Lessons learned decades after an oil spill faded from headlines

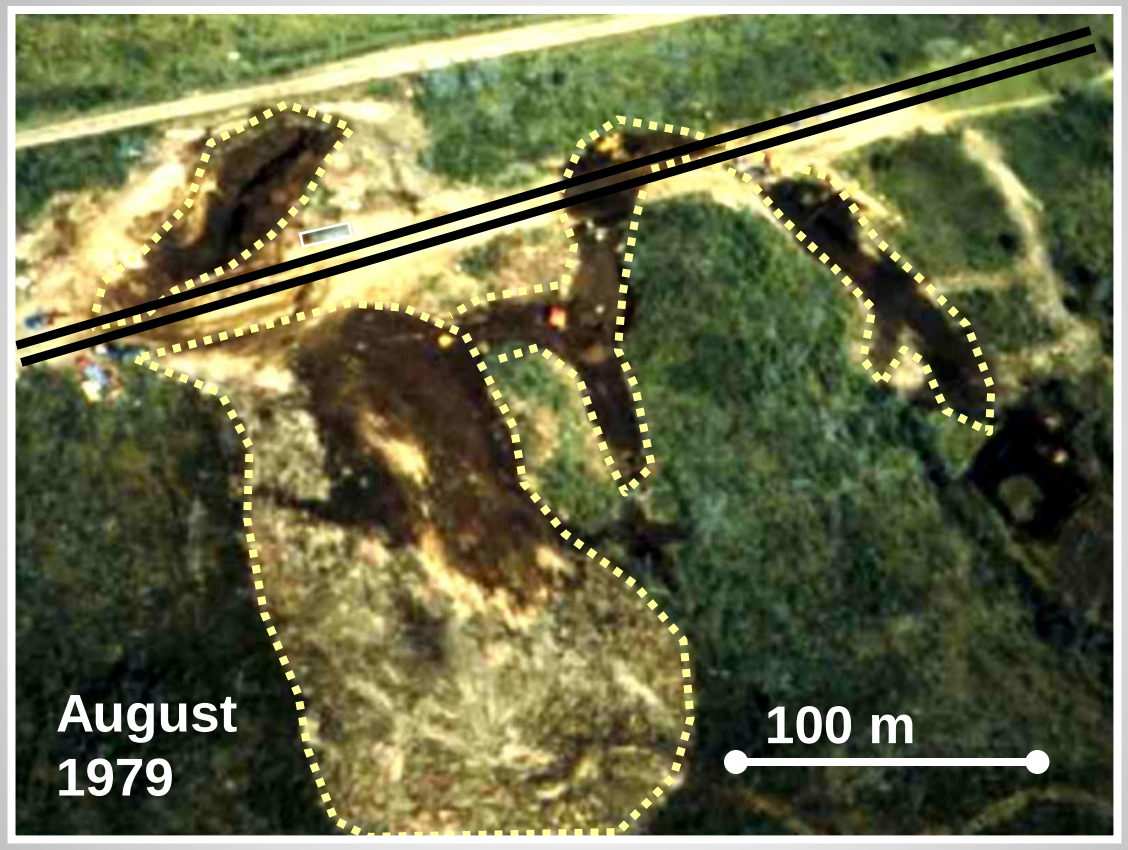


Photo credit: USGS Bemidji project archives

Minnesota

Jared Trost

U. S. Geological Survey

The story begins on August 20, 1979 when Line 3 ruptured

Buried line:
- 500 psi
- 34-inch

Spill:
- 441,000 gallons light crude oil

Cause:
- Bad weld

Setting:
- Sandy sediments
- Water table 1 – 36 feet below land surface

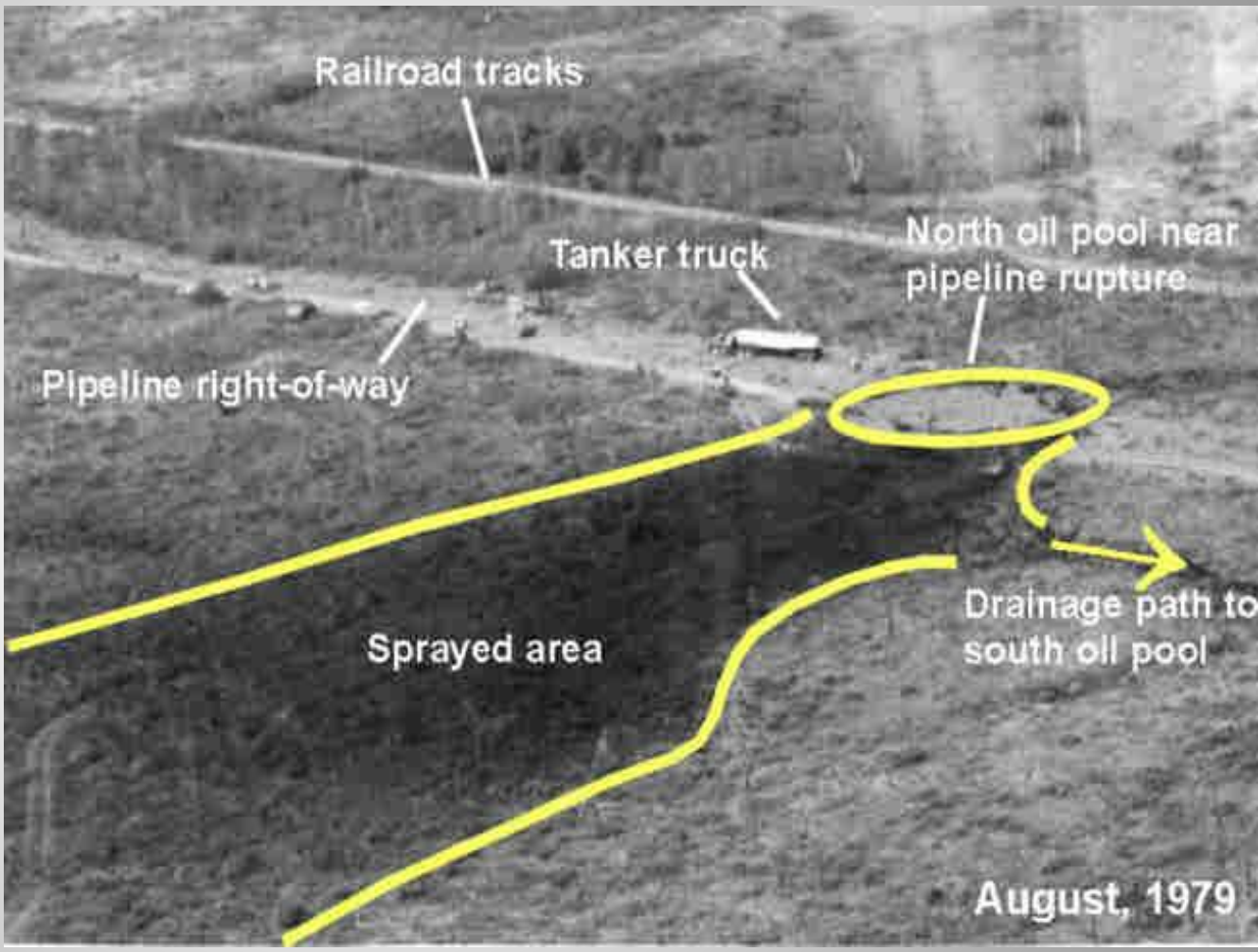


Photo credit: USGS Bemidji project archives

Delin et al., 1998; Natural Resources Engineering Company, 1998)

Crude oil

The crude oil, under approximately 401 pounds pressure at the point where the pipeline broke, evidently blew a small hole in the ground and gushed out for a short time until the pipeline was shut down by remote control from Edmonton, Alberta.

Effects of spill

A small rabbit showed the effects of the Lakehead Pipeline oil spill near Pinewood.

In June the council finally awarded a sewer and water project to [illegible] Underground, St. Cloud. The company successfully obtained a court order to block an award to another bidder and the apparent low bidder agreed to accept a cash settlement from North Central and the hospital.

At the hearing, for which no date has been set, City Manager Dan Daugherty will function as a hearing examiner and all interested parties will be allowed to testify. Daugherty will then make a recommendation to the council.

The council also agreed to postpone awarding a bid to extend sewer service to Diamond Point Park until after the hearing because Steele has also bid on that project.

The council also set a public hearing Sept. 17 to consider a $1.6 million industrial revenue bonding proposal for the Holiday Inn.

The Holiday Inn plans to add four banquet rooms and between 28 and 40 rooms to handle larger conventions.

However, the council added the stipulation that it was not approving or disapproving the proposal at this time. Several council members also questioned whether the hearing should be held until the Holiday Inn can meet the requirements for obtaining municipal revenue bonds.

Doug Cann, attorney for the motel, told the council that his client could not meet a provision requiring its net revenue for the past two years to be equal to the total of its debts, including the proposed bonds.

"It looks like we're doing things in reverse," said councilman Henry Stoutler.

