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Update on Tritium Management at Fermilab

Presentation to Fermilab Community Advisory Board

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Tritium and Environmental Monitoring at Fermilab

- Fermilab has had an environmental monitoring program for about 50 years.
- In 2005, the program detected for the first time tritium in surface water and in the sanitary sewer on the Fermilab site.
  - We immediately informed the regulatory agencies, our neighbors and employees and the public.
  - Formed first Tritium Task Force
  - At present the TTF is composed of representatives from Accelerator Division, Engineering Section, ES&H Section and DOE
- Levels were initially, and continue to be, well below already conservatively protective regulatory limits.
  - Highest level has been less than 20% of limit, but the remainder are <1% of limits
- We strive to minimize tritium discharges, keep the public informed, and seek input on our plans and goals.

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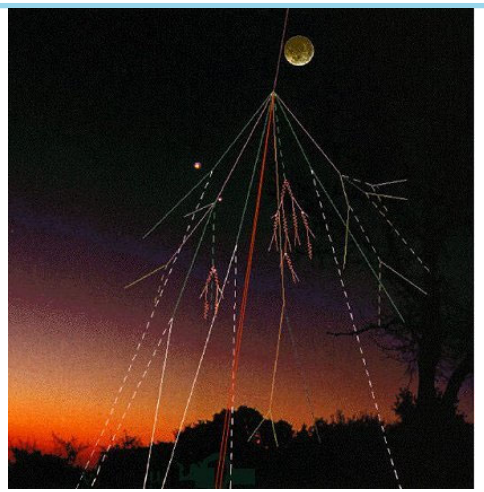
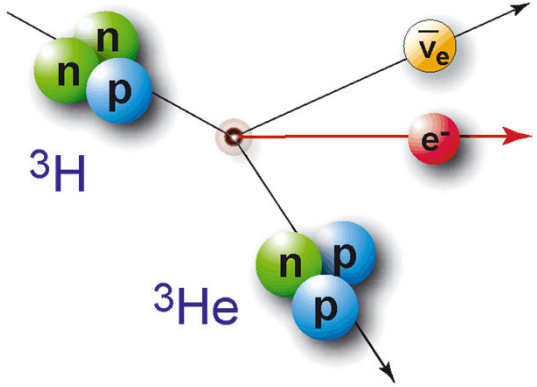
What is Tritium?

- Tritium (^3H) is a weakly radioactive form of hydrogen with a half-life of 12.3 years.
  - In nature, tritium is produced when cosmic particles hit the atmosphere.
  - Residual from nuclear tests (pre-1970s).
  - At Fermilab and other particle accelerators, tritium is a byproduct of operation.



- Its decay emits particles of very low energy that cannot penetrate the skin.
- Tritium can only be harmful if people drink water with high levels of tritium over many years.
  - Tritium does not build up in biological tissues; the biological half-life for tritiated water (HTO) is about 12 days.



