL industry, and to the detriment of adequately protecting USDWs.

Natural attenuation of uranium has been heavily relied upon by the NRC to justify 1) improper selection of excursion parameters, specifically not using uranium as an excursion indicator in horizontal and vertical monitoring wells, 2) improper description of environmental impacts to the groundwater quality as SMALL, and 3) site decommissioning. Therefore, the following discussion will provide EPA justification of requiring improved excursion monitoring, including using uranium as an indicator and measured using appropriate analytical techniques, improved longterm monitoring requirements, but supports the 30 year time frame proposed by the current rule.

Further, EPA has not addressed the situation in which long term groundwater concentrations increase over time. For example, at Smith Highland Ranch ISL

---

[133] https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML13168A521 (pages 40 – 58)
[134] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-ground-water-quality-data.html
[135] http://pbadupws.nrc.gov/docs/ML1027/ML102710343.pdf
[136] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/crow-butte/isr-wellfield-excursion-ground-water-quality-data.html
http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-excursion-ground-water-quality-data.html
http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/willow-creek/isr-wellfield-excursion-ground-water-quality-data.html

operation, mine unit A, groundwater concentrations for uranium in the production well approved by the NRC Staff in 2004[137] for well MP4 were 10.50 mg/L,[138] or roughly 350x EPA's MCL (the NRC Staff approved the restoration report for Smith Highland mine unit A as the wellfield average uranium concentration was 4.32 mg/L, 144x EPA's MCL). According to Cameco's long term monitoring program, uranium concentrations in well MP4 peaked in 2012 at 17.3 mg/L, [139] or roughly 577x EPA's MCL, indicating that the concentrations were increasing in the production zone over time.

Of note, Smith Highland Ranch, mine unit A began stability monitoring on 2/1/1999,[140] while the last unknown sample in the production zone at well MP4 (17.3 mg/L) was taken in 2012. Under EPA's proposed 30 year regulatory time frame, this example indicates Cameco is approximately half way through stability monitoring (~13 years), while the production zone well MP4 has observed peaked uranium concentrations. This situation needs to be addressed in EPA's final rule.

Further, Cameco asserts that 'natural attenuation' was preventing the uranium from migrating towards the long term monitoring wells, LTM-4, M3, and M4, as evidence by uranium concentrations which were consistent with baseline levels:[141]

> *As a condition of approval of the groundwater restoration in Mine Unit A, the WDEQ/LQD required that a long-term monitoring (LTM) plan be developed down gradient of the mining zone. The LTM plan does not contain predicted attenuation values, but rather how the concentration of radium and redox sensitive elements will decrease over time as the restored groundwater moves toward and through the more reducing environment.*
>
> *MP-4 and 1-21 (Plate 1, 1-1 through 1-7) are wells located and completed in the production zone, and samples from these wells are representative of restored production fluids. LTM-4 is a monitor well completed in the flare from the production zone. M-3 and M-4 are wells completed in the 20-sand down gradient of Wells MP-4, 1-21, and LTM-4. Refer to Table 3-6, Long Term Monitoring Plan Data, for the most recent data during the reporting period. The last round of LTM data indicates the predicted values from the LTM Plan are accurately showing natural attenuation is occurring. The predicted values of the ring monitor wells*

---

[137] http://pbadupws.nrc.gov/docs/ML0418/ML041840470.pdf
[138] http://pbadupws.nrc.gov/docs/ML0403/ML040300369.pdf (Page 150)
[139] http://pbadupws.nrc.gov/docs/ML1223/ML12230A015.pdf (Page 52 and 53)
[140] http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/smith-ranch/isr-wellfield-ground-water-quality-data.html

[141] ML12230A015: pg. 21

> *are Fe = <0.1 mg/L; Mn = 0.04 mg/L (-60-yrs); Se = <0.0001 mg/L; U-nat = <0.001 mg/L; and Ra = 8 pCi/L (-60-yrs). Water quality for wells M-3 and M-4 show that the results are within the predicted values.* U_{nat} *is slightly higher than the predicted values; however, it remains well below the baseline level of 0.05 mg/L at the monitor well ring (M-3 and M-4) as well as well LTM-4, which is located inside the monitor well ring.*

However, the 'water level' data[142] suggest that the groundwater flow direction was moving away from LTM-4, not towards it (Figure 8). According to hydrogeology, groundwater flows from high to low potentiometric surface.

Therefore, no hydrological connection existed between the highly contaminated wells in the production zone (MP4 and I21) and the monitoring wells calling into question 'natural attenuation' being responsible for no increasing uranium trends observed at the monitoring well. A more reasonable explanation for uranium not observed increasing at LTM-4, M3, and M4 was the groundwater was moving away from the monitoring wells, presumably to the west/southwest.

[142] http://pbadupws.nrc.gov/docs/ML1223/ML12230A015.pdf (Page 52 and 53)

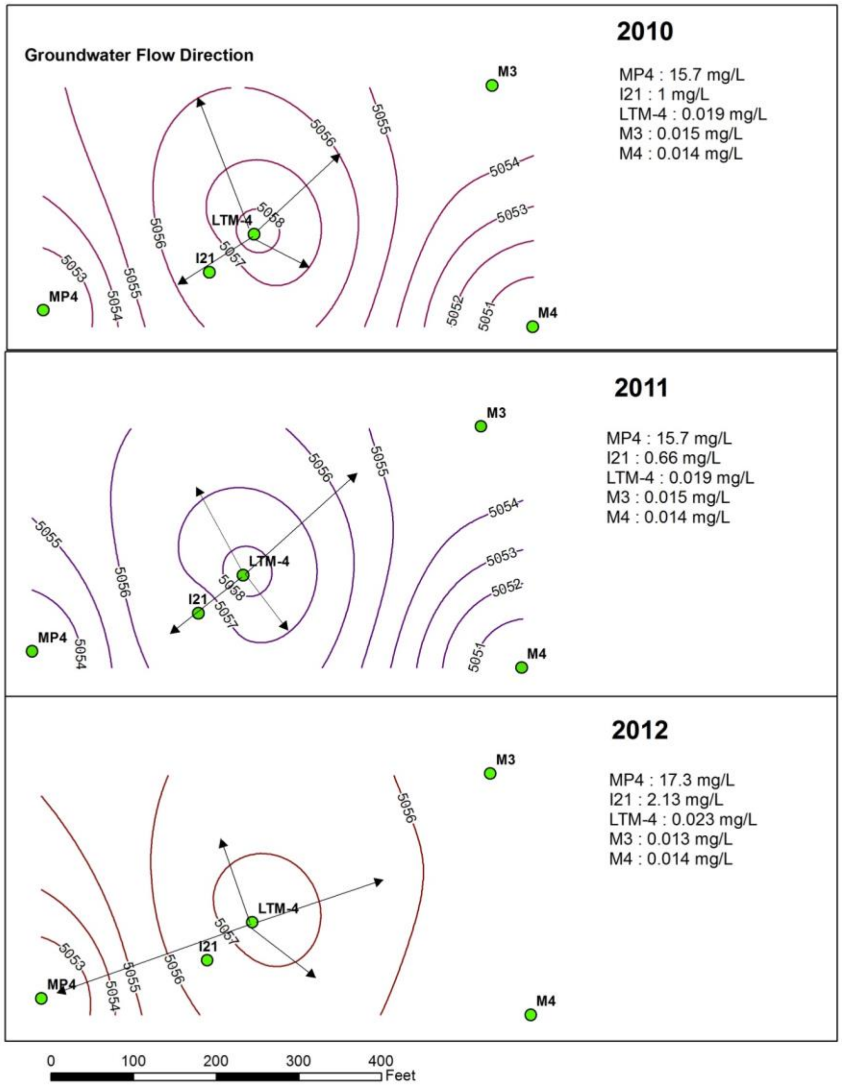


FIGURE 8: POTENTIOMETRIC SURFACE CONTOURS INTERPOLATED FROM WATER LEVEL ELEVATION FOR WELLS MP4, I21, LTM-4, M3, AND M4 AT SMITH HIGHLAND RANCH, MINE UNIT A . ARROWS SHOW THE APPROXIMATE GROUNDWATER FLOW DIRECTION. WELLS MP4 AND I21 WERE PRODUCTION WELLS THAT WERE HIGHLY CONTAMINATED WITH URANIUM POST-RESTORATION AND POST-DECOMMISSIONING APPROVAL BY NRC. AS PART OF THE NRC APPROVAL, CAMECO WAS REQUIRED TO INSTALL WELL LTM-4 'DOWNGRADIENT' OF THE PRODUCTION ZONE TO SHOW URANIUM WAS NOT MIGRATING OFF SITE. HOWEVER, THE WATER LEVEL DATA SUGGESTS THAT WELL LTM-4 WAS NOT DOWNGRADIENT AND GROUNDWATER FLOW WAS MOVING THE OPPOSITE DIRECTION. THIS CALLS INTO QUESTION THE NOTION THAT 'NATURAL ATTENUATION' WAS RESPONSIBLE FOR URANIUM NOT BEING OBSERVED AT LTM-4, M3, AND M4. WATER LEVEL CONTOURS WERE CREATED WITH GEOSPATIAL INTERPOLATION - INVERSE WEIGHTED DISTANCE (IDW).

With this information regarding the science and history of fluid excursions, EPA's rule must require all ISL sampling, throughout all stages of operations, to include proper sampling methods, quality control, and sample documentation before it accepts *any* groundwater samples. Furthermore, these analytical sampling techniques *must be required* in accordance with EPA guidelines) or scientific based Standard Methods). The use and reliance of an unknown, inconsistent, and inadequate analytical technique does not support a scientifically defensible excursion monitoring program and calls in to question much of the assumptions of 'slow', 'lock-in', or 'naturally attenuated' uranium transport behavior. In other words, if uranium is not detected, above an extremely high detection limit, then industry and regulators will be able to assume that it is lagging behind the lixiviant plume. This is not consistent with the empirical data, nor the current understanding of the non-reactivity of Calcium-uranyl-carbonate complexes.

These inadequacies with the NRC's excursion monitoring system, accepted by EPA in the current rule, raises larger issues of what contamination levels are migrating off site at ISL sites. From data from the current monitoring system, there is limited information regarding the potential extent of hazardous material migrating horizontally and vertically away from the production zones. Worse, the data that has been found from numerous horizontal and vertical excursions documented throughout these comments suggest that the current system needs to be addressed in order for EPA to appropriately protect USDWs from contamination.

NRDC recommendations:

- Proper statistical methods to evaluate appropriate UCL levels
- Sample collection and analysis must be to the best scientific standards with proper QA/QC
- Uranium must be used as an excursion indicator, with proper detection limits– as also recommended by EPA's SAB.[143]
- Well screen lengths must be consistent with production zone

In all, these examples highlight the need for a better scientific based monitoring and modeling of contaminant fate and transport from ISR aquifers that can potentially impact surrounding water users. EPA's interpretation of uranium migration as "slow" or "locked-in" is severely underestimating the potentially for hazardous constituents to migrate off-site. Geochemical assumptions about natural attenuation mechanism need to be revisited and better applied to monitoring and modeling ISR sites.

---

[143] http://yosemite.epa.gov/sab/sabproduct.nsf/368203f97a15308a852574ba005bbd01/964968D9229863A0852579A7006EC71A/$File/EPA-SAB-12-005-unsigned.pdf (Page 61)

61. "The potential for excursions may also be a factor in the facility's decision to stop operations and enter the restoration phase ... For an ISR facility, however, such a "standby" period is inappropriate because the migration of constituents mobilized by the prior injection of lixiviant continues even if the decision is made to stop extracting uranium. Excursions beyond the production zone are more likely to occur if the gradient within the wellfield is not maintained. In our view, stopping the extraction cycle must be interpreted as an end to the operational phase and should trigger initiation of the restoration phase. We are interested in stakeholder views on this interpretation." Proposed Rule at 4176.

NRDC Comment

NRDC agrees that stopping the extraction cycle must be interpreted as an end to the operational phase and must trigger initiation of the restoration phase. We agree that "standby" periods are inappropriate constituents mobilized by the prior injection of lixiviant continues even if the decision is made to stop extracting uranium and excursions beyond the production zone are more likely to occur if the gradient within the wellfield is not maintained.

62. "Perhaps the most significant aspect of today's proposal involves the actions to be taken by the operator after groundwater restoration is complete. If insufficient monitoring is conducted, either in duration, frequency, or in the number of wells used to sample the wellfield, it is very possible to reach premature conclusions of stability. In such cases, residual lixiviant or localized areas within the production zone that have not stabilized may cause continued mobilization of uranium and other constituents after monitoring is terminated, potentially leading to contamination downgradient or beyond the boundary of the exempted aquifer. Today's proposal contains provisions related both to the duration of the monitoring and to the sufficiency of the data necessary to determine that stability has been achieved." Proposed Rule at 4176.

NRDC Comment

We think that requiring meaningful baseline characterization before the exempted aquifer has been affected by the drilling of wells, requiring substantially more strict restoration goals and reining in the abuse of ACLs in exempted aquifers is just as important, overdue and necessary as the proposed monitoring provisions. But we agree that proposed monitoring provisions are crucial and we fully support the implementation of a RCRA consistent monitoring regime that finally makes transparent the full impact of ISL recovery.

63. "The initial part of our proposal for long-term stability monitoring addresses the duration of monitoring. Specifically, we are proposing that a facility must demonstrate three consecutive years of stability monitoring and then maintain long-term stability

monitoring for an additional period of 30 years; this timeframe can be shortened by demonstrating long-term geochemical stability through modeling, as described below." Proposed Rule at 4176.

NRDC Comment

EPA's should require at least 5 consecutive years of stability monitoring and then maintenance of long-term stability monitoring for an additional period of 30 years. We think the suggestion to shorten the timeframe demonstrating long-term geochemical stability through modeling can only be supported if at least 5 years of stability monitoring is required.

64. Monitoring option 1 – (selected) "We are proposing that three consecutive years of stability be demonstrated through monitoring as a prerequisite before the modeling would be considered as justification for reducing the monitoring period. The three-year stability demonstration begins when sufficient monitoring data have been collected to allow a showing of statistical significance at a specified level of confidence. … Stability would be demonstrated statistically at the 95 percent confidence level, which we believe will help to ensure that operators collect data of sufficient quantity to support regulatory judgments. Stability would be demonstrated using statistical tests with sufficient power to detect trends with a false negative rate no higher than 5 percent. We believe this will ensure that operators collect data of sufficient quantity and quality with adequate power to support regulatory judgments. As noted in Section II.E.2 of this document, a 95 percent confidence threshold can also be found in the RCRA monitoring program." Proposed Rule at 4177.

NRDC Comment

NRDC supports Option 2 below, but we would have fewer objections to Option 1 if EPA's proposal to shorten the timeframe by demonstrating long-term geochemical stability through modeling is supported by at least 5 years of stability monitoring.

65. Monitoring Option 2 (not selected) "The second option we considered also relies on the RCRA regulatory framework. In this alternative, no provision for shortening the long-term stability monitoring time frame is permitted; thirty years of groundwater monitoring is required. This alternative provides a significant increase in the monitoring period over current industry practice, and the extended time would provide added confidence that the restored wellfield chemistry is remaining stable through this period of time. Thirty years of consistent statistical performance (i.e., no upward trending) would provide strong support for concluding that groundwater systems will remain in a chemically reduced state over time. If upward trending of contaminant concentrations was observed during the monitoring period under this approach, the operator would be required to perform additional corrective action, after which the monitoring period would begin again. We ultimately decided not to pursue this option because it does not sufficiently recognize the site-specific aspects of aquifer restoration or give operators the

incentive to reach license termination sooner by conducting geochemical modeling." Proposed Rule at 4177.

NRDC Comment

NRDC supports option 2 as thirty years of consistent statistical performance with no upward trending provides strong support that groundwater systems will remain in a chemically reduced state over time. With the history of ISL recovery as we've presented to the NRC and in these comments, at almost every site we fully expect operators will need to perform additional corrective action after initial monitoring phases, after which the monitoring period can begin again. While we understand EPA's interest in providing the operator an incentive to reach license termination sooner, we've seen no evidence that such a situation would be possible. Rather than allow for such an out before any data has been collected, we urge EPA to commence with the requirement for 30 years of monitoring as it is entirely consistent with RCRA.

66. Monitoring Option 3 (not selected) "We also considered the option of a performance-based standard without explicitly calling for a long-term monitoring period. … Ultimately, we decided against this approach for several reasons. Statistical analyses alone, without the added requirement of long-term monitoring or the option of geochemical modeling, would provide no assurance that groundwater systems will remain in a chemically reduced state over a longer time frame than that used for data collection. Furthermore, this option does not incorporate RCRA's thirty-year post-closure period. As previously stated, UMTRCA requires that generally applicable standards promulgated under its authority by EPA for non-radiological hazards be consistent with the standards issued under Subtitle C of RCRA. Based on these two reasons, we feel that this approach has greater potential for premature termination of the license. Furthermore, ambiguity in the narrative nature of such standards has the potential to provoke litigation and make implementation difficult." Proposed Rule at 4177-78.

NRDC Comment

This option does not incorporate RCRA's thirty-year post-closure period which makes it inconsistent with UMTRCA requirements. Equally important, given the size of ISL sites and given what we know of the relative quality of background water quality (see JTI003 Storymap and histogram) as well as the significant variability that is typically present in the mineralized zone, failure to require strict monitoring provisions guarantees litigation and makes implementation difficult.

67. "We are not proposing to establish institutional controls for ISR facilities. Active maintenance of the site will cease with the termination of the license, which will occur

when the regulatory agency determines that all license conditions have been met. In this sense, we do not view the long-term stability monitoring period as an institutional control following the ISR restoration phase; rather, we view it as a period of active surveillance to determine the long-term success of the restoration effort. Nor are we proposing to establish passive controls, either at the site or in documents such as local land records. Requirements for survey plats or other records to be maintained would be consistent with RCRA requirements for hazardous waste facilities; however, these typically apply when waste management units remain at the site and are intended to restrict disturbance of the site. Though we are not proposing that such records be established for ISR sites, we strongly encourage NRC and Agreement States to include such provisions in ISR licenses since ISR sites will not be restricted from sale or further development. Such provisions could simply inform the subsequent owner of the previous ISR, groundwater restoration activities and aquifer exemption on the property." Proposed Rule at 4179.

NRDC Comment

Given what we know of conditions at ISL sites, we urge EPA to reconsider this decision and require institutional controls for ISR facilities. Institutional controls, long a part of environmental law, play a crucial role in selecting how best to protect the public from incomplete cleanups where contamination is left on site for extended periods of time. Institutional controls are shorthand descriptions for restrictions placed on land, surface water or groundwater use when it is either technically impossible or economically prohibitive to permanently remove the source of pollution or contamination. The types of restrictions can be "active" institutional controls – often colloquially described as "guns, gates and guards" – or "passive" institutional controls, which range from warning notices to keep trespassers off contaminated sites to deed restrictions specifying how the land can be used henceforth. Regardless of whether institutional controls are active or passive, the purpose is to isolate the remaining contamination or potential harm from the public in an enduring fashion.

The study of institutional controls in environmental law and policy is a legacy of incomplete cleanup of both chemical and radioactive sites around the country. Indeed, the United States has thousands of large and small contaminated sites overlain by a myriad of state and federal regulatory regimes where it was either not cost-effective or technically feasible to reduce the volume of contamination to levels that provide adequate protection for unrestricted uses. Thus, institutional controls exist, agencies adopt policies to implement those controls, and in this instance, given what we know of ISL sites, EPA should require institutional controls.

EPA, along with regulatory requirements for institutional controls in the CERCLA context, has issued environmental radiation protection standards for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes. EPA defines active institutional controls in that context as: "(1) controlling access to a disposal site by any means other than passive institutional controls; (2) performing maintenance operations or remedial actions at a site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance." 40 C.F.R. §191.12. EPA defines passive institutional controls in this context as: "(1) permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system." *Id*. Further, EPA states "active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal." 40 C.F.R. §191.14(a) (emphasis added).

In a thorough report addressing the necessity of institutional controls and the need for them to be more effectively implemented to protect human health and the environment in the context of chemical contamination, in 2005 the Government Accountability Office reviewed (1) the extent to which institutional controls are used at sites addressed by EPA's Superfund and RCRA corrective action programs; (2) the extent to which EPA ensures that institutional controls at these sites are implemented, monitored, and enforced; and (3) EPA's challenges in implementing systems to track these controls. *See Hazardous Waste Sites: Improved Effectiveness Of Controls At Sites Could Better Protect The Public*, Government Accountability Office, GAO-05-163, January 2005, http://www.gao.gov/assets/250/245140.pdf.

The GAO found institutional controls were used at most of the Superfund and RCRA sites where cleanup was completed and waste was left in place. Further, the GAO found that while EPA's guidance advises that four key factors be taken into account in selecting controls for a site (the objective, mechanism, timing and responsibility for the institutional control), 69 of the 108 remedy decision documents examined did not demonstrate that all of these factors were sufficiently considered to ensure that planned controls will be adequately implemented, monitored, and enforced. The GAO explained:

> Although EPA has taken a number of steps to improve the management of institutional controls in recent years, we found that controls at the Superfund sites we reviewed were often not implemented before site deletion, as EPA requires. In some cases, institutional controls were implemented after site deletion while, in other cases, controls were not implemented at all. An EPA program official believed that these deviations from EPA's guidance may have occurred because, during the sometimes lengthy period between the completion of the cleanup and site deletion, site managers may have inadvertently overlooked the need to implement the institutional controls. *Id*. at 6.

With GAO's cautions in mind and what we know of the permanently contaminated state of ISL sites, we think the caution described above – inadvertently failing to follow EPA protective guidance occurred during the lengthy period of cleanup and license termination – should spur EPA to require institutional controls and not simply rely on NRC or industry.

E. EPA's "Summary of Environmental, Cost and Economic Impacts"

68. "Summary of Environmental, Cost and Economic Impacts … Groundwater is a valuable resource, particularly in the Western United States where uranium ISR 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." Proposed Rule at 4180.

NRDC Comment

See Attachment 1, Economic Value of Protecting Groundwater.

F. Part 192-Amended

NRDC Proposed Changes to Text of the Rule

69. Consistent with the technical and legal support offered in the previous pages, EPA's proposed rule under discussion today is an important and proper exercise of EPA's statutory authority. EPA should incorporate NRDC's observations into the rulemaking and strengthen both the text of the rule and preamble language accordingly. A list of necessary textual changes follow, but note that the list is not exhaustive.

70. Make the following deletion in §192.50, Applicability: "This subpart applies to the management of uranium byproduct materials prior to, during and following the processing of uranium ores utilizing uranium in-situ recovery methods, and to the restoration of groundwater at such sites. ~~Unless otherwise specified,~~ all wellfields shall comply with this subpart as of the effective date of this rule."

71. Include uranium as an indicator parameter in §192.51(h).

72. Revise §192.51(l) as follows: "Indicator Parameter. A constituent, such as chloride, conductivity, uranium, and total alkalinity, whose "upper control limit" is used to identify an excursion. Indicator parameters may or may not be contaminants, but relate to geochemical conditions in groundwater."

73. Revise 192.51(w) as follows: "Point(s) of Compliance. Site specific location(s) where groundwater protection standards must be met. During all phases of ISR, excursion monitoring wells can serve as the points of compliance; during the restoration, stability and long-term stability phases, points of compliance may also include monitoring, injection and extraction wells in the production zone, as determined by the regulatory agency. But at no point should the entirety of an exempted aquifer serve as a point of compliance."

74. Revise §192.51(y) as follows: "(y) Preoperational Monitoring. Full characterization and measurement of groundwater conditions in the production zone, and in the groundwater up and down gradient from the production zone, as well as in overlying and underlying aquifers, prior to the licensing and operational phase and fully consistent or comparable to "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance," Environmental Protection Agency, 2009."

75. Revise§192.52(a) as follows: "(a) All operating or in restoration wellfields, new wellfields and expansions of wellfields shall comply with subpart (F) of these amended standards, as of the effective date of this rule. Those wellfields currently in stability monitoring or longterm monitoring at a licensed facility shall comply with the monitoring requirements, §192.53."

76. Revise §192.52(c)(iii) as follows: "(iii) In all cases, the restoration goals,as determined under paragraph (c)(1) of this section, are satisfied at all points of compliance, at injection, production, or at most distant, monitoring wells." Further, EPA should explicitly require that restoration goals that are developed for the ISL site should be for either individual wells, or at most, groups of wells that shall not exceed 1 acre.

77. Commence §192.53(a)(1) with the phrase, "Prior to licensing …"

78. REvise §192.53(a)(iii) as follows: "(iii) The licensee shall, prior to licensing, employ appropriate, RCRA consistent 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 longterm stability monitoring under § 192.52(c)(1) of this subpart. As determined by the licensee and approved by the regulatory agency, background concentration limits may be representative of individual wells or multiple wells, within reasonable limits but not to exceed one acre."

79. Revise §192.53(d)(1) to include production wells, perimeter wells, overlying and underlying wells. In other words, all wells used to establish baseline conditions within the aquifer.

80. Revise §192.53(d)(2)(iii) as follows: "(iii) If the licensee finds that the stability of groundwater meeting the concentration limits determined in § 192.52(c)(1) of this subpart cannot be demonstrated for three consecutive years for one or more constituents, the regulatory agency shall Require the licensee to resume active restoration efforts." Subsection B should be deleted.