(Continued on page 2)

Weather

Mostly cloudy, chance of showers and thunderstorms through Wednesday. High Wednesday mostly in the 70s. Low tonight upper 50s to middle 60s. Winds southeast to east 10 to 15 mph tonight. Probability of measurable precipitation 40 percent tonight and Wednesday.

Lakehead pipeline bursts near Pinewood

By JODY GRAU
Staff Writer

A crude oil pipeline owned by the Lakehead Pipeline Co. burst Monday morning about one and a half miles southeast of Pinewood sending up a geyser of oil which sprayed about ten acres of state-owned jackpine forest land.

The break in the line which runs from Edmonton, Alberta, to Superior, Wis., was reported to the company by a Soo Line maintenance man but the company's superintendent, Tom Gray, said the drop in pressure had already been monitored.

"I had already made the call to have the line shut down when we received the report," Gray said. He added that the portion of the line which is shut down lies between Clearbrook and Superior.

The oil settled into depressions along the Old Fosston Trail forming four pools. The largest of these formed at the break in the line and measured about 75 feet across and about two feet deep according to Willis Mattison, Detroit Lakes regional director of the state Pollution Control Agency.

Mattison said the only surface water apparently affected was a nearby sphagnum bog and that the major environmental concern would be to minimize the possibility of contaminating ground water by cleaning up the spill as quickly as possible.

Lakehead dispatched a clean-up crew immediately following the blow out at about 2:45 a.m. and began calling oil tankers into the area to transport the liquid spill.

Gray said the liquid would be taken to the pump station at Clearbrook and injected back into the other two Lakehead lines. He added that cleanup operations would go on throughout the night.

Mattison reported late yesterday afternoon that eight 8,000 gallon tankers had been filled and that the line was still draining oil. He also estimated that the oil had penetrated about eight inches into the sandy soil.

Jim Mattsson, a wildlife biologist for the Federal Fish and Wildlife Service, said that from what he could see yesterday afternoon the impact on area wildlife would be small.

Although it's possible that waterfowl might mistake the oil for water when they come in to land for the evening, according to Mattsson the number of birds that might be affected would be small. He added that the spill would probably have very little or no effect on deer and other wildlife.

W.C. Cochrane, general manager of Lakehead, said they had no way of knowing what caused the line to burst until they could uncover the line.

"The line was not operated in excessive pressure according to all of our readings," Cochrane said.

Cochrane added that another line breakage had occurred about six years ago but that all the lines had been hydrostatically retested following that incident.

Clean-up workers will probably be working at the spill site for more than a week, according to Cochrane, but around the clock efforts will cease as soon as all the liquid has been pumped up.

Retains DFLer lawyer for case—

Employer claims conflict, fires Republican lawmaker

ST. PAUL (AP) — A Minnesota lawmaker has been fired from his job as a district insurance manager because the company says he can't handle both lawmaking and insurance duties.

Rep. John S. Bierndorf, Owatonna, said he was terminated by Federated Insurance Companies after 13 years as a district manager.

He said the company believes he is a fulltime legislator and can't perform both jobs.

The action could precipitate the first test of a 1974 law that appears to safeguard the private industry jobs of Minnesota legislators.

Bierndorf, an Independent-Republican, has retained the legal services of state Rep. Harry Sieben, a DFLer from Hastings who serves as DFL leader in the House.

Sieben declined to say what action might be taken.

Bierndorf, 54, has been with the Owatonna company for 13 years. He was elected in 1970 and said an arrangement was made at that time under which some, but not all, of his business accounts were assigned to other sales personnel.

"While you're up here, you can't sell as much but I've always felt I've been able to handle the service of my accounts," Bierndorf said in an interview.

The 1974 law says that any legislator who held a permanent job with a private employer when he entered legislative service "shall be continued or restored to such position, or to a position of like seniority, status and pay."

The law says the restoration to a private job must be done

(Continued on page 2)

Bemidji Pioneer, August 21, 1979

210,000 Gallons of Crude Oil Spill In Minnesota Field From Pipeline

The New York Times

PINEWOOD, Minn., Aug. 21 (AP) —34-inch pipeline burst near here yesterday, dumping 210,000 gallons of crude oil onto several acres of brushland, the Minnesota Pollution Control Agency said.

"The oil is contained within several acres and did not reach any waterway," said George Marks, manager of rights of way and claims for the Lakehead Pipeline Company of Superior, Wis., which operates the line.

The spill occurred on uninhabited brush land owned by Beltrami County, a mile and a half from this northwestern Minnesota town. Ralph Kaus, Lakehead district clerk in Bemidji, said the broken line was shut down immediately at Edmonton, Alberta, in Canada.

The line carries crude oil from Edmonton to Superior, where it branches into two smaller lines carrying oil to the upper Middle West.

