This presentation is intended to provide background on naturally occurring uranium in groundwater, describe the risks it poses, explore key data and results, and provide well owners, teachers, community members, and public health officials with information on what steps can be taken to mitigate this risk. The presentation is informed by a U.S. Geological Survey (USGS) preliminary assessment of uranium concentrations in groundwater in northeastern Washington State (Kahle and others, 2018, https://doi.org/10.3133/sim3401).
The presentation will address questions including the following:

**What is uranium?** Where does it occur naturally? How does it enter drinking water?

**Why is uranium in drinking water a concern?** What are the health risks? What health standards exist? Why are we concerned specifically about northeastern Washington State?

**What do (and don’t) we know** about naturally occurring uranium in groundwater in northeastern Washington State? What levels of uranium have been found in the area and where?

**What can we do?** How can well owners test their drinking water? Can drinking water with elevated levels of uranium be treated? What resources are available for concerned private well owners?
What is uranium?

• Radioactive element
• Naturally occurs in the environment (rock, soil, and water) in low concentrations

Uranium (U) is an element that occurs naturally in rock, soil, and water—usually in low concentrations (Argonne National Laboratory, 2007).

Uranium has multiple isotopes that are different forms of the same element with the same chemical properties. All isotopes of uranium are radioactive, meaning that they have an excess of energy and are unstable.
As uranium decays, it releases radiation and forms daughter products. Many of these daughter products are unstable and decay further, releasing additional radiation (DeSimone and others, 2014). Radiation, in the form of alpha (α) and beta particles (β), is matter and energy that are released from the unstable nuclei of uranium and its daughter products.

Uranium-238 is the most common of several natural isotopes and accounts for 99 percent of the mass of natural samples. This diagram shows important daughter products in the U-238 decay series, indicates whether the primary decay mode is through alpha (α) or beta (β) emission, and provides the half-life of these products (length of time required for half of the atoms of a radioactive isotope to decay).

For example, through the decay series of U-238, alpha (α) and beta particles (β) are emitted and radium (Ra) and radon (Rn) are formed as interim radiogenic daughter products. These products, in turn, ultimately decay to a stable form of lead (Pb). U-238 has a half-life of 4.5 billion years, whereas Ra-226 has a half-life of 160 years and Rn-222 has a half-life of only 3.8 days.
Why is uranium in drinking water a concern?

- Long term exposure can lead to
  - Kidney damage
  - Increased risk of developing cancer
- Daughter products
  - Radium
  - Radon

Radiation released by the radioactive decay of uranium and its daughter products pose a risk to human health. Furthermore, the heavy metal characteristics of uranium pose additional and short-term health risks because of its toxic effects on the kidneys. Therefore, long-term exposure to elevated levels of uranium in drinking water can result in kidney damage and an increased risk of developing cancer (U.S. Environmental Protection Agency, 2001).

Two of the potentially harmful daughter products of uranium are radium and radon. The U.S. Environmental Protection Agency (EPA) cautions that chronic exposure to high levels of ingested radium can result in an increased incidence of bone, liver, or breast cancer (U.S. Environmental Protection Agency, 2019a). Radon occurs as a gas that, when dissolved in drinking-water, can be released into indoor air (World Health Organization, 2016). Radon gas is the number one cause of lung cancer among non-smokers and is the second leading cause of lung cancer overall (U.S. Environmental Protection Agency, 2019b).
Drinking water with elevated levels of uranium poses different levels of risk depending on the individual. Factors affecting individual levels of risk include the concentration of uranium in the water, how much water is consumed and for how long, and the age and general health of the individual.

If you are concerned about individual health effects, consider consulting your local health department or health care provider.
The U.S. Environmental Protection Agency (EPA) establishes water-quality standards for public water-supply systems. Standards are established by considering what levels of a contaminant are protective of human health and the feasibility of treating water supplies including analytical methods and costs.

For uranium, the standard is set at 30 micrograms per liter (U.S. Environmental Protection Agency, 2000). Public water-supply systems are required to meet this standard or treat the water before distribution to customers. The EPA rule also regulates radium, and alpha and beta particles owing to their radiological toxicity.

Private well owners are responsible for monitoring the quality of water from their wells; this is not monitored or regulated by the EPA.
Groundwater may dissolve uranium-bearing minerals depending on the geochemistry of the water and the rock. Uranium and its daughter products may be mobilized in the water supply or, in the case of radon, released as gas into the air.

Unlike many water pollutants, all radionuclides dissolved in water are colorless, odorless, and tasteless and, therefore, cannot be detected by our senses (Zapecza, and Szabo, 1988).
Uranium can become concentrated in certain rock types, including some local granitic rocks.

