Slide 1

Uranium in-situ recovery and the proposed Dewey Burdock site, Edgemont, South Dakota

February 7, 2013, public meeting, Hot Springs, SD
May 22, 2013, public meeting, Custer, SD

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Outline

- Overview of uranium in-situ recovery (ISR)
- Groundwater flow and modeling
- Regulatory requirements (NRC and EPA)
- Groundwater quality
- Summary

Note that the rest of this talk will use ISR for in-situ recovery.
NRC = United States Nuclear Regulatory Commission
EPA = United States Environmental Protection Agency

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Uranium ISR overview

- How are these uranium deposits formed?
- How does the uranium ISR process work?

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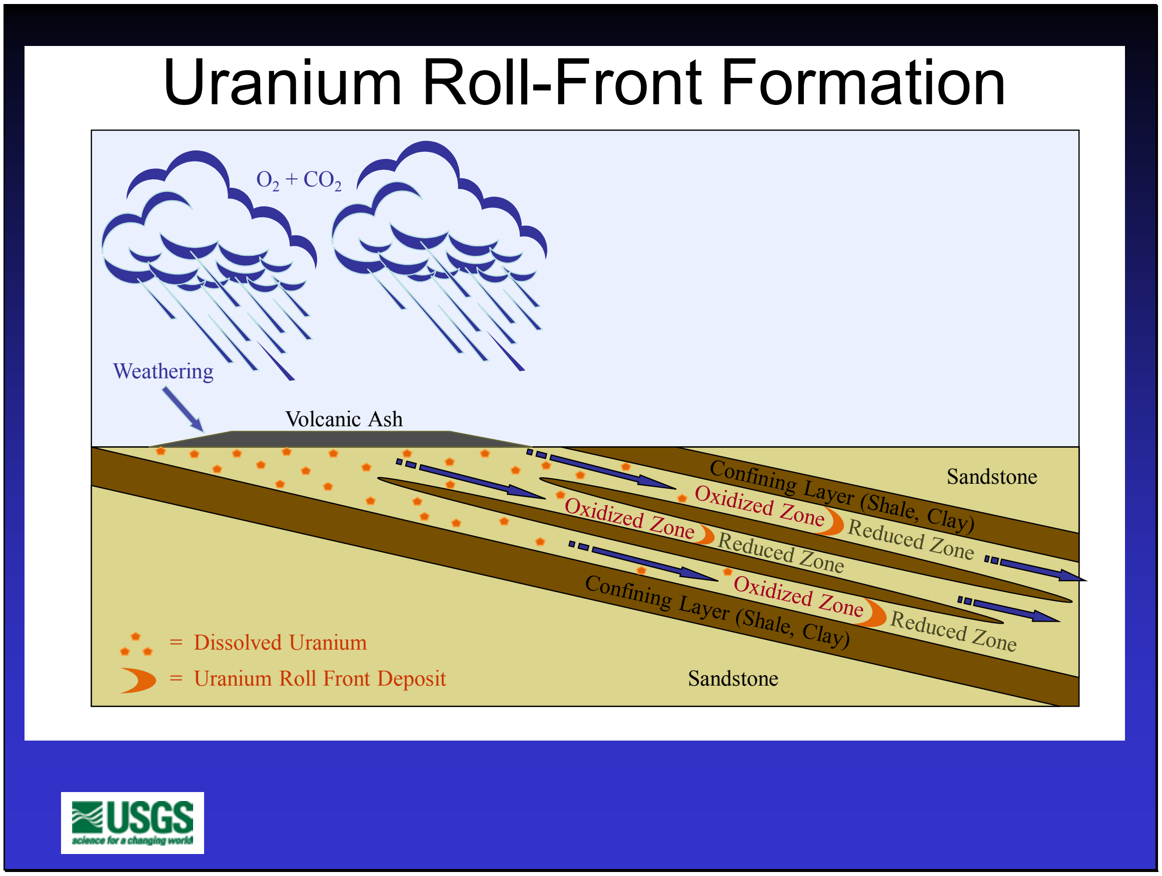
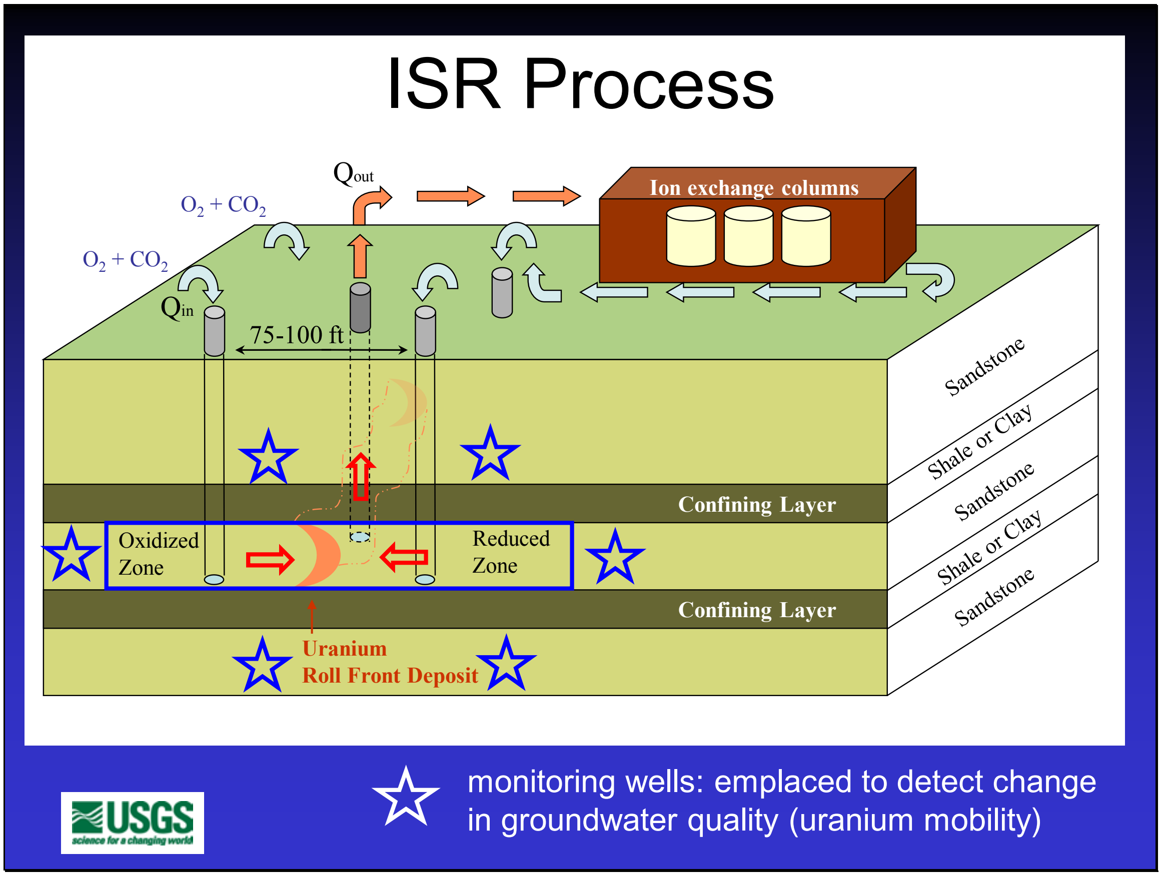


Most sites have stacked roll fronts, due to heterogeneity (multiple layering due to geologic processes).
Confining layer = low permeability.
Oxidized = flow of oxygen through the sandstones has “oxidized” all of the sulfides and organic carbon, results in red rock = highly weathered.
Reduced = sulfides and organic carbon still in place, results in black rock = not highly weathered, rarely seen at the surface.



Typical five-spot injection and production pattern. In three dimensions, the wells follow the uranium deposit. Note the scale of well distances.

Blue box represents uranium recovery zone that does not meet U.S. drinking water standards (generally high uranium and/or radium and/or radon).

Stars represent monitoring wells that are designed to detect any changes in water quality.

For other uranium ISR overviews see: http://www.uraniumproducersamerica.com/situ.html, http://www.nrc.gov/materials/uranium-recovery/extraction-methods/isl-recovery-facilities.html, http://www.uraniumresources.com/isr-technology/isr-overview, and http://www.powertechuranium.com/s/AboutISR.asp?ReportID=268766&_Title=Uranium-In-Situ-Recovery.