81. Revise §192.53(e)(3) to require that stability must be documented for at least a period of 5 years.

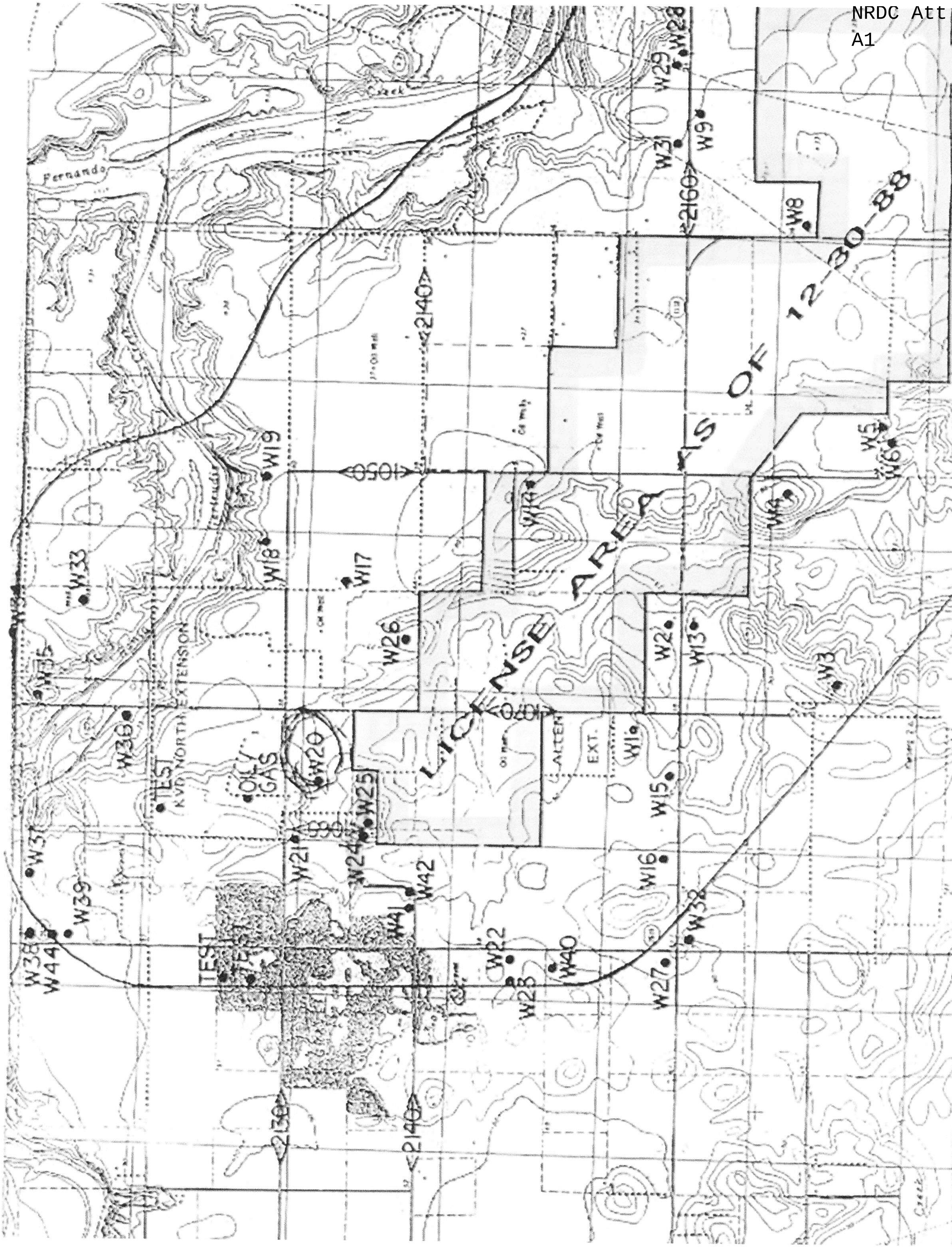
Conclusion

We appreciate the opportunity to comment. If you have any questions, please do not hesitate to contact us.

Sincerely,

Geoffrey H. Fettus
Senior Attorney
Natural Resources Defense Council
1152 15th St. NW, Suite 300
Washington D.C., 20005
(202) 289-2371
gfettus@nrdc.org

Lance N. Larson, Ph.D.
Science Fellow
Natural Resources Defense Council
1152 15th St. NW, Suite 300
Washington D.C., 20005
(202) 513-6279
llarson@nrdc.org


LICENSE AREA AS OF 12-30-88
KVD NORTH EXTENSION
TEST
OILY GAS
ALLEN EXT.
Fernando
Creek
2160
2140
2130
1050
1070
W1
W2
W3
W4
W5
W6
W7
W8
W9
W11
W12
W13
W15
W16
W17
W18
W19
W20
W21
W22
W23
W24
W25
W26
W27
W28
W29
W31
W32
W33
W34
W35
W36
W37
W38
W39
W40
W41
W42
W44

TEL. 512-884-0371 PO BOX 2552 78

JORDAN LABORATORIES, INC.
CHEMISTS AND ENGINEERS
CORPUS CHRISTI, TEXAS
MAY 12, 1988

URI, INC.
12377 MERIT DR., SUITE 750, LB14
DALLAS, TEXAS 75251

REPORT OF ANALYSIS

IDENTIFICATION: A. GARCIA
3-31-88

		ANALYSIS DATE
PH	8.19	4-04-88
SPECIFIC CONDUCTANCE	1640 UMHOS/CM @ 25 DEG.C.	4-27-88

	MG/L	ANALYSIS DATE
TOTAL DISSOLVED SOLIDS (180 DEG.C.)	974	4-11-88
ARSENIC	0.003	4-08-88
COPPER	<0.01	5-03-88
MOLYBDENUM	0.01	5-03-88
SELENIUM	0.003	4-08-88
URANIUM (NATURAL)	0.011	4-18-88

		ANALYSIS DATE
GROSS ALPHA ACTIVITY, PCI/L	9.2 +/- 11	4-27-88
GROSS BETA ACTIVITY, PCI/L	6.3 +/- 6.2	4-27-88
RADIUM 226, PCI/L	1.1 +/- 0.2	4-13-88
THORIUM 230, PCI/L	-0.4 +/- 0.7	5-12-88

LAB. NO. M26-2219

RESPECTFULLY SUBMITTED,

Carl Crownover

CARL F. CROWNOVER

Exhibit Texas Dept of Health (TDH)

URI/Kingsville Dome Project
Combined W-24 &W-25 Garcia Hills Domestic Wells Water Quality Data

Sample ID	Uranium (mg/l)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Specific conductance and PH
12/13/96	0.184	108(+/-)10	45 (+-) 5	0.7 (+-) 0.1	1660 / 8.14
5/23/97	0.220	124 (+-) 11	40 (+-) 5	0.7 (+-) 0.1	1570 / 8.18
8/29/97	0.152	67 (+-) 8	45 (+-) 5	0.5 (+-) 0.1	1620 / 8.18
2/25/98	0.189	88 (+-) 9	32 (+-) 4	0.7 (+-) 0.1	1630 / 8.05
W-24 only 6/18/98	0.152	103 (+-) 10	37 (+-) 5	0.8 (+-) 0.1	1640 / 8.14
W-25 only 6/18/98	0.167	102 (+-) 10	30 (+-) 5	0.9 (+-) 0.1	1630 / 8.20
8/27/98	0.158	94 (+-) 10	36 (+-) 5	0.7 (+-) 0.1	1660 / 8.21
11/25/98	0.209	111 (+-) 10	48 (+-) 5	0.7 (+-) 0.1	1630 / 8.04
3/26/99	0.200	99 (+-) 10	45 (+-) 5	1.2 (+-) 0.1	1620 / 8.15
6/21/99	0.181	96 (+-) 10	49 (+-) 5	0.7 (+-) 0.1	1630 / 8.09
8/24/00	0.151	71 (+-) 8	24 (+-) 4	0.9 (+-) 0.1	1560 / 8.28
9/19/00(Split with TDH)	0.187	Na	Na	0.4 (+-) 0.1	1600 / 8.30
11/6/00	0.168	72 (+-) 7	31 (+-) 5	0.9 (+-) 0.1	Na
2/19/01	0.184	78 (+-) 7	24 (+-) 4	0.7 (+-) 0.1	1570 / 8.15
06/11/01	0.179	72 (+-) 7	38 (+-) 4	0.8 (+-) 0.1	1510 / 8.03
9/13/01	0.160	81 (+-) 8	32 (+-) 4	0.8 (+-) 0.1	1430 / 8.03
12/17/01	0.240	113 (+-) 9	26 (+-) 5	0.9 (+-) 0.1	1610 / 0.1
3/21/02	0.164	89 (+-) 9	33 (+-) 4	0.8 (+-) 0.1	1680 / 8.16
6/26/02	0.141	74 (+-) 8	22 (+-) 4	0.6 (+-) 0.1	1720 / 8.17
9/30/02	0.172	82 (+-) 8	11 (+-) 3	0.8 (+-) 0.1	1660 / 8.13
12/13/02	0.188	126 (+-) 10	28 (+-) 4	0.7 (+-) 0.1	1590 / 8.13
3/11/03	0.180	134 (+-) 11	29 (+-) 4	0.7 (+-) 0.1	1760 / 8.27
6/23/03	0.172	78 (+-) 8	19 (+-) 4	0.7 (+-) 0.1	1600 / 8.11
9/26/03	0.170	135 (+-) 14	21 (+-) 4	0.6 (+-) 0.1	1710 / 8.20
12/12/03	0.187	118 (+-) 13	22 (+-) 4	0.8 (+-) 0.1	1630 / 8.05

The above listed water quality data was obtained from Martin Utley of the TDH/BRC on 4/23/04 (all that could be located) is from the analysis of a water tank located at the Garcia Hills Area in Kleberg County which combines water from two wells, W-24 & W-25. Although the exact completion intervals is unknown on these two wells, W-24 has a well depth of between 750 and 800 feet and the W-25 well has a well depth of 612 feet. Because of the elevated radiometric values sampled in these wells, it is believed that these two wells are completed in the same aquifer as the production zone located in Paa-3 at the Kingsville Dome Mine. Martin Utley who worked for URI during the time of pump testing of Paa-3, said that data was observed in the pump tests which showed aquifer communication appeared to be present between Paa-3 and these two wells. The permit for Paa-3 was issued on 2/6/98, so all data collected prior to that time is prior to mining in that area.

5.0 URI, INC. - KVD

Groundwater Sampling

SUMMARY - Garcia Well #24/25

Year	DATE	Quarter Baseline	pH	umhos/cm COND.	PCi/L G. ALPHA Reading	+/-	PCi/L G. BETA Reanding	+/-	Mg/L U	PCi/L RADIUM Reading	+/-
1997	4/4/1997	1	8.18	1620	104.0	10.0	29.0	5.0	0.186	0.4	0.1
1997	5/23/1997	2	8.18	1570	124.0	11.0	50.0	5.0	0.220	0.9	0.1
1997	8/29/1997	3	8.18	1620	67.0	8.0	45.0	5.0	0.152	0.5	0.1
1997	12/9/1997	4	8.03	1650	121.0	11.0	57.0	6.0	0.190	0.8	0.1
1998	2/25/1998	1	8.05	1630	88.0	9.0	32.0	4.0	0.189	0.7	0.1
1998	6/18/1998	2	8.14	1640	103.0	10.0	37.0	5.0	0.152	0.8	0.1
1998	8/27/1998	3	8.21	1660	94.0	10.0	36.0	5.0	0.158	0.7	0.1
1998	11/25/1998	4	8.04	1630	111.0	10.0	48.0	5.0	0.209	0.7	0.1
1999	3/26/1999	1	8.15	1620	99.0	10.0	42.0	5.0	0.200	1.2	0.1
1999	6/21/1999	2	8.09	1630	96.0	10.0	49.0	2.0	0.181	0.7	0.1
2000	8/24/2000	3	8.28	1560	71.0	8.0	24.0	4.0	0.151	0.9	0.1
2000	9/19/2000	3	8.30	1600	72.0	7.0	31.0	5.0	0.187	0.4	0.1
2001	2/19/2001	1	8.15	1570	78	7	27	4	0.184	0.7	0.1
2001	6/11/2001	2	8.03	1510	72	7	38	4	0.179	0.8	0.1
2001	9/13/2001	3	8.03	1430	81	8	32	4	0.160	0.8	0.1
2001	12/17/2001	4	8.15	1610	113	9	26	5	0.240	0.9	0.1
2002	3/21/2002	1	8.16	1680	89	9	33	4	0.164	0.8	0.1
2002	6/26/2002	2	8.17	1720	74	8	22	4	0.141	0.6	0.1
2002	9/30/2002	3	8.13	1660	82	8	11	3	0.172	0.8	0.1
2002	12/13/2002	4	8.13	1590	126	10	28	4	0.188	0.7	0.1
2003	3/11/2003	1	8.27	1760	134	11	29	4	0.18	0.7	0.1
2003	6/23/2003	2	8.11	1600	78	8	19	4	0.172	0.7	0.1
2003	9/26/2003	3	8.2	1710	135	14	21	4	0.17	0.6	0.1
2003	12/12/2003	4	8.05	1630	118	13	22	4	0.187	0.8	0.1
2004	3/31/2004	1	8.05	1670	136	13	16	4	0.172	0.9	0.1

EL. 361-884-0371

PO BOX 2552 78403

JORDAN LABORATORIES, INCORPORATED
ANALYTICAL & ENVIRONMENTAL CHEMISTS
CORPUS CHRISTI, TEXAS

July 13, 2007

URI, INC.
650 S. Edmonds Lane, Suite 108
Lewisville, Texas 75067

Report of Analysis

Identification: KVD 2nd Qtr. Ground Water
Garcia Well
1246 06-13-07

Method Number			Analysis Date
SM4500-H B.	pH ---------------	7.99	06-14-07
120.1	Specific Conductance	1670 umhos/cm @ 25 Deg.C.	06-14-07
D2907	Uranium, mg/L -------------------------	0.979	07-11-07
7110 B	*Gross Alpha Activity, pCi/L ------------	899	06-15-07
	Counting Error, pCi/L ------------ +/-	35	
7110 B	*Gross Beta Activity, pCi/L -------------	49	06-15-07
	Counting Error, pCi/L ------------ +/-	6	
7500-Ra C.	Radium 226, pCi/L ----------------------	1.1	06-27-07
	Counting Error, pCi/L ------------ +/-	0.1	

Analysts: Nixon & Moore
* Method: 7110 B Calibration: Alpha - Th230 Beta - Cs137

*Note: EPA Method 900.0 is a drinking water screening procedure. Its application to waters of high total dissolved solids may result in unacceptably high counting errors due to limitation on sample size. Recommended max is 500 mg/L.

Alternate method for determining activity may be considered.

Lab. No. M45-1494

Respectfully Submitted,

Carl F. Crownover, Pres.

form: S2-4

NRDC Att. A2

Uranium-tinged well puts family at risk

Published: Monday, August 01, 2005

ASSOCIATED PRESS

RICARDO (AP) - The extended Garcia family has lived for five generations in a cluster of frame and trailer homes known, with some irony, as Garcia Hill because its compound sits maybe a foot higher than the surrounding scrub.

The Garcias have another local distinction: Their water is contaminated with uranium at levels so high the U.S. Environmental Protection Administration has told them to stop drinking it and see their doctors because of a high risk of cancer.

The government and the company that has been mining uranium in the area for the last 20 years told the Garcias the contamination is natural seepage from the vein of the radioactive material that runs near their well, the very uranium that attracted Lewisville-based Uranium Resources Inc. to Kleberg County in the first place.

The Garcias and other Kleberg County residents don't accept that explanation.

"That's weird that it's the only place and nobody else has it," Humberto Garcia said. "It just kind of raises questions. A quarter mile away we have relatives, and their well is OK."

The Garcias and other local residents see the family's plight as an emblem of the problems they say URI has dumped on them for decades.

URI well casings stick out of the ground on Garcia Hill. In the 1980s and early 1990s, URI pumps sucked uranium-filled water from deep underground for processing.

The activity ended when prices plummeted from more than $30 a pound to around $7. Claiming financial problems, the company left without cleaning up the area or restoring the water below.

"The promise was they would take all the uranium and leave the water clean," said Teo Saenz, president of STOP (South Texas Opposes Pollution). "They didn't."

STOP members, who number about a dozen, say an engineer mapped the underground for them in the mid-1990s and accurately predicted that contamination from the mine field would migrate first to the Garcia wells. They now fear poisoned water will seep toward the water supply of nearby Kingsville, population 26,000.

The county reached a settlement in December with URI to clean the water. Under the agreement, the company must clean up its first old mine before starting mining on the third, the second mine before completing the third, then the third mine before starting on the fourth, County Judge Pete De La Garza said. The company also must pay the county $20,000 for an expert to monitor their cleanup.

At a public hearing Monday, Garcia and other local residents will make their case against the company mining a new area, arguing that since the company failed to clean up its former operations it shouldn't be allowed to do more.

Economic Value of Protecting Groundwater: A Response to EPA

Technical Comments Submitted to the U.S. Environmental Protection Agency on Behalf of the Natural Resources Defense Council

In Response to EPA's Economic Analysis for Revised Uranium Mill Tailings Standards (EPA 402-R-14-003)

Comments Contributed by the Conservation Economics Institute -- Evan Hjerpe, Ph.D. and Pete Morton, Ph.D.

Comments on EPA's Draft Economic Analysis of Groundwater and Uranium ISR Rule Revisions (Table of Contents)

Comments on EPA's Draft Economic Analysis of Groundwater and Uranium ISR Rule Revisions

1. Introduction

EPA has recently released a draft economic analysis for proposed revisions to protection standards for uranium mill tailings.[1] With uranium mining operations transitioning from open pit and surface mining to in-situ recovery (ISR) operations taking place below ground, EPA has issued a subpart F to revise 40 CFR Part 192 by adding monitoring requirements to help protect groundwater. EPA's economic analysis (hereafter Economic Analysis) assesses the costs (Section 3), benefits (Section 4), and economic impacts (Section 5) of the proposed rule.

We applaud the EPA for exploring much needed updates to health and environmental standards for uranium operations and for proposing extensive groundwater monitoring before operations begin (baseline data), during operations, and for longer periods after operations are completed. Likewise, the EPA's Economic Analysis of the proposed rule offers a number of clear economic perspectives on the costs and benefits of groundwater protection. However, we see a number of areas where EPA's Economic Analysis could be improved and where economic valuation of protecting groundwater can be incorporated more universally in EPA's rulemaking and in environmental impact assessments.

Below, we provide economic perspective and recommendations for EPA's valuation of groundwater. Our comments relate to the section 4 "Benefits Analysis" (pp. 4-1 – 4-11) of the Economics Analysis. The Benefits Analysis provides a qualitative discussion and a partially quantified description of expected benefits of the proposed rule in two main sections: the first is a broader discussion of conceptual frameworks for valuing groundwater and the second section is an application of valuation methods to the proposed rule.

We organized our two primary sections to assess the quality of conceptual frameworks and methods presented and to assess the quality of the benefits estimates applied to the proposed rule. Our comments are intended to help inform future groundwater protection policy development and analysis. We submit these comments to EPA in an effort to bring awareness to the unique economic characteristics of groundwater and ultimately to facilitate greater protection of our groundwater resources.

2. Conceptual Framework and Methods for Groundwater Valuation

Economically speaking, groundwater is a unique natural resource with distinct attributes (Young and Loomis 2014). Groundwater is connected to surface waters in myriad pathways and time scales. Total stocks and loss and return rates of aquifers are not easily ascertained. Groundwater is a public good, without associated property rights, leading to externalities associated with the tragedy of the commons.

[1] Economic Analysis: Proposed Revisions to the Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings Rule (40 CFR Part 192). Draft Report: EPA 402-R-14-003, November 2014.

In many places, there is no extraction fee for groundwater. These attributes of groundwater lead to an undervaluation of its importance to society (NAS 1997) and a need to economically acknowledge, if not capture, downstream externalities of using groundwater resources (Koundouri 2004).

The first section of the Benefits Analysis is Section 4.1 (p. 4-1), where background economic methodologies for groundwater resources and protection are discussed. EPA provides a good overview of various values and valuation methods for groundwater resources and changes to the quality and quantity of groundwater. EPA's starting point of a Total Economic Value (TEV) perspective is commendable, and supported by the groundwater economics literature (e.g., NAS 1997, Young and Loomis 2014). TEV frameworks have been used to value the benefits of wilderness areas as well as the negative externalities from oil and gas development (Morton 1999, Morton et al 2004, see Appendix A for example categories for oil and gas development). The TEV framework is widely used as a starting valuation framework and has been recommended by the U.S. Department of the Interior[2]. In this section we discuss the importance of incorporating a TEV approach to EPA groundwater valuation.

2.1. Total Economic Value (TEV)

The majority of economic valuation of groundwater has come from the extraction and production perspective for industrial and agricultural development. The Total Economic Value (TEV) framework, however, provides for a more holistic valuation approach to the many beneficial uses of groundwater, along with the many beneficial *in-situ* values of keeping groundwater in the ground. As discussed in the Benefits Analysis (p. 4-2), TEV includes both use and non-use, or passive use, values. Use values include the extraction of groundwater for drinking, irrigation, aesthetics, and recreation. Passive use values include the existence and bequest values for protection of groundwater. Methods for valuing use and passive use values under a TEV framework are illustrated on p. 4-3 of the Benefits Analysis, and include revealed preference methods, stated preference methods, and avoided cost methods.

While we are encouraged to see more mainstreaming of the TEV framework in conceptual economic discussions for EPA groundwater protection policies, we recommend that EPA should actually incorporate more components of TEV in their calculations of benefits for all groundwater policy (e.g., greater accounting for changes in *in-situ* use values, option values, and passive use values). There are also other economic frameworks and filters with which to assess the economic ramifications of groundwater contamination and protection.

All valuation frameworks have overlap, but each one typically highlights particular areas of economic importance. Below, we highlight two important valuation frameworks for groundwater protection policy currently missing from the EPA's Benefits Analysis: ecosystem service valuation and natural resource damage assessments. These frameworks can be conducted under the umbrella TEV approach recommended by EPA and can shed light on groundwater values typically not assessed in traditional benefit-cost analysis (BCA). Individual valuation methods that comprise these frameworks are largely the same, various revealed and stated preference methods, along with avoided cost analyses.

---

[2] For example, see USDOI Instruction Memo for BLM nonmarket valuation at: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2013/IM_2013-131__Ch1.print.html

Synthesizing a number of individual valuation studies can be done statistically via meta-analysis (for an example valuing ecosystem conservation see Hjerpe et al. 2015). Additionally, benefits transfer techniques can be used to apply relevant individual studies, or a synthesized set of studies, directly to the policy site under question.

2.2 Ecosystem Service Framework

Recent developments in the valuation of nature's goods and services provided to humans have been advanced under the Ecosystem Services (ES) framework. Ecosystem services are the benefits from natural capital provided to mankind (Daily 1997 and Costanza et al. 1997) and can be classified as final services (e.g. provisioning services such as drinking water) and intermediate services necessary to produce final services (e.g., regulating services such as recharging surface water).

While the value of many of these ecosystem services may be captured in other economic valuation methods already included in EPA's economic analysis guidance, an ES framework provides a useful, alternative filter with which to view groundwater protection. In particular, an ES framework is well suited to identifying intermediate services related to *in-situ* value, or the value of water remaining in place within the aquifer,[3] such as buffering water supplies, preventing land subsidence, and supporting ecological habitats. These environmental benefits provided by groundwater are most often public goods. Without specific property rights on ecosystem goods (exhibiting economic characteristics of being nonexclusive and nonrival) to allocate prices to *in-situ* values of groundwater, changes in these ecosystem services are the externalities generated from groundwater injury. We recommend EPA incorporate an ES framework for their Benefits Analysis, in addition to the identification of other economic costs, benefits, and impacts.

A recent case study on valuing groundwater resources in South Africa by Bann and Wood (2012) show a number of potential ecosystem services associated with groundwater. Services include provisioning services such as the supply of water for drinking, and a number of regulating services such as the dilution of pollutants, a sink for CO_2, and a recharge for surface waters. Bann and Wood (2012) also outline steps for incorporating groundwater values into decision making by including benefit transfer methods. Table 1 below is the list of potential groundwater services and benefits from Bann and Wood (2012). Additionally, many of these services are discussed in EPA's framework for groundwater benefits (EPA 1995).

2.3. Natural Resource Damage Assessments

From the public's perspective, the benefits of groundwater protection can be viewed as damage avoided from groundwater contamination (Abdallah 1994). Natural resource damage assessments (NRDA) are another framework that can highlight potential damages resulting from groundwater contamination. NRDAs are measures of liability, or damage estimates to be paid to replace, offset, or mitigate lost economic values. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), or Superfund, provided for liability of polluters of hazardous waste. Interestingly, the first legislation to identify injuries to natural resources as compensable damages was the Clean Water Act

---

[3] *In-situ* values are discussed In EPA's Economic Analysis on p. 4-2.

(Kopp and Smith 2013). After these provisions were enacted, the federal government, states, and others filed legal claims to recoup damages from environmental contaminators and utilized natural resource damage assessments to estimate the value of the damages.

Table 1
Potential groundwater services and benefits

Ecosystem service category	Service	Benefit / outcome
Provisioning services	Water supply	Public water supply
		Private / community water supply
		Agriculture
		Industrial abstraction
	Habitat for hypogean species	Species diversity and potential genetic/scientific value
	Sink/source of energy	Energy provision
Regulating services	Recharge to surface waters (rivers, lakes, springs, wetlands, transitional waters)	Protecting the benefits of surface water for consumptive and non-consumptive use (e.g. water abstraction, recreation and tourism, non-use)
	Flood risk regulation	Flood risk reduction (protection of property, agricultural land, human lives)
	Sink for atmospheric carbon dioxide	Carbon capture
	Dilution of pollutants	Reduced impact of contaminants
	Attenuation of pollutants	Reduced impact of contaminants
	Prevents subsidence	Avoidance of subsidence
	Sustains habitats	Reduction of irrigation requirement
Cultural services	Biodiversity non-use	Biological diversity, species, habitat
	Tourism, spiritual, religious, educational experiences	Tourism, spiritual, religious, educational experiences

Source: Bann and Wood 2012. Table 1, p. 463.

Habitat-equivalency analysis (HEA) is an often-used method for determining the magnitude, or scale, of compensatory-restoration actions needed to compensate the public for the losses resulting from natural resource damage (Dunford et al. 2004). HEA consists of a couple basic components to determine NRDAs: estimate the cost of restoring the damaged resource, and estimate the lost values in the interim (NOAA 2006). NRDAs are valuable for determining potential contamination of groundwater, though there are always concerns with whether or not complete restoration of the damaged resource is fully feasible.