Mr. Marks said three Lakehead crews, a total of 18 men, were dispatched to the scene and began pumping the oil remaining in the line into transport trucks.

https://www.nytimes.com/1979/08/22/archives/210000-gallons-of-crude-oil-spill-in-minnesota-field-from-pipeline.html

Cleanup underway at oil spill near Pinewood

By JODY GRAU
Staff Writer

Clean-up efforts at the site of Monday's crude oil spill just southeast of Pinewood continue, but apparently not always in accordance with state Pollution Control Agency standards.

Lakehead Pipeline Co. officials unnecessarily dumped about 100,000 gallons of oil onto the ground in direct opposition to a PCA recommendation, according to Willis Mattison, Detroit Lakes regional manager of the PCA.

Mattison said that about 100,000 gallons of oil had to be pumped out of the pipe to allow for the replacement of the split section and that he had recommended that the oil be pumped directly into tankers for transport. Instead it was pumped onto the ground, he said.

"The agency will have to decide what additional environmental aggravation this action may cause and then decide on what type of enforcement recourse should be followed," said Mattison.

He added that he fully expected some type of recourse to be taken and did not rule out the possibility of the matter ending up in court.

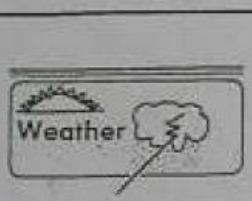
"It seems that getting the pipeline back in operation was their primary concern," Mattison said, adding that at one point Lakehead had 22 people working on replacing the pipeline and only two pumping oil.

Mattison said this morning that he now fears the ground water may be contaminated, which would render the water table in the area totally useless.

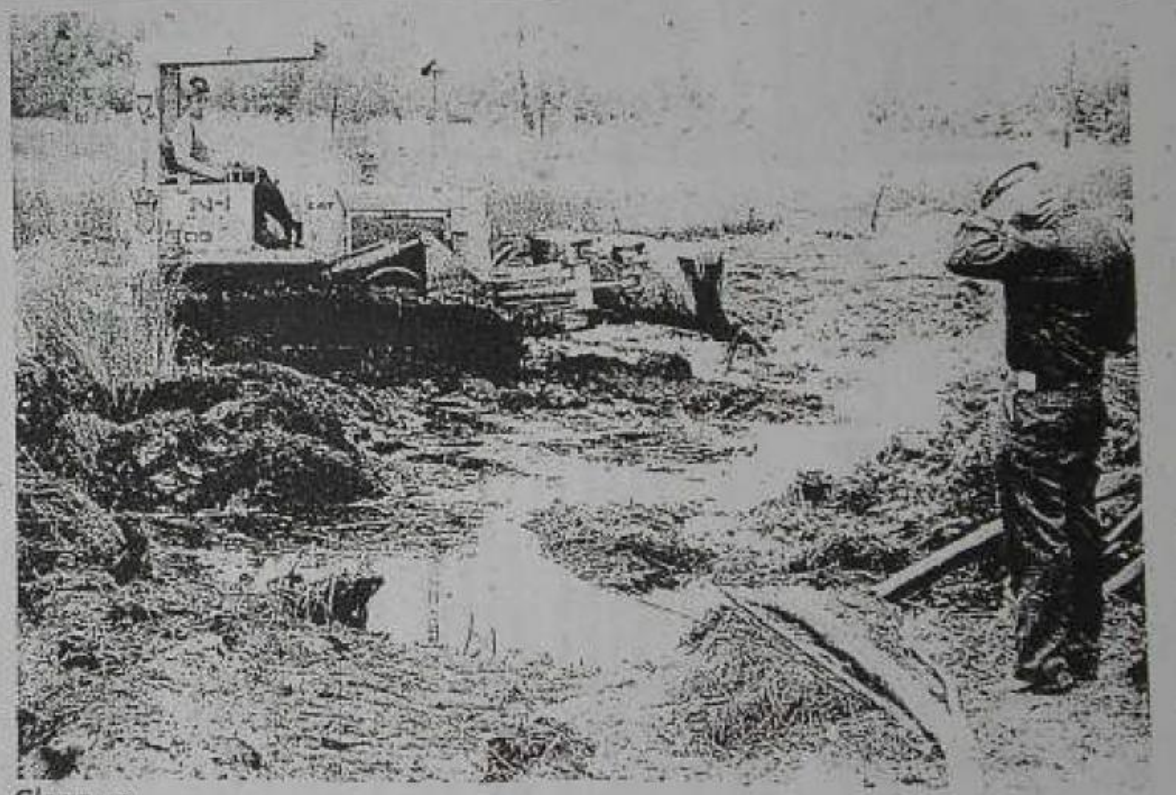
Soil boring operations were under way today and at 11 a.m. incomplete results showed that saturated oil is present down to 15 feet and that oil continues to be present down to at least the depth of 21 feet. Crew members said the soil is sand down to 21 feet and that they hit silty sand at that point and would continue to drill.

