Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Update on Tritium Management at Fermilab

Presentation to Fermilab Community Advisory Board

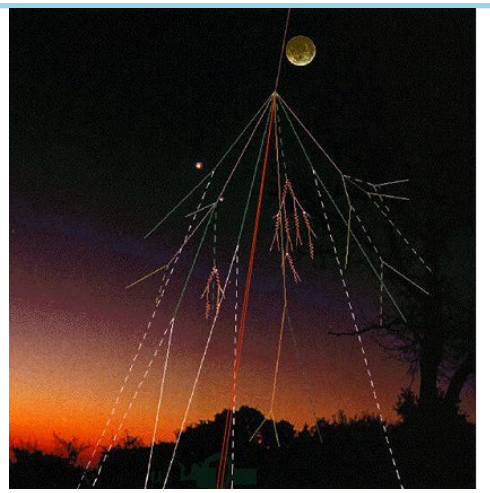
Chris Greer, PhD
Co-Program Manager, Tritium Task Force
Groundwater Manager, Environmental Protection Group/ESH Section
July 25, 2019

Tritium and Environmental Monitoring at Fermilab

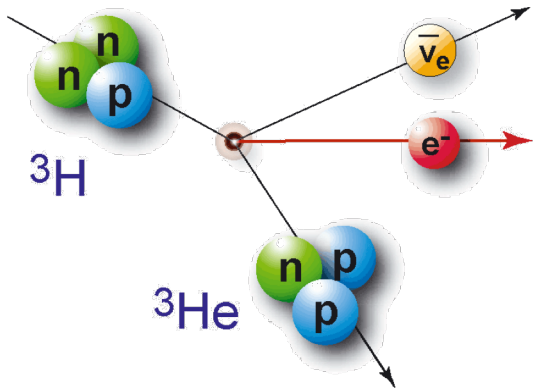
- Fermilab has had an environmental monitoring program for about 50 years.
- In 2005, the program detected for the first time tritium in surface water and in the sanitary sewer on the Fermilab site.
  - We immediately informed the regulatory agencies, our neighbors and employees and the public.
  - Formed first Tritium Task Force
- Levels were initially, and continue to be, well below already conservatively protective regulatory limits.
  - Highest levels are less than 10% of limits
- We strive to minimize tritium discharges, keep the public informed, and seek input on our plans and goals.

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.

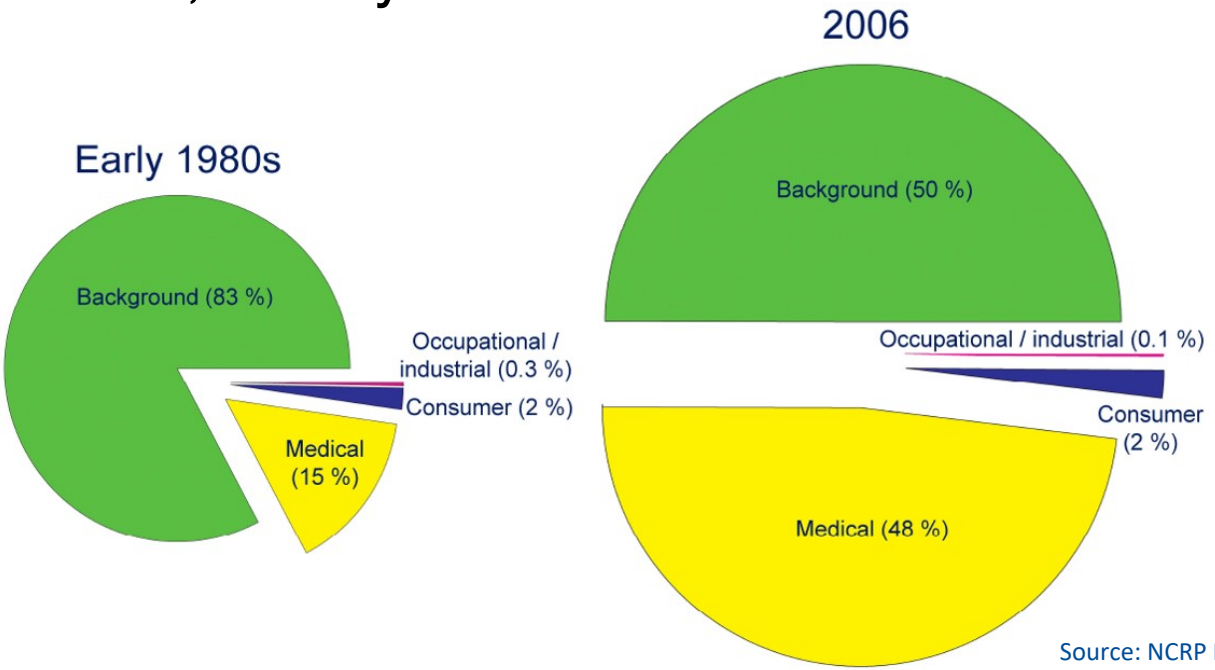
Fermilab

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.