Concerning aquifers, Ando et al. (2004) provide a comprehensive review of economic methods and values used for assessing groundwater damage. While the context of their review is framed around natural resource damage assessments (NRDA) available to states under the CERCLA and other statutes, the concepts for understanding degradation to groundwater and its associated economic effects provides valuable information that can be incorporated into EPA's Benefits analysis of the proposed rule. Prevention of groundwater contamination from uranium ISR sites via the proposed rule provide much greater benefits than those outlined in Section 4.

Damage assessments are sometimes included in stated preference studies (i.e., WTP studies) for groundwater protection (Young and Loomis 2014), but it depends on which damages were introduced to survey respondents and whether or not specific damages were used as an attribute by primary research authors. The most publicized NRDA was conducted to determine compensation from damages from the Exxon Valdez oil spill to the Prince William Sound ecosystem in Alaska. These compensatory damages included lost use and passive use values to local and Native peoples.

Both the Ecosystem Service framework and Natural Resource Damage Assessments have been utilized for estimating TEV of groundwater resources. We recommend that EPA incorporate additional groundwater valuation frameworks and suggest that many of the values pursued may be able to be incorporated into agency BCA of policy changes.

3. Economic Benefits of the Revised Uranium ISR Rulemaking

Section 4.2 (p.4-4) of the Benefits Analysis provides a specific application of the benefits of proposed changes in monitoring requirements. The Benefits Analysis focuses on three main areas of potential benefits, or avoided damages, associated with preventing groundwater contamination: reducing human health risks, protecting groundwater for future generations, and avoiding future remediation costs (pp. 4-5 – 4-7). Of these three, only the avoided future remediation costs are quantified. Human health risks are qualitatively discussed and focus on the "value of statistical life" (VSL) approach, whereas bequest values for future generations are not estimated at all.

To determine potentially avoided remediation costs due to the proposed rule, EPA utilized a "modeled facility" approach to estimate costs of varying uranium contamination scenarios on a modeled mine unit. Estimated avoided remediation costs for a modeled contamination due to the proposed rule range from $8 million to $560 million. The extensive sensitivity analysis in this section, along with the incorporation of the modeled facility approach is laudable and provides quantified estimates that illustrate one category of potential benefits from the proposed rule.

The qualitative discussions on the monetary value of health benefits and bequest values for future generations are a good starting point for examining additional benefits of the proposed rule, but we recommend more rigorous exploration of these categories. Likewise, there are a number of additional benefit categories that are missing from the Benefits Analysis. In this section we examine the primary missing benefit categories and provide recommendations for furthering estimates of the health and bequest benefits from the proposed rule.

3.1 Missing Economic Spillover Damages

Groundwater contamination, especially when involving radioactive heavy metals, creates numerous adverse economic effects. These adverse effects are incurred on site, and spill over to adjacent communities and environments. However, most avoided spillover effects from groundwater contamination across time and space are noticeably absent from the Benefit Analysis. A review of the literature shows additional categories of critical benefits associated with groundwater protection (Spofford et al. 1989, Abdallah 1994, NAS 1997). In addition to the three avoided damages included in the estimated benefits of the proposed rule (human health, bequest values, and remediation costs), spillover effects include damages to adjacent and existing (if leasing) property owners, associated fear and anxiety from communities near contaminated aquifers, and ecological/biophysical damages.

Properties adjacent to groundwater contamination sites lose value. This is a negative externality of extractive development and of uranium ISR operations. For example Muehlenbachs et al. (2012) found a 26 percent reduction in property values just from the risk of groundwater contamination from shale gas development. Likewise, Boxall et al. (2005) found that the risk of health hazards from oil and natural gas facilities had a significant negative association with adjacent property values. Similar cases have been illustrated for the risk of groundwater contamination from other forms of energy development such as coal ash[4] and uranium production[5]. Given recent trends of migrants relocating to regions with greater natural amenities and public lands, particularly in the West where the majority of uranium reserves are located, communities may suffer from macro spillover effects that make them less attractive and ultimately may see affected property values and tax bases.

While fear and anxiety are economic costs to societal well-being in their own right, they can also lead to broader property stigma effects for communities with publicized groundwater contamination. Groundwater contamination from uranium mining, or even the risk of groundwater contamination, can also affect public lands and tourism and recreation regional economic impacts. For example, longstanding issues over uranium mining on public lands adjacent to Grand Canyon National Park[6] create concern among visitors wanting to enjoy the Colorado River and potentially affected tributaries. These community effects are different from the regional economic impacts presented in Section 5, and should be acknowledged in the Benefits Analysis.

Finally, the spillover damages from groundwater contamination on the environment can harm ecological receptors and the biophysical structure that supports natural capital. These environmental damages can affect human health (e.g., consumption of livestock that has ingested pollutants) and can have cascading effects on ecological communities. For a detailed examination of environmental impacts

[4] For coal ash waste contamination and groundwater effects see LA Times story on May 4, 2015, available at: http://www.latimes.com/nation/la-na-coal-ash-pollution-20150504-story.html#page=1
[5] Poisoning the well: how the Feds let industry pollute the nation's underground water supply. ProPublica. 12/11/12. Article available at: http://www.propublica.org/article/poisoning-the-well-how-the-feds-let-industry-pollute-the-nations-undergroun
[6] Science still developing on uranium's environmental impact. AZ Daily Sun. 4/20/15. Article available at: http://azdailysun.com/news/local/science-still-developing-on-uranium-s-environmental-impact/article_108aa9e0-da62-578d-869f-404b427b21c3.html

stemming from uranium ISR operations see Fettus and McKinzie (2012). Environmental damage to ecological receptors and biophysical supporting services are largely ignored in the Benefits Analysis.

Recommendations:

We recommend that EPA include partially quantified descriptions of these missing economic spillover effects in their final Benefits Analysis of proposed monitoring requirements (Section 4.2, pp 4-4 – 4-10). Valuation methods identified in the Conceptual Framework (Section 4.1, p 4-3), such as revealed preference methods like hedonic pricing are available for measuring groundwater pollution effects on property values. However, estimates of these economic effects stemming from groundwater protection are not included in specific Benefits Analysis in Section 4.2. While economic data for uranium pollution of groundwater, or the preferences for preventing uranium groundwater pollution are extremely limited, we recommend EPA provide surrogate estimates (as recommended in NAS 1997) for these spillover effects that have been identified in research on other forms of anthropogenic water pollution, such as effects from fertilizers, pesticides, other heavy metals, bacteria, sediment, and temperature. Incorporating estimates from economic valuations of various types of water pollution will strengthen the Benefits Analysis and would provide greater context to the conceptual scoping exercise.

3.2. Greater Incorporation of Stated Preference Methods Needed

Stated preference methods are useful for measuring willingness to pay (WTP) for nonmarket goods and services. Stated preference methods include contingent valuation techniques and choice experiments, where a hypothetical market is created and executed by relevant stakeholders. These contingent valuation methods are particularly well suited for ascribing value for passive uses, such as existence and bequest values. Thus, research on willingness to pay (WTP) for protecting and improving groundwater quality provide additional means of quantifying the economic values of protecting groundwater.

The Benefits Analysis of the proposed rule includes a discussion of society's nonmarket values for groundwater and highlights a meta-analysis conducted by Poe et al. (2001) that illustrates substantial WTP for groundwater protection. However, in Section 4.2 (pp 4-4 – 4-10), where EPA outlines the benefits of the proposed changes in monitoring requirements, the latest synthesis of nonmarket values for groundwater protection (Poe et al. 2001) are only nominally included in two places and have not been included in the overall benefit aggregation. The two ad-hoc inclusions note that: 1) the value of groundwater protection increases when cancer risks from contamination are involved; and 2) the value of groundwater protection increases when including use and passive use values.

The majority of studies analyzed by Poe et al. (2001) and previously by Boyle et al. (1994) are east of the Mississippi River and focus on nitrates and pesticides as potential groundwater pollutants. However, this rulemaking is concerned with uranium recovery, a potential pollutant with a much greater half-life than nitrates and pesticides. And, as illustrated in Table 2-7, all operating and non-operation ISR plants in the U.S. are located in the West and the Southwest, arid regions where water is more scarce and thus has greater economic value.

One of the three main groups of explanatory variables for overall WTP for groundwater protection as modeled by Boyle et al. (1994) and Poe et al. (2001) is the “environmental commodity.” Environmental commodities include the type and scale of groundwater contamination, the local price of potable water, and the availability and price of substitutes. Since uranium ISR plants are clustered in arid geographies, local prices of potable water are generally higher than those found in primary studies incorporated in Boyle et al. (1994) and Poe et al. (2001), and available substitutes (e.g., surface water) are drastically lower. Given the increased water scarcity in typical geographies where ISR operations are taking place, overall WTP for groundwater protection in these regions is likely to be much higher than average WTP estimated in Poe et al. (2001).

Recommendations:

We recommend that synthesized WTP estimates for groundwater protection be included in the benefit calculations of the proposed rule. The “modeled facility” approach used to calculate avoided remediation costs can include a modeled affected population with which to apply individual and/or household WTP estimates. While bequest values may not be able to be isolated, providing surrogate estimates of broad WTP would be inclusive of bequest and other passive use values.

Benefits transfer of this type can be problematic due to the numerous differences between sampled study sites and the proposed policy site, and we recommend extensive caution when illustrating estimates from various locations and various groundwater pollutants. But, in the same vein as the modeled facility approach for avoided remediation costs (Section 4.2.3), acknowledging and applying a modeled WTP estimate provides a point of reference and further illustration of the true benefits of the proposed rule. Currently, the draft Benefits Analysis treats these significant nonmarket values as zero, which greatly undervalues the affected resource----scarce Western groundwater.

Inclusion of WTP estimates and nonmarket values in general, through benefit transfer techniques, would generally be applied to policy sites using the aggregated mean WTP found in synthesized WTP estimates from primary studies. However, application of WTP estimates for groundwater protection in this case deserve special treatment given the unique pollutant of concern under consideration and the distinct geographic locations of ISR. Given the influence of these independent variables on the overall WTP for groundwater protection, we recommend using WTP estimates well above the mean as found in Poe et al. (2001) for any proposed rulemaking focused on uranium ISR. Additionally, WTP extends beyond just the local affected populations, especially when considering ISR on or adjacent to aquifers in public lands. Thus, we recommend a broader and more inclusive framing of WTP for groundwater protection.

3.3. Interim Lost Use, Averting Behavior, and Additional Health Costs

There are a number of other damages, beyond those detailed in the benefits application of the proposed rule (Section 4.2), that occur when groundwater becomes contaminated or even has the risk of contamination. Only three main types of benefits are included in Section 4: reducing human health risks, protecting groundwater for future generations, and avoided remediation costs. But groundwater contamination results in numerous damages and extensive liabilities for responsible parties that go far beyond those outlined in Section 4. Standard economic theory treats avoided costs as benefits. And while much caution should be taken to prevent double counting and to accurately assess who is benefitting (e.g. operators, individuals, or society), we recommend greater acknowledgement of avoided costs. Along with human health, environmental costs, and remediation costs, these costs should include the value of interim lost use (Ando et al. 2004).

We recommend including the value of interim lost use, which is currently missing from Section 4. For example, groundwater contamination from a uranium ISR operator would generate human health and spillover effects discussed above, but would also result in the potential loss of other production uses of the contaminated groundwater such as for irrigation. Similar to interim lost uses are other costs incurred during the contamination period such as averting behaviors by affected populations (e.g., purchasing bottled water), mobilization costs of communities to access new water sources, medical costs for treatment that society would likely bear the brunt of, and lost utility/labor of sickened people (NAS 1997). These are real economic ramifications of contaminating groundwater with mobile uranium and should be acknowledged. The duration of the injury to contaminated aquifers is a critically important valuation concept and is often underestimated due to the slow-moving nature of groundwater and the irreversibility of some contamination (Ando and Khanna 2004).

3.4 Other Recommendations for Estimating the Benefits of the Proposed Rule

The Benefits Analysis (Section 4) provides a cursory introduction to groundwater economics and a partial application of the benefits of the proposed rule, but falls short of fully accounting for the benefits of avoiding groundwater contamination from uranium ISR operations. In this section, we have illustrated economic effects of groundwater pollution that are largely missing from the Benefits Analysis and suggest greater quantification of with/without scenarios.

Other recommendations for a more comprehensive Benefits Analysis section include:

- Emphasize the importance of site and geographic variation in benefits analysis;
- Incorporate findings from avoided costs and environmental damages estimated in other forms of groundwater contamination resulting from fracking techniques for oil and gas;
- Include greater sensitivity analysis for quantification of benefits. EPA does extensive sensitivity analysis for illustrating costs to ISR operators of the proposed rule (e.g. ES-5) and for avoided remediation costs. We feel that other benefit categories should also be subjected to extensive sensitivity analysis (recommended in NAS 1997).
- Incorporate more of the EPA's own guidance on economic analysis and groundwater. Specifically, EPA (1995) cautions managers not to overlook indirect effects of groundwater contamination when conducting regulatory impact analysis. Similarly, EPA (2014) advocates for an "effect by effect" approach in assessing benefits to ensure all effects are included.

4. Broad Recommendations for Groundwater Valuation

Beyond the economic analysis discussed for a uranium ISR rulemaking, we encourage EPA to add greater economic investigation for all groundwater protection policy. EPA has presented the economic characteristics of groundwater thoroughly in the Section 1 Introduction of the Economic Analysis, particularly in the outlining of market failures of not fully accounting for groundwater pollution from industrial development and the justification for regulatory intervention (p. 1-2). But, EPA largely fails to acknowledge or capture these externalities in their regulatory impact analyses. Further regulatory adjustments are needed to fully account for these negative externalities.

Much of the EPA economic analysis is predicated on benefit cost analysis (BCA) and economic impact analysis. Economic impact analysis (EIA) evaluates the changes in macro regional market indicators of output, employment, income, and taxes. Economic impacts are traditionally not considered as benefits or costs, as they do not represent changes in societal welfare but rather geographic transfers of income and capital. The benefits and costs in BCA are representative of changes in well being and utility, but can vary based on the perspective of an individual, a business, a community, a country, and even a future generation. These various views on whose welfare is being affected are problematic for comparing apples to apples in BCA. In an attempt to avoid double counting, it seems as if EPA too often errs on the side of leaving out many benefits of regulatory revisions, leaving many BCAs of water resources light on the full accounting of costs and benefits. Not all benefits or avoided costs can be incorporated into BCA due to various perspectives on who is benefiting and who will pay for damages. Instead of boiling down all economic welfare effects into inputs for BCA, we recommend that some be included and others be acknowledged as economic effects unable to be combined with others.

Uranium, and associated radioactive metals, are unique pollutants of concern for groundwater and need special treatment given their extremely slow rate of decay and the intense toxicity and radioactive nature of exposing these elements. Combining the longevity of exposed uranium with the slow rate of travel for groundwater in many aquifers limits the dispersal and dilution effectiveness found in surface waters. Because groundwater contamination can be hidden and undiscovered for long periods of time, and ISR operations represent newer technology, the Benefits Analysis of the proposed rule has a limited set of information and data on the risk of groundwater contamination from uranium ISR.

In cases where there is lack of quantitative data, EPA's economic guidance suggests the following approach. "Thus, even when data are insufficient to support particular types of economic analysis, the conceptual scoping exercise can provide useful insights" (p. 1-2, EPA Guidelines for Economic Analysis 2014). We agree that scoping in these cases provides valuable information, but recommend more comprehensive scoping when dealing with such uncertainty and with pollutants of such high concern.

4.1. Accounting for Groundwater-Associated Negative Externalities

Most EPA economic analysis fails to fully account for the spillover effects, or negative externalities, that occur when groundwater becomes contaminated from subsurface mining. Many of these spillover effects are not easily categorized as either a cost or a market impact, as they often illustrate characteristics of both. For example, adverse effects on adjacent property values stemming from subsurface mining operations and potential groundwater pollution have both a regional market effect (pulling down entire community property values and attractiveness) and personal costs for individual properties owners that experience before-and-after subsurface mining changes. Yet, these effects are often missing from any of the economic analyses (even the Socioeconomic Affected Environment sections).

Other indirect effects, such as the burden on societal health care costs, stemming from adverse human health effects from groundwater contamination are generally not included in the full accounting of costs. While accounting for the full suite of negative externalities from exposing groundwater to potential contamination requires greater analysis and greater resources for monitoring socioeconomic effects, EPA's current treatment of these externalities is extremely limited, treating them as zero cost to society well-being. We recommend greater qualitative acknowledgment of these groundwater-associated negative externalities at a minimum, and encourage EPA to attempt quantification of these costs in many cases (even as a scoping exercise).

Full evaluation of marginal effects of policy changes requires extensive knowledge of the type and size of goods and services provided by groundwater under current conditions, along with knowledge of the type and size of changes to these services under policy revision. With myriad groundwater goods and services and limited existing data, we understand that it is often impossible to accurately account for all impacts or changes to ecosystem services. But, in these cases, we recommend greater acknowledgement of the diverse array of services and at a minimum, a checklist and identification of suspected direction of change in these services under policy revision. For example, under a modeled groundwater contamination scenario we would expect the drinking water service to decrease in quality. A compiled list of anticipated enhancement (positive effect) of the quantity and quality of services, or anticipated degradation (negative effect) of individual services, would provide greater information for policy analysis and a more complete scoping exercise.

4.2. Strengthening Standards for Aquifer Exemptions

The Underground Injection Control (UIC) program under the Safe Drinking Water Act (SWDA) allows for certain cases of wastewater injection into groundwater for oil and gas production facilities. These "Aquifer Exemptions" have also been utilized by uranium ISR operators (Noël 2015). The aquifer exemptions have recently come under greater scrutiny as the exemption applications have greatly increased and tracking of exemptions has been haphazard,[7] and there has been a systematic failure to study the long term cumulative effects of sacrificing aquifers to uranium mining and other forms of resource extraction (Fettus and McKinzie 2012).

There are a number of economic considerations for the aquifer exemption program, but most policy revisions by EPA in this area have been reactionary and with little thought to long term groundwater values and scarcity. The three primary criteria for receiving aquifer exemptions most relevant for economic considerations include: 1) the aquifer is currently not used for drinking water, 2) the aquifer is not reasonably expected to serve as a source of drinking water in the future, 3) the aquifer has a dissolved solids count between 3,000 and 10,000 mg/l (Noël 2015).

Many of these aquifer exemptions are occurring in the arid West, where water scarcity is increasing dramatically. The arbitrary criteria for exemptions are unable to keep pace with rapidly expanding groundwater demand and with technological advancements. Groundwater with heavy sediment that

[7] Poisoning the well: how the Feds let industry pollute the nation's underground water supply. ProPublica. 12/11/12. Article available at: http://www.propublica.org/article/poisoning-the-well-how-the-feds-let-industry-pollute-the-nations-undergroun

was unable to be technically treated a couple decades ago are now a possibility for drinking water sources. Similarly, aquifers that were cost prohibitive to utilize as drinking water a couple of decades ago, are now potentially cost effective to access given increasing scarcity and increasing prices for groundwater. Given rapidly changing technology, demands, and demographics, we recommend the EPA strengthen the standards for aquifer exemptions based on economic realities.

5. Summary

Groundwater is the "hidden old growth" of water resources, and should be treated with special attention. We are encouraged to see EPA tackle long overdue revisions to monitoring requirements for uranium ISR operations. We commend EPA for acknowledging the holistic economic values at stake with groundwater degradation and protection. In particular, we commend EPA for advocating for a Total Economic Value framework and for clearly articulating the externalities and market failures associated with the development of groundwater resources. However, we recommend that EPA incorporate these economic concepts more fully when conducting benefits analysis of the proposed rule.

There are numerous economic values affected by water policy, and numerous valuation methods to account for changes in values generated by policy revisions.[8] The myriad values and measurement techniques can lead to double counting of benefits, but can also lead to being too cautious and settling for partial lists of values. EPA's own guidance on preparing economic analyses (EPA 2014, p. 7-3) advocates an "effect-by-effect" approach for benefits analysis and encourages the use of multiple valuation methods. Given that uranium pollution to groundwater resources can be irreversible and permanent, we recommend following the Precautionary Principle and erring on the side of limiting overall risk whenever possible. We believe that in addition to the groundwater monitoring components included in the proposed rule, the EPA should consider adding socioeconomic monitoring programs as necessary protocol for uranium ISR operators as well.

[8] For exhaustive lists of economic services, effects, and valuation methods for estimating effects of groundwater policy changes see Tables 1 and 2 in EPA 1995. For a complete list of economic valuation methods for all water resources, see Table 2.1 in Young and Loomis 2014.

6. References

Abdalla, C. W. (1994). Groundwater values from avoidance cost studies: implications for policy and future research. *American Journal of Agricultural Economics*, *76*(5), 1062-1067.

Ando, A. W., & Khanna, M. (2004). Natural resource damage assessment methods: lessons in simplicity from state trustees. *Contemporary Economic Policy*, *22*(4), 504-519.

Ando, A.W., M. Khanna, A. Wildermuth, and S. Vig. 2004. Natural resource damage assessments: methods and cases. *Technical report for Illinois Waste Management and Research Center*, RR-108.

Bann, C., & Wood, S. C. (2012). Valuing groundwater: a practical approach for integrating groundwater economic values into decision making-A case study in Namibia, Southern Africa. *Water SA*, *38*(3), 461-466.

Boxall, P. C., Chan, W. H., & McMillan, M. L. (2005). The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis. *Resource and energy economics*, *27*(3), 248-269.

Boyle, K. J., Poe, G. L., & Bergstrom, J. C. (1994). What do we know about groundwater values? Preliminary implications from a meta analysis of contingent-valuation studies. *American Journal of Agricultural Economics*,*76*(5), 1055-1061.

Costanza R, et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*. 387: 253-260.

Daily, G. (Ed.). (1997). *Nature's services: societal dependence on natural ecosystems*. Island Press.

Dunford, R. W., Ginn, T. C., & Desvousges, W. H. (2004). The use of habitat equivalency analysis in natural resource damage assessments. *Ecological economics*, *48*(1), 49-70.

EPA. 1995. A framework for measuring the economic benefits of ground water. Technical Report for EPA: EPA 230-B-95-003. 62p.

EPA. 2014. Guidelines for preparing economic analyses. May 2014 Technical Report for EPA. 300p.

Fettus, G. H., & McKinzie, M.G. 2012. Nuclear fuel's dirty beginnings: environmental damage and public health risks from uranium mining in the American West. Technical Report for Natural Resource Defense Council. 16.p.

Hjerpe, E., A. Hussain, and S. Phillips. 2015. Valuing type and scope of ecosystem conservation: a meta-analysis. *Journal of Forest Economics* 21(1): 32-50.

Kopp, R. J., & Smith, V. K. (2013). *Valuing natural assets: the economics of natural resource damage assessment*. Routledge.

Koundouri, P. (2004). Current issues in the economics of groundwater resource management. *Journal of Economic Surveys*, *18*(5), 703-740.

Morton, P. 1999. The Economic Benefits of Wilderness: Theory and Practice. University of Denver Law Review. Volume 76, No. 2 pp. 465-518.

Morton, P., C. Weller, J. Thomson, M. Haefele, and N. Culver. 2004. Drilling in the Rockies: How much and what cost? Special Energy Session of the 69th North American Wildlife and Natural Resources Conference, Spokane, WA. Wildlife Management Institute, Washington, DC. 33 pages.

Muehlenbachs, L., E. Spiller, and C. Timmins (2013). Shale Gas Development and the Costs of Groundwater Contamination Risk. RFF Discussion Paper 12-40.

National Academy of Sciences (NAS), 1997. *Valuing Groundwater: Economic Concepts and Approaches*. Committee on Valuing Groundwater, National Research Council.

National Oceanic and Atmospheric Administration. (2006). Habitat Equivalency Analysis: An Overview**.** Technical Report, Washington, DC.

Noël, J. 2015. Aquifer exemptions: a first-ever look at the regulatory program that writes off drinking water resources for oil, gas and uranium profits. Technical Report for Clean Water Action/Clean Water Fund. 19p.

Poe, G., K. Boyle, and J. Bergstrom, 2001. A Preliminary Meta Analysis of Contingent Values for Groundwater Quality Revisited. In *The Economic Value of Water Quality*. J. Bergstrom, K. Boyle, and G. Poe, eds. Northampton, MA: Edward Elgar.

Spofford, W.A., A.J. Krupnick, and E.F. Wood. Uncertainties in estimates of the costs and benefits of groundwater remediation: results of a cost-benefit analysis. Washington DC: Resources for the Future Discussion Paper QE89- 15, 1989.

Young, R. A., & Loomis, J. B. (2014). *Determing the Economic Value of Water: Concepts and Methods*. Routledge.

Appendix A: TEV Framework for the Hidden Costs from Oil and Natural Gas Drilling that Spillover into our Communities and Environment

Direct use costs – displacement or loss of land for habitat, recreation opportunities, hunting, farmland, grazing, reclamation costs, water quantity and drought

Community concerns – NOx, VOCs, ozone and kids health, truck traffic and infrastructure costs, property values, loss of local control, displaced jobs and revenues due to “crowding out”, natural amenities and quality of life issues, loss of retirement income, displaced farming due to competition for water, boom-bust cycles, revenue lag and fiscal risks, water treatment plants and recycled fracking water, draining of reservoirs for fracking water and the loss of fishing and recreation revenue

Science benefits foregone -- loss of natural areas for scientific study

Off-site damages – fugitive methane emissions, water pollution from spills, noise pollution from compressor stations, visual impacts, erosion from well pads and roads, pipeline explosion risks, road dust on petroglyphs and snowpack, seismic activity from injection wells

Biodiversity impacts – loss and fragmentation of wildlife habitat by roads and well pads, pipelines are conduits for invasive weeds, endocrine disrupters impact to amphibians and fish, produced water holding ponds and bird deaths

Ecosystem service costs – water lost to fracking, impacts to aquifer re-charge and wetland function, carbon lost via land use change, fossil fuels and climate change

Passive use benefits foregone -- loss of option, bequest and existence benefits generated by open space, parks and wildlands.