Mattison said oil residue breaks down very slowly under ground and that

(Continued on page 13)



Showers and thunderstorms ending this evening with partial clearing by late tonight. Low mid to upper 50s. Thursday partly sunny. High mid to upper 70s. Winds northerly under 10 mph tonight. Probability of measurable rain 30 per cent tonight.



Clean up underway

A bulldozer was being used today at the oil spill site near Pinewood to route oil covered marsh water into pools so that the oil can be pumped off the surface.

Pioneer photo by Jody Grau

Bemidji Pioneer, August 1979

Remediation included: excavation, pumping, and burning

Photo credit: Bemidji Pioneer, August 1979

Photo credit: USGS Bemidji project archives

Photo credit: USGS Bemidji project archives

Photo credit: USGS Bemidji project archives

USGS science for a changing world

Pioneer photo by Jim Almendinger

250,000 gallon break!!!

Nearly a quarter of a million gallons of crude oil poured out of this split section of a Lakehead Pipeline Co. line near Pinewood Monday. Lakehead officials said the pipe would undergo metallurgical testing to determine what caused the four-and-a-half foot rent in the 34-inch line.

Oil clean-up to take months

PINEWOOD, Minn. (AP) — The cleanup of crude oil from a pipeline break north of Bemidji this week will take months, a Minnesota Pollution Control Agency official predicted Thursday.

The project is being complicated by the fact that some of the oil has seeped into the water table 15 feet below ground level.

An estimated 210,000 gallons of crude oil Monday poured from a ruptured 34-inch pipe carrying oil from Edmonton, Alberta, to Superior, Wis. The break occurred near Pinewood, about 30 miles northwest of Bemidji.

Lakehead officials have indicated that the total amount of oil lost in the spill may be as much as 250,000 gallons.

Richard Cable, head of the spills unit of the Minnesota Pollution Control Agency, said officials were trying to determine which direction the underground water was moving and were studying ways of removing the oil.

"The cleanup will take months, depending on what we have to do," Cable said. "And this could be something that would continue for years because we will to continue monitoring the spill site."

Officials of Lakehead Pipeline Co. estimated that the cleanup work would cost the company at least $150,000.

"We'll have to pay for cleaning up the oil, restoring the land as much as possible and possibly even reforesting the area," said Wes Cochrane, Lakehead vice president. "We'll do what has to be done, then add up the cost."

The pipe burst along a lateral weld and the pumps were automatically shut down by monitoring equipment that detected a pressure drop. A geyser of oil shot into the air when the pipe broke, covering five acres of vegetation and forming several large pools of oil. Tanker trucks hauled away considerable standing oil as repairs were completed on the broken line.

Cochrane said the section of pipe that broke would undergo metallurgical testing to determine why it failed. He said the oil in the pipeline at the time of the rupture was running at a pressure of 500 pounds per square inch, well below the maximum operating pressure of 656 pounds.

"We don't know what caused the break, but it wasn't pressure," the Lakehead official added.

John Aho, a MPCA geologist, went to the scene to determine what methods of containing and removing the oil would be most effective.

"The crews are working in a sandy, bog area, which makes removal of the oil more difficult," Cable said. "When we determine which way the water is moving, we can set up pumps downstream and try to remove it."

Trenches at least as deep as the water table probably will be dug around the perimeter of the spill to aid in recovery and to keep the oil from spreading, Cable said. He added that all of the contaminated soil may have to be removed.

Northern Tier

WASHINGTON (AP) — The Energy and Agriculture departments say the Northern Tier pipeline proposal is the best way to bring Alaska crude oil from the West Coast to the Midwest. It is the only one of four proposed pipelines that would lie entirely in the United States.

The proposal by the Northern Tier Pipeline Co. was the only one to receive more than one recommendation from federal agencies asked to comment on the plan.

One proposal, that of the Kitimat Pipe Line Ltd., was not picked by any of the federal agencies involved.

Interior Secretary Cecil Andrus must recommend one of the proposals to President Carter by Oct. 15. Carter will make the final decision.

The proposals have sparked sharp disagreement among the federal agencies involved, according to their comments released Thursday by the Interior Department.

The Pioneer

Serving the Minnesota North Country since 1896

Bemidji Pioneer, August 1979

A few decades later…

The story has changed…

StarTribune

In Bemidji, a research site reveals secrets of an oil spill

The site of a pipeline rupture has become a research center unlike any other in the world.