General Radiation Doses in the US

- Radiation we all receive: U.S. Average is 620 mrem each year, about half from natural and the remainder from man-made sources, mostly medical.



Source: NCRP Report 160

- Dose Limits:
  - General Fermilab employees: 100 mrem in a year
  - Offsite public via air: 10 mrem in a year

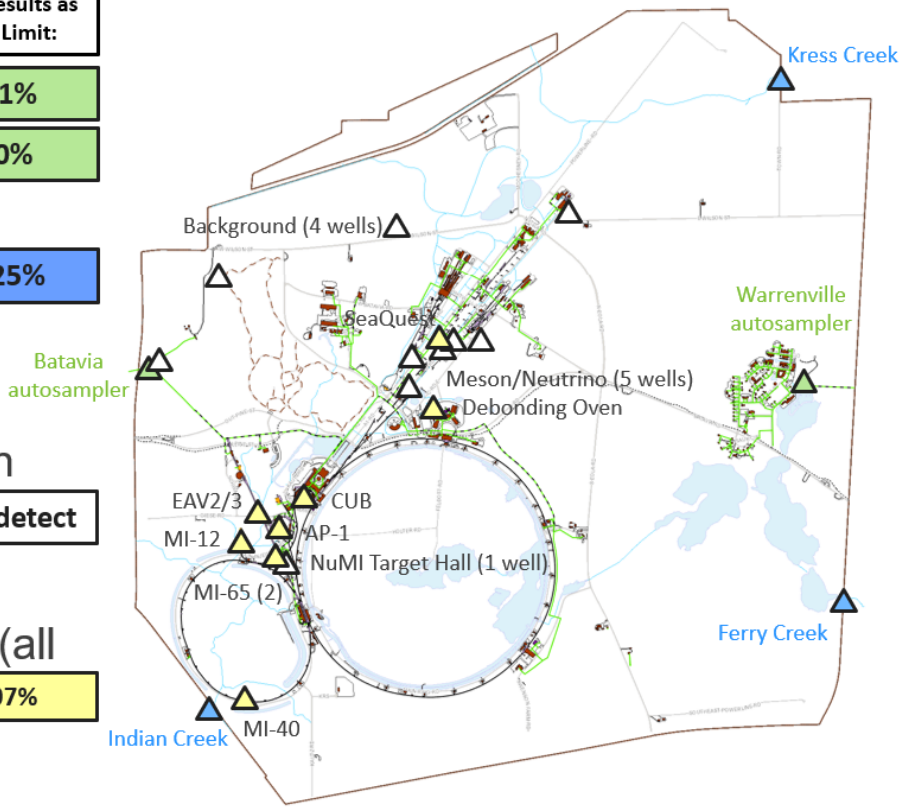
Brief Fermilab Tritium Management Timeline

- 2005
  - Cooling pond water with very low levels of tritium reached Indian Creek
  - Formation of first Tritium Task Force
- 2012
  - Tritium Working Group began tracing source(s) of tritium in sanitary sewer system
- 2016
  - Concentrations increased with beam power
  - Participated in an External Review of Tritium Management
    - Recommendation: reorganize into panels to maintain tactical strength but integrate into an overall task force approach
- 2017
  - Follow-up External Review validated and refined plans
  - Implement additional mitigation steps to prepare for even higher accelerator beam intensities

Tritium Discharges Relative to Regulatory Limits

- 2018 tritium results were well below regulatory discharge limits
  - Started additional monitoring to identify migration routes in more detail and develop effective mitigation measures

	2018 results as % of Limit:
Sanitary Sewer	
– 9,500 pCi/ml	0.1%
– 5 Ci in a year	10%
Surface Water	
– 1,900 pCi/ml	0.25%
Groundwater	
– 1 pCi/ml (Class 1 Resource Aquifer in bedrock)	Non-detect
Air	
– 10 mrem in a year (all radionuclides)	0.07%



Standards for Surface and Drinking Water

- DOE surface water limit: 1,900 pCi/ml (picocuries per milliliter).
- Federal limit for drinking water systems: 20 pCi/ml.

What do these standards mean?