Reference: Morton, P., et al. (2004). Drilling in the Rockies: How Much and at What Cost? Proceedings of a Special Energy Session of the 69th North American Wildlife and Natural Resources Conference, Spokane, WA. Wildlife Management Institute

AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE
10.1002/2013EF000214

Key Points:
- Integrated assessment modeling of water
- Largest water stress projected in the Southwest of the U.S.
- Emission abatement policy help reduce water stress intensity and variability

Corresponding author:
E. Blanc, eblanc@mit.edu

Citation:
Blanc, E., K. Strzepek, A. Schlosser, H. Jacoby, A. Gueneau, C. Fant, S. Rausch, and J. Reilly (2014), Modeling U.S. water resources under climate change, *Earth's Future, 2*, doi:10.1002/2013EF000214.

Received 25 OCT 2013
Accepted 24 FEB 2014
Accepted article online 24 FEB 2014

Modeling U.S. water resources under climate change

Elodie Blanc[1], Kenneth Strzepek[1], Adam Schlosser[1], Henry Jacoby[1], Arthur Gueneau[1,2], Charles Fant[1], Sebastian Rausch[1,3], and John Reilly[1]

[1] Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [2] International Food Policy Research Institute, Washington, DC, USA, [3] Department of Management, Technology, and Economics, ETH Zurich, Zurich, Switzerland

Abstract Water is at the center of a complex and dynamic system involving climatic, biological, hydrological, physical, and human interactions. We demonstrate a new modeling system that integrates climatic and hydrological determinants of water supply with economic and biological drivers of sectoral and regional water requirement while taking into account constraints of engineered water storage and transport systems. This modeling system is an extension of the Massachusetts Institute of Technology (MIT) Integrated Global System Model framework and is unique in its consistent treatment of factors affecting water resources and water requirements. Irrigation demand, for example, is driven by the same climatic conditions that drive evapotranspiration in natural systems and runoff, and future scenarios of water demand for power plant cooling are consistent with energy scenarios driving climate change. To illustrate the modeling system we select "wet" and "dry" patterns of precipitation for the United States from general circulation models used in the Climate Model Intercomparison Project (CMIP3). Results suggest that population and economic growth alone would increase water stress in the United States through mid-century. Climate change generally increases water stress with the largest increases in the Southwest. By identifying areas of potential stress in the absence of specific adaptation responses, the modeling system can help direct attention to water planning that might then limit use or add storage in potentially stressed regions, while illustrating how avoiding climate change through mitigation could change likely outcomes.

1. Introduction

Water availability is a growing global concern [*UN*, 2012], and many rivers are affected by water scarcity and quality issues. Troubling examples include the Ganges and Indus in India; the Amu Dar'ya and Syr Dar'ya in Central Asia; the Murray and Darling in Australia; and the Yellow and Yangtze in China [*Postel*, 2000]. The United States is no exception, with the Colorado and the Rio Grande rivers so severely exploited that they often do not reach the oceans [*Benke and Cushing*, 2005]. A significant area of the Southwest of the United States is prone to water scarcity with more than 75% of the river flow used for agriculture, industries, and domestic purposes [*IWMI*, 2007]. *Pritchett et al.*'s [2009] survey of more than 6000 people in the 17 westernmost states of the continental United States shows that respondents are aware of the water scarcity issue, but believe that it is less important in their own state than in other states.

Heavy exploitation of many U.S. water resources is the consequence of growing population and economic activity, and lack of conservation measures. Under the threat of climate change, and the likely effects on surface hydrology, the water issue is even more pressing. These issues have been extensively studied, more recently taking account of climatic effects [e.g., *Vörösmarty et al.*, 2000; *Oki et al.*, 2001; *Arnell*, 2004; *Alcamo et al.*, 2007; *Shen et al.*, 2008; *Brown et al.*, 2013]. *Barnett and Pierce* [2008] estimate that there is a 50% chance that Lake Mead, the largest man-made reservoir in the United States, will be dry by 2021.

Water modeling efforts vary greatly in terms of scope (hydrologic detail, handling of vegetation, and integration of economic drivers), spatial scale (river basin to global), and time scale (daily to yearly). Water resources are often estimated using macroscale hydrological models, such as Water Balance Model (WBM) [*Vörösmarty et al.*, 1998, 2000], WaterGAP [*Alcamo et al.*, 2007], or H08 [*Hanasaki et al.*, 2008]. However, most hydrological models represent hydrological processes in a stylized fashion and do not consider important surface energy balance issues. Additionally, they are often only loosely coupled with climate models used to analyze the effects of climate on surface hydrology. Land surface models, such as the Community Land Model (CLM) [*Oleson et al.*, 2008], address both these issues. To represent water demand, some studies consider only a single sector of the economy. For instance, *Vassolo and Döll* [2005] and *Davies et al*. [2013] focus on thermoelectric and industrial water uses. Other studies detail water use only for irrigation [e.g., *Vörösmarty et al*., 1998, 2000]. Such efforts may fail to consider how changes in water demand from other sectors may affect water availability to the sector of interest.

There are other issues regarding the integration of the many drivers of water stress. While many studies consider the impact of anthropogenic climate change on water supply using climate model outputs or account for the effects of economic activity using a national or global economic model, few models, if any, are set up to consider the interdependence of these influences. Coupling of natural and social science components, and the assessment of the resulting complex effects on water, has been attempted in only a small number of integrated frameworks, such as TARGETS [*Rotmans and de Vries*, 1997], WorldWater [*Simonovic*, 2002], IMPACT-WATER [*Cai and Rosegrant*, 2002], WATERSIM [*de Fraiture*, 2007], and ANEMI [*Davies and Simonovic*, 2011].

However, the spatial and temporal scales of models are also important. Small river basin scale models provide very precise and useful management tools at the watershed level. For instance, the California Value Integrated Network (CALVIN) model [*Draper et al*., 2003], a hydro-economic optimization model, provides a very detailed representation of California's water system. But small-scale models do not easily connect to studies of global influences. Global-scale models, on the other hand, such as IMPACT-WATER [*Cai and Rosegrant*, 2002] and WATERSIM [*de Fraiture*, 2007], provide larger-scale analysis capacities, but they provide results of limited use in understanding local problems. The annual time scale of some models [e.g., *Vörösmarty et al*., 2000; *Oki et al*., 2001; *Alcamo and Henrichs*, 2002; *Arnell*, 2004; *Islam et al*., 2007; *Viviroli et al*., 2007] is often inadequate to assess water stress as it does not account for intra-annual variability.

High-quality water resource assessments meeting the desired scope, scale, and time step for climate-effect studies are rare because of data and modeling limitations. For the continental United States, for example, the challenge of such water models can be explained by the diversity of factors to consider: the United States comprises more than 3000 stream catchments, 18 Koppen-Geiger climate zones (half of the global range), and three major water rights paradigms over 50 states. A useful modeling framework at this scale requires a collection of tools that reflect the reality of water management while remaining computationally efficient.

In this article, we apply a framework that combines treatment of climatic, biological, and physical interactions that determine runoff, engineered systems of storage and transport, and multiple sources of water demand to meet residential, industrial, energy, and agricultural activity needs. The system is an extension of the Massachusetts Institute of Technology (MIT) Integrated Global System Model (IGSM) framework and is unique in its consistent treatment of factors affecting water resources and water demand. Irrigation demand, for example, is driven by the same climatic conditions that drive evapotranspiration in natural systems and runoff, and future scenarios of water demand for power plant cooling are consistent with energy scenarios driving climate change. This analysis builds on the MIT IGSM-Water Resource System (IGSM-WRS) [*Strzepek et al*., 2012b], which was developed to address the many shortcomings of existing modeling frameworks and, most importantly, to facilitate integration of water resource, land surface, and climate and economic processes. To analyze water issues specific to the United States, we develop a U.S. version of this approach, termed the IGSM-WRS-US, with greater sectoral and water basin detail. Specifically:

(i) U.S. waters are modeled at a 99-basin level compared to 14 U.S. basins in the global model.
(ii) The economy is modeled for 11 U.S. regions, replacing the single-nation representation in the global application, with water demand for power plant cooling modeled for 134 regions.
(iii) Interbasin transfers (IBTs), which are not considered in the global application, are included.
(iv) The systems supplying irrigation water and management practices at the crop level are based on county-level data, and calibrated to observed water application, which is often less than the water necessary to obtain maximum yield.
(v) An improved estimation of energy demand is incorporated, allowing a better estimation of water requirements for mining (MI) and thermoelectric power generation.
(vi) Detailed estimation of water requirements for public supply (PS) and self-supply (SS) sectors is added.

10.1002/2013EF000214

The IGSM-WRS-US was developed to identify areas of potential water stress, considering the multiple factors affecting available resources and competing demands from all sectors, including requirement for in-stream flows that are needed to maintain freshwater ecosystems. As such, it can point in the direction for further, more detailed, analysis and for longer-term water resource planning that could identify effective adaptation responses. For this reason, adaptation — other than reallocation or IBTs — is not evaluated endogenously. As an illustration, we provide an evaluation of two greenhouse gas (GHG) emission scenarios combined with two climate change scenarios to provide insights on the spatial and temporal patterns of climate impacts on water resources in the United States.

The description of the model and its application is organized as follows. First, in section 2, we summarize the various model components and how they are integrated into the modeling framework. Section 3 presents the core of the water allocation system. Section 4 describes the treatment of the hydrologic inputs: runoff, groundwater, IBTs, and basin storage. Section 5 describes the modeling components that project water requirements for SS, PS, MI, irrigation, and thermoelectric cooling and the treatment of environmental flow requirements (EFRs). Results are presented in section 6. Section 7 concludes with a review of the effort undertaken and a discussion of the advantages and limitations of the approach in analyzing water management in a changing world.

2. Integrated Assessment Structure

In the IGSM-WRS-US framework, the interaction of water resources and anthropogenic water requirements are analyzed using an integrated set of economic and earth system models. A schematic of the framework is provided in Figure 1 with the economic, climatic, and hydrologic drivers on the left-hand side and the water system on the right-hand side.

Within the integrated assessment framework, IGSM [*Sokolov et al*., 2005], the global economy is represented by the Emissions Prediction and Policy Analysis (EPPA) model [*Paltsev et al*., 2005]. This general equilibrium model simulates GHG emissions associated with the economic activity at the global level every 5 years. Interpolated hourly, global GHG concentrations are inputs into the MIT Earth System Model (MESM) [*Sokolov et al*., 2009], which encompasses both climate and land surface models. Latitudinally resolved climate variables are distributed longitudinally using precipitation patterns from archived global circulation models (GCMs) using a hybridized frequency distribution (HFD) approach [*Schlosser et al*., 2012] to provide hourly climate variables needed to simulate hydroclimatic conditions. Runoff is simulated as an output of CLM (version 3.5).

Daily accumulated precipitation and average temperature are used to drive the biophysical crop model, CliCrop [*Fant et al*., 2012], are also simulated using the HFD approach, and are thus consistent with the climatic conditions used to simulate runoff. With these climate inputs, CliCrop simulates daily crop water requirements to maximize crop yields.

The EPPA model, in addition to simulating global GHG emissions contributing to simulated changes in climate, provides projections of U.S. economic activity resulting from different global policies. To obtain region-specific economic activity, EPPA provides boundary conditions to the U.S. Regional Economic and Environmental Policy (USREP) model coupled with the Regional Energy Deployment System (ReEDS) model [*Rausch and Mowers*, 2012]. The USREP model [*Rausch et al*., 2010] provides economic projections driving water requirements. The ReEDS model [*Short et al*., 2009] integrated with USREP provides highly resolved (region and technology) projections of electricity production. Thermal power generation by region from USREP-ReEDS is used by the Withdrawal and Consumption for Thermo-electric Systems (WiCTS) model [*Strzepek et al*., 2012a] to compute monthly water withdrawal and consumption (see section 5.1.1). Also, gross domestic product (GDP) and population outputs from USREP are inputs to the calculation of water requirements for the other sectors, which are based on econometric estimated relationships.

The right-hand side of Figure 1 describes the water system components of the framework, WRS-US. Water requirements are composed of anthropogenic water needs for five sectors and environmental requirements. More details on these model components are provided in section 5. Water resources simulation is provided in section 4. The estimated resources and requirements are inputs to a Water System Management (WSM) module. As detailed in section 3, WSM computes water balance and water stress for each

10.1002/2013EF000214

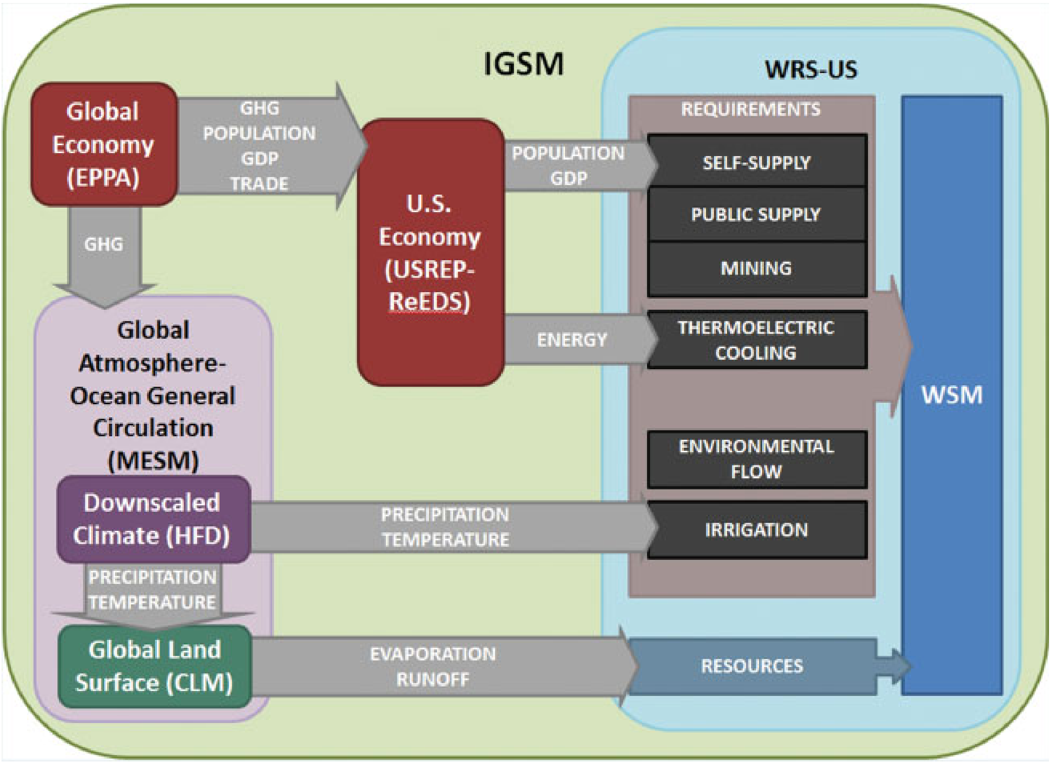


Figure 1. Schematic of the IGSM-WRS-US framework illustrating the connections between the different components of the IGSM framework and the WRS-US components. Notes: The description, spatial and temporal scales of the models are summarized in Table B1. HFD, hybridized frequency distribution; EPPA, Emissions Prediction and Policy Analysis; USREP, U.S. Regional Economic and Environmental Policy; ReEDS, Regional Energy Deployment System; CLM, Community Land Model; WSM, Water System Management.

basin. In this application, there is no feedback effect between sectoral water stress and national economic activity or agricultural production. There is also no measure of adaptation taken to prevent water stress and no land-use change from areas where water is scarce to locations with greater water availability. International trade is also not taken into account as a response to water stressed activities in the United States.

In summary, projections of economic activity under a given policy determine global GHG emissions, which in turn drive GHG concentrations and changes in climate. Weather, associated with this climate, determines runoff and evaporation (which affects water resources) and changes in crop growth (which influences water requirements). Economic activity, associated with the global policy, also drives changes in the economic activity at the regional level, which results in changes in sectoral water requirements. Given resources and requirements, the water is allocated across sectors in each basin and water stress occurs if water resources are less than water requirements within the basin.

The set of models used in this analysis and their characteristics are summarized in Table 1. This table provides information on the spatial and temporal scales of the models. Details regarding the downscaling or aggregation techniques used to integrate the models together are provided in section 4 for water resources and in section 5 for water requirements.

3. Basin-Level WSM Structure

The WSM model is based on the Water System Module developed by the International Food Policy Research Institute [*Rosegrant et al*., 2008]. In this framework, however, the WSM module follows the 99 Assessment Sub-Region (ASR) delineation set out by the U.S. Water Resources Council [*USWRC*, 1978] shown in Figure 2. The color scale represents the distance of the basin from the outlet. Dark green basins are located the furthest upstream and dark orange basins are the closest to the sea or border. Purple basins are closed and have no outlet.

10.1002/2013EF000214

Table 1. Summary of Model Characteristics Considered in the WRS-US Framework

Model	Reference	Spatial Scale	Temporal Scale
EPPA	[*Paltsev et al.*, 2005]	16 regions globally (1 U.S. region)	5 years
USREP	[*Rausch et al.*, 2010]	11 U.S. regions	2 years
ReEDS	[*Short et al.*, 2009]	134 U.S. regions	2 years
MESM	[*Sokolov et al.*, 2009]	$2^\circ \times 2.5^\circ$ grid	hour
HFD	[*Schlosser et al.*, 2012]	$2^\circ \times 2.5^\circ$ grid	hour
CliCrop	[*Fant et al.*, 2012]	$2^\circ \times 2.5^\circ$ grid	day
CLM	[*Oleson et al.*, 2008]	$2^\circ \times 2.5^\circ$ grid	hour
WSM	This issue	99 ASRs	month

Note: See acronym description in Notes of Figure 1.

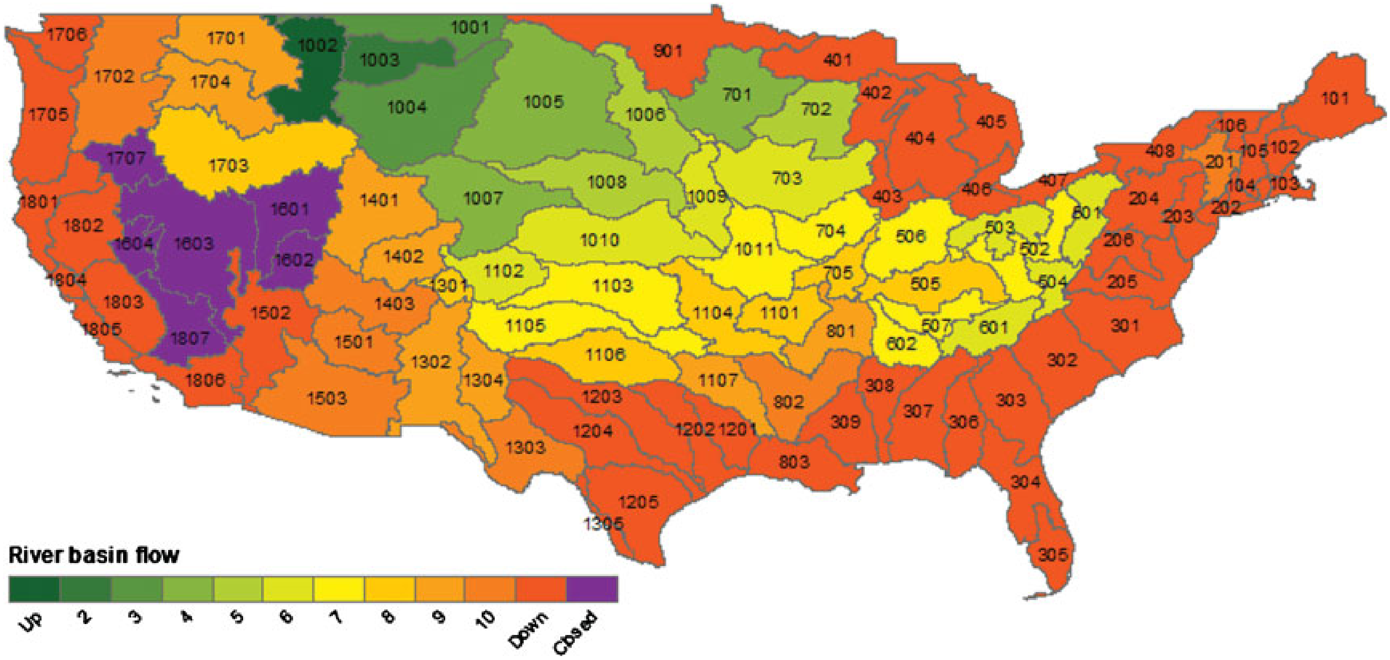


Figure 2. River basins in the continental U.S. and river flow structure.

For each ASR, the model allocates available water among users each month while minimizing annual water deficits (i.e., water requirements that are not met) and smooths deficit across months. The allocation of water for each ASR is solved simultaneously for the months of each year. Upstream basins are solved first, and the calculation proceeds downstream following the structure of river flows. Water spilled from upstream basins becomes the inflow for downstream basins. Closed basins are solved last.

A schematic of reservoir operation is presented in Figure 3. All water storage in the ASR is aggregated into a single virtual reservoir (STO). Total water supply (TWS) is composed of this surface water storage plus groundwater supply (GWS). In this application, we do not consider water from desalination or groundwater recharge. STO receives the river basin runoff (RUN) and inflows from upstream basins (INF). This version of WRS also accounts for IBT. Part of the STO is lost through evaporation (EVP).

Releases from surface storage (REL) and GWS constitute the TWS, which is used to fulfill the water requirements of the different sectors (SWR). (We use the term "requirements" instead of "demand" as the model does not yet consider the potential effect of changes in water price on its use. Water requirements for each sector are estimated based on recent experience and therefore implicitly assume current or recent prices.) We identify five sectors: thermoelectric plant cooling (TH), irrigation (IR), PS, SS, and MI. For all

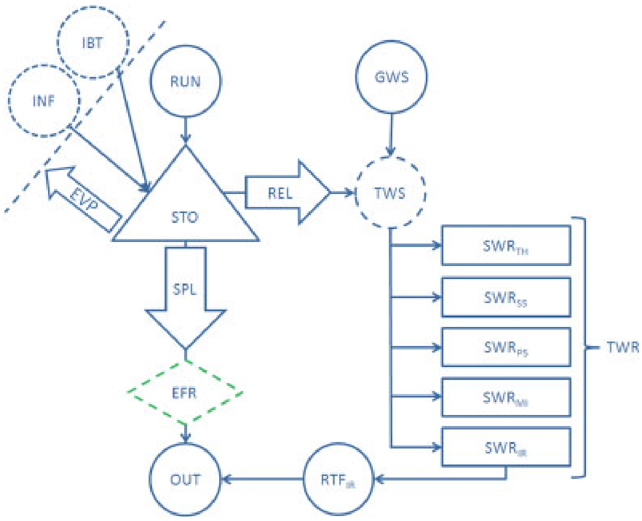


Figure 3. Schematic of the Water System Management (WSM) module at ASR scale in the WRS-US. Notes: Total water requirement (TWR) is calculated by summing self-supply (SWR_{SS}), public supply (SWR_{PS}), mining (SWR_{MI}), and irrigation (SWR_{IR}) requirements. Surface water supply comes from inflow from upstream basins (INF) and local basin natural runoff (RUN) and goes into the virtual reservoir storage (STO) where evaporation (EVP) is deducted. The reservoir operating rules attempt to balance the water requirements (TWR) with the total available water (TAW). Water requirements are met by groundwater supply (GWS) and releases from the virtual reservoir (REL). Water is released to the downstream basin (SPL) accounting for environmental flow requirements (EFR).

sectors, except irrigation, water requirements are represented by consumptive use on the assumption that any return flow (withdrawal in excess of consumption) is likely returned to the ASR storage within the month. This assumption is not appropriate for irrigation, because return flow, which may be substantial, may not be returned to the ASR storage immediately. Instead, the water lost in conveyance and field inefficiency is accounted as a return flow (RTF_{IR}), which will contribute to the outflow of the basin (OUT) in the next month. For thermoelectric cooling, the temperature of the return flow can influence reuse. However, given the spatial and temporal scales of the model, we assumed that water requirements for this sector are better represented by consumptive use.

The degree to which total water requirements (TWRs) are met is determined by the total water supplied (TWS). This water is allocated proportionally among all sectors, except irrigation. Water is available for irrigation only if there is sufficient water to meet the requirements of all other sectors. This assumption is based on the relative economic value of water in these different uses. If TWS is insufficient to meet the nonirrigation requirements, those sectors take an equal proportional cut.

After accounting for water supply to the different sectors and evaporation from surface storage, excess water in each ASR is spilled onto its downstream basin (SPL) while respecting a minimum EFR to constitute the outflow, which is the inflow of the downstream ASR.

4. Water Resources Simulation

Surface water resources are largely a function of local climate, which in turn is influenced by GHG concentrations in the atmosphere. To provide meteorological variables (precipitation, temperature, and reference evapotranspiration) at the relevant scales of the WRS, we use the HFD approach [*Schlosser et al*., 2012]. Projected regional temperature and precipitation data, at $2° \times 2.5°$ resolution on an hourly scale, are used as inputs into the land surface model to determine runoff. The estimated total basin runoff, accounting for upstream basin inflows and IBTs, constitutes the surface water resources, which are then combined with GWS. Each of these components is estimated at the ASR level following the methodology outlined below.

