Update on Tritium Management at Fermilab

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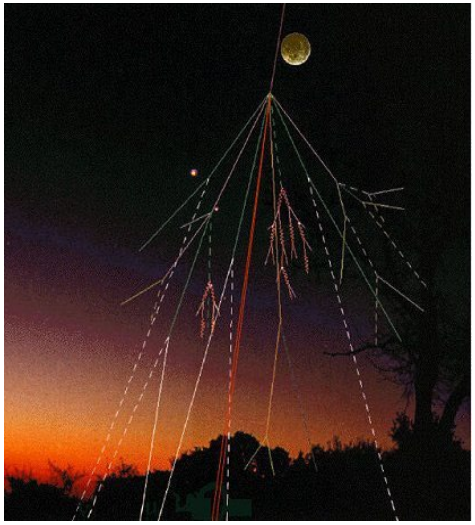
Fermilab Community Advisory Board Meeting
23 May 2024

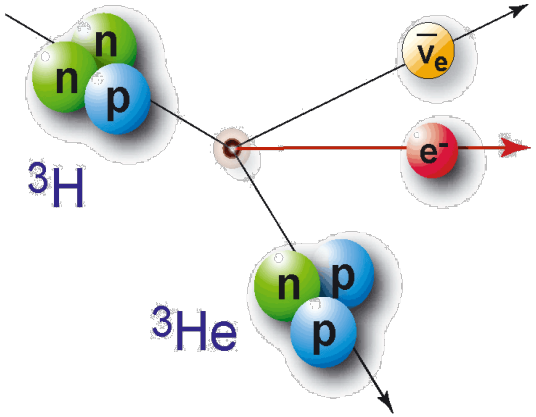
Tritium and Environmental Monitoring at Fermilab

- 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.
- Levels were, and continue to be, well below already conservatively protective regulatory limits.
  - Highest level has been <20% of limit; the rest are <1% of limits
- We strive to minimize tritium discharges, keep the public informed, and seek input on our plans and goals.
- We have a Tritium Task Force and a new Tritium Management Dept that implement improvements to reduce tritium levels
  - The TTF includes accelerator and engineering experts as well as ES&H and DOE staff

What is Tritium?

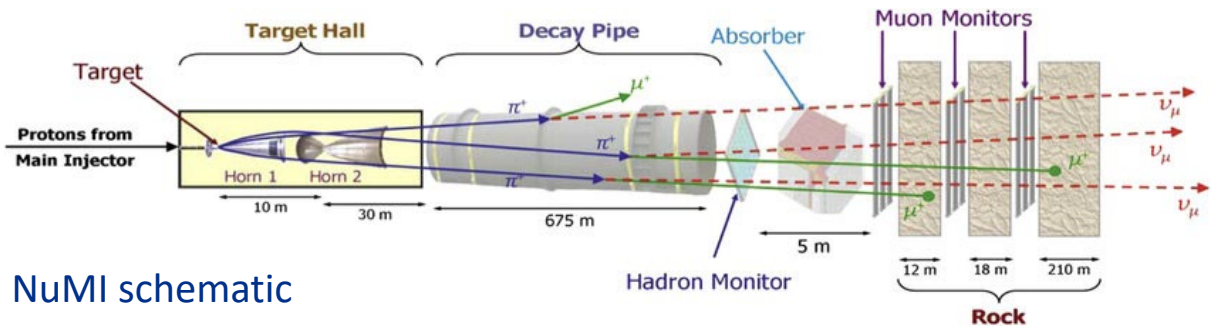
- Tritium (^3H) is a weakly radioactive form of hydrogen with a half-life of 12.3 years.
  - In nature, tritium is produced when cosmic particles hit the atmosphere.
  - Residual from nuclear tests (pre-1970s).
  - At Fermilab and other particle accelerators, tritium is a byproduct of operation.
- Its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





Tritium: A Byproduct of 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 are stable, others are radionuclides like ^3H.
- Upon exposure to air, the ^3H atoms combine with oxygen to make HTO molecules (tritiated water) with the same structure as H_2O (water).
  - HTO "water" moves just like regular water.