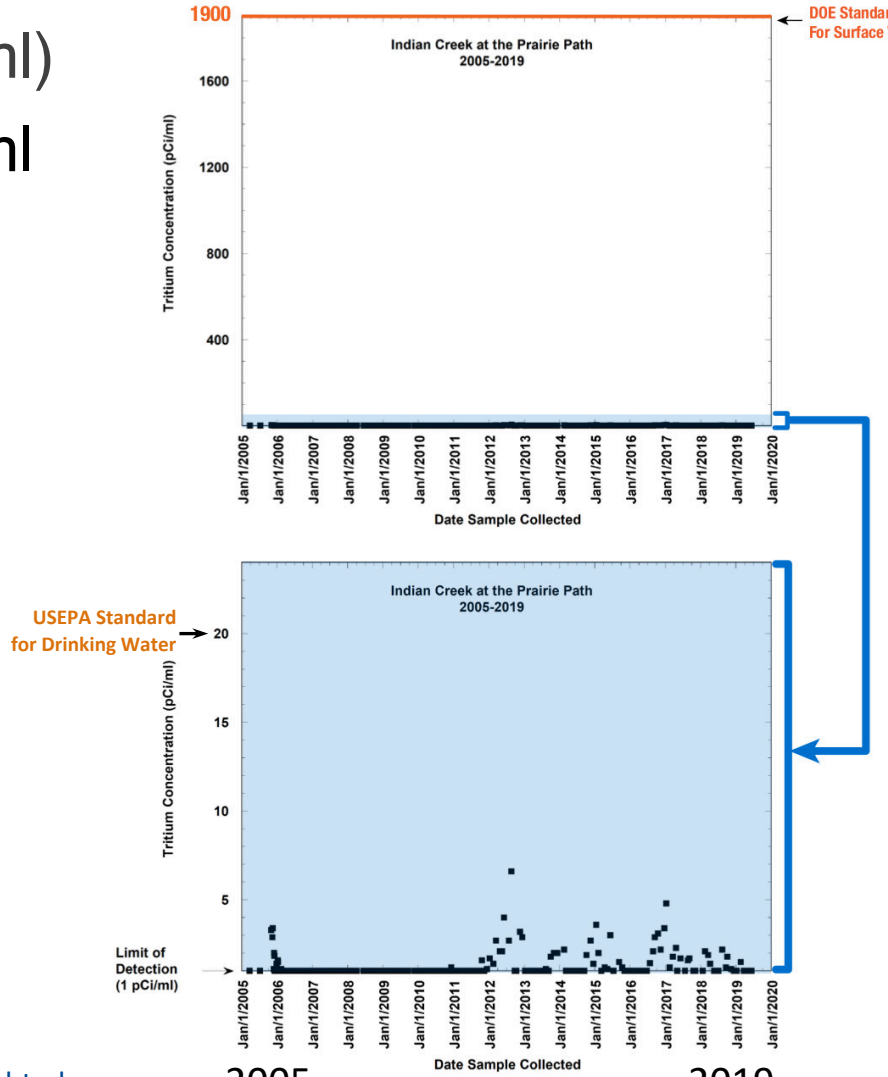
- 1 picocurie (pCi) = 0.037 atoms decaying each second.
- Threshold for measurement is usually taken to be 1 pCi/ml.
  - A user of 1,900 pCi/ml water for their household water source full time would receive a radiation dose of 100 mrem each year.
  - A user of 20 pCi/ml water for their household water 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 folks fish in it.