4.1. Runoff

Runoff represents the water flowing over the surface and immediately below the surface of the ground and is caused by rainfall or snow melt. In this study, runoff is estimated using CLM. CLM models soil-plant-canopy processes of the surface and subsurface, which include key fluxes to the hydroclimate system. The hydrologic component of CLM estimates runoff taking explicit account of infiltration, canopy interception, root-active and deep-layer soil hydrothermal processes, soil evaporation, evapotranspiration, snowpack, and melt. CLM provides gridded runoff data to the ASRs and the management of the runoff routing is endogenously determined by WRS-US—inflows from upstream basins are sequentially estimated starting by the further upstream basins.

Recent studies show that CLM simulates mean annual cycles of runoff over continental-scale basins rather well [e.g., *Lawrence et al*., 2011]. Yet at the scale of the 99 U.S. ASRs employed herein, runoff estimates of CLM require further refinement. Following *Strzepek et al*. [2012b], monthly runoff of CLM at each basin is adjusted using the maintenance of variance extension (MOVE) procedure [*Hirsch*, 1982]. This technique is commonly used to transfer streamflow information from gauged to ungauged basins. To standardize streamflow, MOVE requires estimates of the first two moments (mean and standard deviation) of runoff for every ASR. However, observed data on natural flow at the ASR basins (which most closely represents runoff generated by CLM) are not available due to human interference via river management (e.g., dams). We therefore use the U.S. Water Resources Council [*USWRC*, 1978] data set, which provides statistics (mean and standard deviation of a log-normal distribution) representative of monthly natural flow for the 99 ASRs for the 1954–1977 period.

To apply MOVE to CLM runoff at the ASR level, we first calculate the CLM monthly runoff, $Q_{\mathrm{CLM}}(m,y)$, and its mean, $\mu(m)_{\mathrm{CLM}}$, and standard deviation, $\sigma(m)_{\mathrm{CLM}}$, over the period 1954–1977. Using the mean and standard deviation for the USWRC flows over the same period, $\mu(m)_{\mathrm{USWRC}}$ and $\sigma(m)_{\mathrm{USWRC}}$, we then transform the CLM runoff to estimate WRS-US basin runoff, RUN:

$$\mathrm{RUN}\,(m,y) = \mu_{\mathrm{USWRC}}\,(m) + \frac{\sigma_{\mathrm{USWRC}}\,(m)}{\sigma_{\mathrm{CLM}}\,(m)} * \left(Q_{\mathrm{CLM}}\,(m,y) - \mu_{\mathrm{CLM}}\,(m)\right),$$

where $\frac{\sigma(m)_{\mathrm{USWRC}}}{\sigma(m)_{\mathrm{CLM}}}$ is the bias correction factor.

The procedure assumes that monthly streamflows over the period 1954–1977 are stationary. However, under climate change, this assumption is unlikely to hold. To address this issue, we apply a nonstationary extension to the MOVE technique. We use a 10 year moving average of CLM monthly runoff, $\mu_{\mathrm{CLM\_MA10}}(m,y)$, and estimate a trend relative to the 1954–1977 baseline:

$$\mathrm{TR}_{\mathrm{CLM}}\,(m,y) = \frac{\mu_{\mathrm{CLM\_MA10}}\,(m,y)}{\mu_{\mathrm{CLM}}\,(m)}.$$

RUN is then transformed following the formula:

$$\mathrm{RUN}\,(m,y) = \mu_{\mathrm{USWRC}}\,(m) + \mathrm{TR}_{\mathrm{CLM}}\,(m,y) + \frac{\sigma_{\mathrm{USWRC}}\,(m)}{\sigma_{\mathrm{CLM}}\,(m)} * \left(Q_{\mathrm{CLM}}\,(m,y) - \mu_{\mathrm{CLM\_MA10}}\,(m)\right).$$

As demonstrated in Figure 4, the MOVE procedure successfully adjusts CLM runoff to match that of the USWRC estimates. Accordingly, these adjusted runoff values (at a monthly time scale) are then provided as runoff (RUN) within the WSM module presented in Figure 3.

4.2. Surface Storage

Surface storage is composed of constructed and natural reservoirs. The constructed reservoir storage for the base year is assumed to be equal to the maximum storage capacity, which is sourced from the National Inventory of Dams database [*USACE*, 2013]. The storage capacity of natural reservoirs is provided by the land surface model, CLM.

4.3. Interbasin Water Transfers

Water is transferred from water-abundant basins to water-limited ones via conveyance systems such as canals and aqueducts. These transfers are most common in the Western United States. We model them by assuming that a fixed amount of water is transferred annually based on past observations. In this application, we account for transfers (i) from the Colorado River to the Metropolitan Water District (1193 MCM), the Imperial Irrigation District (3305 MCM), and the Coachella Valley (398 MCM) in California through the All American Canal [*U.S. Bureau of Reclamation*, 2009]; (ii) from the Colorado River to Southern California (1604 MCM) via the Colorado River aqueduct [*Zetland*, 2011]; and (iii) from the Sacramento Valley to the San Joaquin Valley (7078 MCM) and from the Tulare region to Southern California (684 MCM) via the California State Water Project [*Connell-Buck et al*., 2011].

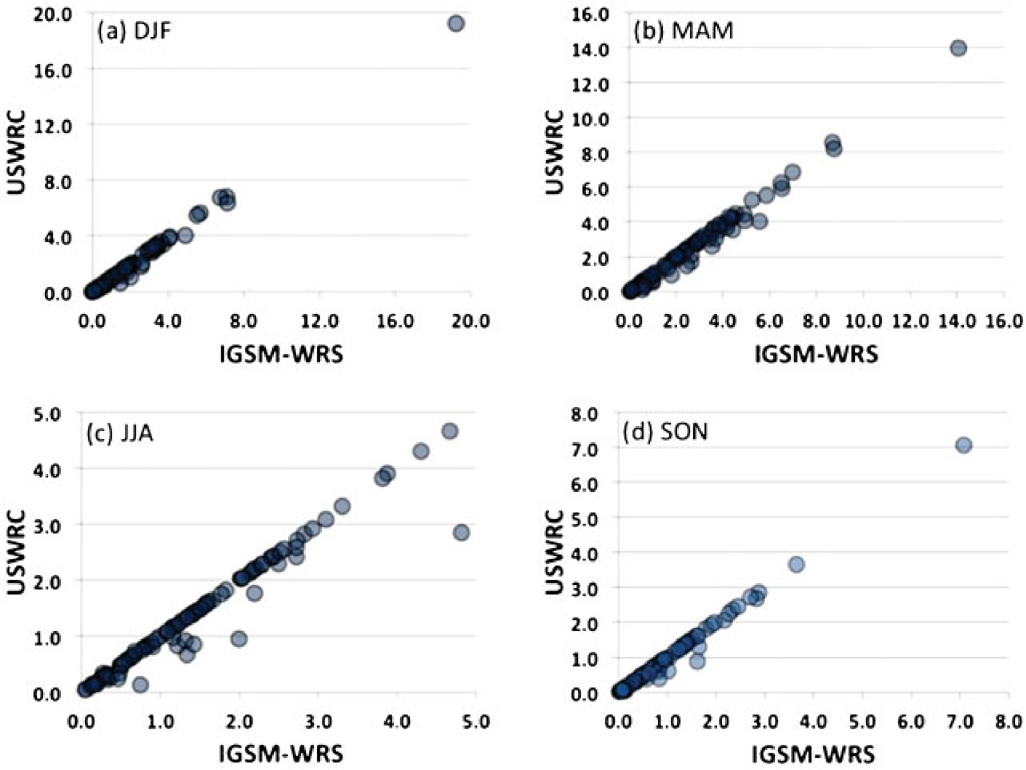


Figure 4. Seasonal-mean natural flow of the CLM values adjusted via the MOVE procedure (abscissa values) compared against the empirical estimate of the USWRC (1978) study (ordinate values) for the period 1954–1977. Scatterplots present the comparisons of the 99 ASRs seasonal mean for (a) December to February (DJF), (b) March to May (MAM), (c) June to August (JJA), and (d) September to November (SON). All flow values are given in units of billion cubic meters (BCMs) per month.

4.4. Groundwater

Groundwater reservoirs (aquifers) represent an important source of freshwater as they store 25% of global freshwater [*USGS*, 2012]. The depletion and recharge of these reserves is a controversial issue globally [*van der Gun*, 2012]. Numerous methods have been devised to estimate groundwater recharge, but they are prone to uncertainties and errors [*Scanlon et al*., 2002]. In this study, GWS is assumed to be limited to the 2005 groundwater uses estimated by *USGS* [2011] at the county level. This estimation is based on the assumption that the amount of groundwater used in 2005 is representative of annual water availability. To obtain groundwater data at the basin level, we aggregate the county-level data within each basin. When a county intersects with different ASRs, we assume that the county belongs to the ASR where the majority of its area is located. Groundwater recharge modeling is a topic of future research.

5. Water Requirements Simulation

5.1. Sectoral Water Requirements

As presented in Figure 5a, freshwater in the United States is mainly withdrawn for thermoelectric cooling and irrigation, which represented 42% and 36% of total freshwater, respectively, in 2005 [*USGS*, 2011]. In terms of consumption (Figure 5b), however, thermoelectric cooling is a small sector. Irrigation, on the other hand, consumes 60% of the water withdrawn. As explained in section 3, we consider withdrawal for the irrigation requirement and consumption for the other sectors. This combination of estimates leads to Figure 5c, which shows that the largest user in the United States is irrigation, with 87% of TWRs measured at the ASR level.

These water requirements are projected using population and GDP growth estimated by the USREP model, a recursive-dynamic multiregion, multicommodity general equilibrium model of the U.S. economy. Population growth is exogenous in USREP, and projections by state are taken from the *U.S. Census Bureau* [2000]. USREP has a 2 year time step and divides the continental United States into 11 regions. The

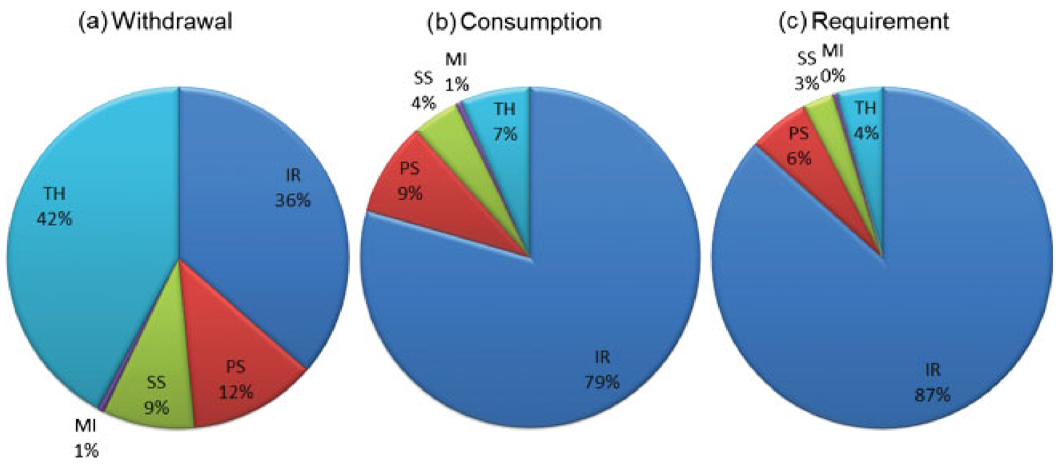


Figure 5. U.S. water withdrawal, consumption, and requirement by sector in 2005. Notes: Pie charts constructed using withdrawal and consumption data estimated by *USGS* [2011]. Water requirements for irrigation correspond to irrigation withdrawal. Requirements for the other sectors correspond to consumption. TH, thermoelectric cooling; IR, irrigation; SS, self-supply; PS, public supply; MI, mining.

regional population and GDP growth rates estimated by USREP are interpolated to obtain annual figures for the corresponding ASRs. We assume that GDP and population remain constant across the year. USREP is run with external conditions (prices and trade) set to be consistent with the global simulations of the EPPA model, which provides GHG concentration associated with the level of economic activity. These GHG emissions are input to the climate simulations. These climate projections will impact future water requirements for irrigation. The remainder of this section presents the methods used to estimate water requirements at the ASR level for each sector.

5.1.1. Thermoelectric Cooling

Water withdrawn for power plant cooling either goes through cooling towers or ponds before being reused (recirculating or recycle systems) or is returned to the stream (once-through systems)—dry cooling is used only in 1% of U.S. thermal electric generation [*DOE*, 2006]. The share of withdrawn water that is consumed depends on the cooling system employed [*Templin et al*., 1997]. In recirculating/recycling systems, water goes through cooling towers or ponds and is then reused so that a large share of the water withdrawn from the stream is consumed. In once-through systems, the water is used once and returned to the stream so that a relatively small share of the withdrawn water is consumed. U.S. power systems requiring thermoelectric cooling are represented using the ReEDS model, a recursive-dynamic linear programming model that simulates the least-cost expansion of electricity generation capacity and transmission, with detailed treatment of renewable electric options. ReEDS is composed of 134 power control areas and models electricity generation by fuel type (fossil fuel, nuclear) and cooling system (once-through, recycle). The ReEDS model is fully integrated in USREP. This allows us to include general equilibrium economy-wide effects while capturing important electricity-sector details with respect to technology innovation and investments in transmission capacity. The integrated USREP-ReEDS model and the methodology used to link the two models are presented in *Rausch and Mowers* [2012].

Based on the electricity system demand provided by the ReEDS model, monthly withdrawal and consumption in thermoelectric cooling is estimated using the WiCTS model [*Strzepek et al*., 2012a]. In this version of the model, we estimate water requirements for thermoelectric cooling (SWR_{TH}) considering consumption only, assuming that nonconsumed withdrawals are returned to the ASR within the same period. The temperature of the water returned to the stream is often a concern both for the environment and for immediate reuse. In this regard, water can be thought as thermal consumption. We are currently not capable of modeling this type of water consumption. We, therefore, only account for evaporative consumption occurring during the cooling process.

To validate the accuracy of the thermoelectric cooling water requirement estimates, we compared WiCTS total thermoelectric cooling withdrawal estimates for the year 2006 with USGS withdrawal for the year

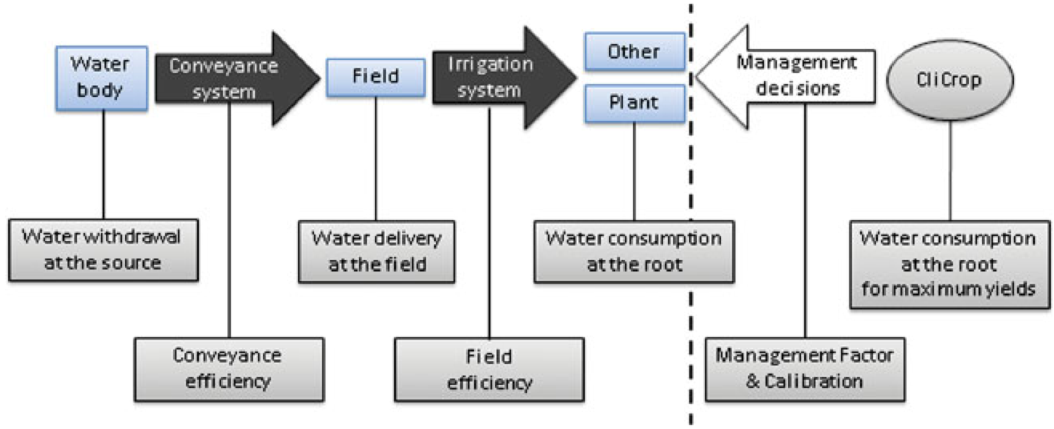


Figure 6. Schematic of Irrigation System Model in WRS-US. Notes: Irrigation requirements at the root are estimated by the biophysical model CliCrop and adjusted by management practices. Ultimate withdrawals to meet the requirements take account of losses in the field and in conveyance from the source to the field.

2005 (which is the latest available data). Over the United States, the WiCTS estimate of 206 billion gal/d is very close to the USGS estimate of 201 billion gal/d in 2005.

5.1.2. Irrigation

To estimate water use for irrigation, we need to consider several aspects of the delivery system. As represented in Figure 6, water withdrawn from the stream or reservoir is delivered to the cropping field via a conveyance system (e.g., canal and pipes). Depending on the type of system installed, part of the water withdrawn is lost through seepage and/or evaporation. This fraction of water reaching the field (i.e., delivery at the field) is represented by conveyance efficiency (CEF). The water delivered at the field is either applied to crops directly or used for irrigation-related activities (e.g., frost prevention and leaching) or lost in the field distribution system. The fraction of water reaching the plant is called field efficiency (FEF) and depends on the irrigation system used (e.g., sprinkler and drip).

To estimate the water requirement at the crop level, we use the CliCrop model, which estimates crop water required at the root to eliminate all water stress. As actual irrigation practices may not correspond to optimal amounts of water estimated by CliCrop, we develop a crop-specific management factor and a region-specific calibration that allows us to adjust modeled irrigation water use to observed use. As a benchmark for estimating this factor, we use water consumption data extracted from the Farm and Ranch Irrigation Survey (FRIS), which provides detailed information on farm irrigation practices in 2003 [*USDA*, 2003]. FRIS reports, for each crop and each state, the amount of irrigation water consumption at the field and the irrigated area. Each of these steps is explained in greater detail in the supporting information (Appendix A).

To validate the accuracy of our irrigation estimation procedure, we present a comparison of predicted irrigation withdrawal with observed irrigation withdrawal in Figure 7. To obtain the predicted values, we use climate input data from the National Climatic Center (NCC) [*Ngo-Duc et al*., 2005] for the period 1980–2000 (NCC is available only until 2000) as input into CliCrop. The observed values are sourced from *USGS* [2011]. We provide the withdrawal data per unit of land irrigated as is common in the literature. Figure 7 shows that predicted data are close, although somewhat overestimate irrigation compared to the observed data, which is supported by a correlation coefficient of 0.74.

5.1.3. Other Sectors

Other water requirements are classified into three groups: PS, SS, and MI as defined by *USGS* [2011]. PS withdrawal refers to water use for residential purposes, commercial activities, and industrial activities provided by public and private water suppliers. SS water withdrawal includes water use for residential purposes, commercial, industrial, livestock, and aquaculture activities sourced directly by the user. MI water withdrawal is defined as “water use during quarrying rocks and extracting minerals from the land” [*USGS*, 2011]. Water use for shale gas fracking is embedded in the MI category.

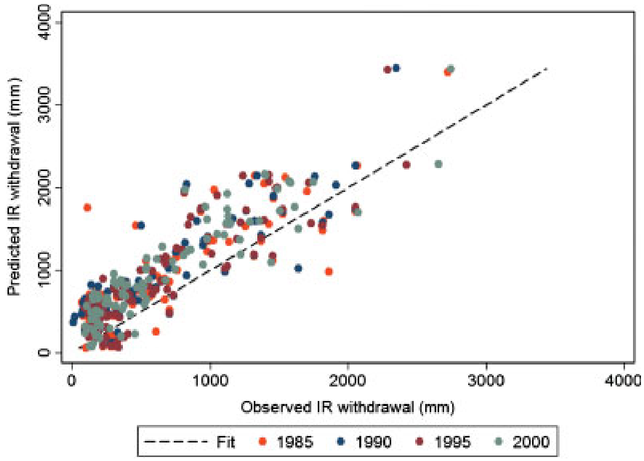


Figure 7. Comparison of predicted values of irrigation annual water withdrawals per unit of land irrigated with observed withdrawal per unit of land irrigated values at the ASR level. Note: We have removed one outlier for the Sabine-Neches in the Texas Gulf region (ASR 1201) for 1995 for which the observed IR withdrawal corresponds to 8727 mm/yr and predicted IR withdrawal corresponds to 1094 mm/yr.

Water withdrawal for each of these sectors is estimated econometrically using water data collected at the county level by *USGS* [2011]. Details of the econometric analysis are provided in Appendix B. Future water requirements for these sectors are projected by estimating consumption. Sectoral consumption is assumed to be a constant share of sectoral withdrawals, which is obtained by applying the population and GDP growth estimates from the USREP model to the corresponding variables in the regression for each sector presented in Appendix B.

To demonstrate the ability of the model to predict future water requirements for the PS, SS, and MI sectors, we compare the model estimates to historical data. We project sectoral withdrawal for past years using the econometric estimates described in Appendix B and compare these to observed withdrawal for each sector collected by USGS every 5 years from 1985 to 2005. A graphical comparison provided in Figure 8 shows that the econometric model performs reasonably well. Fitted values for each year are distinguished by color to highlight eventual annual outliers. Except for the SS in 1995, no other year appears to stand out. The best predictions are obtained with the PS model. The total water withdrawal predicted over the United States matches the observations very closely. Water requirements for the MI sector show the highest dispersion around the econometric fit.

5.2. Environmental Water Requirements

In the United States, water is regulated by national legislations such as the 1969 National Environmental Policy Act and the 1972 Clean Water Act. In addition, water resource management is decentralized by state and region, which has led to a variety of additional regional water policies [*Hirji and Davis*, 2009]. These policies usually protect water ecosystems through the regulation of water levels and flows.

To model these environmental requirements, we apply two constraints on surface water in the model. First, releases from surface storage are limited to a proportion of the storage capacity in order to respect an environmental minimum storage threshold. Minimum lake levels are usually determined as an elevation below which the water body should not fall, and they vary by district. We assume a minimum surface water storage of 10% of the surface water storage capacity. Second, the spill from each basin must meet a minimum EFR. The determination of the volume and timing of these flows should also be determined locally. According to L. Anantha and P. Dandekar (Towards restoring flows into the earth's arteries: A primer on environmental flows, 2012, http://www.internationalrivers.org/files/attached-files/eflows_primer_062012.pdf), more than 200 methodologies have been considered to asses global environmental flows. The first environmental flow protection rule considered a minimum flow of 10% of mean annual runoff [*WCD*, 2000]. More recently, *Smakhtin et al*. [2004] consider that flows that are exceeded 90% of the time (Q90 flows) are sufficient to maintain riparian zones in "fair" condition. In a comprehensive review of EFR definitions, *Acreman and Dunbar* [2004] note that "no method is necessarily better than another" and depend on the application. In this application, we set an EFR equivalent to 10% of mean monthly flow for each ASR.

Other environmental concerns relate to water temperature and water quality (often measured by the biochemical oxygen demand). However, we are currently not able to represent these issues.

10.1002/2013EF000214

6. Application: Projection Through 2050

Water uses and resources are modeled to 2050, considering both alternative emission scenarios and potential regional shifts in climate patterns. Starting in 2010, two emission scenarios are considered: (i) an unconstrained emissions (UCE) scenario assumes that no specific effort is made to abate GHG emissions, and (ii) a "level 1 stabilization" (L1S) scenario assumes that GHG emissions are restricted to limit the atmospheric concentration of CO_2 equivalent GHGs to 450 ppm [*Clarke et al*., 2007]. These scenarios serve as inputs into the IGSM 2D model using median parameter values of climate sensitivity, rate of ocean heat uptake, and aerosol forcing [e.g., *Forest et al*., 2008].

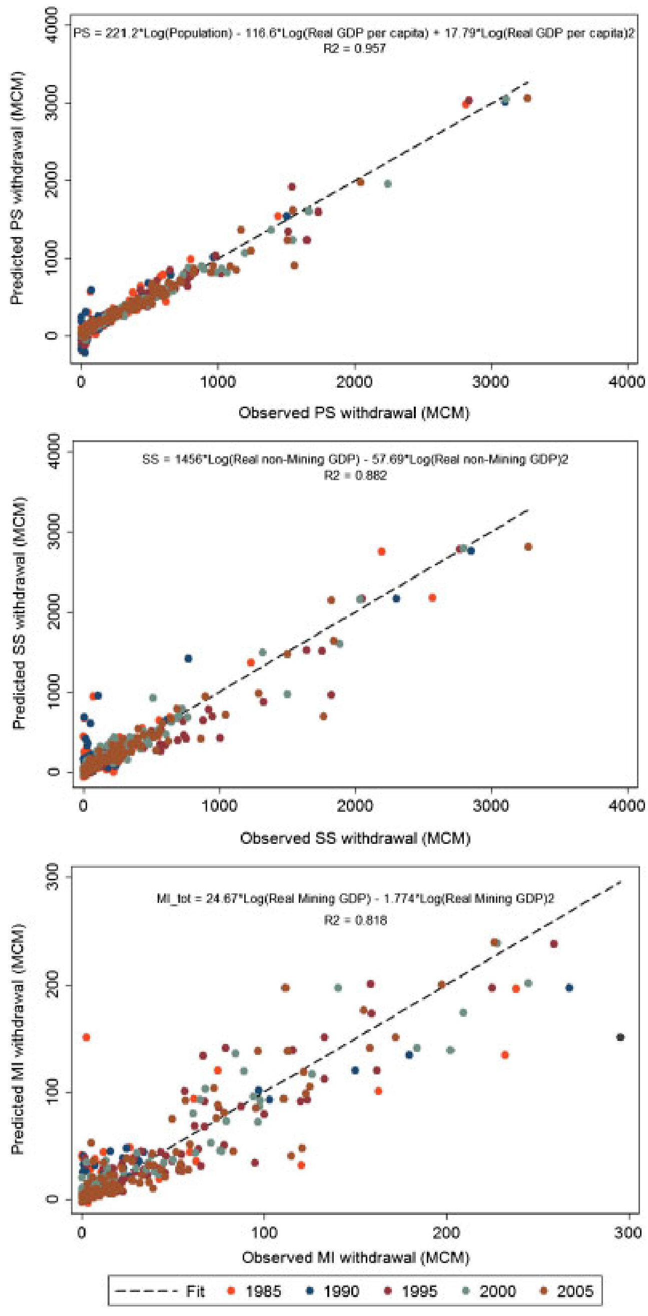


Figure 8. Comparison of predicted values of public supply (PS), self-supply (SS), and mining (MI) annual water withdrawals with observed withdrawal values at the ASR level.