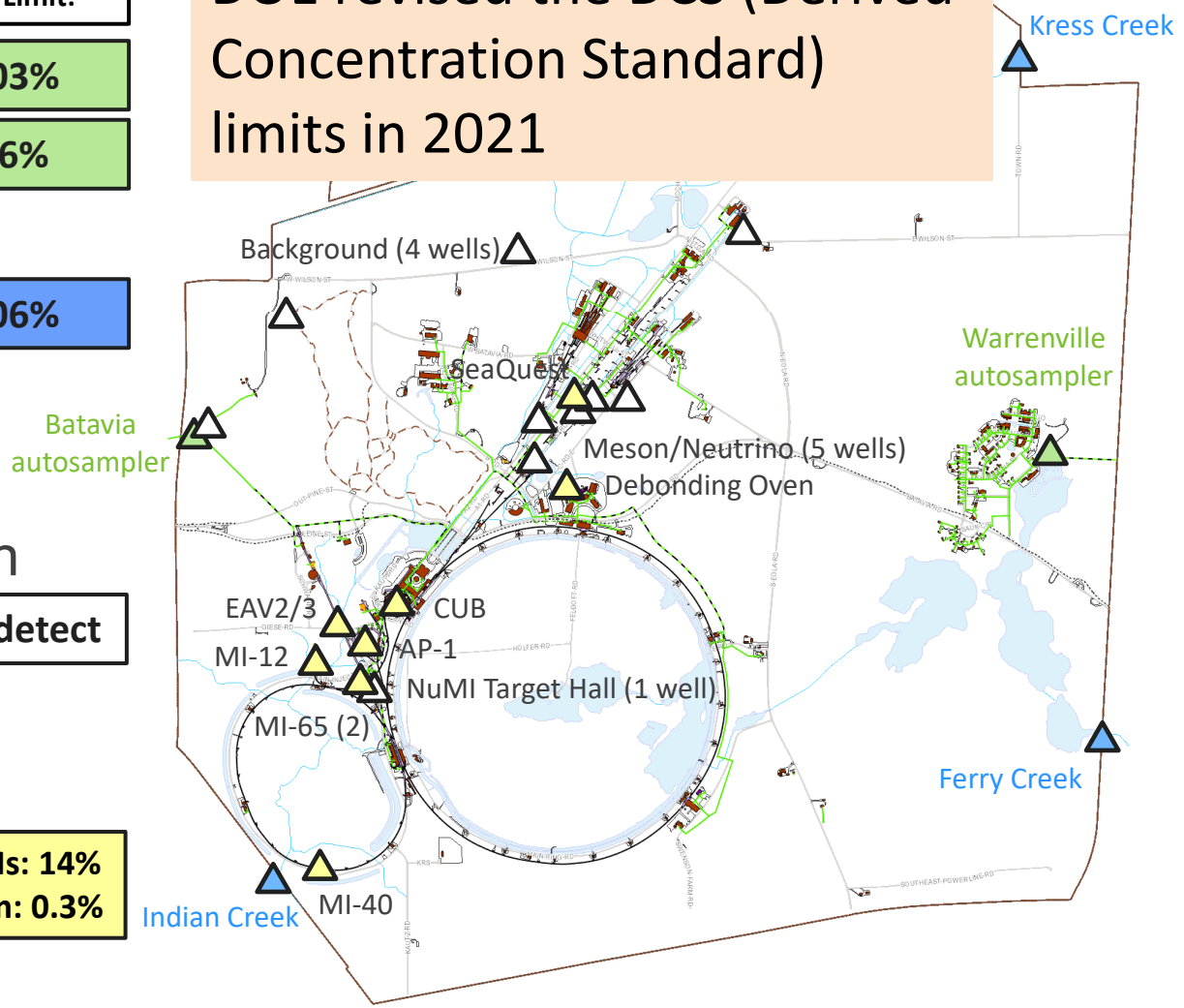
Where does Tritium come from at Accelerators?

- High-energy protons hitting or traveling through materials produce tritium (^3H).
  - Typical materials used in experiments at Fermilab: iron, concrete, carbon, air, water, etc.
- When protons or other particles hit nuclei in the atoms in materials, they “shatter” these nuclei into pieces.
  - Some of the pieces left over are stable nuclei.
  - Others are radionuclides, including tritium (^3H) atoms.
- Upon exposure to air, the ^3H atoms combine with oxygen to make HTO molecules (tritiated water), just like the familiar H_2O.
  - HTO “water” moves just like regular water.
  - Fermilab monitors multiple water and air routes

Tritium Discharges Relative to Regulatory Limits

	2020 results as % of Limit:
△ Sanitary Sewer	
13,000 9,500 pCi/ml	0.03%
– 5 Ci in a year	2.6%
△ Surface Water	
2,600 1,900 pCi/ml	0.06%
△ Groundwater	
– 1 pCi/ml (Class 1 Resource Aquifer in bedrock)	Non-detect
△ Air	
– 0.1 mrem/year (all radionuclides)	All APIs: 14% Tritium: 0.3%

DOE revised the DCS (Derived Concentration Standard) limits in 2021



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Standards for Surface and Drinking Water

- DOE Surface water limit: 2,600 pCi/ml (picocuries per milliliter).
- Federal limit for drinking water systems: 20 pCi/ml.

What do these standards mean?