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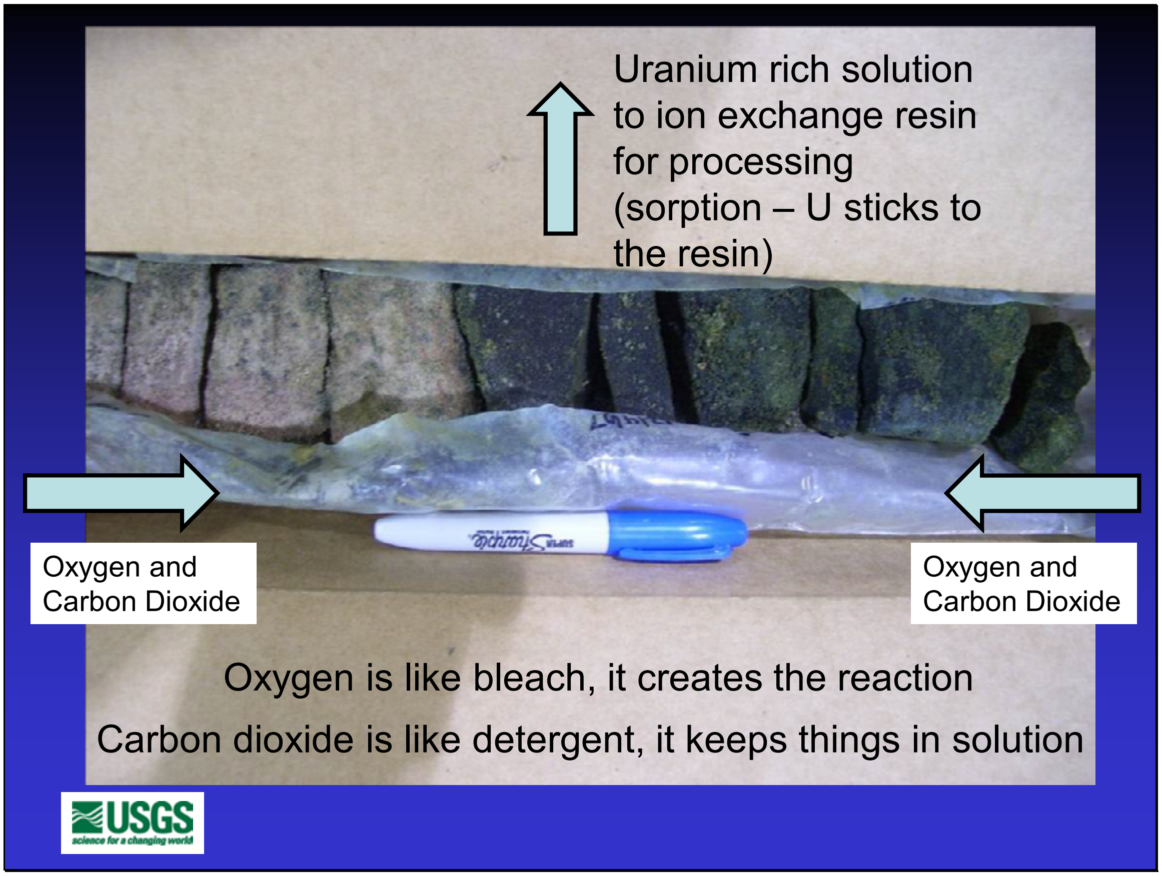

Actual Dewey Burdock core. Pink zone is oxidized, so very little uranium, and pyrite has been converted to iron hydroxides. Black zone is reduced, which has uranium ore and pyrite.

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There is no radiation hazard in this photo. Pure uranium (yellowcake) is an alpha radiation emitter, which will not penetrate the skin. Daughter products like radon could be an issue, which is why this work is being done outside (photo is from South Texas, in colder climates this yellowcake scraping is done indoors with fans to vent radon buildup).

NRC is involved in permitting uranium ISR because they consider this a milling process. NRC is not involved with conventional uranium mining (underground or open pit, other agencies are involved).

See http://www.nrc.gov/materials/uranium-recovery.html and http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-uranium-recovery.html for more details.

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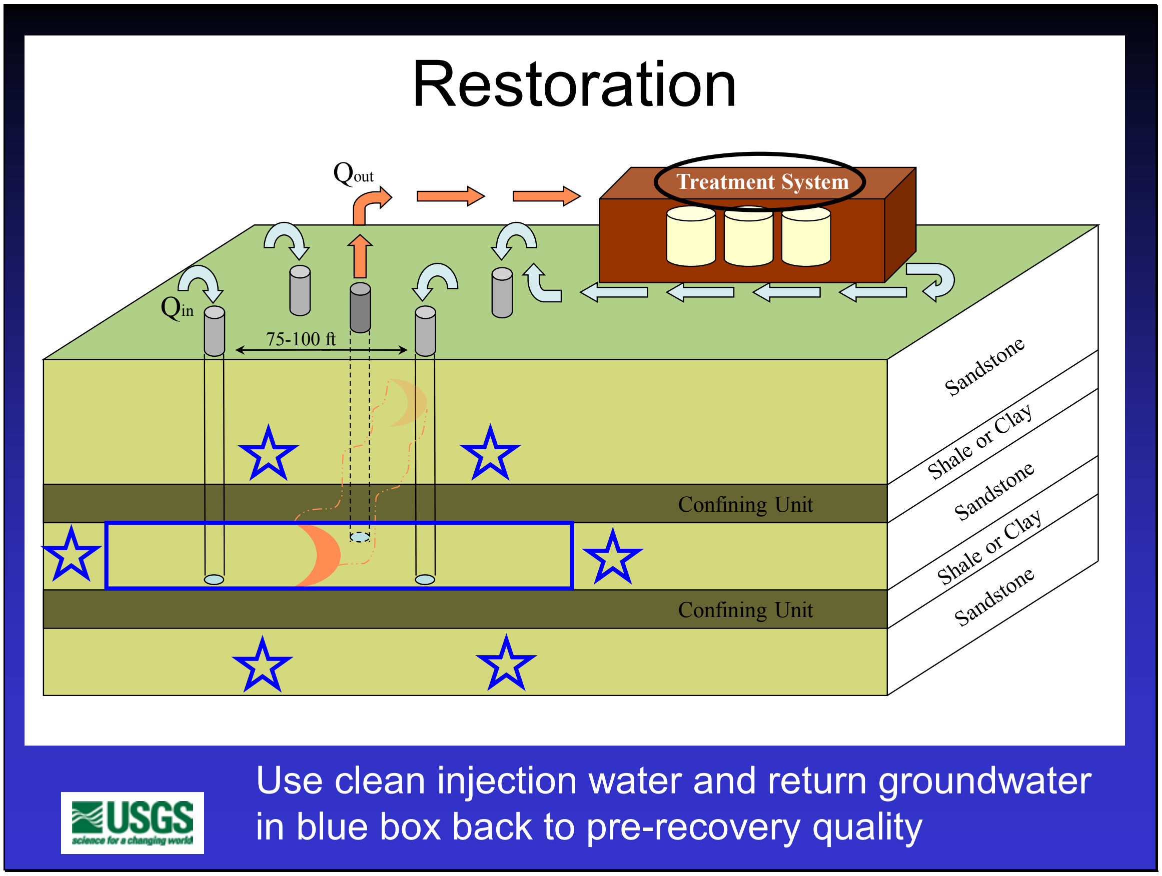

Goal with restoration process after uranium recovery is to get the "blue box zone" back to pre-recovery groundwater quality.
Pumping scenario is similar to uranium recovery, but now the water goes through a treatment system, not ion exchange resins for uranium recovery.
Treatment system is often done using reverse osmosis (which creates a concentrated brine that must be disposed).

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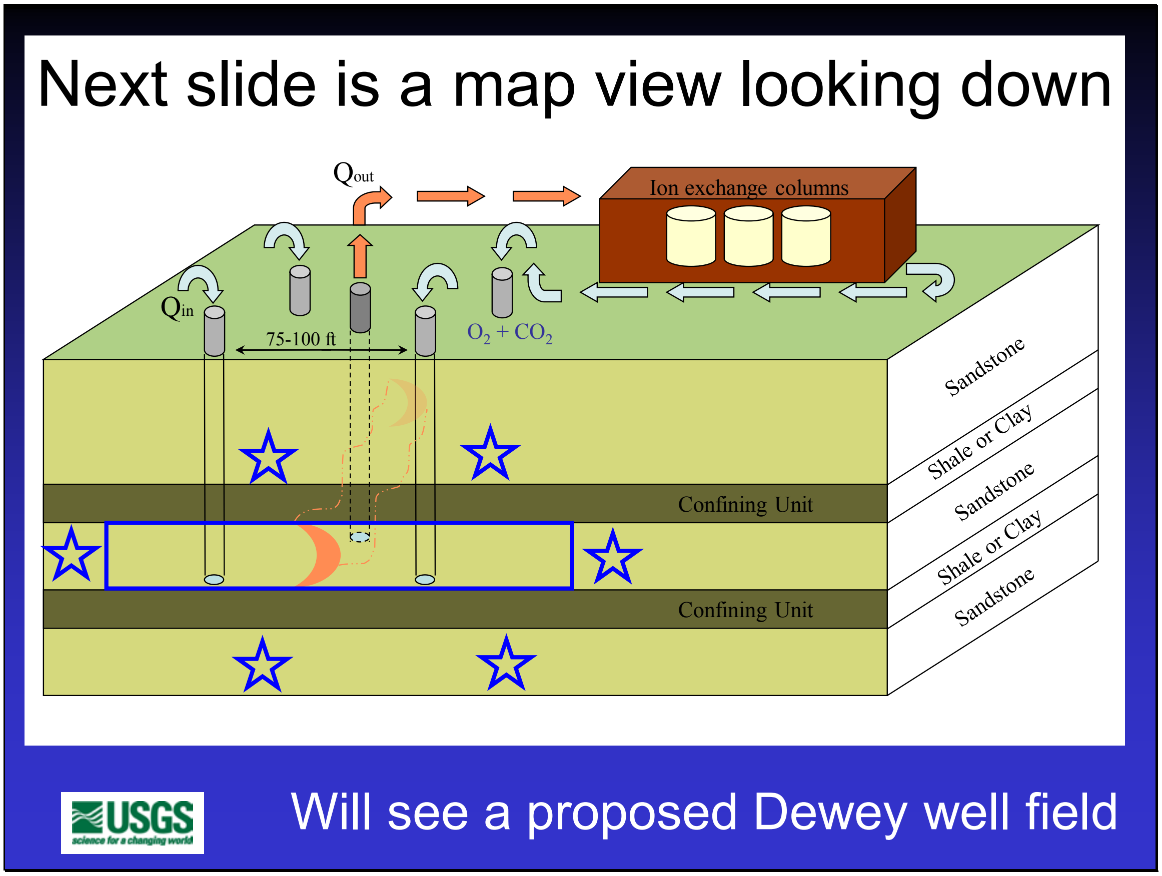

Next slide will look at Dewey production, injection wells and monitoring wells from above.