Geologic processes can concentrate uranium in certain rock types so that uranium-bearing minerals may be found in association with these rocks or younger sedimentary deposits derived from these rocks.

Uranium can be highly concentrated in intrusive igneous rocks, primarily granitic rocks, and also is found in sedimentary rocks such as black shales, soils above limestone, and phosphate rocks (Ayotte and others, 2007, 2011).
A geologic map of northeastern Washington State shows the widespread presence of intrusive igneous rocks (pinks and reds). The map shows uranium assay sites and mines, indicating that uranium has been found in the region in high enough concentrations to economically extract.

Uranium ore was discovered in Washington in the 1950s, and was mined at several locations including the Midnite and Sherwood Mines on the Spokane Reservation in Stevens County, and the smaller Daybreak Mine on the western side of Mount Spokane in Spokane County. Extraction of uranium ore at these mines largely ended by the early 1980s (Dahlkamp, 2011).

Because of the presence of uranium-rich granitic rocks and the general mobility of uranium in circulating groundwater, the regions that are likely susceptible to occurrences of uranium in groundwater include Pend Oreille, Stevens, and Ferry Counties, as well as eastern Okanogan, northern Spokane, and northernmost Lincoln Counties.
This map of Washington State shows potential exposure to radon in air, based on the presence of uranium-bearing rocks or sediment. The high (red) and moderately high (orange) hazard classifications found in northeastern Washington State show the geologic potential for elevated uranium levels since radon is a daughter product of uranium decay.
The potential for naturally occurring uranium to enter drinking water is concerning because many rural residents of northeastern Washington State rely on private wells to supply their drinking water.

After receiving reports of elevated levels of uranium in wells drilled in this region, the U.S. Geological Survey selected a study area in northeastern Washington State, shown by the red outline on the figure. This area was selected based on the geologic potential for elevated levels of uranium in groundwater and the availability of data.

The study area selected for this investigation encompasses about 13,000 square miles. In 2010, the area population was about 563,000. Most of the study area is rural with small towns interspersed throughout the region. The study area also includes three Indian reservations with small towns and scattered population. The study area includes all of Ferry, Stevens, and Pend Oreille Counties; most of Spokane County; and parts of Okanogan, Douglas, Grant, and Lincoln Counties.
Of the population of 563,000 in the study area, about 438,000 (78 percent) residents are served by public water systems, and 125,000 (22 percent) residents are served by private domestic wells (Washington State Department of Health, 2017; Washington State Office of Financial Management, 2017).
This figure shows the distribution of the roughly 43,000 existing water wells that serve a population of about 125,000 in the study area.
What levels of uranium are in area wells?

- 2018 study compiled historical and recent data to investigate what levels of uranium had been found in area wells
- Only 4% of the roughly 43,000 wells in the study area had been sampled for uranium

To learn more about uranium in the groundwater of northeastern Washington, the U.S. Geological Survey made a preliminary assessment of naturally occurring uranium in untreated groundwater, relying on historical data and limited recent sampling (Kahle and others, 2018).

Of the roughly 43,000 existing water wells in the study area, only 1,755 (4%) had been sampled for uranium concentrations. Many of these wells were sampled in the 1970s and 1980s as part of the National Uranium Resource Evaluation (NURE) program, which sought to identify areas favorable for uranium exploration throughout the United States (Smith, 1997). Other historical uranium concentration data were compiled from State and local health departments, and from sampling done by the Spokane Tribe and the USGS. Much of the uranium concentration data originate from private wells that are only tested at the discretion of the well owner or when they are newly constructed, so much of the study area remains underrepresented.
Uranium was detected in 60% of the 1,742 historically sampled wells (1977–2015).
5% (87 wells) exceeded the 30 micrograms per liter health standard.

Of the approximately 43,000 water wells in the study area, 1,742 (4 percent) wells were historically (1977-2015) sampled for uranium concentration. Uranium was detected in samples from 60 percent of these wells and samples from 87 wells (5 percent) exceeded the health standard for uranium (Kahle and others, 2018).
• An additional 13 wells were sampled in areas suspected of having elevated levels of uranium in the groundwater

In 2017, the USGS collected groundwater samples from 13 private domestic wells in areas without recent (2000s) water-quality data and where granite or shale was predominant—thus, in areas suspected of having a high likelihood of elevated uranium levels in the groundwater.
Uranium was detected in all 13 wells sampled for this study; concentrations ranged from 1.03 to 1,180 micrograms per liter. Uranium concentrations of groundwater samples from 6 of the 13 wells (46%) exceeded the health standard for uranium.