Surface Water Boundary Results: Indian Creek

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

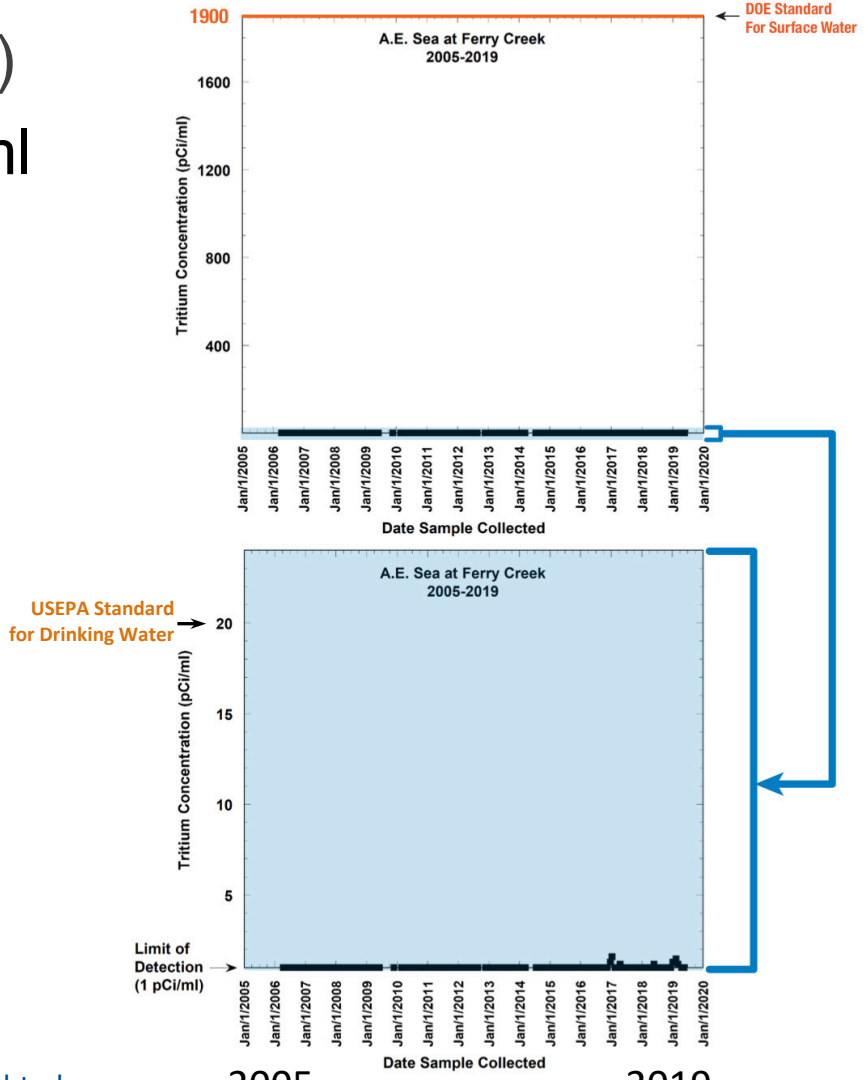


Data plot online at: https://www.fnal.gov/pub/tritium/indian-creek.html

Fermilab

Surface Water Boundary Results: Ferry Creek

- <2 pCi/ml (usually <1 pCi/ml)
- Regulatory limit: 1,900 pCi/ml