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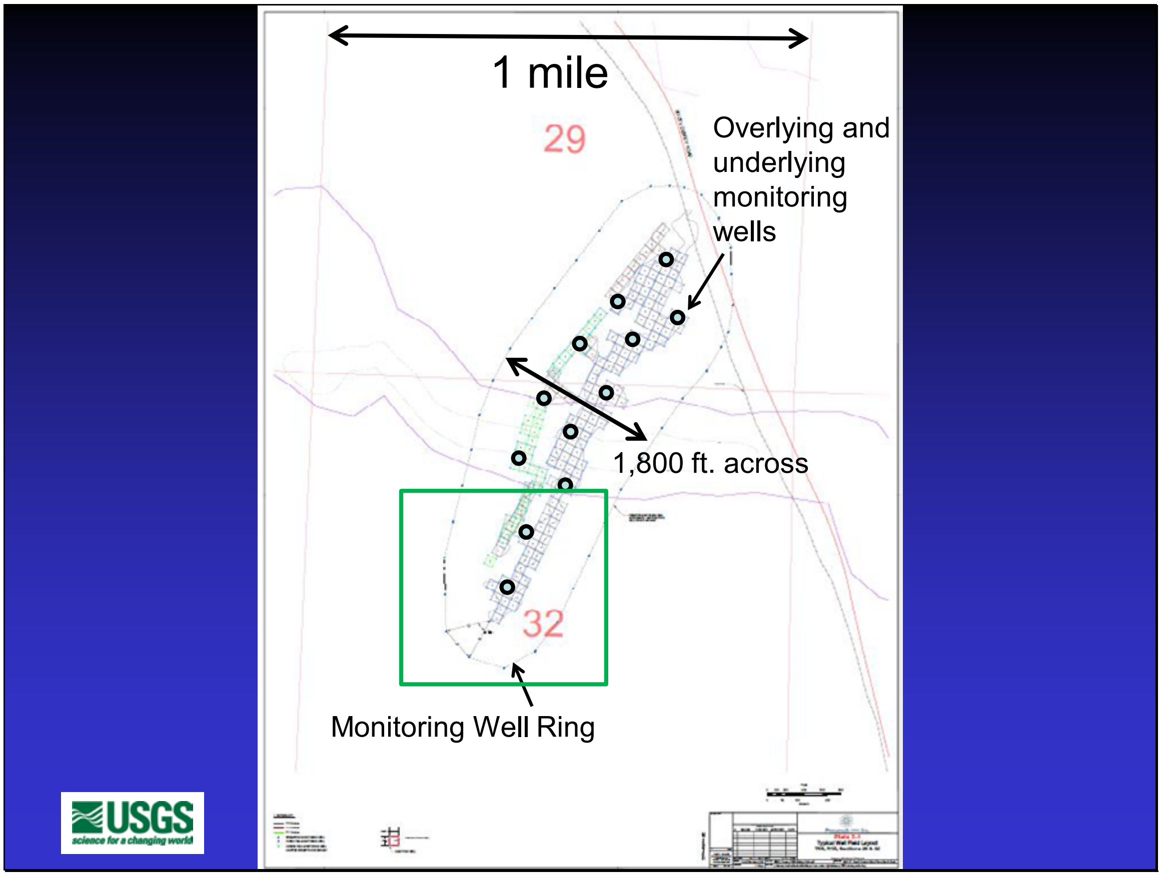
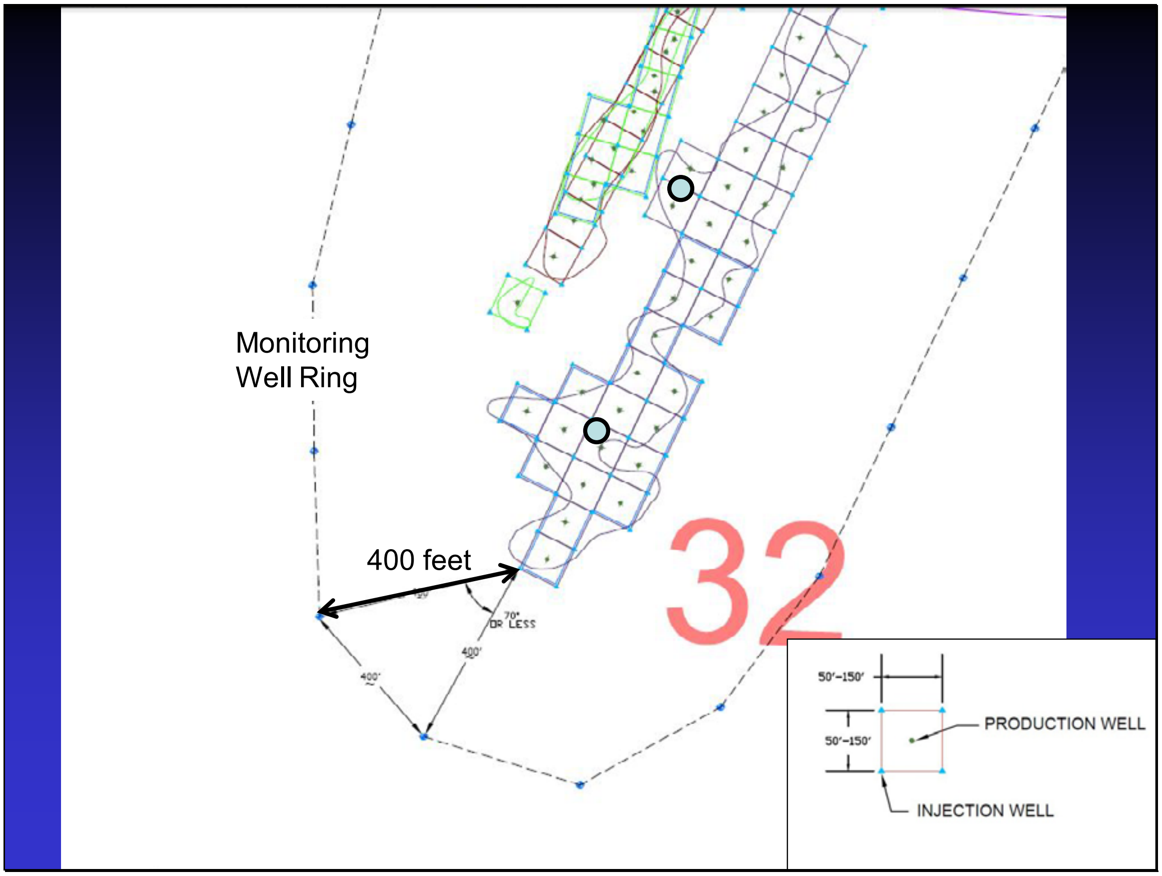


Note 1 mile section lines. Can flip back and forth between previous slide.
Map source is: Dewey-Burdock Project Report to Accompany Inyan Kara Water Right Permit Application, Custer and Fall River Counties, South Dakota, prepared by Powertech (USA), Inc., June 2012, 60 p., Plate 2-1, Typical Well Field Layout. This map will be used several times in this talk.
Map can be found at: http://denr.sd.gov/powertech/wr/Inyankara/Plates/Plate%202-1%20Typical%20Well%20Field%20Layout.pdf

Slide 11



Zoomed in to southern part of well field on previous slide. Note scale on well spacing and distance to monitoring well ring. Well field surrounds the uranium ore body (curved solid lines).

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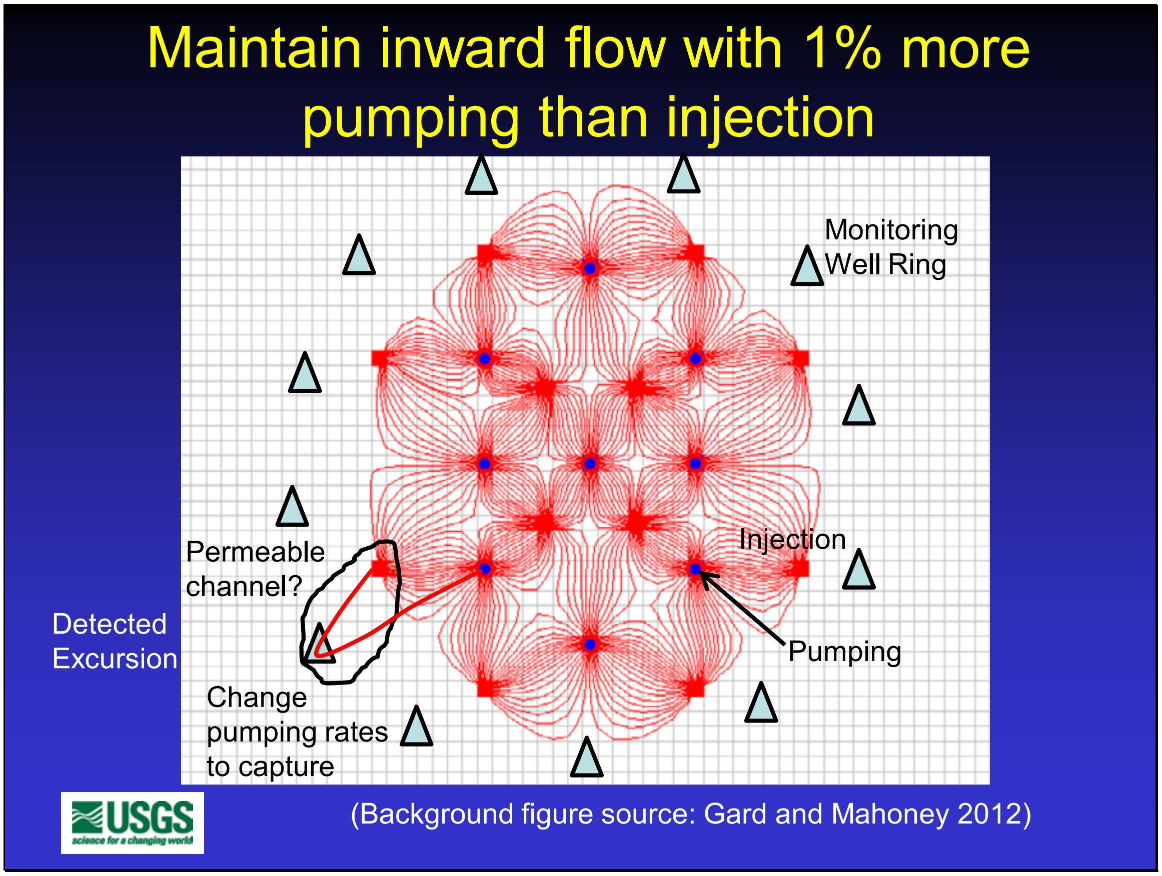

Red lines indicate the track of a water particle. Blue dots are production wells, red dots are injection wells.
This pattern occurs with a homogeneous aquifer, which does not occur naturally. Heterogeneities are a possibility (sand channels, etc.), thus excursions do occur.
Other issues that allow excursion (not all inclusive) are: improperly abandoned wells, casing failure, and improper well field balance (p. 2-48, NRC Generic Impact Statement (GEIS), reference is listed in slide 24 notes).
Historically, horizontal excursions were controlled in weeks to months, but since vertical excursions are more difficult to detect, some wells were on excursion status for up to 8 years (p. 2-47 and 2-48 in NRC GEIS, see reference in slide 24 notes).
Reference for figure: Gard, M., and J. Mahoney, 2012. *Evaluating the Effects of Uranium K_d on the Restoration of ISL Wellfields Using PHT3D*, Uranium Recovery Workshop, May 2-3, 2012, Denver, CO, http://www.nrc.gov/materials/uranium-recovery/public-meetings/ur-workshops/gard.pdf.