To provide meteorological variables at the relevant scale for WRS, we then downscale the results using the HFD approach. We use two representative shifts in the regional climate patterns, or "climate-change kernels"—as determined from climate model projections from the Coupled Model Intercomparison Project Phase 3 (CMIP3) [*Meehl et al*., 2007]—to explore a plausible range of relatively dry and wet trending conditions over the majority of U.S. ASRs. The Geophysical Fluid Dynamics Laboratory (GFDL) version 2.1 [*Delworth et al.*, 2006] and the NCAR Community Climate System Model (CCSM) version 3 [*Collins et al*., 2006] provide representative "dry" and "wet" projections, respectively. Hereafter, we refer to these climate model outcomes as U.S.-DRY and U.S.-WET.

The two climate change scenarios considered in this study are assumed to be representative of the patterns from the CMIP3 climate model projections of hydroclimate change through the 21st century [as described by *Schlosser et al*., 2012]. In this particular study, we determine the "wet" and "dry" characterizations from the CMIP3 climate models' projections of climate-moisture index change over the contiguous United States. Due to the spatially heterogeneous nature of the hydrologic cycle, for every basin within the United States, the U.S.-WET and U.S.-DRY cases would not necessarily be reflective of an "extreme" condition. Rather, on average a majority of basins would see "dry" or "wet" outcomes. Generally speaking, the U.S.-DRY pattern is characterized by substantially drier conditions (particularly in the summer) throughout most of the United States. The widespread relative decreases in precipitation will coincide with strong relative warming as global temperature increases. The U.S.-WET case replaces the drying conditions in many regions with relatively wetter conditions and less warming (relatively to their U.S.-DRY conditions). Results from the WRS-US model forced by these two climate-change kernels aim at providing insight into the impact of climate change on water-management risks under two differing climate responses.

To explore the relative influence of the economic effect of policy (L1S and UCE) versus the climatic effect, we also consider a scenario of no climate change. For this case, labeled "NoCC," we assume that the climate is similar to the twentieth century. We use data from a run of the IGSM driven by historical GHG concentrations.

6.1. Water Requirements Projections

Water requirements for each sector are projected following the methodology described in section 5.1. To calculate requirements for the thermoelectric cooling, PS, SS, and MI sectors, WRS-US requires predictions of population, total GDP, and value added of the MI sector (where value added measures income generated by each sector). These inputs are predicted by the USREP model under the two emission scenarios described above. Population is projected to increase steadily over the period 2005–2050 with no difference between the UCE and L1S scenarios. Differences between scenarios are predicted for total GDP, with larger increases under the UCE scenario than under L1S, especially in Texas. Predictions for value added in the MI sector differ, especially under the L1S scenario, where it is expected to decrease by 2050. Reduced MI activities (especially coal MI) under the constrained GHG emissions scenario explain this trend. Irrigation water requirements are projected using the CliCrop model. In this study, we assume that there will be no change in the location and amount of irrigated cropland. This condition can be relaxed in subsequent model development as production, area under production, and the location of production may change in the future, with or without climate change. Our goal is to identify currently irrigated areas that may be subject to water limits.

As shown in Figure 9, U.S. water requirements are projected to increase for all sectors under the UCE scenario. Under the L1S scenario, however, water requirements decrease overall for thermal cooling and MI, which reflects a change in energy production due to a slower pace of economic growth and a transition to cleaner energy. Beyond 2030, significant shares of electricity are generated from nonthermal renewables, and as a result, electricity from coal—the largest source of thermal power generation—is gradually reduced. Hence, the water required for cooling of thermal power plants greatly decreases (in our case, requirements for this sector are represented by water consumption). Water requirements for irrigation are driven indirectly through the effect of the different policy scenarios on climate. Figure 9 shows some increases in irrigation water requirements over time, especially under the UCE scenario. Under the scenario of no climate change, irrigation requirements are expected to decrease. Water requirements for self-service are expected to grow steadily. For PS, however, we observe a nonlinear trend reflecting the fact that the effect of a higher requirement is offset by greater water use efficiency as GDP per capita increases. In total, water requirements are projected to increase with the largest increases in water requirements being projected under the UCE scenario.

As shown in Figure 10, the share of TWRs for each sector (averaged over the projection period) reflects the evolution of water requirements for the different scenarios and climate patterns. The pie chart shows that the share of irrigation requirements is larger under the U.S.-DRY climate pattern. Thermoelectric cooling is lower under the L1S scenario than under the UCE scenario.

Water requirements at the ASR level are provided in Figures 11 and 12. In these figures, we first present water requirements in quantitative terms for the base period (2005–2009). We next show for the projection period (2041–2050) the changes relative to the base period (in %) under the two scenarios and three climate patterns. Figure 11 shows that the largest water requirements in the base period originate from the Upper/Central Snake (ASR 1703) and San Joaquin-Tulare (ASR 1803) basins. The graph shows no difference between requirements across the three scenarios in the base period. Total requirements are indeed very similar by the end of 2009.

In the period 2041–2050 TWRs are projected to increase by more than 300% in the Little Colorado (ASR 1501), Lower Rio Grande (ASR 1305), and Richelieu (ASR 106) basins. Increases are generally slightly lower

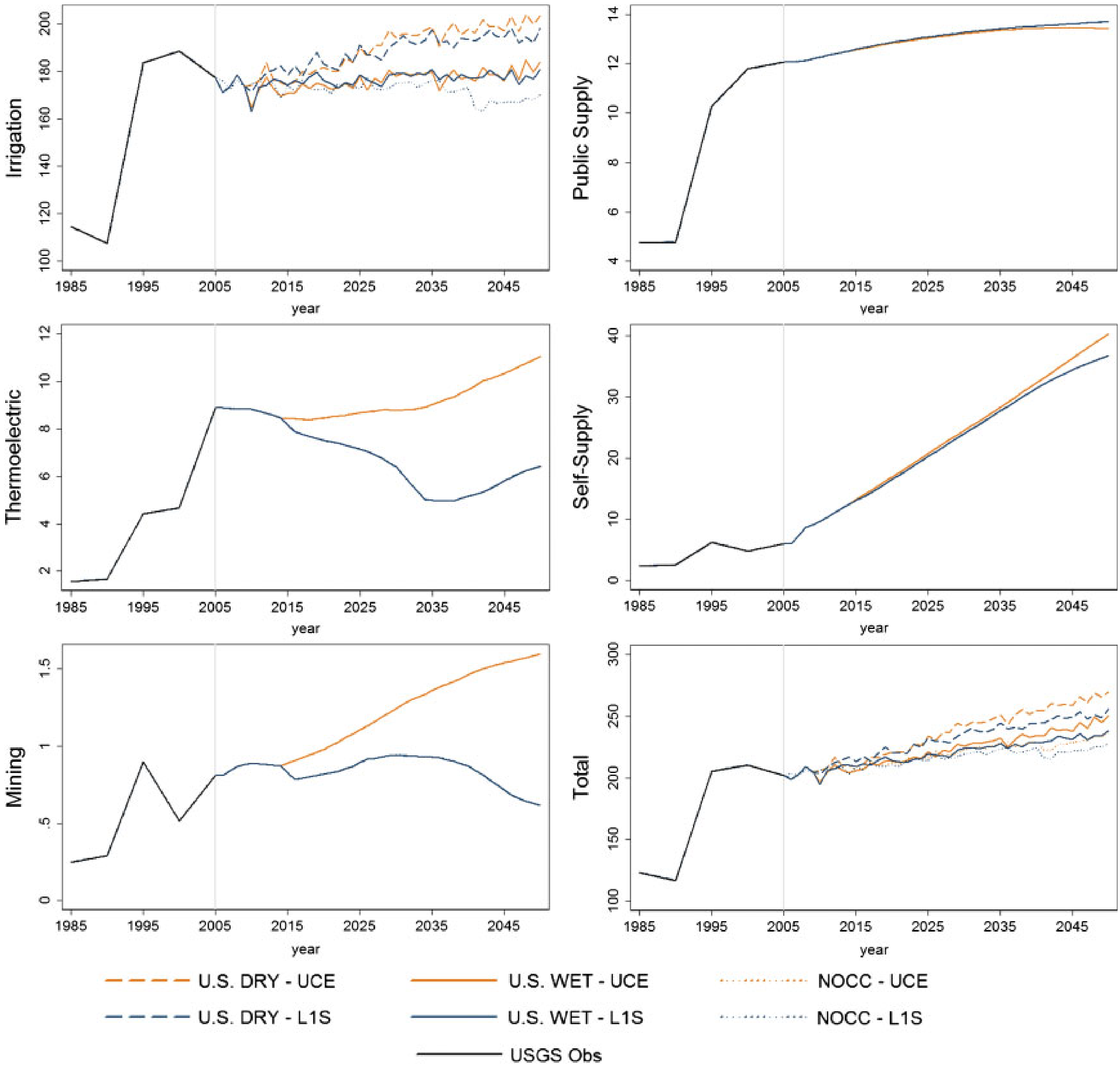


Figure 9. U.S. water requirements (in 1000 MCM) from 1985 to 2050.

under the L1S scenario than under the UCE scenario. Small regional divergences across scenarios are projected in the Indiana/West Virginia region with decreases in water requirements projected under the L1S scenario. Similar to what is observed in Figure 9, TWR increases are projected to be the largest under the U.S.-DRY climate change pattern.

We also provide a geographical representation for irrigation, which is the largest user in the United States. As shown in Figure 12, the Upper/Central Snake (ASR 1703) and San Joaquin-Tulare (ASR 1803) basins have the largest irrigation requirements. Very little water is used for irrigation in the East due to high precipitation and relatively low evaporative demand. Water requirements for irrigation purposes are expected to increase in the West under both climate change patterns. Depending on the climate pattern

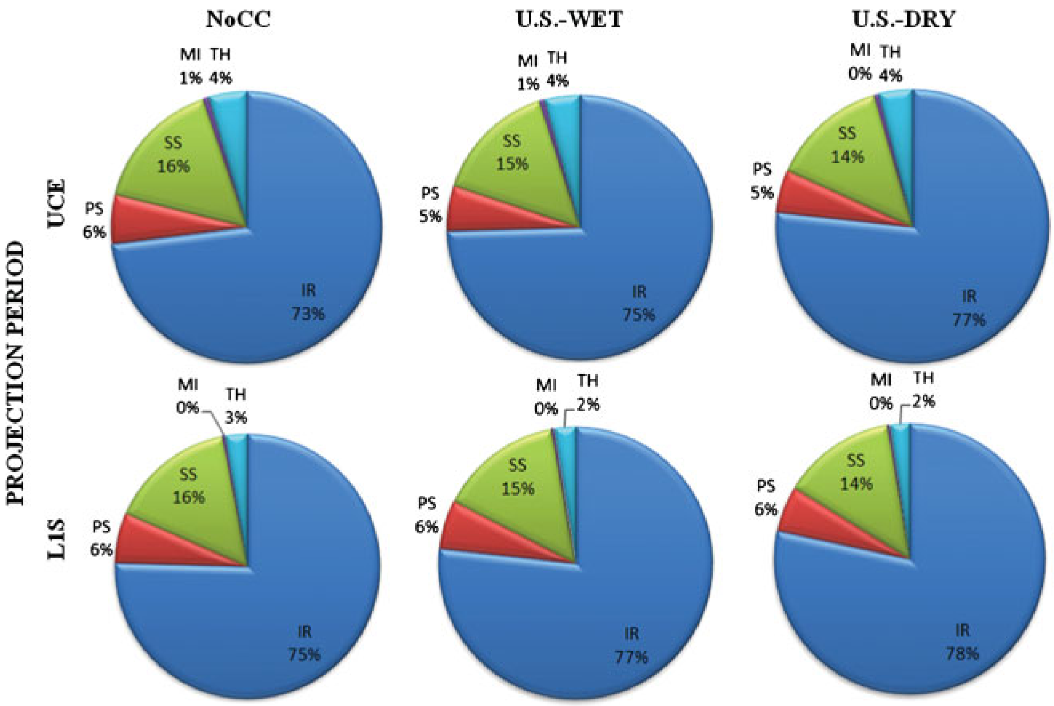


Figure 10. Average total water requirements for the projection period (2041–2050). Notes: Pie charts constructed using the sum of total water requirements over all ASRs. TH, thermoelectric cooling; IR, irrigation; SS, self-supply; PS, public supply; MI, mining.

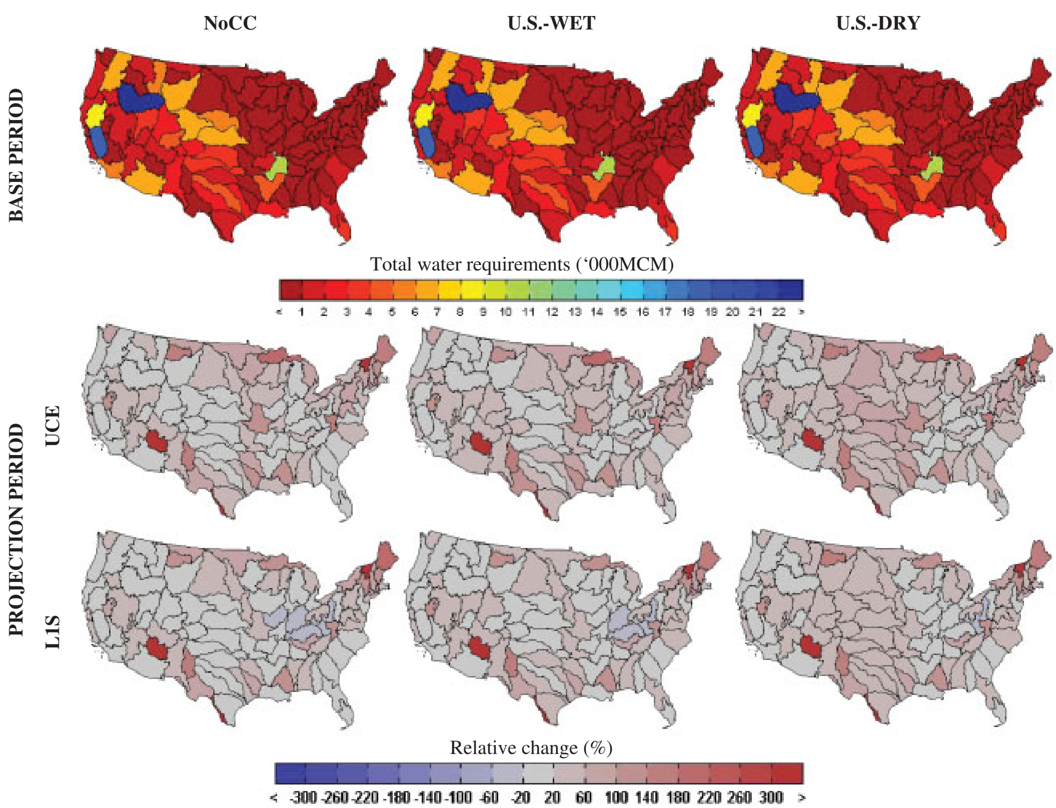


Figure 11. Total water requirement (in '000 MCM) for the base period (2005–2009) and relative change (in %) for the projection period (2041–2050). Note: For presentation purposes, estimates for the base period displayed in the first part of the graph are averaged over the L1S and UCE scenarios. However, relative change figures are calculated based on the scenario-specific estimates.

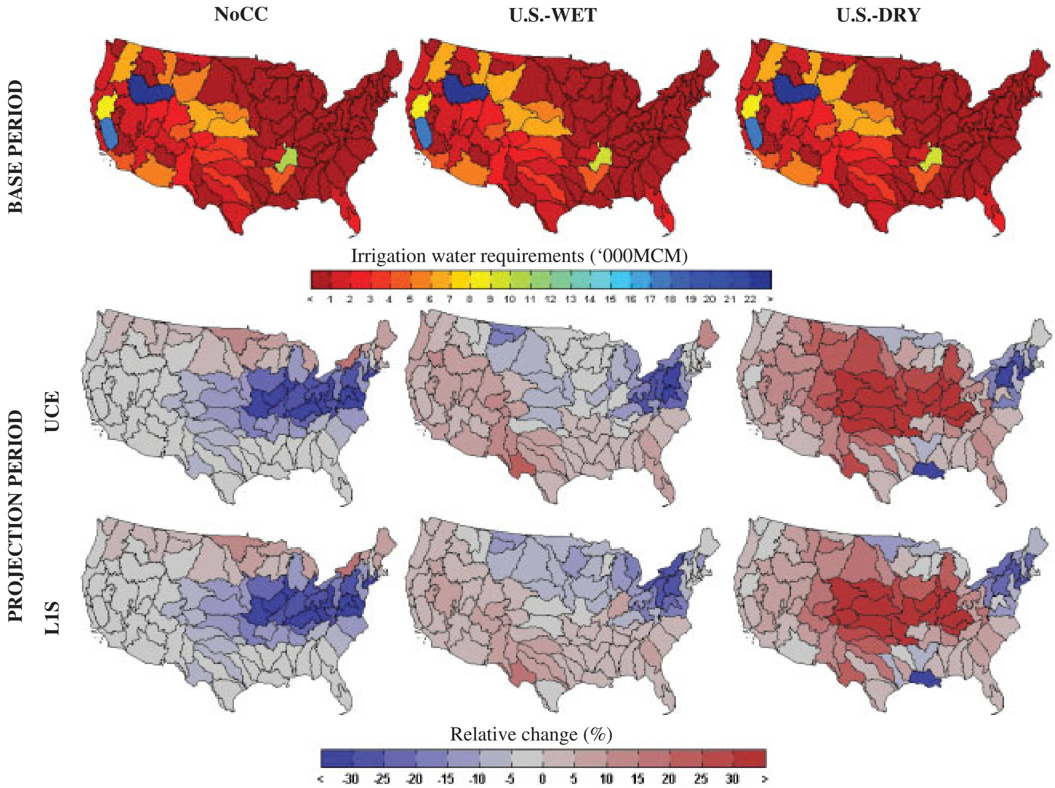


Figure 12. Irrigation water requirement (in '000 MCM) for the base period (2005–2009) and relative change (in %) for the projection period (2041–2050). Note: See Note of Figure 11.

considered, however, irrigation water requirements differ in the North-Central part of the United States, with decreases projected under the U.S.-WET climate pattern and increases under the U.S.-DRY climate pattern. The NoCC climate pattern projects water requirement increases along the Canadian border. All climate patterns show a decrease in irrigation water requirements in the Northeast.

6.2. Water Resource Projections

As described in section 4, runoff is projected using bias-corrected estimates from CLM under the two policy scenarios and three climate patterns. Total basin natural runoff (not including inflows from upstream basins) is projected to slightly increase toward the mid-century in all cases but to be generally lower under the L1S than under the UCE scenario. For each policy, the projected runoff is very similar for the two climate change patterns (wet vs. dry). Runoff under the NoCC climate pattern has slightly different interannual variations.

A geographical representation of natural runoff, provided in Figure 13, shows absolute values for the base period (2005–2009) and percentage changes for the projection period (2041–2050). The figure shows large spatial discrepancies at the regional level. In the Southwest, where runoff is relatively small in the base period, runoff is projected to slightly decrease under all climate patterns. In the U.S.-WET case, however, some increases are projected in some of these Southwest basins as well as in most other basins of the country. In the U.S.-DRY case, large decreases in runoff are predicted over most of the West.

6.3. Water Stress Projections

Using the sectoral water requirements and water resource estimates presented above, we evaluate water stress using two indicators: the water supply-requirement ratio (SRR) and the water stress index (WSI).

6.3.1. Supply-Requirement Ratio

SRR is calculated monthly as the ratio of TWS over total water required for each sector. This water stress indicator is used to represent physical constraints on anthropogenic water use. Projections of SRR from

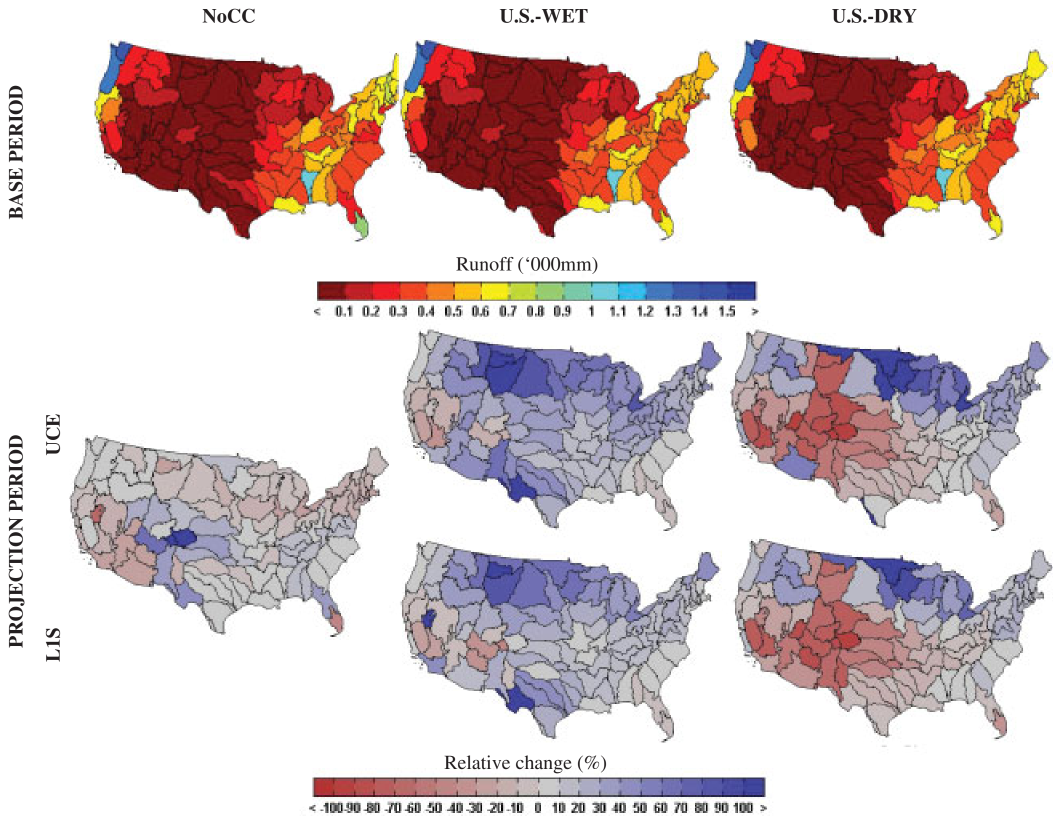


Figure 13. Average annual natural runoff (in '000 mm) for the base period (2005–2009) and relative change (in %) for the projection period (2041–2050). Note: See Note of Figure 11.

2005 to 2050 are presented in Figure 14 as an annual average for all ASRs weighted by their sectoral water requirements. The figure shows that water stress is generally increasing (as the average SRR decreases) under all climate patterns, and especially under the U.S.-DRY climate pattern. The water stress is slightly smaller under stringent GHG controls.

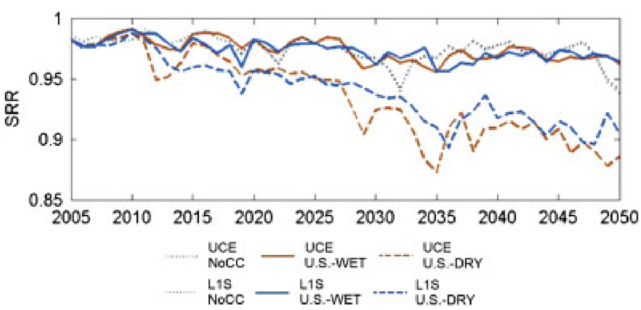


Figure 14. Weighted average over all ASR of the mean annual depletion-requirements ratio (SRR) from 2005 to 2050.

The representation of SRR by ASR provided in Figure 15 indicates that most water requirements are met in the base period. Water stress is observed in only four basins: Gila (ASR 1503), Sevier Lake (ASR 1602), Rio Grande Headwaters (ASR 1301), and Upper Arkansas (ASR 1102). The SRR is projected to decrease (or remain constant) in all cases, except in the Rio Grande Headwaters (ASR 1301) basin under the NoCC climate pattern. The largest decreases in SRR (i.e., increases in water scarcity) are projected in the Little Colorado (ASR 1501) basin where water requirements are mainly self-supplied. In the U.S.-DRY case, the decrease in SRR spreads further to the North and shows larger reductions overall.