NuMI schematic

Far detector in MN

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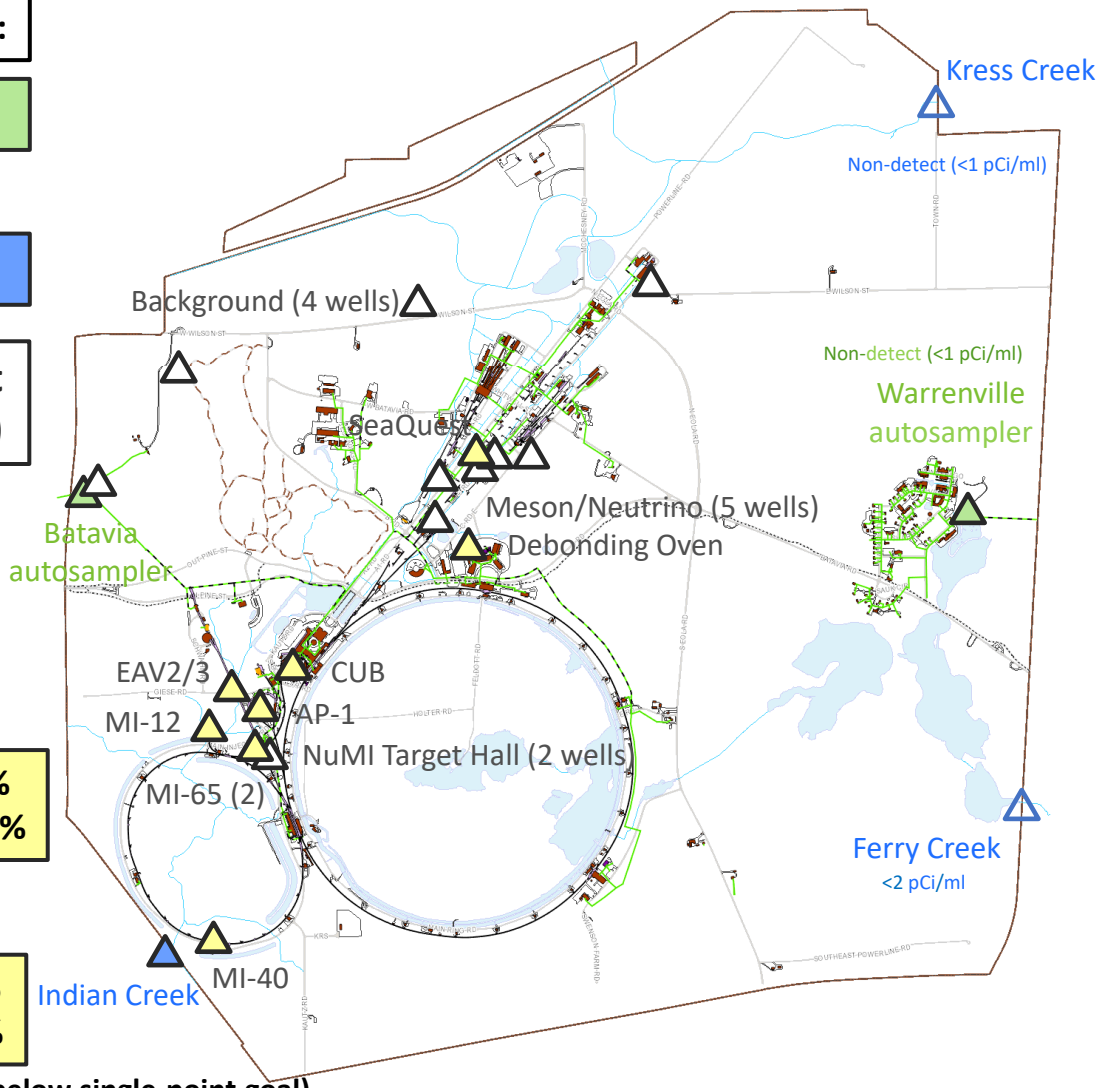
Tritium Discharges in 2023 Relative to Regulatory Limits

2023 results as % of Limit:

- Sanitary Sewer
  - 5 Ci in a year — **<4.7%**
- Surface Water
  - 2,600 pCi/ml — **<0.2%**
- Groundwater
  - 1 pCi/ml (Class 1 Aquifer in bedrock) — **Non-detect (<1 pCi/ml)**
- Air (all Accelerator-Produced Isotopes, or APIs)
  - 10 mrem/year dose from all emissions — **All APIs: 0.8%** **Tritium: 0.004%**
  - 0.1 mrem/year from any 1 emission point — **All APIs: 78%** **Tritium: 0.4%**

***ALL emissions (below single-point goal)**



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Standards for Surface and Drinking Water

- DOE Surface water limit for offsite discharge: 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. For comparison, a head CT scan creates about 200 mrem (source: NRC). https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html
  - 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

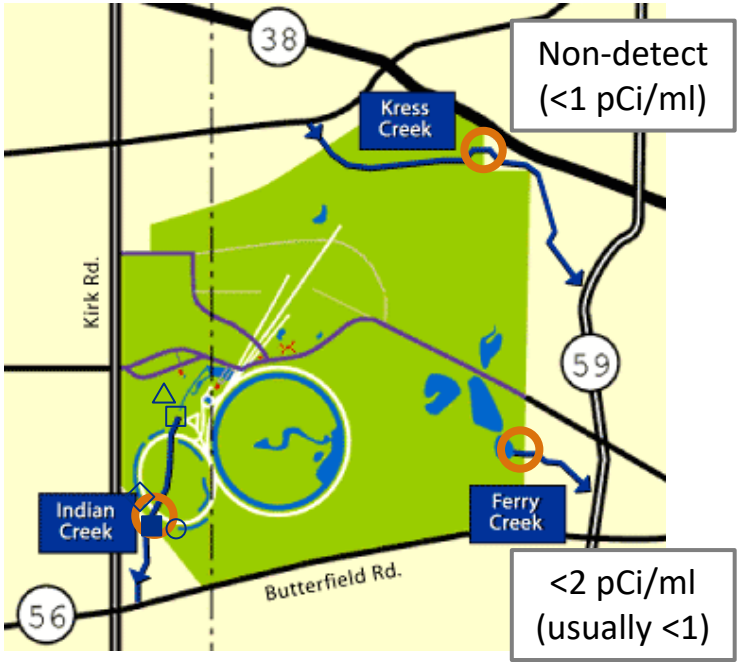
- The Fermilab site has numerous ponds and is the origin of Indian Creek and Ferry Creek

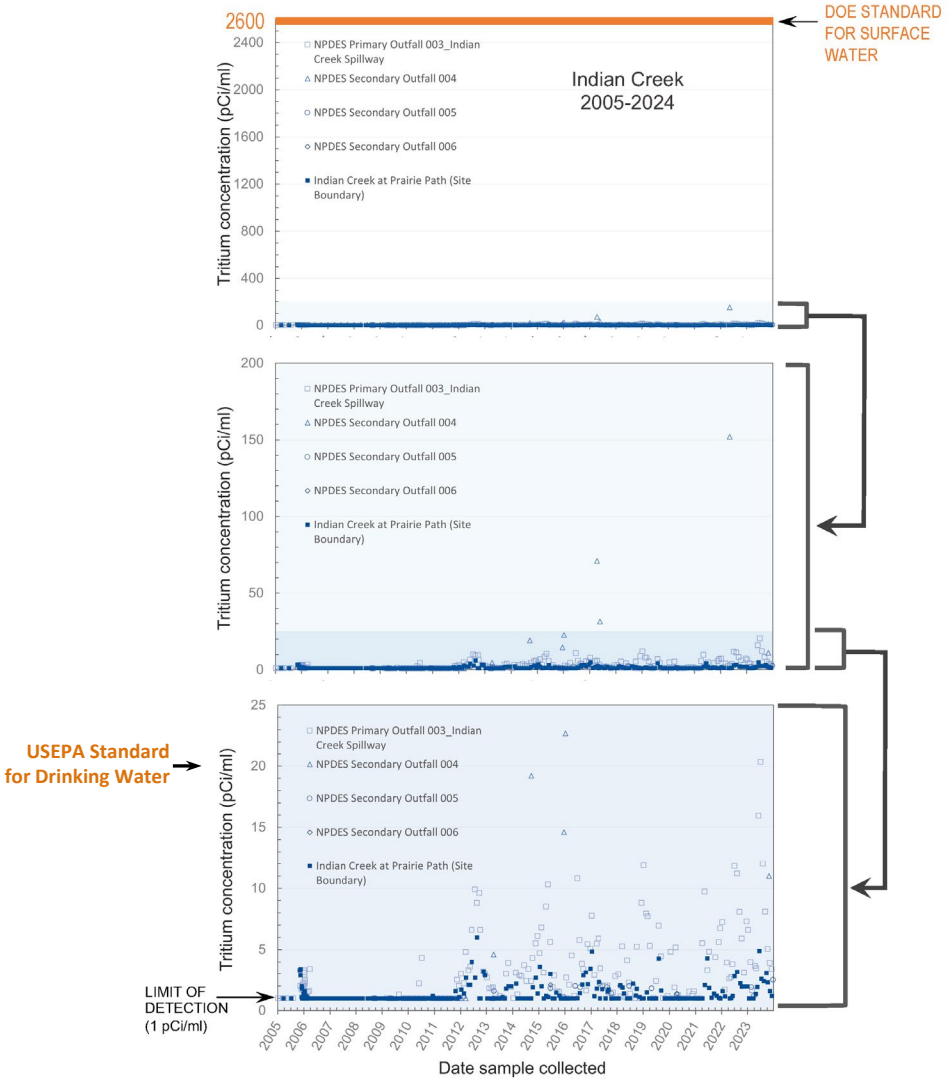
Fermilab uses water to cool accelerators and other equipment