By David Shaffer Star Tribune | JUNE 15, 2014 — 7:12PM

wtopnews

wtopstaff
June 8, 2014, 5:06 PM

Minnesota oil spill of 1979 still aids in research

At an old Minnesota oil spill site, scientists discover oil-eating microbes

MPRnews

Dan Gunderson Bemidji, Minn. June 4, 2014 9:00 a.m.

https://www.startribune.com/in-bemidji-a-research-site-reveals-secrets-of-an-oil-spill/263118021/

https://wtop.com/news/2014/06/minnesota-oil-spill-of-1979-still-aids-in-research/

https://www.mprnews.org/story/2014/06/03/bemidji-oil-spill-site-research

USGS science for a changing world

Sometimes the headlines miss important things

There is widespread petroleum contamination left in place that isn't from pipelines…

- Over 550,000 Leaking Underground Storage Tanks releases nationwide (USEPA, 2021)
- Risk-Based Corrective Action for cleanup
- In Minnesota 8,360 (~44%) sites are marked as having contaminant remaining* (MPCA, 2021)

*based on the best readily available information, may represent a minimum.

Photo credit: https://www.nachi.org/underground-fuel-storage-tank-hazards-inspection.htm

USGS science for a changing world

Outline of Bemidji Research Talk

- Introduction to USGS research and site
- Description of biodegradation processes
- Long term changes
  - –Crude oil source zone
  - –Groundwater plumes

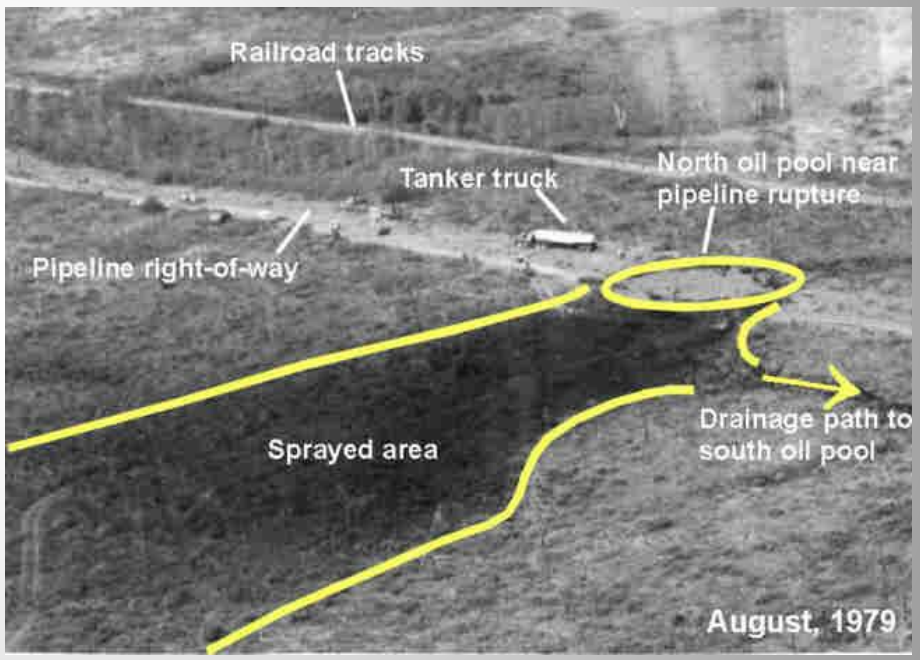


Photo credit: USGS Bemidji project archives

Bemidji Site Research

- Began in 1983
- Part of the USGS Toxic Substances Hydrology Program
- Goals
  - Study the fate, transport, and natural attenuation of crude oil and refined petroleum fuels in the subsurface
  - Provide results to industry, consultants, regulatory, educational, and research institutions