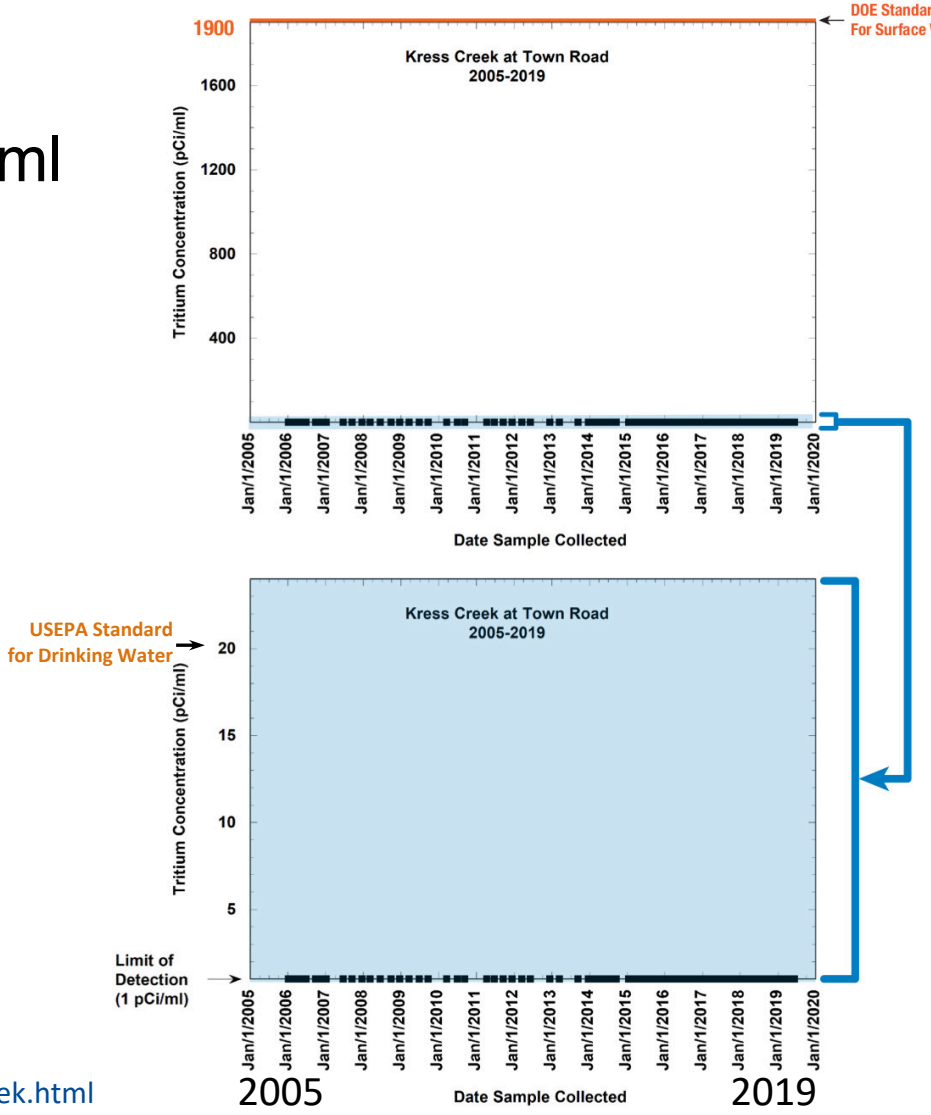


Data plot online at: https://www.fnal.gov/pub/tritium/ferry-creek.html

Fermilab

Surface Water Boundary Results: Kress Creek

- <1 pCi/ml
- Regulatory limit: 1,900 pCi/ml



Data plot online at: https://www.fnal.gov/pub/tritium/kress-creek.html

Fermilab

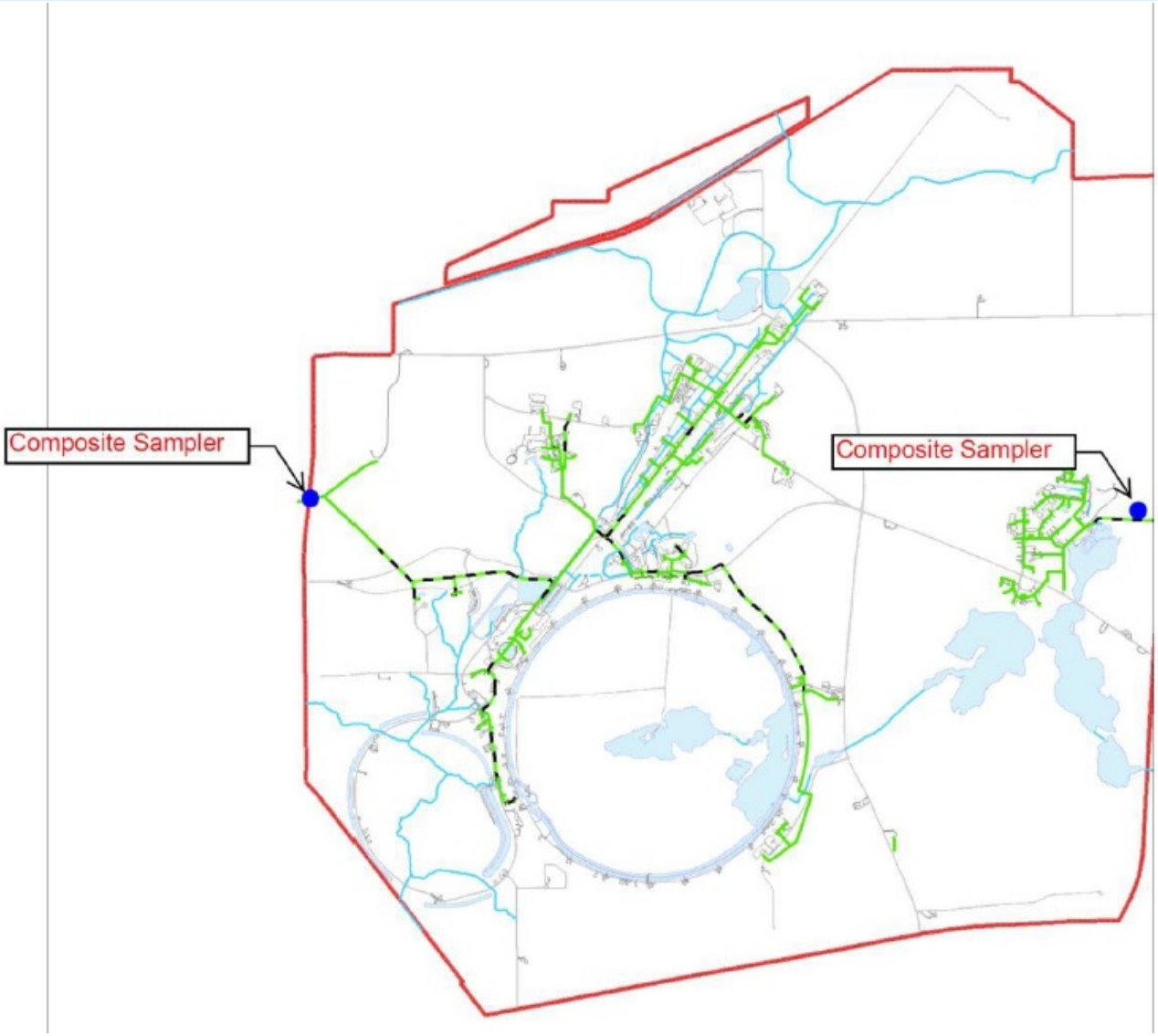
Fishing at Fermilab? – Not a concern!