- Our pond system is part of an “industrial cooling water system” (ICW)
- ~250,000,000 gallons

Surface Water Boundary Results: Indian Creek

- 6 pCi/ml or lower
- Regulatory limit: 2,600 pCi/ml
- Inputs: 1 primary and 3 secondary NPDES outfalls

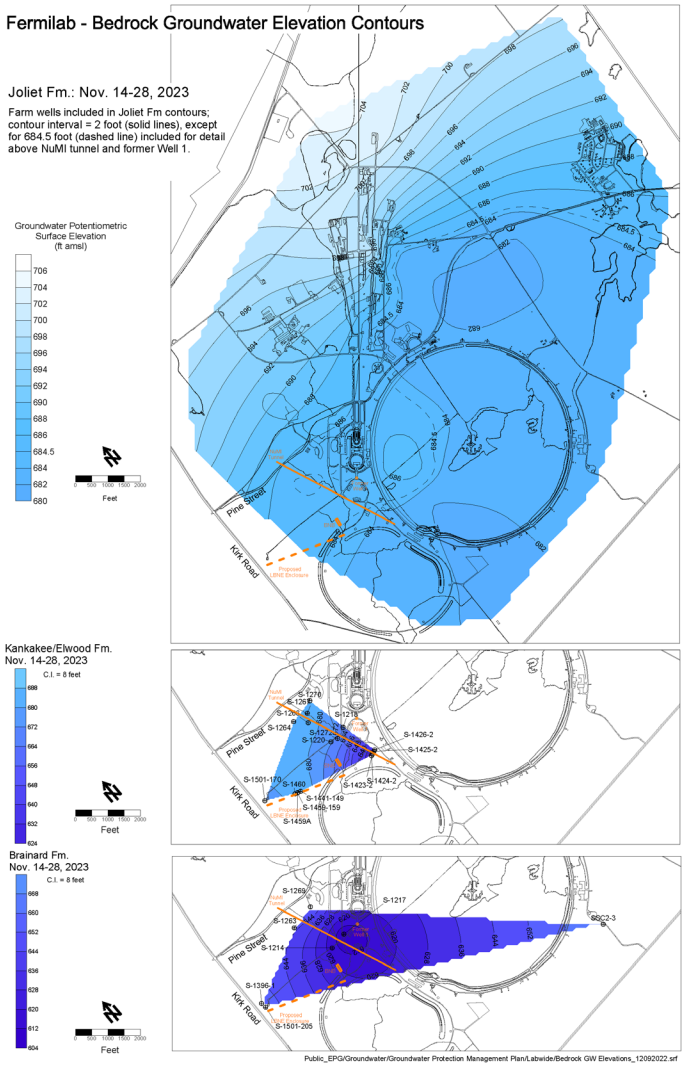




Data plots and maps for all three creeks online at:
https://www.fnal.gov/pub/tritium

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.
  - Eleven bedrock wells are sampled annually.
  - More than 100 wells are measured annually to determine flow directions.