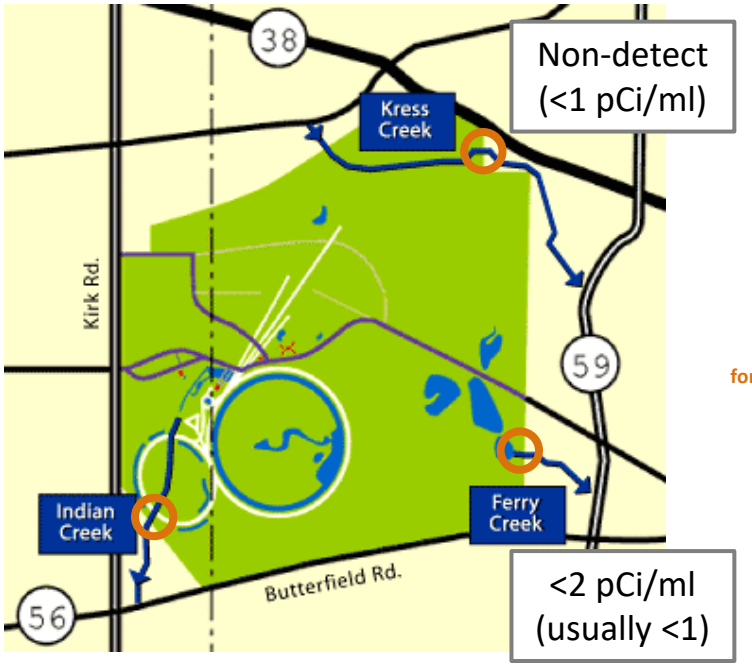
- 1 picocurie (pCi) = 0.037 atoms decaying each second.
- Threshold for measurement is usually taken to be 1 pCi/ml.
  - A user of 2,600 pCi/ml water for their household water source full time would receive a radiation dose of 100 mrem each year.
  - A user of 20 pCi/ml water for their household water source is assigned a dose of 4 mrem each year by U.S. EPA.
  - Globally, rainwater is 0.16 to 0.32 pCi/ml due to cosmic rays and leftovers from nuclear weapons tests (ending in 1960s).

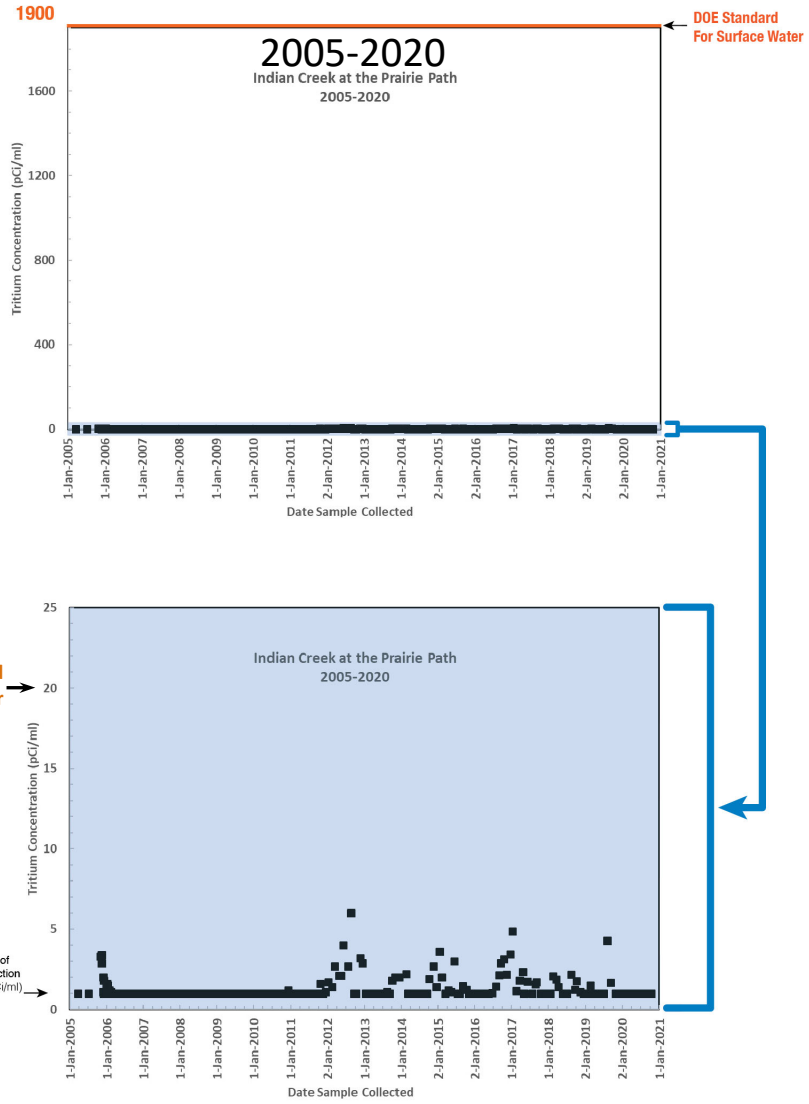
How Surface Water at Fermilab Connects to the Community