- If someone were to catch and eat 50 pounds of fish each year, compared to a national average of 18 pounds, and
- If our ponds were at 1,900 pCi/ml of tritium,
- Their dose would be only 3.34 mrem, even if no water is cooked out of the fish.
  - All ponds (not just public ones) are below 50 pCi/ml, most are less than 10 pCi/ml.
- We see no need to restrict site access!

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

Monitoring Tritium in the Sanitary Sewer System



Requirements and Results for Sanitary Sewer

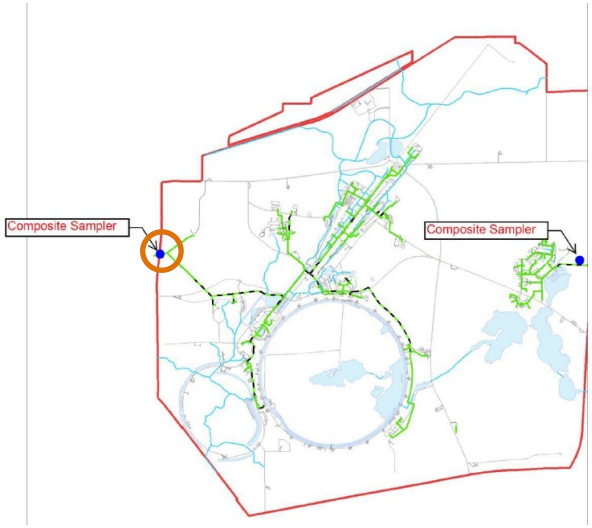
- A limit of 9,500 pCi/ml applies to sewer (DOE Order 458.1).
- A limit of 5 Ci to the total amount of tritium discharged to the sewers each year also applies.
  - Most sewage from Fermilab goes to Batavia, a little of it goes to Warrenville in separate systems.
- Sewer discharges must be reported to local municipalities (Batavia, Aurora, etc.) annually by the Department of Energy.
  - The DOE site office at Fermilab does this every year right after the end of the Federal *fiscal* year, i.e. after September 30.
  - CAB members receive the results, too.
- We have never found tritium in sewers going to Warrenville.
- We have found and reported low levels of tritium in sewers going to Batavia.

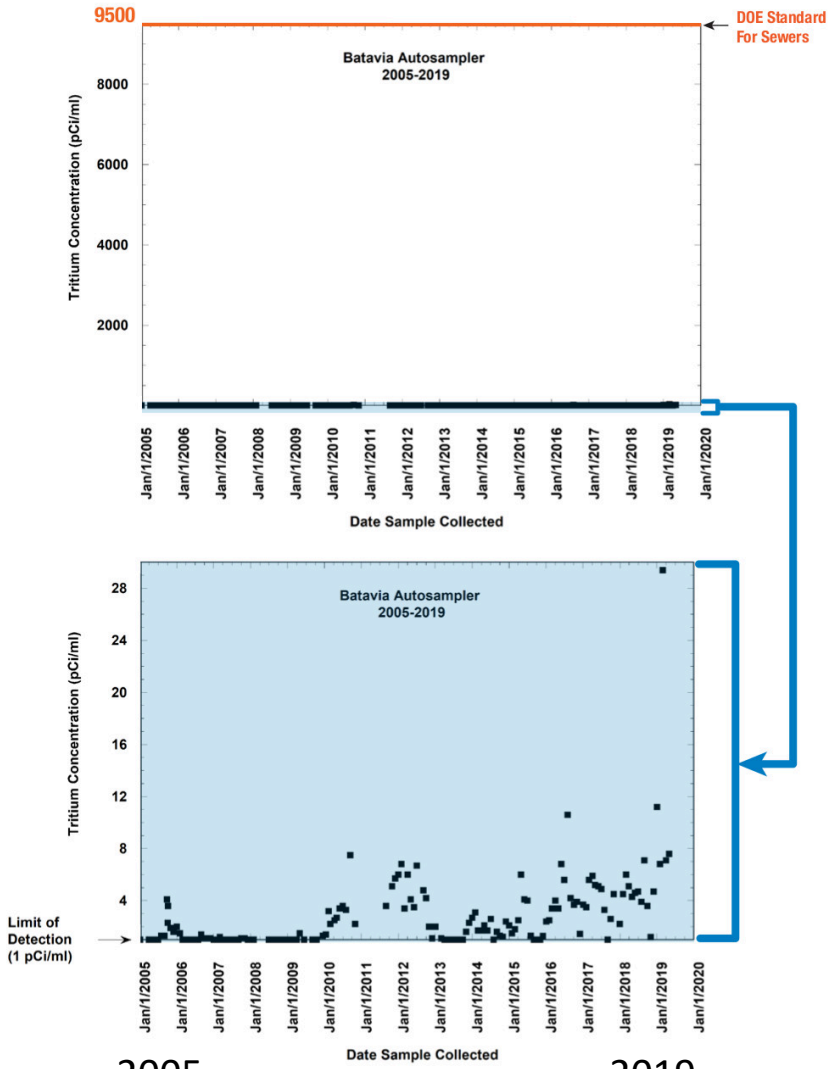
Low Levels of Tritium in the Sewer System