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End of general uranium ISR operations section

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USGS role at Dewey Burdock

- Received about ½ of our funding from the EPA
  - Main concern is protecting groundwater quality
- Main focus is predictive modeling of possible long term influences on groundwater quality (work is still ongoing)
- Did independent water quality analyses
  - Did not find any major differences (Johnson, 2012, but full statistical analysis has not been done by the USGS)
- Also analyzed isotopes to better understand current groundwater conditions (Johnson, 2012)
  - Did not see any evidence of cross communication between aquifers under natural flow conditions

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Johnson, R.H., 2012, Geochemical data from groundwater at the proposed Dewey Burdock uranium in-situ recovery mine, Edgemont, South Dakota: U.S. Geological Survey, Open-File Report 2012–1070, 11 p. (http://pubs.usgs.gov/of/2012/1070/)

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USGS role at Dewey Burdock

- I have also been involved in meetings that presented Powertech’s groundwater flow modeling (used to predict impacts on groundwater supply)
- From those meetings, I would conclude that reasonable standards were used to develop and calibrate the groundwater model. A full model review was done by the U.S. Nuclear Regulatory Commission (2012 Draft Environmental Impact Statement)

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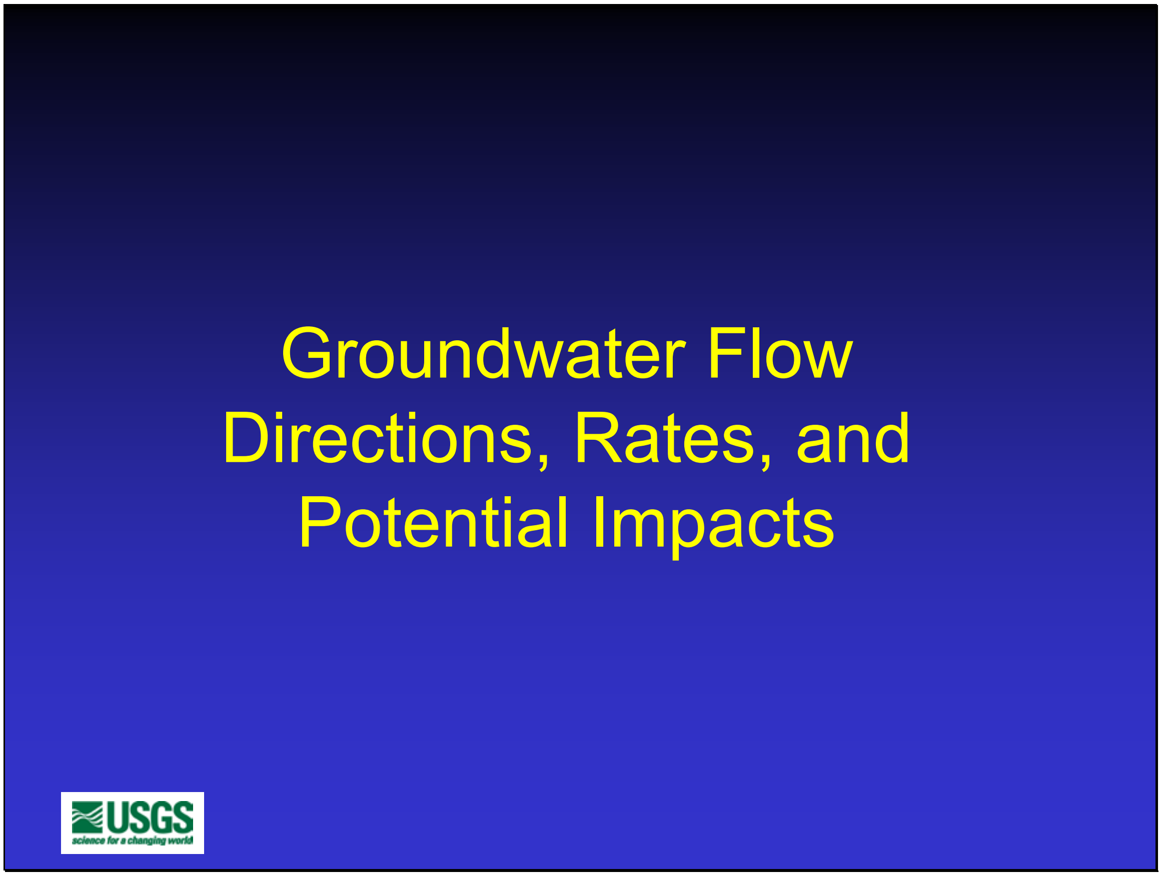

Decisions on water rights applications by Powertech are made by the South Dakota Department of Natural Resources (another talk at this meeting).

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Groundwater Flow Directions and Rates

- Groundwater flow is toward the southwest at approximately 6.7 ft/yr (average estimate by Powertech, 2012)
- Regionally, groundwater flows around the southern end of the Black Hills (Carter and others, 2002)
- ≈ 10,000 years for groundwater to get to Edgemont with 13 mile distance and 6.7 ft/yr groundwater flow rate (conservative estimate on distance)

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Powertech, 2012, Dewey-Burdock project report to accompany Inyan Kara water right permit application, Custer and Fall River counties, South Dakota, prepared by Powertech (USA), Inc., 60 p.
http://denr.sd.gov/des/wr/ptech.aspx under appendix D groundwater model.
Report lists average Fall River groundwater velocity at 6.1 ft/yr and Chilson at 7.3 ft/yr, so average for Inyan Kara is 6.7 ft/yr. Velocity calculations were completed using Darcy’s Law. Thus, using an assumed hydraulic conductivity and porosity values with measured hydraulic head values.
Carter, J.M., Driscoll, D.G., Williamson, J.E., and Lindquist, V.A., 2002, Atlas of water resources in the Black Hills area, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA 747, 120 p.

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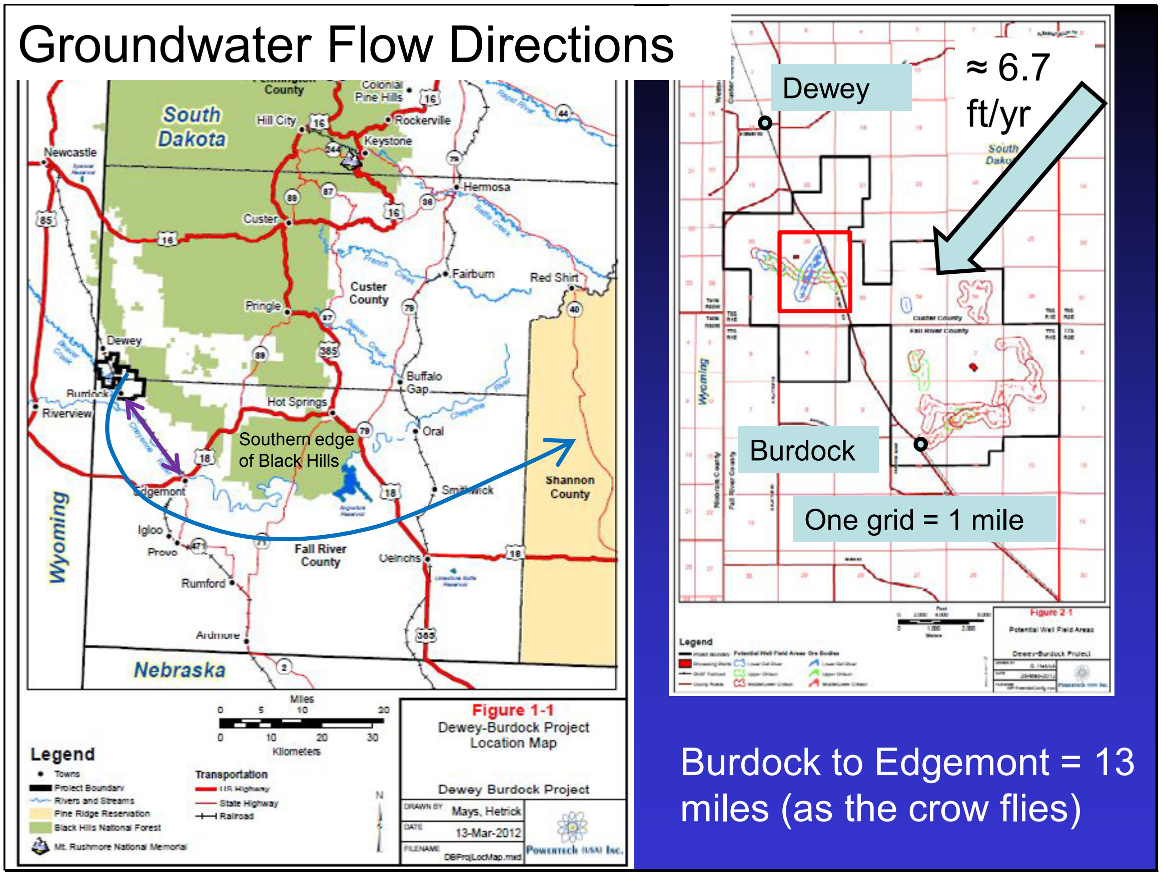

Maps are from: Powertech, 2012, Dewey-Burdock Project Report to Accompany Inyan Kara Water Right Permit Application, Custer and Fall River Counties, South Dakota, prepared by Powertech (USA), Inc., June 2012, 60 p.
http://denr.sd.gov/powertech/wr/Inyankara/Report/InyanKaraWR_Report.pdf
Map on the right shows project boundaries and potential well field area ore bodies.
Scale is the key point for this slide. Note that flow rates are in the Inyan Kara group, not the Madison.
Regional groundwater flow direction is based on
Carter, J.M., Driscoll, D.G., Williamson, J.E., and Lindquist, V.A., 2002, Atlas of water resources in the Black Hills area, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA 747, 120 p.
Local groundwater flow direction is based on Powertech (2012), reference is listed in the notes on slide 17.