Uranium concentrations in water samples from two wells were 1,130 and 1,180 micrograms per liter, respectively—nearly 40 times the health standard (Kahle and others, 2018).
There is a general, but inconsistent relation between the locations of sampling sites with elevated uranium concentrations and mapped surface geologic units. The geologic material that supplies groundwater to a well is a better indicator for the potential occurrence of elevated uranium in groundwater produced from the well. This relation is demonstrated by an analysis of 332 wells with uranium concentration sampling and available driller’s logs which record the geologic material of the open interval, that is, the material that supplies groundwater to the well.

Uranium concentrations did not exceed the health standard of 30 micrograms per liter for wells completed in basalt, limestone, or quartzite. However, uranium concentrations exceeded the standard in 18 and 14 percent of wells completed in granite and shale, respectively. Similarly, uranium concentrations exceeded the standard in 12 percent of wells completed in multiple geologic units, but this was due to the wells being partially open to granite or shale. Uranium concentration was greater than the standard in 1 of 130 wells completed in unconsolidated sediment, such as sand and gravel.
Wells with groundwater samples with uranium concentrations greater than or equal to 30 micrograms per liter are labeled.

Locations of wells with associated uranium concentrations showing generalized geologic material of open interval, Ferry, Pend Oreille, and Stevens Counties, Washington.

From Kahle and others, 2018

This figure shows the spatial distribution of the 332 wells described in the previous slide. The well locations are colored to indicate the geologic material supplying groundwater to the well. Wells with groundwater samples with uranium concentrations greater than or equal to 30 micrograms per liter are labeled.
Although much has been learned about uranium in the groundwater of northeastern Washington, if existing data gaps are addressed in the future, they could provide area residents with a better understanding of the occurrence and distribution of uranium and other radionuclides in area groundwater.

Key data gaps include the following:

• Much of the study area is underrepresented in terms of available uranium concentration data and much of the existing data are decades old.
• The local geochemical conditions that largely govern the mobility of uranium are poorly understood and would be helpful in understanding its occurrence in area groundwater.
• The uranium decay sequence includes other radionuclides of concern (radium, radon, and alpha particles) but very little is known about their presence in area groundwater.
Public water-supply operators are required to test their water periodically for uranium and other constituents, but no monitoring requirements exist for private wells. The only way to know if a private well has elevated levels of uranium or other radionuclides is to test for them. Private well owners are responsible for the quality and safety of their well water.

Water from most wells in the area has concentrations of uranium below the drinking water standard, but the amount of uranium in area groundwater varies greatly from place to place. Closely-spaced wells of similar depths can produce water with very different uranium concentrations.

Well owners may want to consider testing for uranium, radium, and radon. Although these elements are chemically related, one may be present at elevated levels even if others are not because of their different geochemical properties.
Local health departments often can provide more information about testing drinking water for uranium and other radionuclides of concern. The Washington State Department of Ecology maintains a database of laboratories that are certified to conduct testing, accessible at https://apps.ecology.wa.gov/laboratorysearch/.

Well owners can search the database for laboratories that accept public samples (samples collected by private individuals unaffiliated with an agency). They also can search by analyte to find laboratories that can test for uranium and other radionuclides. Contact information for the laboratories is provided. The cost of testing varies, but generally is low (less than $100, as of March 2020).
Laboratories will provide well owners with instructions on how to collect and submit a water sample for testing.

Generally, the laboratory will provide the well owner with a sample bottle to fill with their drinking water, which they will then mail to the laboratory for analysis. Once testing is completed, the laboratory will send the well owner the results.
Uranium and other radionuclides can be effectively removed from drinking water. If you are a private well owner concerned about elevated uranium levels in your drinking water, a short-term option is to drink bottled water. A long-term solution is to install a treatment system to remove uranium as well as other radioactive elements from your drinking water. Treatment systems can be installed directly at the tap and can be relatively low cost.

Local health departments often can provide information about treatment options available in areas they serve.
Several existing resources provide private well owners with more information:

Local health departments often can provide information about water testing and treatment options available in the areas that they serve.
A Washington State Department of Health fact sheet describing Radionuclides in Drinking Water is available at https://www.doh.wa.gov/portals/1/Documents/pubs/331-056.pdf.
A U.S. Environmental Protection Agency web page about Natural Radionuclides in Private Wells is available at https://www.epa.gov/radtown/natural-radionuclides-private-wells.
A U.S. Environmental Protection Agency web page about Uranium is available at https://www.epa.gov/radiation/radionuclide-basics-uranium.
A Washington State Department of Health web page and interactive map about radon risk in air are available at https://www.doh.wa.gov/YouandYourFamily/HealthyHome/Contaminants/Radon.
The U.S. Geological Survey maintains a web site dedicated to ongoing scientific studies of radionuclides in water at https://www.usgs.gov/mission-areas/water-resources/science/radionuclides?qt-science_center_objects=0#qt-science_center_objects.
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