Monitoring Tritium in the Sanitary Sewer

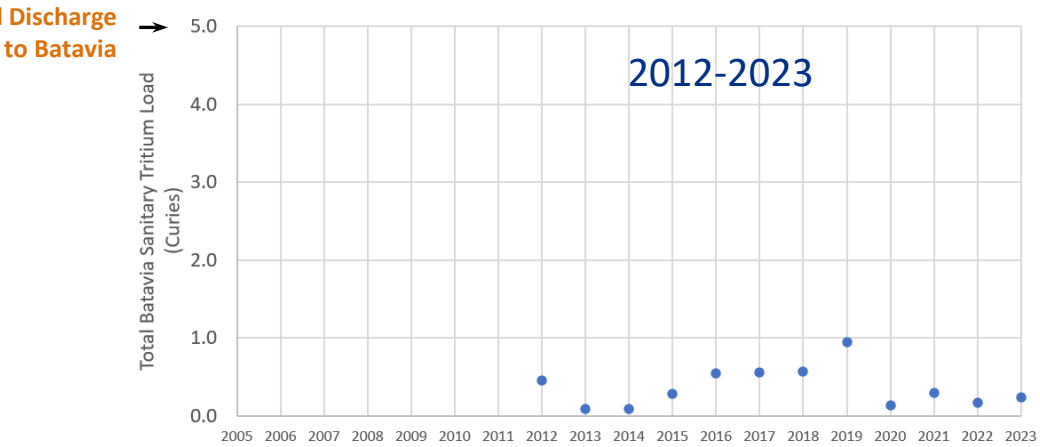
Composite Sampler
(to Batavia system)

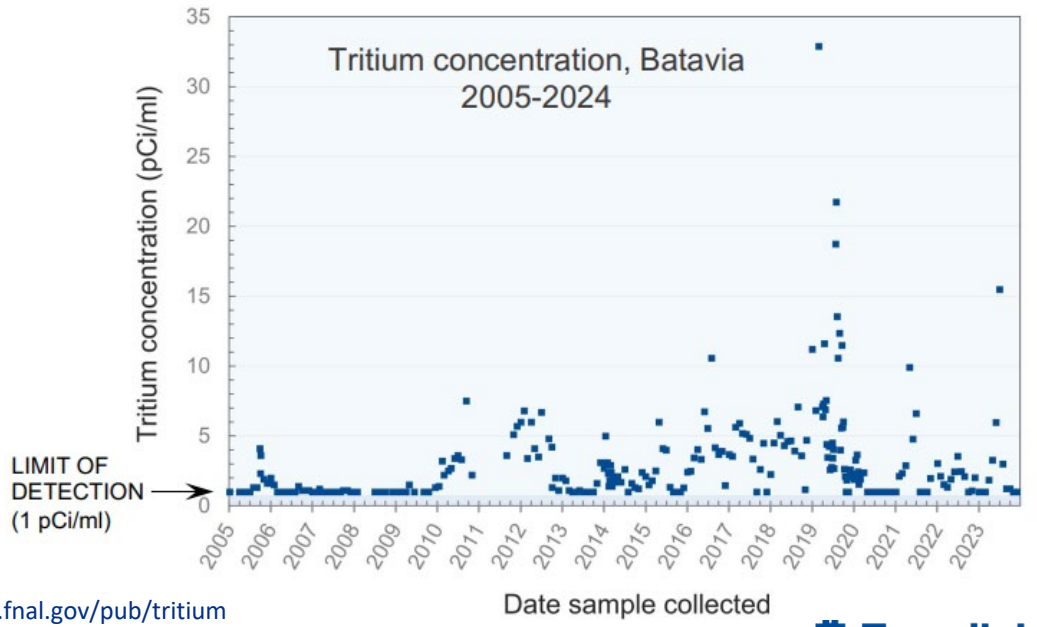
Composite Sampler
(to Warrenville system)