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Groundwater Use

- Uranium ISR operations use about a 1% bleed, which means 99% of the water is recirculated, but 1% or less is permanently extracted to provide overall inward flow
- 1% bleed to be disposed: either deep well injection or land application
- Groundwater flow modeling provides an estimate of hydraulic head drawdown (water levels in wells)

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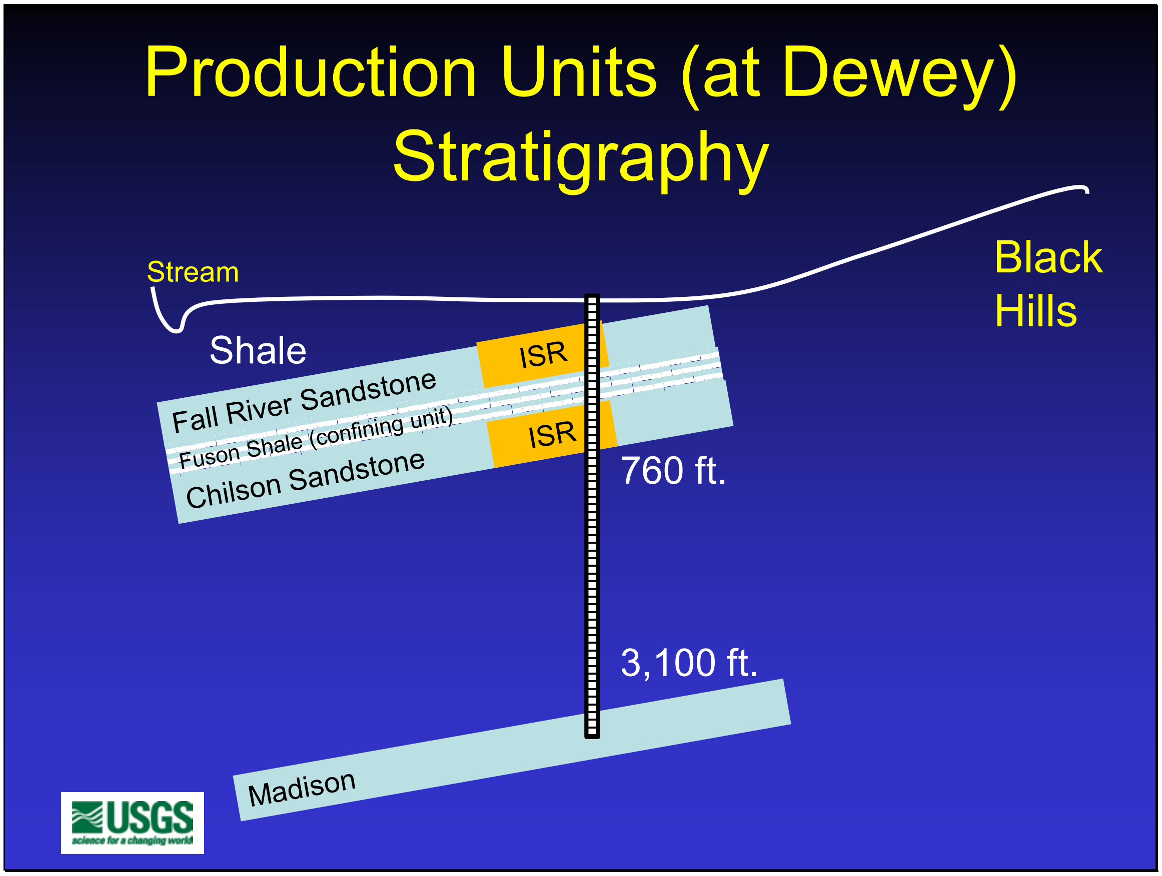

Note intervening shale unit between the stream and the Fall River – groundwater is unlikely to be in direct communication with the surface water.

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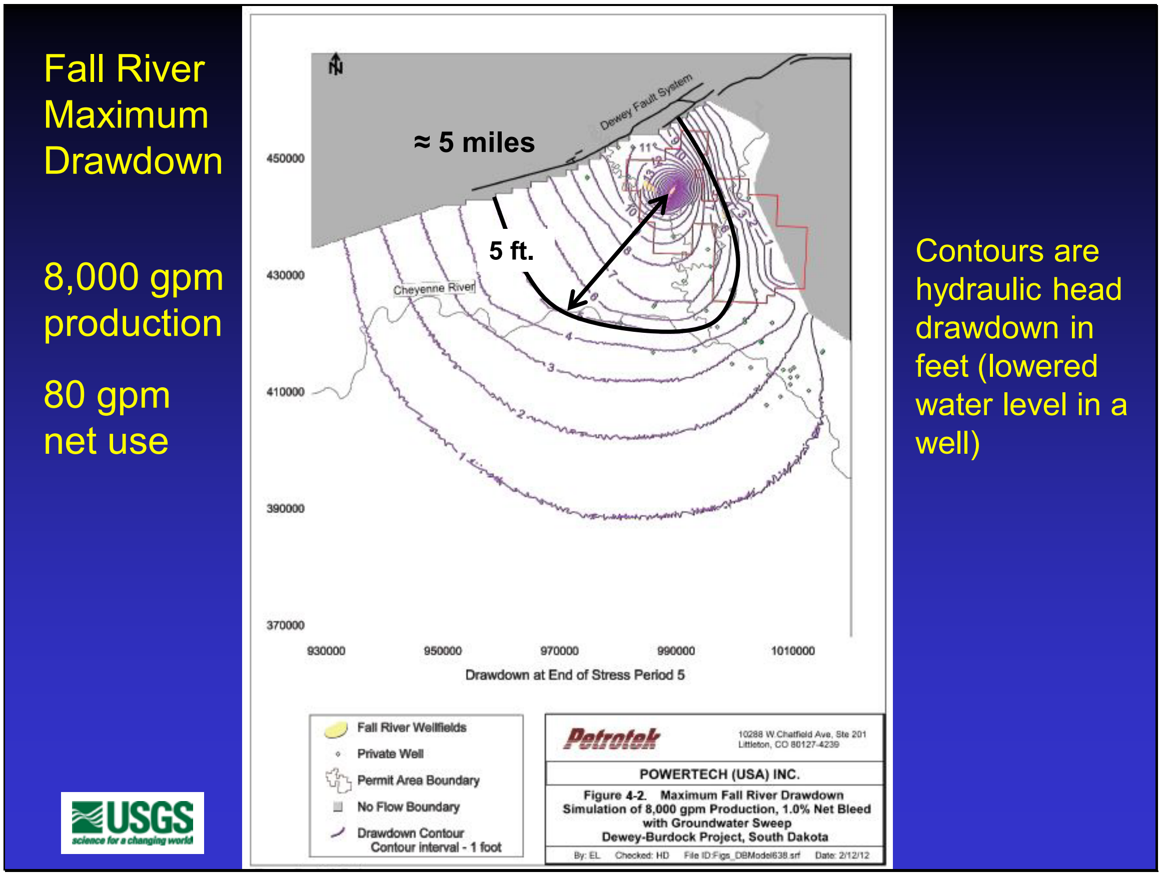

NRC staff reviewed the applicant’s numerical groundwater model and calibration, and it determined that the model was appropriately developed and sufficiently calibrated (quote from p. 4-62 in NRC Supplemental Environmental Impact Statement (SEIS), reference is listed in the notes on slide 24).
Figure is from Powertech (2012) with reference listed in the notes on slide 17.