- 3 creeks leave Fermilab.
  - The Fermilab site has numerous ponds and is the origin of Indian Creek and Ferry Creek.
- Fermilab uses water to cool accelerators and other equipment.
  - Our pond system is part of an “industrial cooling water system” (ICW).
  - ~250,000,000 gallons!
- No one drinks our pond water, but some fish in it.

Surface Water Boundary Results: Indian Creek

- <10 pCi/ml (usually <5 pCi/ml)
- Regulatory limit: 2,600 pCi/ml
  - 1,900 pCi/ml through 2020





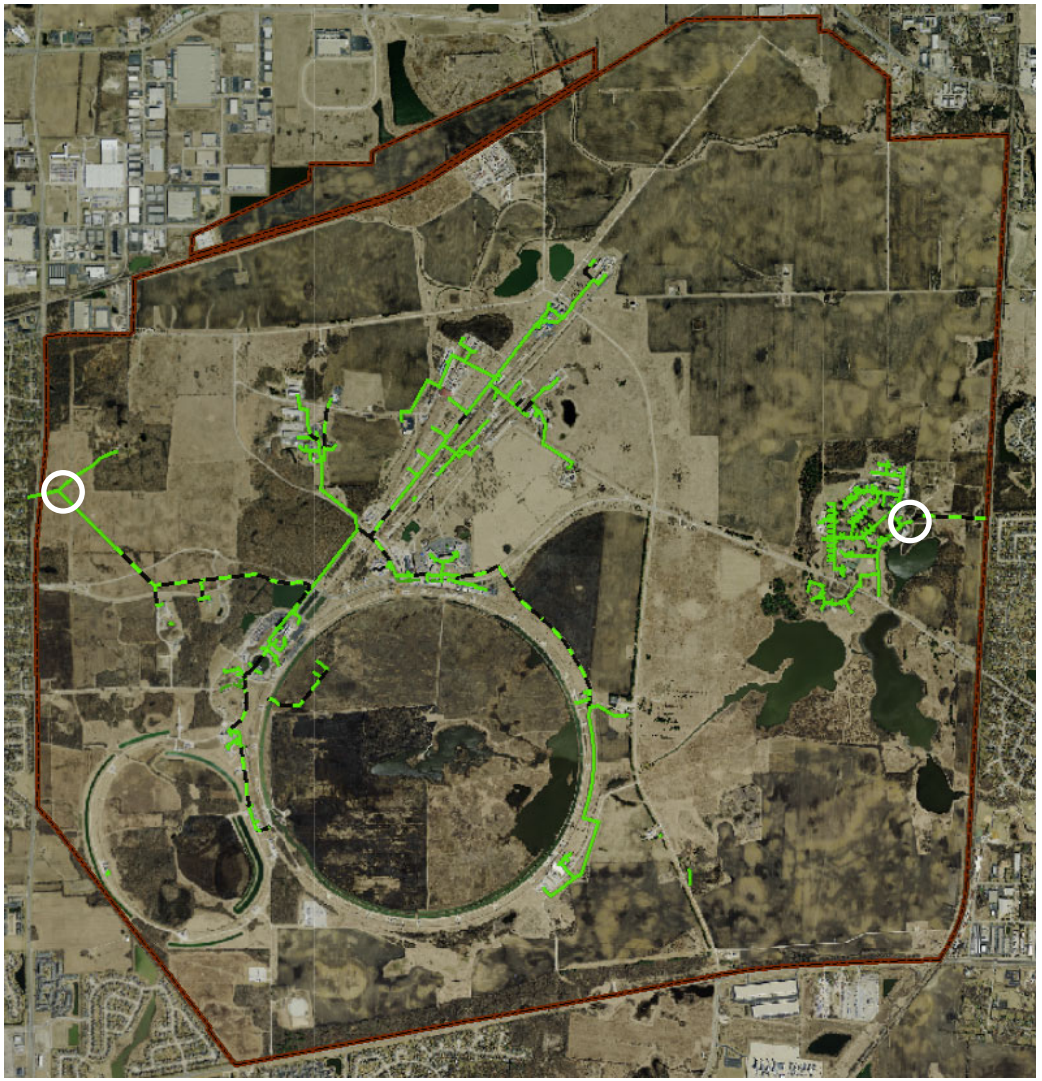
Data plots for all three creeks online at:
https://www.fnal.gov/pub/tritium