To isolate the effect of GHG emission mitigation policies on water stress, we calculate the difference between the average annual SRRs (SRR_{L1S} minus SRR_{UCE}) in 2050 for each climate pattern. The blue-colored basins presented in Figure 16 correspond to basins where the SRR under the L1S scenario is higher than under the UCE scenario. For most basins affected by water stress, the climate mitigation

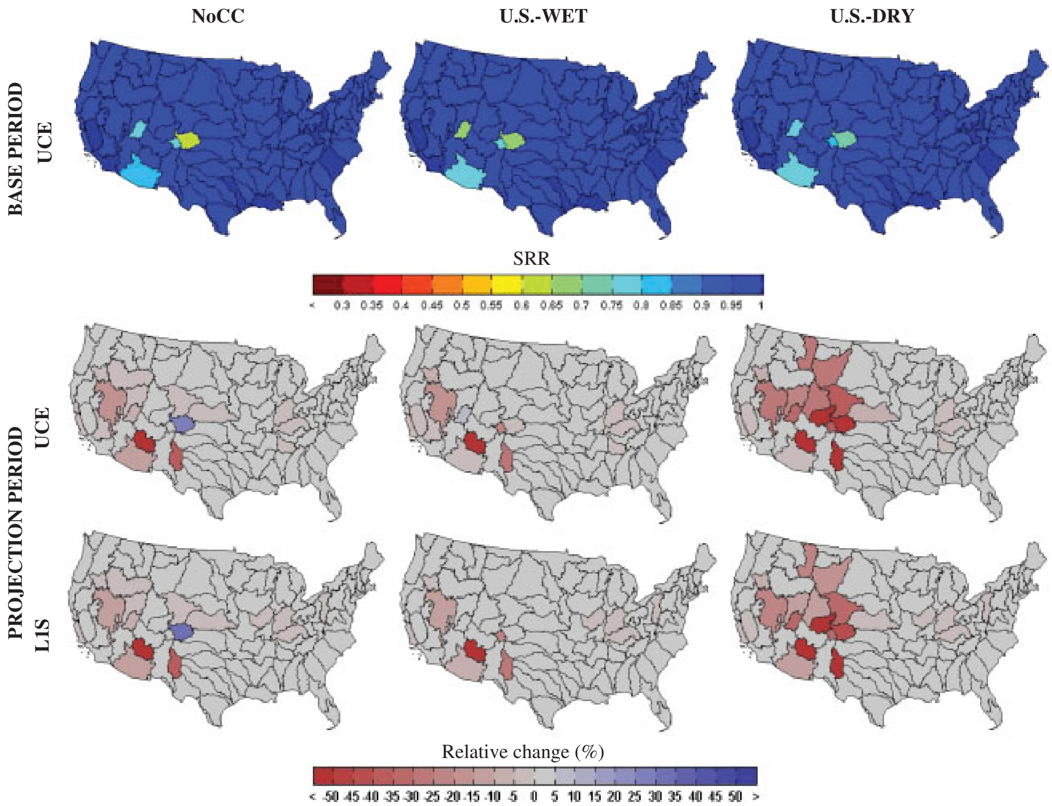


Figure 15. Average supply-requirements ratio (SRR) for the base period (2005–2009) and the projection period (2041–2050). Note: See Note of Figure 11.

policy will be effective at reducing water stress under both climate patterns, but the beneficial effect of a policy is small. However, for the Gila (ASR 1503), Little Colorado (ASR 1501), and Upper Pecos (ASR 1304) basins, climate policies worsen water stress in both the U.S.-Dry and U.S.-WET cases. This counterintuitive result is explained by a smaller runoff in the L1S scenario than under the UCE scenario in both climate patterns. This result is explained by a lower runoff rates in the L1S scenario than under the UCE scenario in both climate patterns, and indicates that the acceleration of that basin's hydroclimate toward a wetter cycle has been buffered under the L1S scenario. This result simply underscores that unconstrained climate change, in some cases, can lead to greater water supply resulting from stronger precipitation trends. The presence of this result for some basins in both the U.S.-WET and the U.S.-DRY cases indicates two conditions at play: (i) the characterization of U.S.-WET and U.S.-DRY was made in the context of averaged conditions over the United States and may not be reflective of every basin's result, and (ii) the zonal-scale trends of the IGSM's water-cycle response dominate over the U.S.-WET and U.S.-DRY patterns we have applied over the United States. For the Sevier Lake (ASR 1602) and the Rio Grande Headwaters (ASR 1301) basins, however, the impact of a climate policy on water stress depends on the climate pattern used. In the NoCC case, where policy scenarios affect water requirements but not water resources, the graph shows a unanimous beneficial effect of a reduction in water requirements driven by the L1S scenario.

The average number of ASRs affected by monthly water stress (i.e., ASRs where monthly SRR < 1) rises from around 5 (with on average 6 months of water stress per year) in the base period to around 7–15 (with on average 7 months of water stress per year) in the projection period. To focus on the effect of water stress within the year, we provide in Figure 17 a series of box plots of monthly SRRs for the basins significantly affected by water stress in the prediction period. The figure shows that the spread of the SRRs (i.e., water stress variability) is larger under the U.S.-DRY case for all basins except the Upper Pecos (ASR 1304) basin. For this basin, the plot shows that the water stress is consistently more important under the U.S.-DRY case than under the U.S.-WET case. The boxes for the L1S scenario are generally smaller and

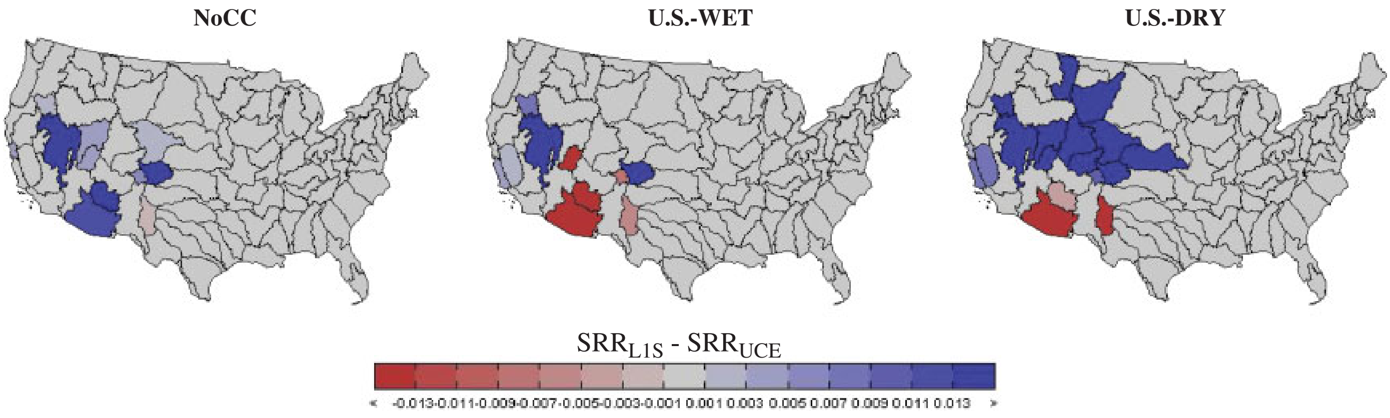


Figure 16. Difference between the average depletion-requirements ratio (SRR) under the L1S and UCE scenarios for each climate pattern in the projection period (2041–2050).

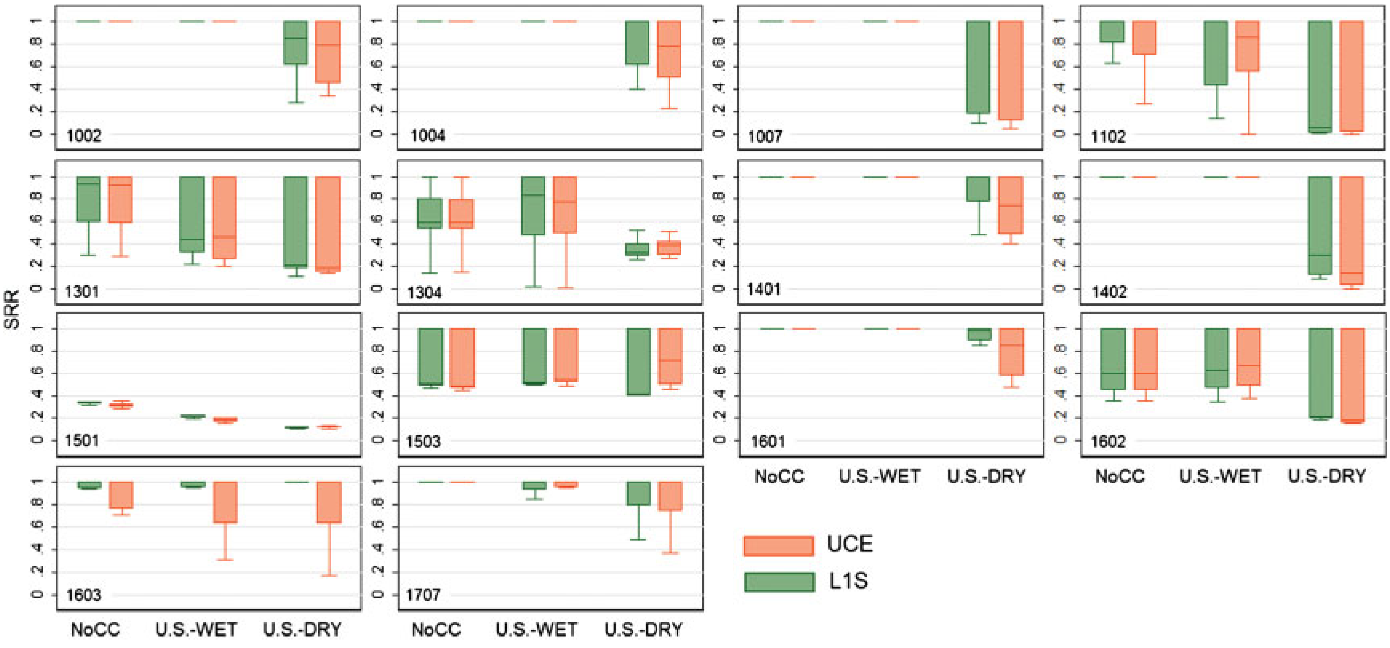


Figure 17. Box plot of the monthly deficit SRRs over all ASRs for the projection period (2041–2050). Notes: Each box represents, for each climate pattern and scenario, the range of monthly SRRs between the 25th and 75th percentile. The line inside each box represents the median. The whiskers represent adjacent values (=1.5*(upper quartile − lower quartile)).

closer to one than those for the UCE scenario, which shows that the climate policy is effective at reducing water stress severity and variability.

6.3.2. Water Stress Index

Water scarcity can also be estimated using the WSI developed by *Smakhtin et al*. [2005]. This index is used to estimate the pressure that human water use exerts on renewable surface freshwater. In this regard, this index is closer to a measure of water reliability. This index is calculated as a ratio of mean annual withdrawals for all sectors over mean annual runoff minus environmental requirements. Due to the spatial disaggregation of this study, we account for inflow from upstream basins to estimate total annual runoff. The environmental water requirements are implicitly accounted in the inflows, which are constrained to minimum environmental flows. The severity of water stress is classified as "heavily exploited" when $0.6 \leq WSI \leq 1$ and "overexploited" when $WSI > 1$. In the literature, similar WSIs are computed and generally consider a threshold of 0.4 to indicate sever water limitation [*Vörösmarty et al*., 2000; *Wada et al*., 2011].

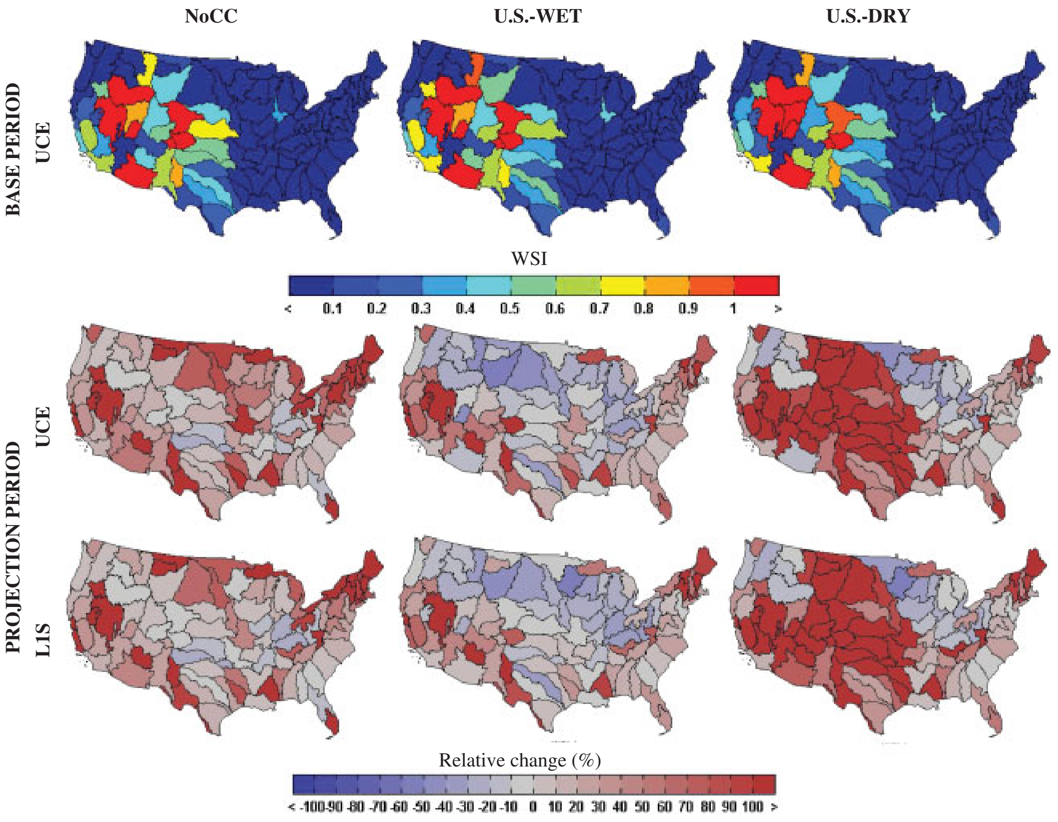


Figure 18. Average water stress index (WSI) for the base period (2005–2009) and the projection period (2041–2050). Note: See Note of Figure 11.

Figure 18 shows that in the base period, surface freshwater is generally heavily exploited in the Western United States and is overexploited in seven basins. Considering a threshold of 0.4 commonly used in the literature, 30 basins are affected by water scarcity. We find historical water stress geographical patterns over the United States similar to *Wada et al*. [2011] and *Vörösmarty et al*. [2000] (with the exception of Florida).

In the prediction period, WSI is generally increasing in the Central and Western United States under the U.S.-DRY climate pattern and decreasing in the Northeast. In the U.S.-WET case, the WSI is projected to decrease generally, except on the coasts. The WSI is projected to increase more uniformly under the NoCC climate pattern.

This index shows that although most basins will not be affected by unmet water requirements as shown by the SRR ratio, a large number of basins in the West will experience increasing pressure on water resources. This will be especially the case under the U.S.-DRY climate pattern, where overexploited basins are more prone to water shortages.

7. Conclusions

This article presents IGSM-WRS-US, a model of U.S. water resource systems. It is unique in its consistent treatment of the complex interactions of climatic, biological, physical, and economic elements. By identifying areas of potential stress in the absence of specific adaptation responses, the modeling system can help direct attention to water planning, while illustrating how avoiding climate change through mitigation policy could change likely outcomes. For this exercise, we downscale the IGSM-WRS model to the 99 ASR level for the continental United States. We also produce new estimates of water resources and water requirements for five sectors. The extended framework is used to allocate these water resources among the different sectors to minimize water stress, which measures the degree to which water requirements cannot be met. As an illustration, the model is used to project water stress through 2050 under two climate policies.

We estimate that, with or without climate change, average annual water stress is predicted to increase in the Southwest. This increase is mostly attributable to increases in water requirements. The study reveals that the choice of climate pattern considered for projections greatly influences the outcome of the model. On average, larger water stresses are projected under the U.S.-DRY climate pattern than under the U.S.-WET pattern. The impact of a constrained GHG emission policy (L1S scenario) will generally lessen the increase of mean annual water stress, especially in the U.S.-DRY case. However, water stress will be lower under an unconstrained emission policy (UCE scenario) than under a climate policy (L1S scenario) in some basins, i.e., 38% of the water-stressed basins in the U.S.-WET case and 14% in the U.S.-DRY case. A more detailed analysis of water stress at the monthly level reveals that the extent and intensity of monthly water stress is less under the L1S scenario than under the UCE scenario in most basins. The WSI measure, representing the reliability of water resources, shows that, although most basins will not be affected by unmet water requirements in the future (as shown by the SRR measure), a large number of basins in the West will see increased pressure on water resources, especially under the U.S.-DRY climate pattern.

In developing an integrated model of changes in water supply, climate change, and water use, some simplifications are necessary. The most important of these simulations is the assumption that irrigated areas remain unchanged in the future. In principle, we may see adjustments in areas affected by more frequent water shortages where maintenance of irrigation infrastructures may become uneconomic. On the other hand, irrigation may expand in areas with ample water supplies (e.g., groundwater) but subject to more droughts. Alternatively, losses of food production in some regions could be addressed via a spatial shift of cropland elsewhere in the United States or abroad. In this regard, international trade would have important implications on food availability given the role it currently plays in the U.S. economy. The expansion of biofuel production would also need to be considered, as it may become an important user of irrigation. We also assume that current rates of groundwater withdrawal are sustainable. If they are not, either because withdrawal exceeds recharge or climate reduces recharge, then irrigation dependent on groundwater may cease and possibly increase pressure on surface water flows. Another simplification, inherent to this modeling framework, is the lack of adaptation strategy. In this framework, no measure is taken to avoid water stress. For SS, PS, and MI, the econometric estimates take into account energy efficiency measures as represented by the nonlinear relationship between GDP and water withdrawal. However, even these conservation measures are prescribed and do not respond to water shortage relevant to the basin considered. These simplifications represent opportunities for further research.

Notwithstanding these simplifications, IGSM-WRS-US is an important tool for climate change impact assessments, policy evaluations, and advances in earth system modeling. It has the substantial advantages over other water models to be part of a larger framework, which allows integrated assessments of water resources and uses in the context of global climate and economic changes. The endogenous estimation of climate change also allows the consideration of climate change uncertainty in assessments of water resources and water stress. The framework will also support the development of feedbacks to assess the implications of water stress on the economy.

This model framework also represents a significant improvement compared to global water models. By focusing on the United States, we take advantage of water-use data detailed at the county level to estimate and project water requirements. The spatial disaggregation allows the detection of local water issues, such as the water deficit in the West. Future applications could focus on the impact of such water stress on economic activities, such as food production or naval transportation. It would also allow investigating uncertainty in future climate impacts deriving from uncertainty in climate response [*Monier and Gao*, 2014], multiple levels of mitigation policy, and uncertainty in the economic drivers of water use. This downscaled model also lays the foundations for further investigation of water allocation strategies, which are not possible at wide river basin delineations.

Appendix A: Irrigation Water Requirements Estimation

A1. Water Consumption at the Root Level

CliCrop is a biophysical model developed for use in integrated assessment frameworks [*Fant et al*., 2012]. It is global, fast, and requires a minimal set of inputs. It is based on the Food and Agriculture Organization (FAO)'s CropWat model [*Allen et al*., 1998] for crop phenology and irrigation requirements and

Table A1. Correspondence Between Crops Modeled by CliCrop and Actual Crops

CliCrop Crop Type	Actual Crop Type
Forage/Alfalfa	Forage/alfalfa
	Pastureland
	Orchards
Cotton	Cotton
Grains or barley	Grains or barley
Groundnuts	Groundnuts
Maize	Maize (grain and silage)
	Berries
Potatoes	Vegetables
	Other
Pulses	Pulses
Rice	Rice
Sorghum	Sorghum
Soybeans	Soybeans
Sugar beets	Sugar beets
Sugar cane	Sugar cane
Wheat (average spring/winter wheat)	Wheat, spring and winter

on the Soil and Water Assessment Tool (SWAT) [*Neitsch et al*., 2005] for soil hydrology. CliCrop runs on a daily time scale, has a $2° \times 2.5°$ grid resolution for the globe, and estimates crop water requirements (in mm/crop/month) to obtain maximum yields under given weather conditions for 13 of the most commonly grown crops. The irrigation requirement at the roots of the plant is defined as the difference between the evapotranspiration requirement [as defined by *Allen et al*., 1998] and the actual evapotranspiration as computed by CliCrop. For water requirements of crops not modeled by CliCrop, we use crops with similar irrigation needs as proxies (the generic crops used in CliCrop as proxies for crop water requirements in the United States are presented in Table A1). For each crop, the planting date has been specified according to data from the Centre for Sustainability and the Global Environment (SAGE), University of Wisconsin [*Sacks et al*., 2010].

Annual water consumption CON_{IR} is estimated at the county level for each crop using monthly crop water consumption estimated by CliCrop and irrigated area, ARE_{IR}, sourced from FRIS:

$$CON_{IR} = \sum_{month} \sum_{crops} CON_{IR}(crop, month) \times ARE_{IR}(crop) \tag{A1}$$

As the delineations of states and ASRs do not match perfectly, we estimate water consumption data at the county level. FRIS [*USDA*, 2003] provides irrigated area detailed by crop. However, these data are provided at the state level only. *USGS* [2011] provides irrigated area every 5 years at the county level but does not detail irrigated area by crop. To obtain irrigated area for each crop at the county level, we use county-level total irrigated area estimated by USGS for the year 2005 and state-level crop-specific irrigated areas estimated by FRIS for the year 2003. We allocate state-level irrigated areas from FRIS using the ratio of total irrigated area at the county level within each state from USGS following the formula:

$$ARE_{IR}(crop, county) = ARE\_FRIS_{IR}(crop, state) \cdot \frac{ARE\_USGS_{IR}(county)}{\sum_{state} ARE\_USGS_{IR}(county)} \tag{A2}$$

To obtain water consumption at the ASR level, we aggregate county-level consumptions for all counties lying within the ASR. For counties overlapping several ASRs, the matching is based on the share of the county area lying within the ASR.

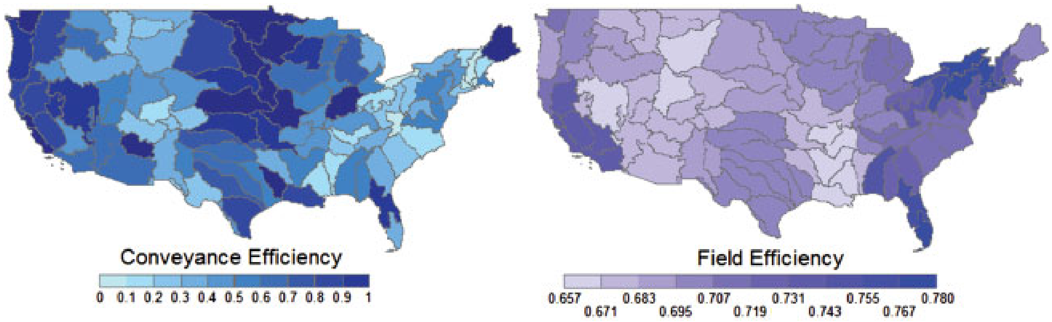


Figure A1. Conveyance and field efficiencies.

A2. Crop-Specific Management Factor

The CliCrop estimate of water requirements corresponds to the level of water necessary to eliminate water stress in the crop and, assuming that other factors are not limiting, achieve maximum yield. In practice, however, farmers may not aim to maximize yields. For instance, lower-valued crops such as forage may not justify irrigation expenses associated with maximum yields. For other crops, water is used for irrigation-related activities (e.g., field flooding to harvest cranberries). Alternatively, CliCrop's representation may be imperfect as it uses a proxy for some crops. To account for varying irrigation practices and modeling errors, we estimate for each crop an average management factor over the United States enabling us to adjust the water consumption estimated by CliCrop to the water actually consumed. Actual water consumption data (i.e., water used to obtain actual yields) are obtained using FRIS survey data on water delivery at the field, to which we apply a FEF (shown in Figure A1 and presented in the next subsection).

To estimate the U.S.-wide crop-specific management factors, *M*, we employ a univariate regression for each crop at the county level:

$$\mathrm{CON}_{\mathrm{IR,FRIS}}\,(\mathrm{crop, county}) = M\,(\mathrm{crop}) \times \mathrm{CON}_{\mathrm{IR,CLICROP}}\,(\mathrm{crop, county}) + \epsilon, \tag{A3}$$

where $\mathrm{CON}_{\mathrm{IR,FRIS}}$ is the irrigation water consumption at the root calculated from FRIS data for 2003 (see paragraph on water consumption at the field for details regarding the calculation of water consumption at the root using the system efficiency). We consider $\mathrm{CON}_{\mathrm{IR,CLICROP}}$ as an annual average of CliCrop water consumption over the period 1998–2003, as survey responses from farmers might not be strictly representative of 2003 (most water withdrawals are not metered) but rather a short-term average of water uses. The results of these regressions are reported in Table A2.

Management factors lower than 1.0 indicate that farmers irrigate less than is necessary to obtain maximal yields. As expected, small *M* factors are obtained for low-value crops such as pasture. For other crops, management factors higher than 1.0 capture irrigation-related uses (e.g., berries) or imperfect crop representation by CliCrop. For wheat, the low coefficient can be explained by the fact that this crop is irrigated differently in winter and summer. The allocation of irrigation across the year is not known, so we assume that CliCrop takes an average of irrigation need between the two seasons. For vegetables, the high management factor is due to the fact that vegetables are proxied by potatoes in CliCrop. We estimate future water consumption for each crop by multiplying CliCrop crop water consumption by the corresponding management factor.

A3. Region-Specific Irrigation-Related Uses

A portion of irrigation water is also used for preirrigation, frost protection, chemical application, weed control, field preparation, crop cooling, harvesting, dust suppression, and leaching of salts from the root zone [*Kenny*, 2004]. Most of these irrigation-related uses are region specific (e.g., soil leaching in dry regions and frost protection in cool regions). However, CliCrop is not designed to capture these uses. FRIS data, on the other hand, include all irrigation-related water uses but do not distinguish the amount of water used specifically for irrigation from the water used for other purposes. To estimate these other irrigation uses, we calculate irrigation consumption for other purposes at the ASR level, $\mathrm{CON}_{\mathrm{IRO}}$, as the difference between

Table A2. Univariate Regression Results for the Estimation of the Management Factors

Crops	*M*	Standard Errors	Observations	R^2
Forage	0.695***	0.00704	1570	0.861
Pasture	0.579***	0.00692	2564	0.732
Cotton	0.695***	0.0237	284	0.753
Grains	0.902***	0.0369	154	0.796
Groundnuts	0.466***	0.00818	134	0.961
Maize	1.304***	0.0152	1036	0.876
Pulses	1.390***	0.0492	151	0.842
Rice	0.664***	0.0209	108	0.904
Sorghum	0.570***	0.0114	200	0.926
Soybeans	1.311***	0.0216	569	0.866
Sugarbeets	1.335***	0.0724	60	0.852
Wheat	0.562***	0.0125	458	0.815
Vegetables	1.669***	0.0249	1210	0.788
Potatoes	1.837***	0.0333	3082	0.497
Berries	1.334***	0.0425	239	0.805
Orchard	1.837***	0.0657	668	0.540
Other	0.824***	0.00644	925	0.947

***$p < 0.01$.

FRIS and CliCrop water consumption at the county level:

$$\mathrm{CON}_{\mathrm{IRO}} = \sum_{\mathrm{cnt}} \mathrm{CON}_{\mathrm{IR,FRIS}}(\mathrm{crop,county}) - \sum_{\mathrm{cnt}} M(\mathrm{crop}) \times \mathrm{CON}_{\mathrm{IR,CLICROP}}(\mathrm{crop,county}) \tag{A4}$$

$\mathrm{CON}_{\mathrm{IRO}}$ is assumed to remain constant at the 2005 level (this assumption merits further study as water resource changes might influence irrigation-related water consumption). To obtain monthly calibration, we spread the calibration constant across the year proportionally to irrigation water consumption estimated by CliCrop.