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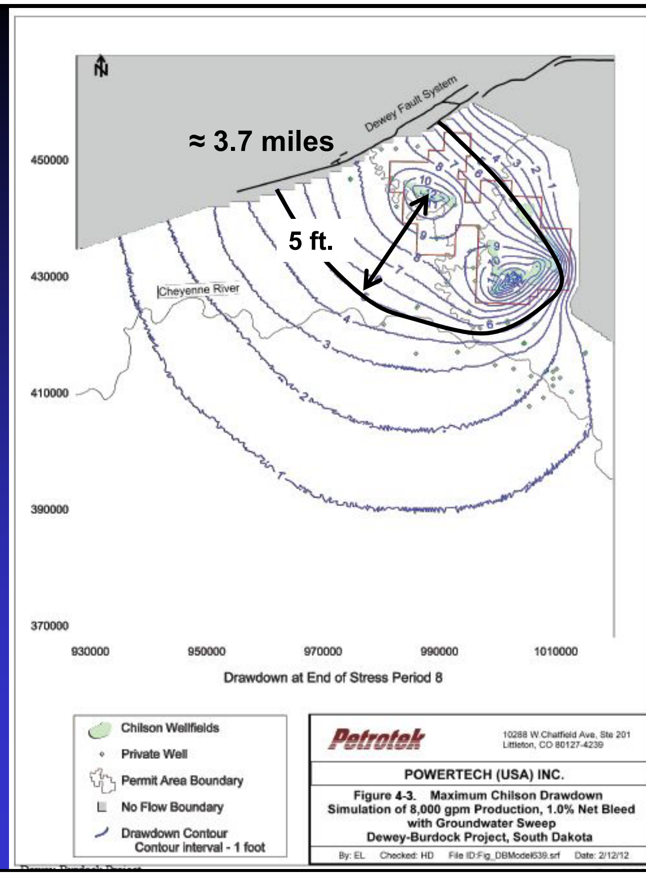
Chilson Maximum Drawdown

8,000 gpm production

80 gpm net use



Contours are hydraulic head drawdown in feet (lowered water level in a well)

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NRC and EPA Regulations

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Slide 24

Regulatory roles

- NRC has a generic environmental impact statement (GEIS) that covers all uranium ISR sites with supplemental environmental impact statements (SEIS) that are site specific,
  - NRC has issued a draft SEIS for Dewey Burdock
- EPA Region 8 Underground Injection Control (UIC) Program regulates:
  - class III wells: uranium ISR injection
  - class V well: deep injection
  - aquifer exemption (look at details on this)

GEIS
United States Nuclear Regulatory Commission, 2009, Generic environmental impact statement for in-situ leach uranium milling facilities, NUREG-1910, vol. 1: chapters 1-4 and vol. 2: chapters 5-12 and appendices A-G, Final Report.
Link to GEIS and all SEIS reports can be found at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1910/

SEIS for Dewey Burdock
United States Nuclear Regulatory Commission, 2012, Environmental impact statement for the Dewey-Burdock project in Custer and Fall River counties, South Dakota, Supplement to the generic environmental impact statement for in-situ leach uranium milling facilities, NUREG-1910, supplement 4, vol. 1 (chapters 1-4) vol. 2 (chapter 5 and appendices), draft report for comment.
Volume 1 (chapters 1-4) is available at:
http://pbadupws.nrc.gov/docs/ML1231/ML12312A039.pdf
Volume 2 (chapter 5 and appendices) is available at:
http://pbadupws.nrc.gov/docs/ML1231/ML12312A040.pdf

Information on EPA Region 8 Underground Injection Control Program (UIC) can be found at:
http://www.epa.gov/region8/water/uic/

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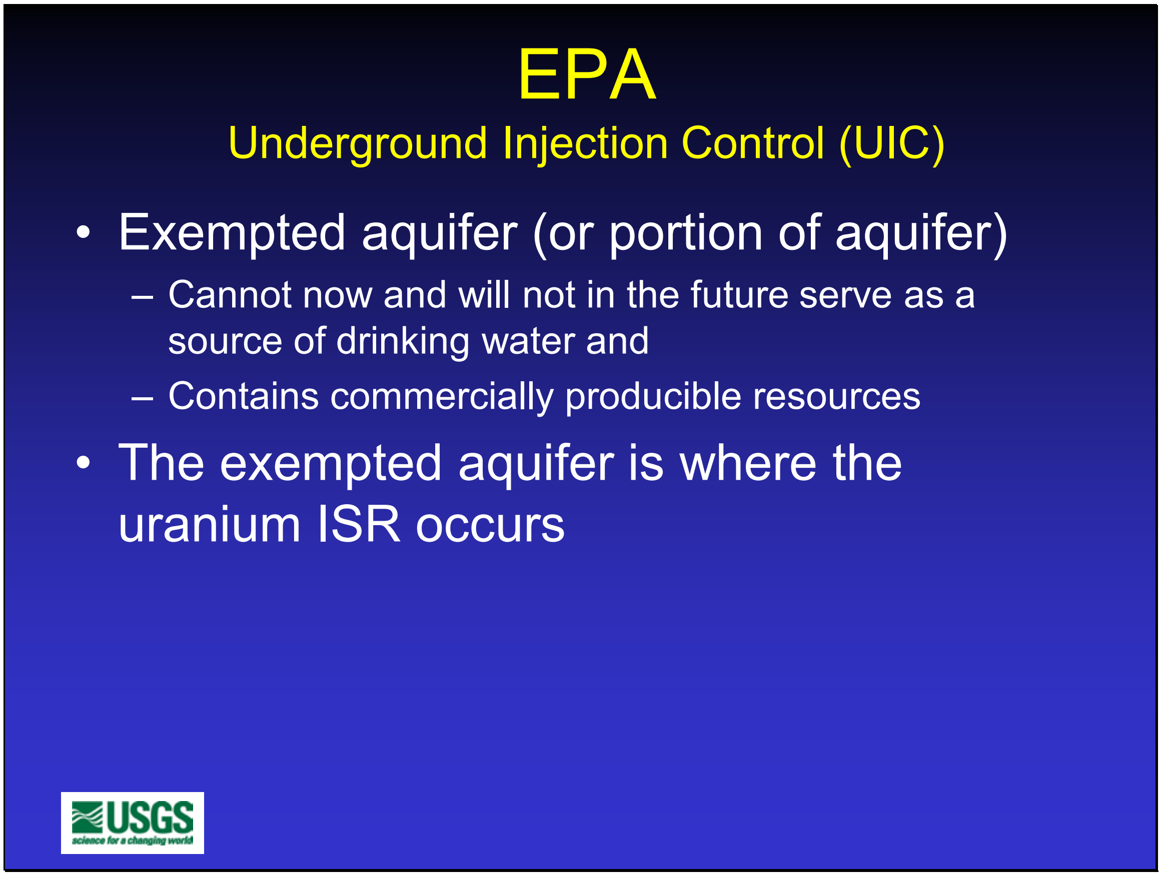

For definition of exempted aquifer, see EPA glossary of terms at: http://water.epa.gov/type/groundwater/uic/glossary.cfm

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Dewey Burdock
Current Groundwater Quality

- Groundwater in the ore zones
  - Uranium is generally below EPA drinking water standards
  - Radium and radon are generally above primary EPA drinking water standards
  - Sulfate is above secondary EPA drinking water standards

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Source of data for uranium and sulfate:
Johnson, R.H., 2012, Geochemical data from groundwater at the proposed Dewey Burdock uranium in-situ recovery mine, Edgemont, South Dakota: U.S. Geological Survey, Open-File Report 2012–1070, 11 p. (http://pubs.usgs.gov/of/2012/1070/)
Source of data for uranium, sulfate, radium and radon:
Powertech, 2009, Dewey-Burdock project, Application for NRC uranium recovery license Fall River and Custer counties, South Dakota--Environmental report, Docket No. 040-09075, ML092870160 (http://pbadupws.nrc.gov/docs/ML0928/ML092870160.html).

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Uranium ISR Process

- Uranium ISR operations mobilize uranium
- Restoration goal is to return to pre-recovery water quality to prevent groundwater quality changes downgradient
- Reality, difficult to get to pre-recovery groundwater quality for <u>all elements</u>

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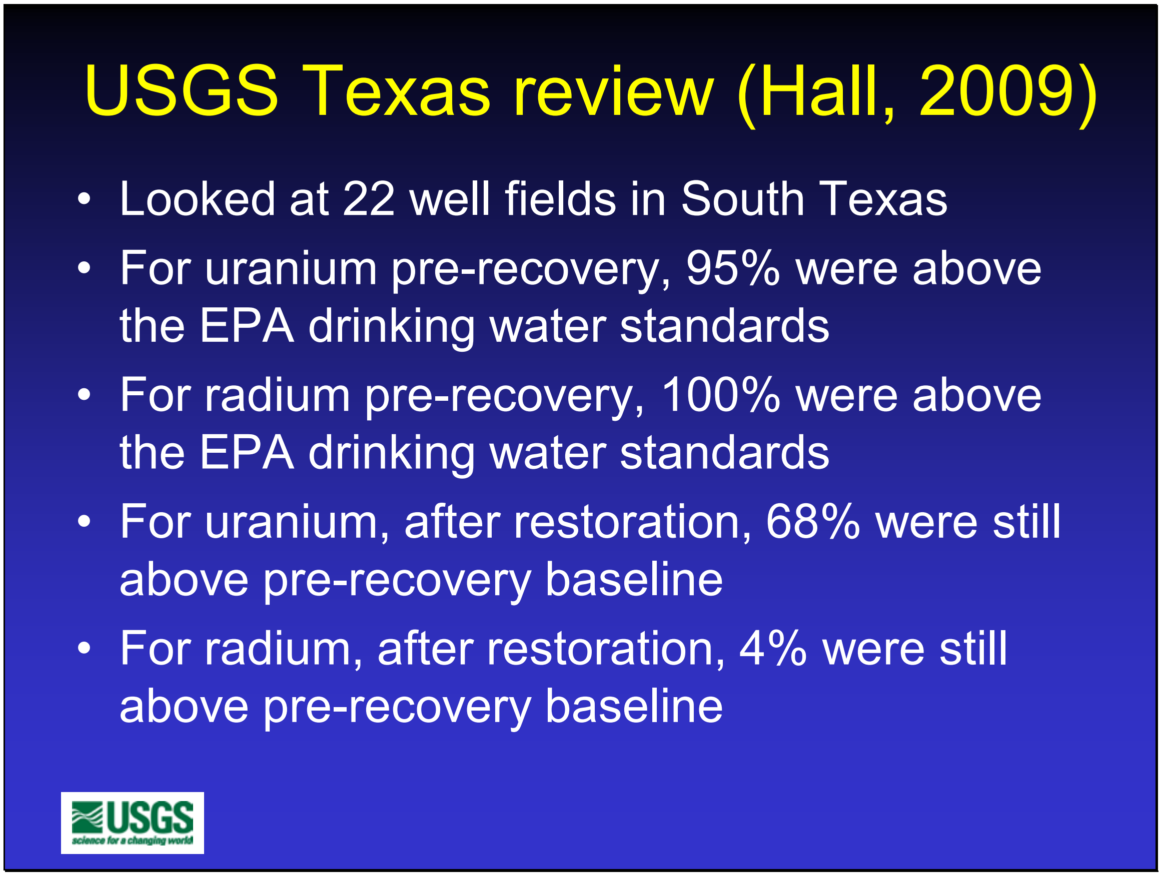

Source: Hall, S., 2009, Groundwater restoration at uranium in-situ recovery mines, south Texas coastal plain: U.S. Geological Survey Open-File Report 2009–1143, 32 p. (http://pubs.usgs.gov/of/2009/1143/)
Another summary of restoration quality can be found on pages 2-48 through 2-51 of the NRC GEIS (reference is in the notes on slide 24).