Groundwater

- We must protect Illinois Class I “Resource” Groundwater.
  - Found in bedrock beneath Fermilab (60-90 feet deep).
  - Must stay below 1 pCi/ml in Class I aquifers (i.e, those considered by Illinois to be “useful” for drinking water).
- We design and operate our experiments so that any tritium produced stays out of groundwater.
  - Fermilab employs a hydrogeologist on its staff as an advisor.
- We have never found tritium in Class I groundwater.
  - At least ten wells are sampled annually.
  - More than 100 wells are measured annually to determine flow directions.

Monitoring Tritium in the Sanitary Sewer System

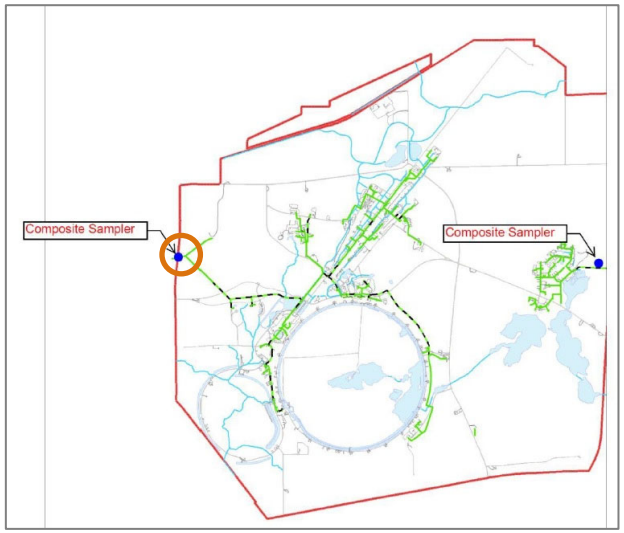
Composite Sampler
(to Batavia system)



Composite Sampler
(to Warrenville system)

Sanitary Sewer Boundary Results: Batavia

- <35 pCi/ml (usually <20 pCi/ml)
- Regulatory limit: 13,000 pCi/ml
  - 9,500 pCi/ml through 2020
- 2020 annual total activity load was ~2.5% of 5 Ci limit