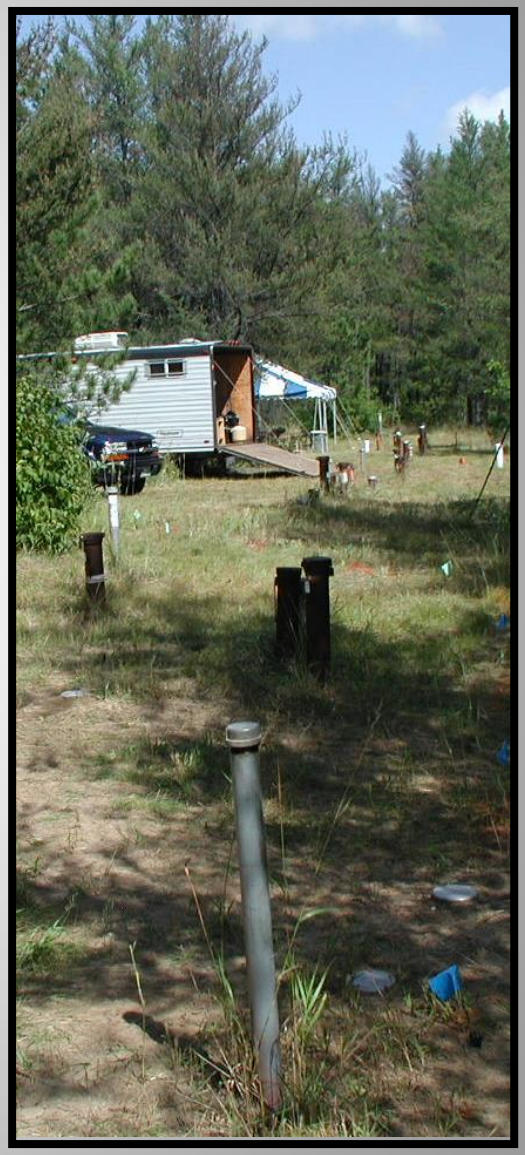
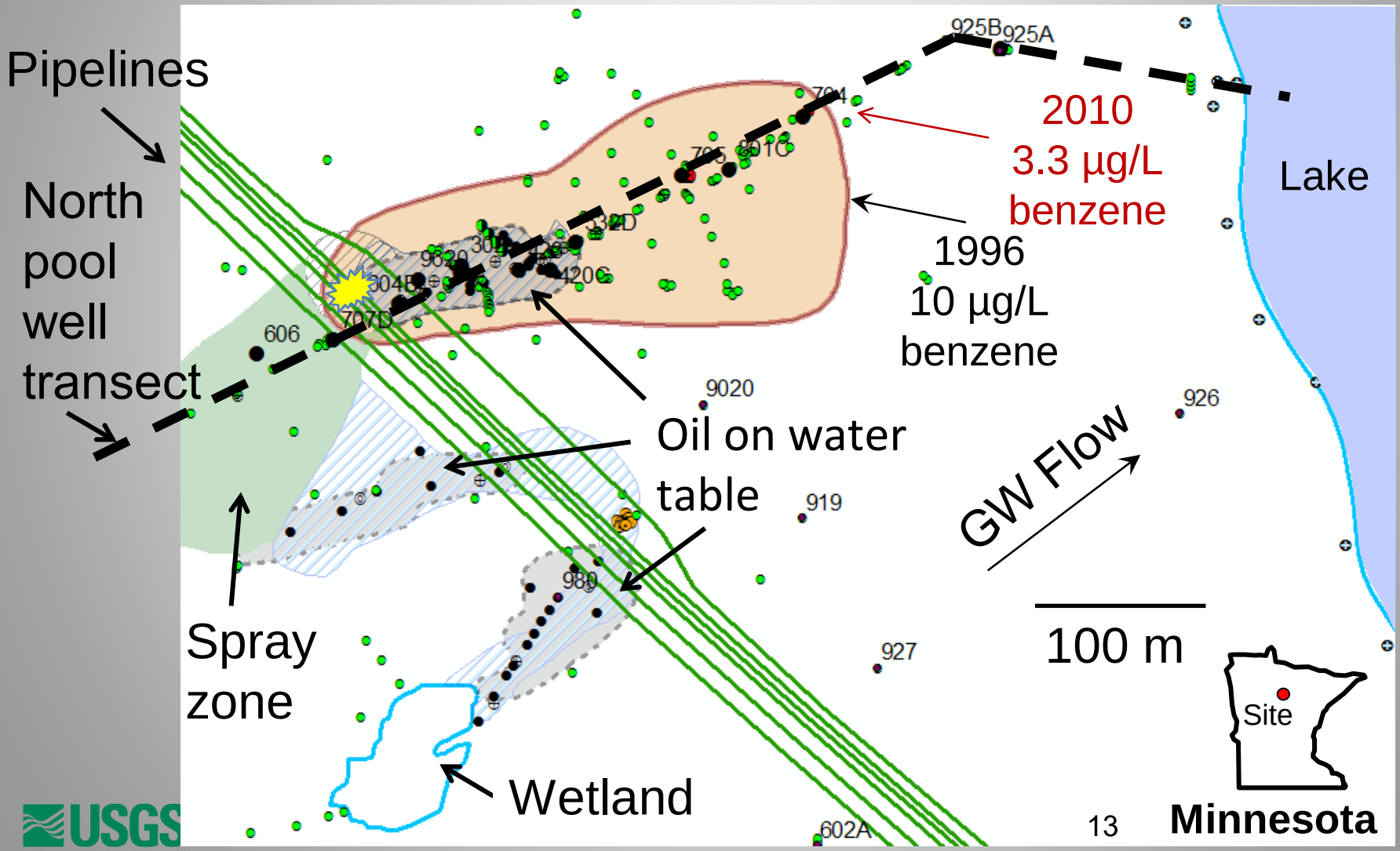