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NRC SEIS

Nuclear Regulatory Commission Supplemental Environmental Impact Statement

- Require licensees to return water quality parameters to standards in 10 CFR Part 40, Appendix A, Criterion 5B(5). At the point of compliance, hazardous constituents (uranium, radium, arsenic, etc.) must not exceed:
  - NRC approved background concentrations
  - Established maximum contaminant levels (10 CFR Part 40 , Appendix A, Table 5C)
  - Alternate concentration limits (ACLs) that are established by the NRC

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Listed information can be found on page B-1 in the NRC SEIS for Dewey Burdock (reference and links can be found in the notes for slide 24).

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NRC SEIS

Nuclear Regulatory Commission
Supplemental Environmental Impact Statement

- "The staff will not approve an ACL if it will impact any adjacent USDWs." USDW = underground source of drinking water
- "The use of modeling and additional groundwater monitoring may be necessary to show that ACLs in ISR well fields would not adversely impact USDWs."

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Quotes are from page B-3 in the NRC SEIS for Dewey Burdock (reference and links can be found in the notes for slide 24).

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EPA

Underground Injection Control (UIC)

USDW = underground source of drinking water is an aquifer or its portion:

- Which supplies any public water system, or
  Which contains a sufficient quantity of ground water to supply a public water system; and
- Currently supplies drinking water for human consumption, or
- Contains fewer than 10,000 mg/l total dissolved solids; and
- Which is not an exempted aquifer.

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For EPA glossary of terms see: http://water.epa.gov/type/groundwater/uic/glossary.cfm

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EPA

Underground Injection Control (UIC)

- Concern is protection of groundwater quality at the aquifer exemption boundary
- "UIC regulation 40 CFR 144.12 prohibits the movement of any contaminant into the underground source of drinking water located outside the aquifer exemption boundary" (NRC, 2012)
- Contaminant = "any physical, chemical, biological, or radiological substance or matter in water" (NRC, 2012 and 40 CFR 144.3)

Quotes are from page 2-35 in the NRC SEIS for Dewey Burdock (NRC, 2012, reference and links can be found in the notes for slide 24).

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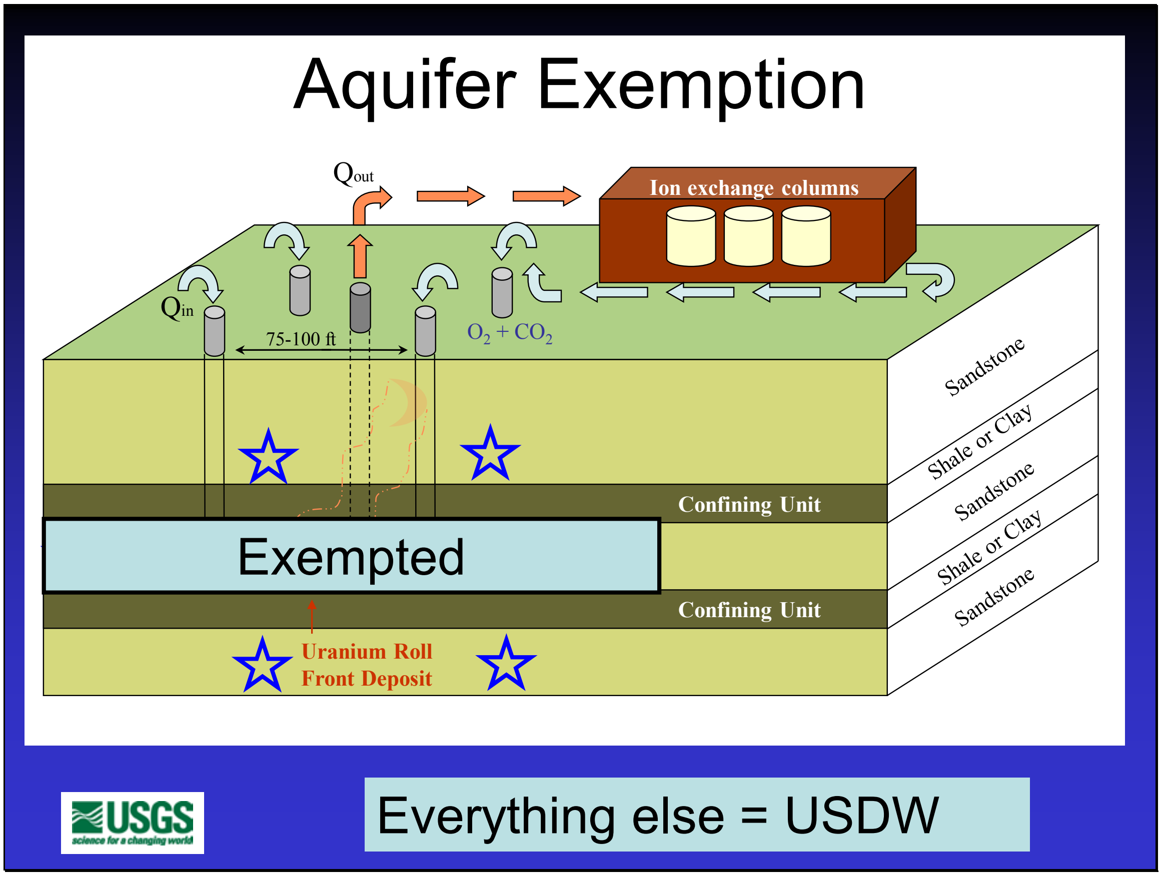

Aquifer Exemption
Qout
Ion exchange columns
Qin
75-100 ft
O2 + CO2
Sandstone
Shale or Clay
Sandstone
Shale or Clay
Sandstone
Confining Unit
Exempted
Confining Unit
Uranium Roll
Front Deposit
USGS
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Everything else = USDW

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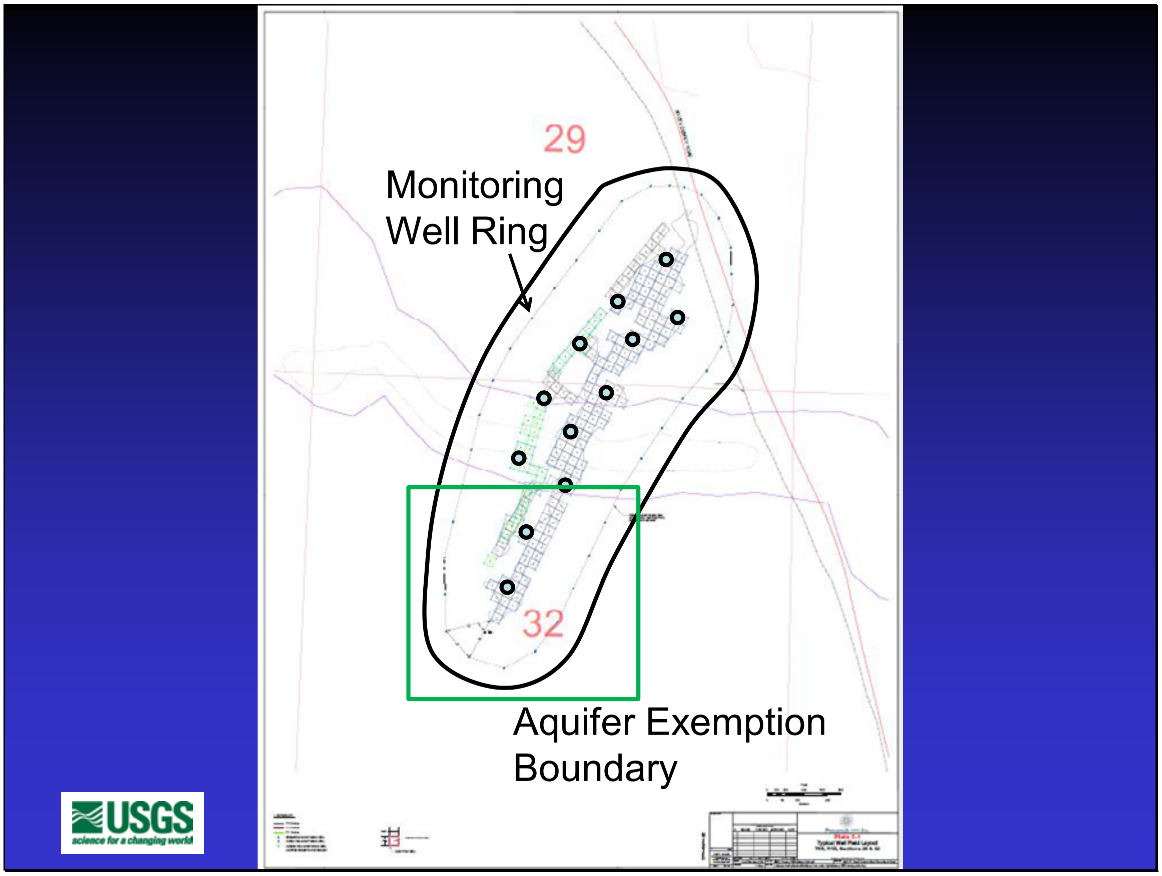
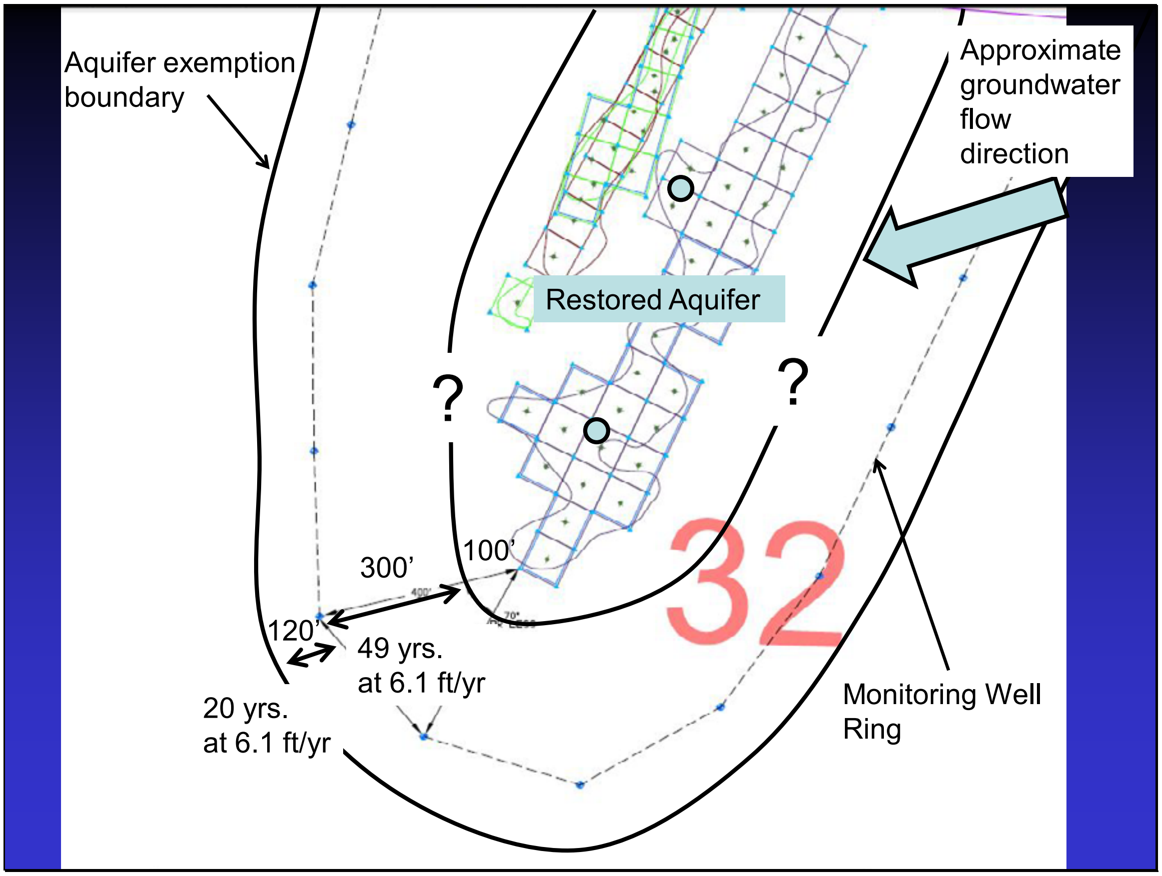