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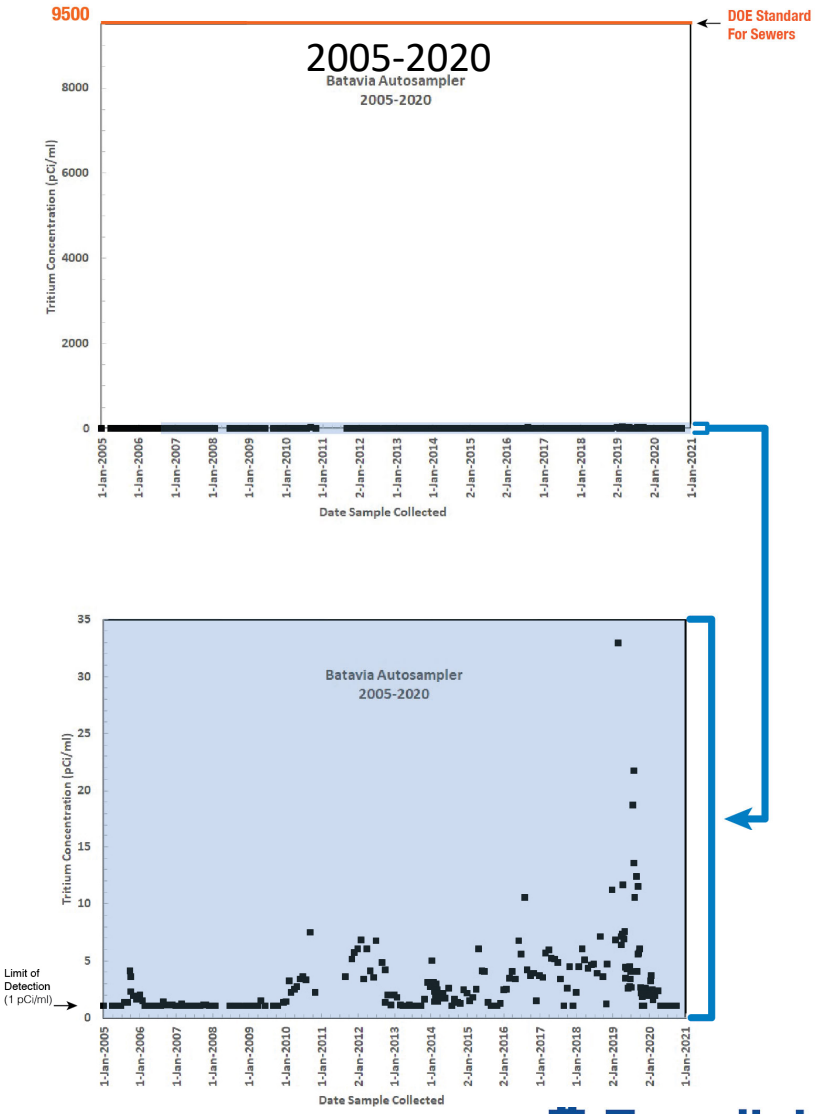
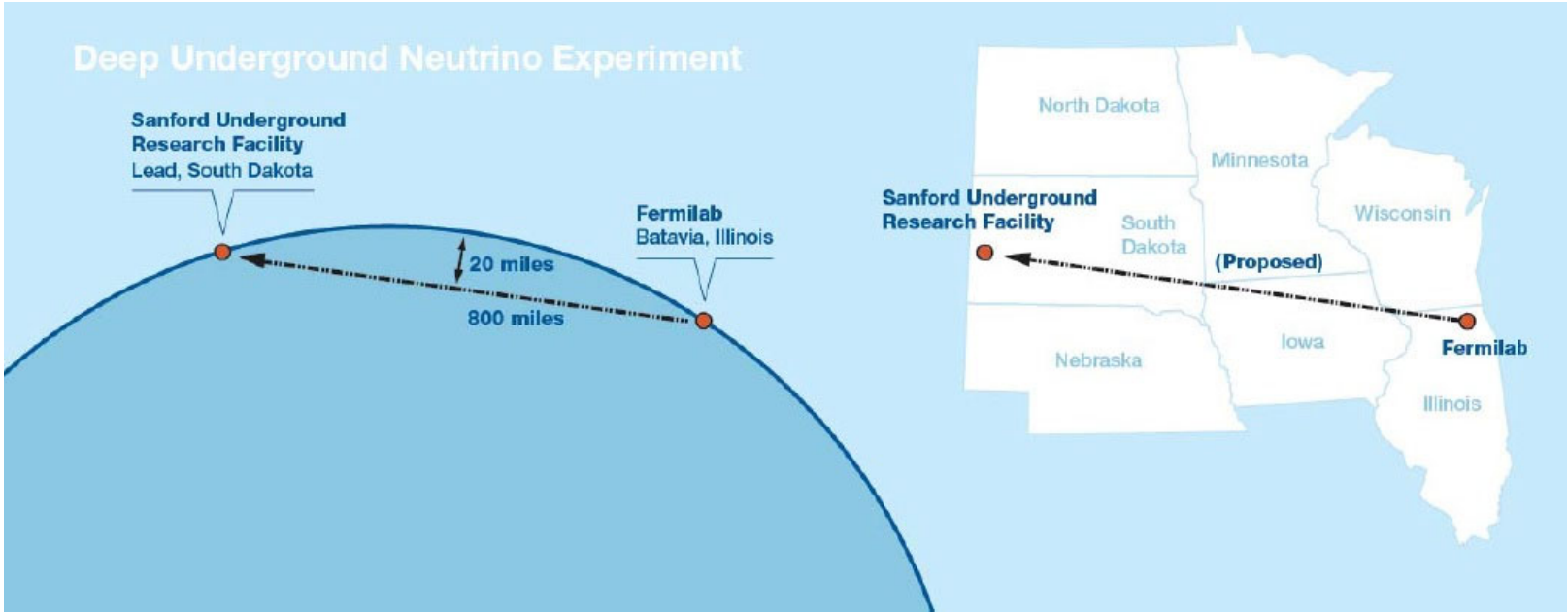