Non-detect
(<1 pCi/ml)

Sanitary Sewer Boundary Results: Batavia

- 2023 annual total activity load was 4.7% of 5 Ci annual limit
  - Beam power was higher than in 2019 but condensate is now:
    - Routed away from sanitary sewer system during periods of high concentration and
    - Shipped offsite for disposal while a new evaporator system is being designed
- <35 pCi/ml (usually <20 pCi/ml)





Data plots online at: https://www.fnal.gov/pub/tritium

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More Recent Tritium Management Efforts

- In 2019 we finished installation of a canopy and liner over the BNB berm, under which we produce neutrinos for Short Baseline Neutrino (SBN) experiments
  - Infiltration reduced by >90%, which means less HTO is produced
  - First phase of shallow groundwater monitoring wells: all <1 pCi/ml since 2021
    - Additional bedrock wells to be installed and added to sampling program

Tritium Management Efforts: Functional Rather Than Fashionable

PIP-II Cryogenic Building: "Pulsed" proton source pattern

SBN Far Detector Building: Neutrino "spray" pattern

BNB Canopy: Highly-customized "farm shed" including skylight panels, egress doors and a removable section for absorber access, that happens to be ageing well (IMO)

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More Recent Tritium Management Efforts

2022 external review of Fermilab tritium management

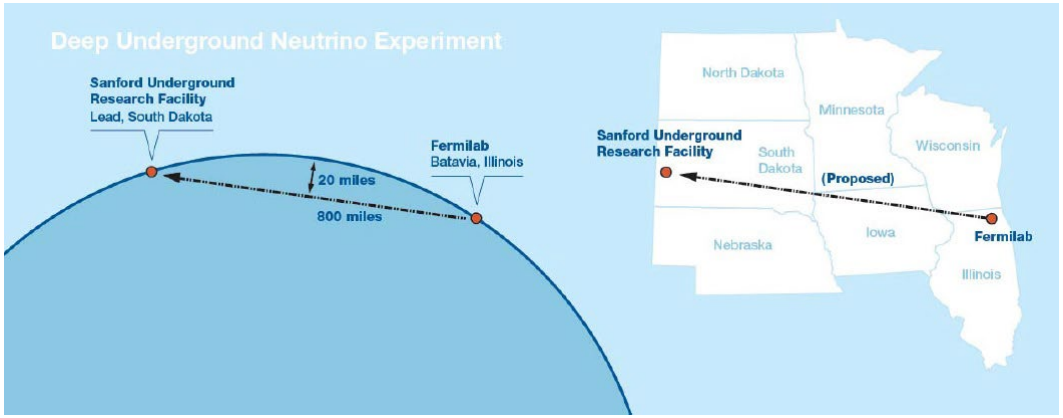
- Commendations included: BNB canopy, applying lessons learned to LBNF design, public communication
- Recommendations included: expand automated and groundwater monitoring, elevate and expand tritium management and funding, ICW management, etc.

Future Experiments: LBNF-DUNE

Long Baseline Neutrino Facility – Deep Underground Neutrino Experiment

Similar concept to NuMI, but keeping the production of tritium well below regulatory limits is a major focus on the design of this new, higher beam power facility via:

- Excluding, rather than capturing, groundwater along the active Near Site beamline at Fermilab
- Reducing total depth of Near Site construction into bedrock
- Maintaining a nitrogen atmosphere rather than ambient air atmosphere in the target chase during beam operation




Excavation of far detector caverns completed in February 2024

Keeping the Public Informed

- We held Environmental Assessment meetings for LBNF/DUNE in 2015.
- We inform the Community Advisory Board.
- We update and post tritium data on our public tritium webpages.
- The DOE Fermi Site Office sends a summary of tritium monitoring results at Fermilab to local officials every year.
- Also publicly available:
  - Annual environmental reports
  - FESHM Chapters
    - Fermilab ESH Manual

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?

We strive to be good stewards of the Fermilab site. Please let us know if you have concerns.

Questions from the CAB?

1. …