- Since 2005, we have seen measurable tritium concentrations in the Batavia, and only the Batavia, sewer system.
  - The low concentrations detected correlate to the tritium monitored from the NuMI beamline.
- Sewer discharge goes to Batavia sewage treatment plant, then into the Fox River, where the low concentrations get very much diluted.
  - Met with officials in Batavia and Aurora to inform and discuss
  - City of Aurora uses Fox River water for part of its water supply.
    - The tritium concentration in the river is less than 0.01 pCi/ml
- Possible connections between industrial cooling water and air emission systems, that do contain tritium, and the sewers are being investigated.

Sanitary Sewer Boundary Results: Batavia

- <30 pCi/ml (usually <12 pCi/ml)
- Regulatory limit: 9,500 pCi/ml
- 2016-2018 annual total activity loads are ~10% of 5 Ci limit





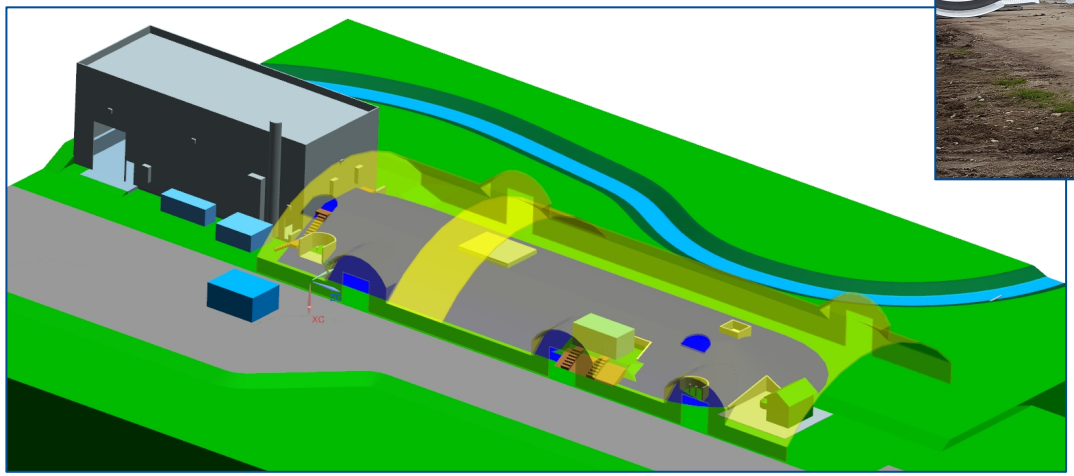
Data plot online at: https://www.fnal.gov/pub/tritium/indian-creek.html