Example of a Recent Improvement

- In 2019 we finished installation of a canopy and liner over the BNB berm, under which we produce neutrinos for on-site experiments
  - They reduce moisture by >95% in the neutrino-producing area, which means less HTO is produced
  - First phase of shallow groundwater monitoring wells: all <1 pCi/ml

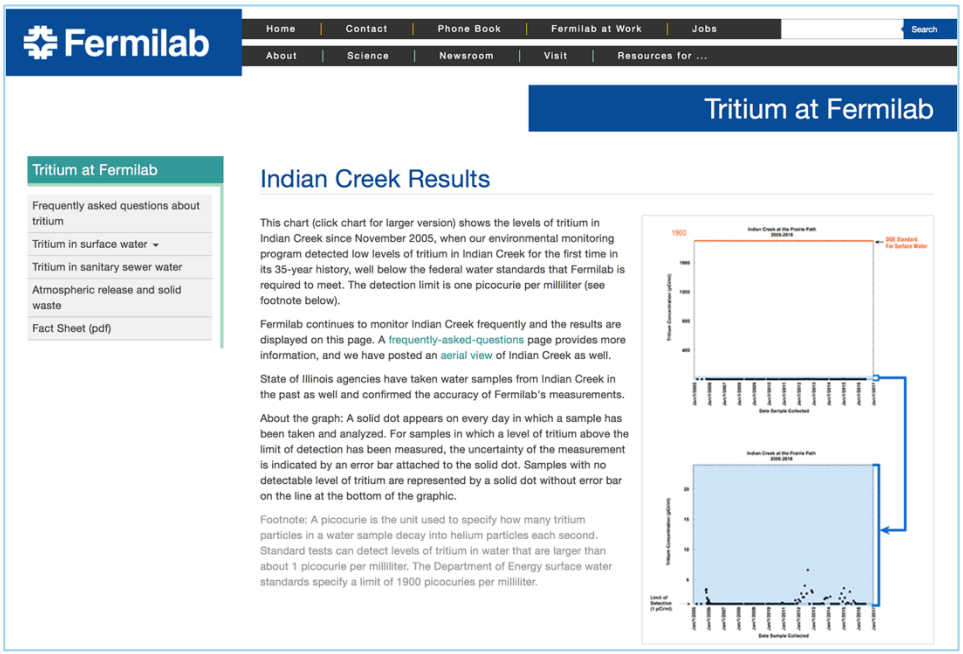
Future experiments: LBNF/DUNE



- We are planning a new neutrino beamline at Fermilab to send a stream of neutrinos to the LBNF/DUNE experiment in South Dakota.
  - This will be a new neutrino beam to operate after our neutrino experiment in Minnesota is retired.
- Improved tritium management is a major focus on the design of this new, higher beam power facility.

Keeping the Public Informed

- We held Environmental Assessment meetings for LBNF/DUNE in 2015.
- We inform you: the Community Advisory Board.
- We update and post tritium data on our public tritium webpages.
- Also publicly available:
  - Annual environmental reports
  - FESHM Chapters (Fermilab ESH Manual)



https://www.fnal.gov/pub/tritium/index.html

Questions for the CAB

Members of the Community Advisory Board are one of Fermilab's connections to the community. As such, we'd like to know:

- How should we keep the community informed and maintain a dialogue?
- Are there specific groups or persons we should reach out to?
- What questions and recommendations do you have?
- Do you consider us a good steward of the Fermilab site or do you have concerns?

Additional Questions for Us?

- Q: Is tritium the only concern radioactively speaking?
  - A: Tritium is not the only API (accelerator-produced isotope), but it is the one we focus on because it has the greatest potential for migration, and most of the other APIs have lower half lives than tritium.