Map source is from Dewey-Burdock Project Report to Accompany Inyan Kara Water Right Permit Application, Custer and Fall River Counties, South Dakota, prepared by Powertech (USA), Inc., June 2012, 60 p., Plate 2-1, Typical Well Field Layout http://denr.sd.gov/powertech/wr/Inyankara/Plates/Plate%202-1%20Typical%20Well%20Field%20Layout.pdf



Note that during production and restoration, the groundwater flow rates are much faster. This slide represents post-restoration and back to natural flow conditions.
120 feet to aquifer exemption boundary is based on Powertech's class III injection well permit application (Shea, V., 2013, personal communication), which should be available online through EPA soon.
Groundwater flow rate (6.1 ft/yr) and approximate flow direction are for the Fall River Formation based on:
Powertech, 2012, Dewey-Burdock project report to accompany Inyan Kara water right permit application, Custer and Fall River counties, South Dakota, prepared by Powertech (USA), Inc., 60 p.
http://denr.sd.gov/des/wr/ptech.aspx under appendix D groundwater model.

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USGS research

- Provide a scientifically based procedure for adequately modeling down gradient, longer term groundwater quality
- Decisions on environmental compliance and regulations will be up to the EPA and NRC

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Summary

- Injection of oxygen and carbon dioxide dissolves and mobilizes uranium
- Establish overall inward groundwater flow to reduce possibility of escaping solutions (excursions)
- Monitoring well ring is used to detect any excursions
- 1% bleed does lower the surrounding groundwater levels (scale is a few miles)

Land subsidence is not an issue at uranium ISR sites.

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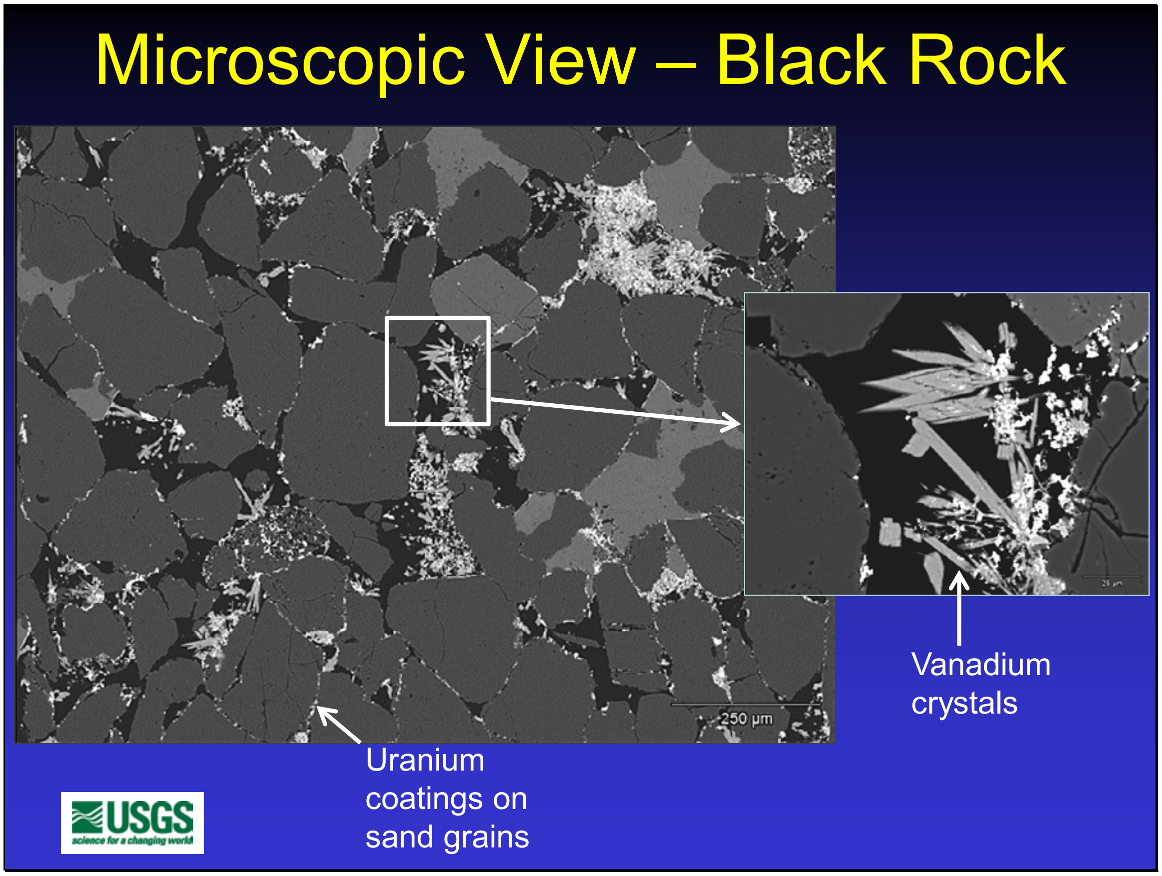
Summary

- Regulations do not allow any impacts to the groundwater quality outside of the aquifer exemption boundary, which is on the order of hundreds of feet from the restored zone
- USGS is providing scientific expertise on modeling methods to help understand any potential changes to downgradient groundwater quality
- Final monitoring/modeling requirements are up to the regulators



Last slide for general interest to leave up during questions.
Black rock = unoxidized material. Image is from a sample in the Dewey area, Fall River Formation.

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References

Carter, J.M., Driscoll, D.G., Williamson, J.E., and Lindquist, V.A., 2002, Atlas of water resources in the Black Hills area, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA 747, 120 p.

Gard, M., and J. Mahoney, 2012. *Evaluating the Effects of Uranium K_d on the Restoration of ISL Wellfields Using PHT3D*, Uranium Recovery Workshop, May 2-3, 2012, Denver, CO, http://www.nrc.gov/materials/uranium-recovery/public-meetings/ur-workshops/gard.pdf.

Hall, S., 2009, Groundwater restoration at uranium in-situ recovery mines, south Texas coastal plain: U.S. Geological Survey Open-File Report 2009–1143, 32 p. (http://pubs.usgs.gov/of/2009/1143/)

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Powertech, 2009, Dewey-Burdock project, Application for NRC uranium recovery license Fall River and Custer counties, South Dakota--Environmental report, Docket No. 040-09075, ML092870160 (http://pbadupws.nrc.gov/docs/ML0928/ML092870160.html).

Powertech, 2012, Dewey-Burdock project report to accompany Inyan Kara water right permit application, Custer and Fall River counties, South Dakota, prepared by Powertech (USA), Inc., 60 p.

United States Nuclear Regulatory Commission, 2009, Generic environmental impact statement for in-situ leach uranium milling facilities, NUREG-1910, vol. 1: chapters 1-4 and vol. 2: chapters 5-12 and appendices A-G, Final Report.

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