Air Emissions

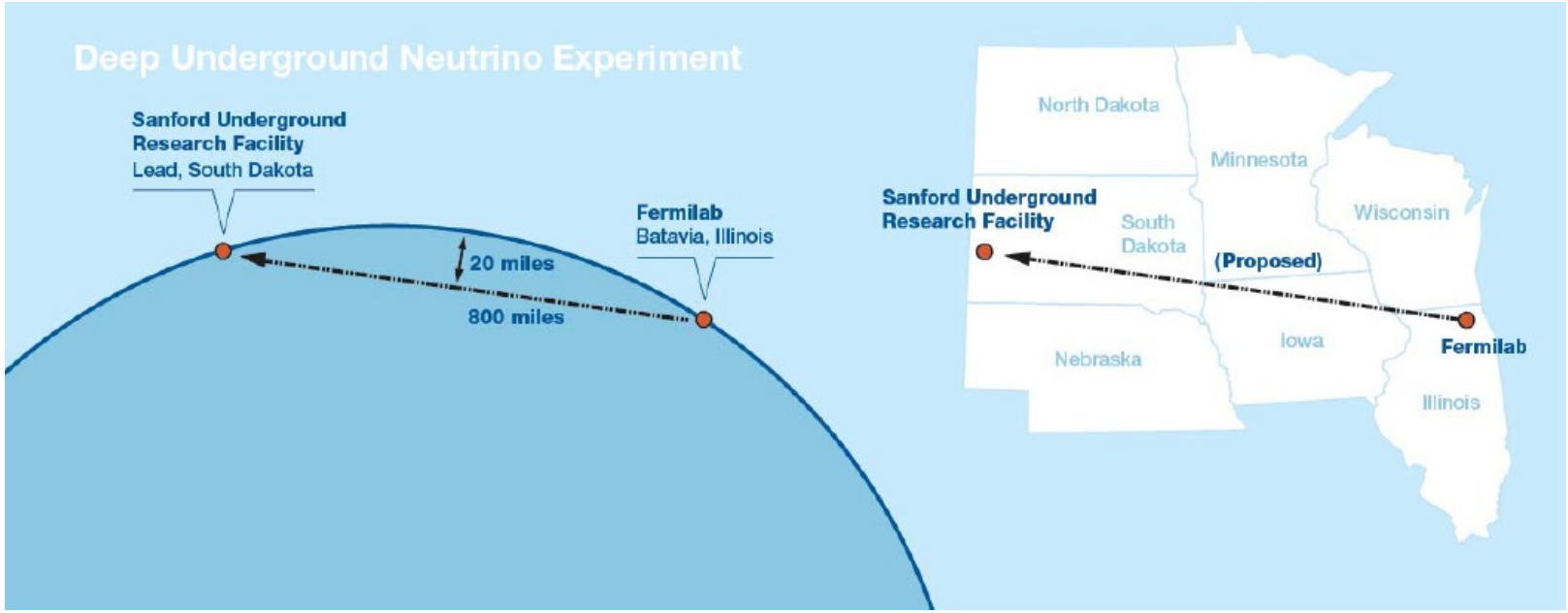
- Limits apply to airborne emissions of radionuclides.
- We sample our ventilation exhausts for radionuclides and identify the quantities and types of radionuclides emitted.
  - Verified by instrumentation that operates whenever our accelerators are operating.
- U. S. EPA limits our emissions to those that would result in a dose of 10 mrem to someone standing a full year on our property line.
  - We stay below 0.1 mrem each year for all radionuclides, not just tritium.

Example of a Recent Improvement

- Finished installation of canopy and liner over the BNB berm, under which we produce neutrinos for on-site experiments
  - They reduce moisture in the neutrino-producing area, which means less HTO is produced
- Initial results:
  - The newly completed canopy and surface liner have reduced vertical infiltration by ~80%



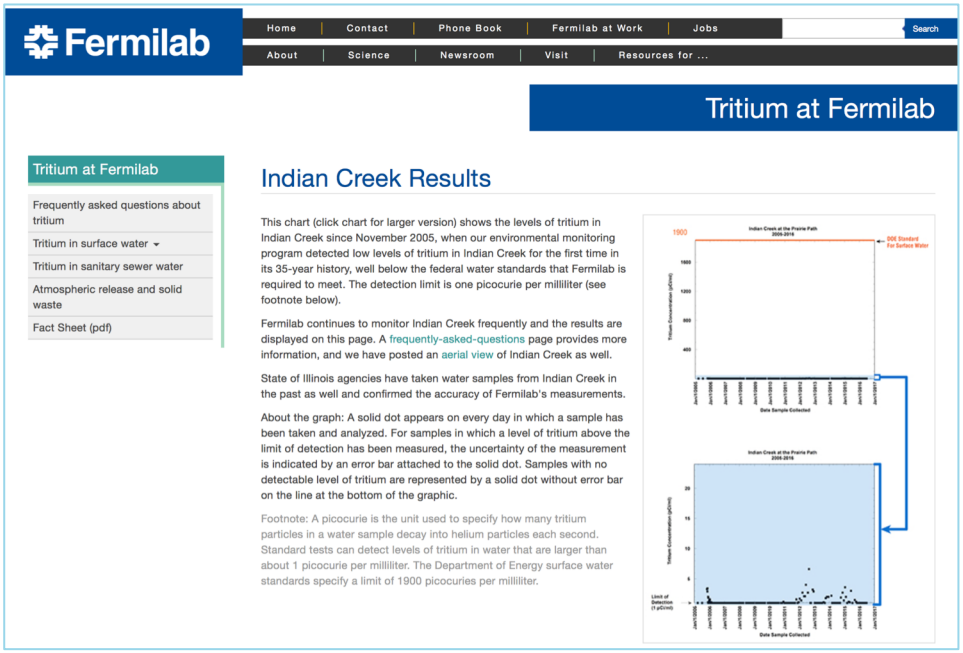
Future experiments: LBNF/DUNE



- 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?