A4. Field Efficiency

As explained above, some water losses occur at the irrigation apparatus level: furrows are, for example, less efficient than sprinklers or drip irrigation. These losses are represented by irrigation FEFs also called application efficiencies. To account for these water losses, we calculate the average efficiency for each technique [*Kenny*, 2004] weighted by the area over which such system is in use in each state. We assume that the FEF is the same for each county within a state. FEFs at the ASR level are represented in Figure A1.

A5. Water Delivery at the Field

Water delivery at the field represents the amount of water delivered to the farm for irrigation purposes. It is estimated by applying the FEFs discussed above, to water consumption at the root for crop and other irrigation-related purposes:

$$\mathrm{DEL}_{\mathrm{IR}} = \frac{\sum_{\mathrm{cnt,crop}} \mathrm{CON}_{\mathrm{IRO}}(\mathrm{crop,county}) + M(\mathrm{crop}) \times \mathrm{CON}_{\mathrm{IR,CLICROP}}(\mathrm{crop,county})}{\mathrm{FEF}} \tag{A5}$$

We then aggregate all the county-level water consumption at the ASR level.

A6. Conveyance Efficiency

A major portion of agricultural water loss occurs in transport between the source and the field. This loss is usually represented by a CEF, which is calculated as the ratio of water reaching the field over the water withdrawn at the source [*Howell*, 2003]. We determine CEF for each ASR using county irrigation data of withdrawal sourced from *USGS* [2011] for 2005 and delivery at the field data from FRIS for 2003 (water delivery data and water withdrawal data are not available for the same year). CEFs calculated for each ASR are shown in Figure A1.

A7. Water Withdrawal at the Stream

Irrigation water withdrawal at the stream is the total amount of water diverted from the natural hydrologic system for irrigation purposes. To calculate water withdrawal, WTH, we apply the CEF to the field delivery, DEL:

$$\mathrm{WTH}_{\mathrm{IR}} = \mathrm{DEL}_{\mathrm{IR}}/\mathrm{CEF} \tag{A6}$$

Appendix B: Public Supply, Self-Supply, and Mining Estimation

Water withdrawals for the PS, SS, and MI sectors are estimated using panel data econometric techniques. We use county-level data on water withdrawals from *USGS* [2011]. USGS provides water withdrawal data every 5 years from 1985 until 2005. Water withdrawals are given in millions of gallons per day (Mgal/d). *USGS* [2011] also provides population estimates by county. These county-level estimates are aggregated at the ASR level. Sectoral- and state-level GDP is sourced from the Bureau of Economic Analysis [*BEA*, 2011]. To obtain GDP at the ASR level, we assign the GDP for the state where the ASR lies in. When the ASR is spread across different states, we apply the weighted average based on the area of the ASR contained within the state.

County-level water withdrawal data are aggregated at the ASR level. However, there are no water-use data available for two river basins (ASR 1602 and 1807). As indicated in Figure 2, these basins are closed and are sparsely populated. We assume that there is no water requirement in these regions.

Water withdrawal for PS is specified as:

$$\mathrm{PS} = f\left(\log(\mathrm{pop}), \log(\mathrm{GDP}/\mathrm{pop}), \log(\mathrm{GDP}/\mathrm{pop})^2\right), \tag{B1}$$

where PS is a function of total population (pop), real gross domestic product per capita (GDP/pop), and a square term of GDP/pop to represent nonlinear effects. The regression results provided in Table B1 indicate that as population increase, PS water requirement increases, and that as GDP per capita grows, households become more environmentally conscious and reduce water use per capita. The square term, however, represents a concave relationship and indicates that the marginal decrease in water requirement due to an increase in GDP per capita diminishes as the economy develops. This structural change represents the temporal continuation of the income growth effect on domestic water use reported by *Alcamo et al.* [2003], where household water consumption increases rapidly as larger incomes enable access to plumbing and appliances, then stabilizes once these needs are satisfied.

SS water requirement is specified as a function of GDP for all sectors except MI and its square term:

$$\mathrm{SS} = f\left(\log\left(\mathrm{GDP}_{\mathrm{noMI}}\right), \log\left(\mathrm{GDP}_{\mathrm{noMI}}\right)^2\right) \tag{B2}$$

The estimated relationship, also presented in Table B1, shows that as GDP grows, water requirement increases, but the marginal increase becomes smaller as the agents become more efficient in their water use and shift toward less industrial, i.e., water intensive, activities.

Water withdrawals for MI purposes are estimated as a function of MI GDP and its square term:

$$\mathrm{MI} = f\left(\log\left(\mathrm{GDP}_{\mathrm{MI}}\right), \log\left(\mathrm{GDP}_{\mathrm{MI}}\right)^2\right) \tag{B3}$$

GDP has a nonlinear effect on MI water withdrawal similar to that estimated for SS.

We have not modeled explicitly the effect that environmental regulation would have on water conservation. However, the implementation of regulation can be indirectly taken into account by the effect of GDP as countries' preference for cleaner environment increase with income [*Lucas et al.*, 1992].

Table B1. Water Withdrawals Regression Results

Variables	PS	SS	MI
Log(Population)	221.2***		
	(5.103)		
Log(Real GDP per capita)	−116.6***		
	(6.755)		
Log(Real GDP per capita)^2	17.79***		
	(0.463)		
Log(Real nonmining GDP)		1456***	
		(136.1)	
Log(Real nonmining GDP)^2		−57.69***	
		(5.721)	
Log(Real mining GDP)			24.67**
			(10.35)
Log(Real mining GDP)^2			−1.774*
			(0.913)
Observations	422	422	370
R^2	0.957	0.882	0.818
Number of groups	99	99	98

Notes: Dependent variable is annual water withdrawal in Mgal/d for each sector. Standard errors in parentheses. Significance levels: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Water withdrawals for these sectors are estimated using a panel estimator providing Driscoll-Kraay standard errors, which are robust to very wide forms of temporal and cross-sectional correlation. River basin fixed effects are included to account for unobserved characteristics that vary across basins but not over time.

Due to data limitations, we make several assumptions in order to comply with the model definition (see section 3), which treats the water requirements for these sectors (SWR) not as withdrawal but as consumption. First, consumptive-use data, which represent the amount of water not returned to the source for immediate reuse, are available only until 1995. To calculate water consumption for other years, we assume that the proportion of water consumption in water withdrawal remains the same as in 1995. Second, water withdrawals for the PS, SS, and MI sectors are estimated only annually. To obtain monthly water values, we assume that withdrawals are spread evenly across the year (this assumption can be modified in future development of the model). Third, the data set does not provide details regarding water demanded that was not met. This might be the case for some sectors, such as PS, for example, when a city applies water restrictions during dry periods. We assume that estimated water requirements were always met by water supplied.

Acknowledgments
The Joint Program on the Science and Policy of Global Change is funded by the U.S. Department of Energy, Office of Science under grants DE-FG02-94ER61937, DE-FG02-93ER61677, DEFG02-08ER64597, and DE-FG02-06ER64320; the U.S. Environmental Protection Agency under grants XA-83344601-0, XA-83240101, XA-83042801-0, PI-83412601-0, RD-83096001, and RD-83427901-0; the U.S. National Science Foundation under grants SES-0825915, EFRI-0835414, ATM-0120468, BCS-0410344, ATM-0329759, and DMS-0426845; the U.S. National Aeronautics and Space Administration under grants NNX07AI49G, NNX08AY59A, NNX06AC30A, NNX09AK26G, NNX08AL73G, NNX09AI26G, NNG04GJ80G, NNG04GP30G, and NNA06CN09A; the U.S. National Oceanic and Atmospheric Administration under grants DG1330-05-CN-1308, NA070AR4310050, and NA16GP2290; the U.S. Federal Aviation Administration under grant 06-C-NE-MIT; the Electric Power Research Institute under grant EPP32616/C15124; and a consortium of 40 industrial and foundation sponsors (for the complete list see http://globalchange.mit.edu/sponsors/current.html).

References

Acreman, M., and M. J. Dunbar (2004), Defining environmental river flow requirements: A review, *Hydrol. Earth Syst. Sci.*, *8*(5), 861–876.

Alcamo, J., and T. Henrichs (2002), Critical regions: A model-based estimation of world water resources sensitive to global changes, *Aquat. Sci.*, *64*, 352–362.

Alcamo, J., P. Döll, T. Henrichs, F. Kaspar, B. Lehner, T. Rösch, and S. Siebert (2003), Development and testing of the watergap2 global model of water use and availability, *Hydrol. Sci.*, *48*(3), 317–337.

Alcamo, J., M. Flörke, and M. Märker (2007), Future long-term changes in global water resources driven by socio-economic and climatic changes, *Hydrol. Sci. J.*, *52*(2), 247–275.

Allen, R. G., L. S. Pereira, D. Raes, and M. Smith (1998), *Crop Evapotranspiration—Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper*, Food and Agricultural Organization, Rome, Italy.

Arnell, N. W. (2004), Climate change and global water resources: Sres emissions and socio-economic scenarios, *Global Environ. Change*, *14*(1), 31–52.

Barnett, T. P., and D. W. Pierce (2008), When will lake mead go dry?, *Water Resour. Res.*, *44*(3), W03201, doi:10.1029/2007wr006704.

BEA (2011), *Regional Economic Accounts*, US Department of Commerce, Bureau of Economic Analysis, Washington, D. C. [Available at http://bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=1.]

Benke, A. C., and C. E. Cushing (2005), Background and approach, in *Rivers of North America*, edited by A. C. Benke and C. E. Cushing, pp. 1–18, Elsevier Academic Press, London, U. K.

Brown, T. C., R. Foti, and J. A. Ramirez (2013), Projected freshwater withdrawals in the United States under a changing climate, *Water Resour. Res.*, *49*(3), 1–18, doi:10.1002/wrcr.20076.

Cai, X., and M. Rosegrant (2002), Global water demand and supply projections. Part 1: A modeling approach, *Water Int.*, *27*(3), 159–169.

Clarke, L., J. Edmonds, H. Jacoby, H. Pitcher, J. Reilly, and R. Richels (2007), Scenarios of greenhouse gas emissions and atmospheric concentrations, Sub-report 2.1a of synthesis and assessment product 2.1, 106 pp., U.S. Clim. Change Sci. Program and the Subcommittee on Global Change Res., Dep. of Energy, Office of Biol. and Environ. Res., Washington, D. C.

Collins, W. D., et al. (2006), The community climate system model version 3 (CCSM3), *J. Clim.*, *19*, 2122–2143.

Connell-Buck, C. R., J. Medellín-Azuara, J. R. Lund, and K. Madani (2011), Adapting California's water system to warm vs. dry climates, *Clim. Change*, *109*(Suppl 1), 133–149.

Davies, E. G. R., and S. P. Simonovic (2011), Global water resources modeling with an integrated model of the social-economic-environmental system, *Adv. Water Resour.*, *34*(6), 684–700.

Davies, E. G. R., P. Kyle, and J. A. Edmonds (2013), An integrated assessment of global and regional water demands for electricity generation to 2095, *Adv. Water Resour.*, *52*, 296–313.

de Fraiture, C. (2007), Integrated water and food analysis at the global and basin level. An application of WATERSIM, *Water Resour. Manage.*, *21*(1), 185–198.

Delworth, T. L., et al. (2006), GFDL's cm2 global coupled climate models. Part i: Formulation and simulation characteristics, *J. Clim.*, *19*, 643–674.

DOE (2006), Estimating freshwater needs to meet future thermoelectric generation requirements, *DOE/NETL-2006/1235*, Dep. of Energy, Pittsburg, Pa.

Draper, A. J., M. W. Jenkins, K. W. Kirby, J. R. Lund, and R. E. Howitt (2003), Economic-engineering optimization for California water management, *J. Water Resour. Plann. Manage.*, *129*(3), 155–164.

Fant, C., K. Strzepek, A. Gueneau, S. Awadalla, E. Blanc, W. Farmer, and C. A. Schlosser (2012), CliCrop: A crop water-stress and irrigation demand model for an integrated global assessment modeling approach, *Joint Program Report Series 214*, MIT Joint Program on the Sci. and Policy of Global Change, Cambridge, Mass.

Forest, C. E., P. H. Stone, and A. P. Sokolov (2008), Constraining climate model parameters from observed 20th century changes, *Tellus*, *60*(5), 911–920.

Hanasaki, N., S. Kanae, T. Oki, K. Masuda, K. Motoya, N. Shirakawa, Y. Shen, and K. Tanaka (2008), An integrated model for the assessment of global water resources—Part 1: Model description and input meteorological forcing, *Hydrol. Earth Syst. Sci.*, *12*, 1007–1025.

Hirji, R., and R. Davis (2009), Environmental flows in water resources policies, plans, and projects: Case studies, *Environment Department Papers, Natural Resource Management Series 117*, The World Bank Environ. Dep., Washington, D. C.

Hirsch, R. M. (1982), A comparison of four record extension techniques, *Water Resour. Res.*, *18*(4), 1081–1088, doi:10.1029/WR018i004p01081.

Howell, T. A. (2003), Irrigation efficiency, in *Encyclopedia of Water Science*, edited by A. Stewart and T. A. Howell, pp. 467–472, Marcel Dekker, New York.

Islam, M. S., T. Oki, S. Kanae, N. Hanasaki, Y. Agata, and K. Yoshimura (2007), A grid-based assessment of global water scarcity including virtual water trading, *Water Resour. Manage.*, *21*, 19–33.

Kenny, J. F. (2004), Guidelines for preparation of state water-use estimates for 2000, *U.S. Geological Survey Techniques and Methods 4-A-4*, 49 pp., U.S. Geol. Surv., Reston, Va.

Lawrence, D., et al. (2011), Parameterization, improvements and functional and structural advances in version 4 of the community land model, *J. Adv. Model. Earth Syst.*, *3*(1), 1–27.

Lucas, R. E. B., D. Wheeler, and H. Hettige (1992), Economic development, environmental regulation, and the international migration of toxic industrial pollution: 1960-88, *World Bank Policy Research Working Paper 1062*, World Bank, Washington, D. C.

Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor (2007), The WCRP CMIP3 multi-model dataset: A new era in climate change research, *Bull. Am. Meteorol. Soc.*, *88*, 1383–1394.

Molden, D., K. Frenken, R. Barker, C. de Fraiture, B. Mati, M. Svendsen, C. Sadoff, and C. M. Finlayson (2007), Trends in water and agricultural development, in *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*, edited by D. Molden, pp. 57–89, Earthscan/International Water Management Institute: London, U. K./Colombo, Srilanka.

Monier, E., and X. Gao (2014), Climate change impacts on extreme events in the united states: An uncertainty analysis, *Clim. Change* in press.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, J. R. Williams, and K. W. King (2005), Soil and water assessment tool (SWAT) theoretical documentation, *BRC Rep.*, Blackland Research Center, Texas Agricultural Experiment Station, Temple, Tex.

Ngo-Duc, T., K. Laval, J. Polcher, A. Lombard, and A. Cazenave (2005), Construction, validation and applications of the 53 year atmospheric forcing NCC, in *5th International Scientific Conference on the Global Energy and Water Cycle: Observing and Predicting the Earth's Water and Energy Cycle: Current State of Knowledge and Future Research Requirements*, Orange County, Calif.

Oki, T., Y. Agata, S. Kanae, T. Saruhashi, D. Yang, and K. Musiake (2001), Global assessment of current water resources using total runoff integrating pathways, *Hydrol. Sci. J.*, *46*(6), 983–995.

Oleson, K. W., et al. (2008), Improvements to the community land model and their impact on the hydrological cycle, *J. Geophys. Res.: Biogeosci.*, *113*(G1), G01021, doi:10.1029/2007jg000563.

Paltsev, S., J. M. Reilly, H. D. Jacoby, R. S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian, and M. Babiker (2005), The MIT emissions prediction and policy analysis (EPPA) model: Version 4, *Joint Program Report Series 125*, MIT Joint Program on the Sci. and Policy of Global Change, Cambridge, Mass.

Postel, S. (2000), Entering an era of water scarcity: The challenges ahead, *Ecol. Appl.*, *10*, 941–948.

Pritchett, J., A. Bright, A. Shortsleeve, J. Thorvaldson, T. Bauder, and R. Waskom (2009), Public perceptions, preferences and values for water in the west: A survey of western and Colorado residents, *Special Report 17*, Colorado Water Inst., Fort Collins, Colo.

Rausch, S., and M. Mowers (2012), Distributional and efficiency impacts of clean and renewable energy standards for electricity, *Resour. Energy Econ.*, 1–30, doi:10.1016/j.reseneeco.2013.09.001.

Rausch, S., G. E. Metcalf, J. M. Reilly, and S. Paltsev (2010), Distributional implications of alternative U.S. Greenhouse gas control measures, *B.E. J. Econ. Anal. Policy*, *10*(2).

Rosegrant, M. W., C. Ringler, S. Msangi, T. B. Sulser, T. Zhu, and S. A. Cline (2008), *International Model for Policy Analysis of Agricultural Commodities and Trade (Impact): Model Description*, International Food Policy Research Institute, Washington, D. C.

Rotmans, J., and B. de Vries (1997), in *Perspectives on Global Change: The TARGETS Approach*, edited by J. Rotmans and B. de Vries, pp. 1–479, Cambridge Univ. Press, Cambridge, U. K.

Sacks, W. J., D. Deryng, J. A. Foley, and N. Ramankutty (2010), Crop planting dates: An analysis of global patterns, *Global Ecol. Biogeogr. Lett.*, *19*(5), 607–620.
Scanlon, B., R. Healy, and P. Cook (2002), Choosing appropriate techniques for quantifying groundwater recharge, *Hydrol. J.*, *10*(1), 18–39.
Schlosser, C. A., X. Gao, K. Strzepek, A. Sokolov, C. E. Forest, S. Awadalla, and W. Farmer (2012), Quantifying the likelihood of regional climate change: A hybridized approach, *J. Clim.*, *26*, 3394–3414.
Shen, Y., T. Oki, N. Utsumi, S. Kanae, and N. Hanasakid (2008), Projection of future world water resources under SRES scenarios: Water withdrawal, *Hydrol. Sci. J.*, *53*, 11–33.
Short, W., N. Blair, P. Sullivan, and T. Mai (2009), ReEDS model documentation: Base case data and model description, *NREL Rep.*, National Renewable Energy Laboratory, Golden, Colo.
Simonovic, S. P. (2002), World water dynamics: Global modeling of water resources, *J. Environ. Manage.*, *66*, 249–267.
Smakhtin, V., C. Revenga, and P. Döll (2004), A pilot global assessment of environmental water requirements and scarcity, *Water Int.*, *29*, 307–317.
Smakhtin, V., C. Revanga, and P. Doll (2005), Taking into account environmental water requirements in globalscale water resources assessments, *Comprehensive Assessment Res. Rep. 2*, Comprehensive Assessment Secretariat, Colombo, Sri Lanka.
Sokolov, A. P., et al. (2005), The MIT integrated global system model (IGSM) version 2: Model description and baseline evaluation, *Joint Program Report Series 124*, MIT Joint Program on the Sci. and Policy of Global Change, Cambridge, Mass.
Sokolov, A., et al. (2009), Probabilistic forecast for 21st century climate based on uncertainties in emissions (without policy) and climate parameters, *J. Clim.*, *22*(19), 5175–5204.
Strzepek, K., J. Baker, W. Farmer, and C. A. Schlosser (2012a), Modeling water withdrawal and consumption for electricity generation in the united states, *MIT Joint Program Report 222*, MIT Joint Program on the Sci. and Policy of Global Change, Cambridge, Mass.
Strzepek, K., C. A. Schlosser, A. Gueneau, X. Gao, É. Blanc, C. Fant, B. Rasheed, and H. D. Jacoby (2012b), Modeling water resource systems under climate change: IGSM-WRS, *Joint Program Report Series 236*, MIT Joint Program on the Sci. and Policy of Global Change, Cambridge, Mass.
Templin, W. E., R. A. Herbert, C. B. Stainaker, M. Horn, and W. B. Solley (1997), Water use, in *National Handbook of Recommended Methods for Water Data Acquisition* Chapter 11, U.S. Geol. Surv., Boulder, Colo. [Available at http://pubs.usgs.gov/chapter11.]
U.S. Bureau of Reclamation (2009), Colorado river accounting and water use report, U.S. Bureau of Reclamation, Denver, Colo.
U.S. Census Bureau (2000), U.S. Population projections: State interim population projections by age and sex: 2004-2030, U.S. Census Bureau.
UN (2012), The millennium development goals report 2012, United Nations. [Available at http://www.un.org/millenniumgoals/pdf/MDG%20Report%202012.pdf.]
USACE (2013), CorpsMap, National Inventory of Dams (NID), USACE. [Available at http://geo.usace.army.mil/pgis/f?p=397:1:0::NO.]
USDA (2003), 2003 farm and ranch irrigation survey, United States Department of Agriculture. [Available at http://www.agcensus.usda.gov/Publications/2002/FRIS/index.asp.]
USGS (2011), Water use in the United States, USGS. [Available at http://water.usgs.gov/watuse/data/.]
USGS (2012), General facts and concepts about ground water, USGS. [Available at http://pubs.usgs.gov/circ/circ1186/html/gen_facts.html.]
USWRC (1978), *The Nation's Water Resources 1975-2000*, U.S. Gov. Print. Off., Washington, D. C.
van der Gun, J. (2012), *Groundwater and Global Change: Trends, Opportunities and Challenges,* Side Publication Series 1, UNESCO, Paris.
Vassolo, S., and P. Döll (2005), Global-scale gridded estimates of thermoelectric power and manufacturing water use, *Water Resour. Res.*, *41*, 1–11, doi: 10.1029/2004WR003360.
Viviroli, D., H. H. Dürr, B. Messerli, M. Meybeck, and R. Weingartner (2007), Mountains of the world, water towers for humanity: Topology, mapping and global significance, *Water Resour. Res.*, *43*, W07447, doi: 10.1029/2006WR005653.
Vörösmarty, C. J., C. A. Federer, and A. Schloss (1998), Potential evaporation functions compared on U.S. Watersheds: Implications for global-scale water balance and terrestrial ecosystem modeling, *J. Hydrol.*, *207*, 147–169.
Vörösmarty, C. J., P. Green, J. Salisbury, and R. B. Lammers (2000), Global water resources: Vulnerability from climate change and population growth, *Science*, *289*, 284–288.
Wada, Y., L. P. H. van Beek, D. Viviroli, H. H. Dürr, R. Weingartner, and M. F. P. Bierkens (2011), Global monthly water stress: 2. Water demand and severity of water stress, *Water Resour. Res.*, *47*, 1–17, doi:10.1029/2010WR009792.
WCD (2000), Dams and development: A new framework for decision-making, World Commission on Dams, Berkeley, Calif. [Available at http://wwwdams.org//docs/report/wcdreport.pdf.]
Zetland, D. (2011), Colorado river aqueduct, in *Encyclopedia of Water Politics and Policy in the United States*, edited by S. L. Danver and J. R. Burch, p. 420, CQ Press/SAGE, Washington, D. C.

Committee on Oversight and Government Reform
Witness Disclosure Requirement – "Truth in Testimony"
Required by House Rule XI, Clause 2(g)(5)

Name: Geoffrey H. Fettus

1. Please list any federal grants or contracts (including subgrants or subcontracts) you have received since October 1, 2012. Include the source and amount of each grant or contract.

I have not received any federal grants or contracts since October 1, 2012.

2. Please list any entity you are testifying on behalf of and briefly describe your relationship with these entities.

NRDC, Senior Attorney

3. Please list any federal grants or contracts (including subgrants or subcontracts) received since October 1, 2012, by the entity(ies) you listed above. Include the source and amount of each grant or contract.

EPA - Environmental Protection Agency $1,122,675.00

I certify that the above information is true and correct.
Signature: [signature]

Date: 6/22/2016

Geoffrey Fettus is a Senior Attorney in the Energy & Transportation Program in the Washington DC office of the Natural Resources Defense Council (NRDC). As a litigator, Mr. Fettus has been lead attorney for NRDC and the environmental community on several matters. Key cases include the recent "Waste Confidence" victory over the Nuclear Regulatory Commission in the United States Court of Appeals for the D.C. Circuit. *New York, et al. v. NRC*, 681 F.3d 471 (D.C. Cir. 2012). Mr. Fettus was also lead attorney for environmental groups in the successful challenge to the Environmental Protection Agency's radiation protection standards for the proposed Yucca Mountain nuclear waste repository. *NEI v. EPA,* 373 F.3d 1251 (C.A.D.C. 2004). And Mr. Fettus was lead attorney for NRDC and Idaho-based group challenge to Energy Department administrative order that would have allowed agency to abandon millions of gallons of high-level radioactive waste in shallow burial in leaking tanks. *NRDC, et al. v. Abraham*, 271 F.Supp. 2d 1260 (D. Idaho 2003), *judgment r'vsd*, 388 F.3d 701 (9th Cir. 2004).

Mr. Fettus has also been a lead attorney for national environmental community on nuclear waste, toxic cleanup, uranium mining and other energy issues. On the policy front, Mr. Fettus has been lead attorney for NRDC and other environmental groups on several pending matters before Congress, federal agencies, and a number of states. He has testified before Congress numerous times on nuclear waste, uranium mining, and Energy Department cleanup programs. He has also served as a lead negotiator for environmental groups on issues relating to the potential role for nuclear power in climate change legislation. Prior to NRDC, Mr. Fettus was a Staff Attorney at the New Mexico Environmental Law Center and an Assistant Attorney General in New Mexico's Office of the Attorney General, Environmental Enforcement Division. He has a J.D. from the University of Wisconsin Law School and a B.A. from Haverford College.