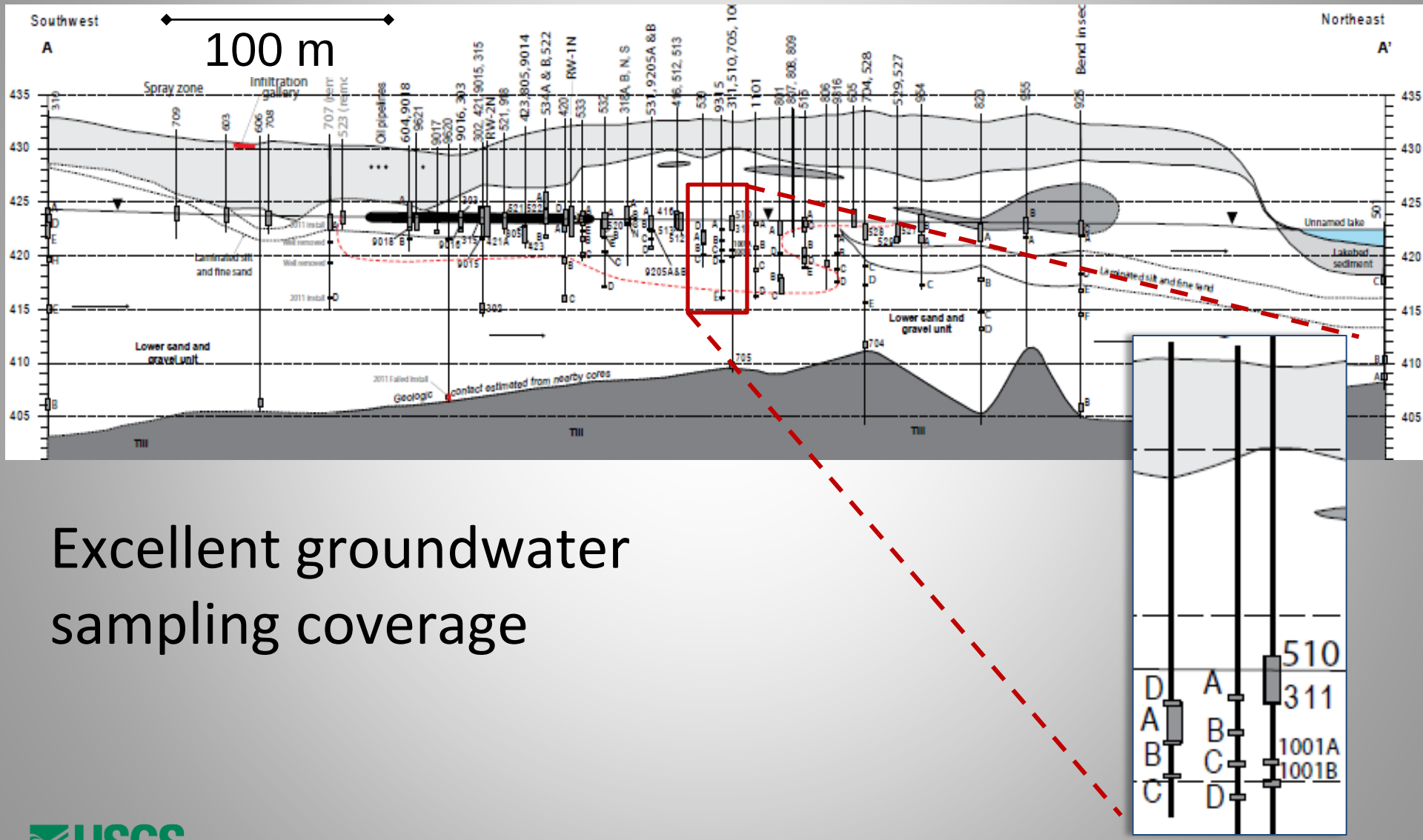
Photo credit: Geoff Delin, USGS

USGS science for a changing world

The site: an underground observatory comprising 300+ water, oil, and vapor observation wells used to study the spray zone, oil source zone, and groundwater plume



North Pool Well Transect

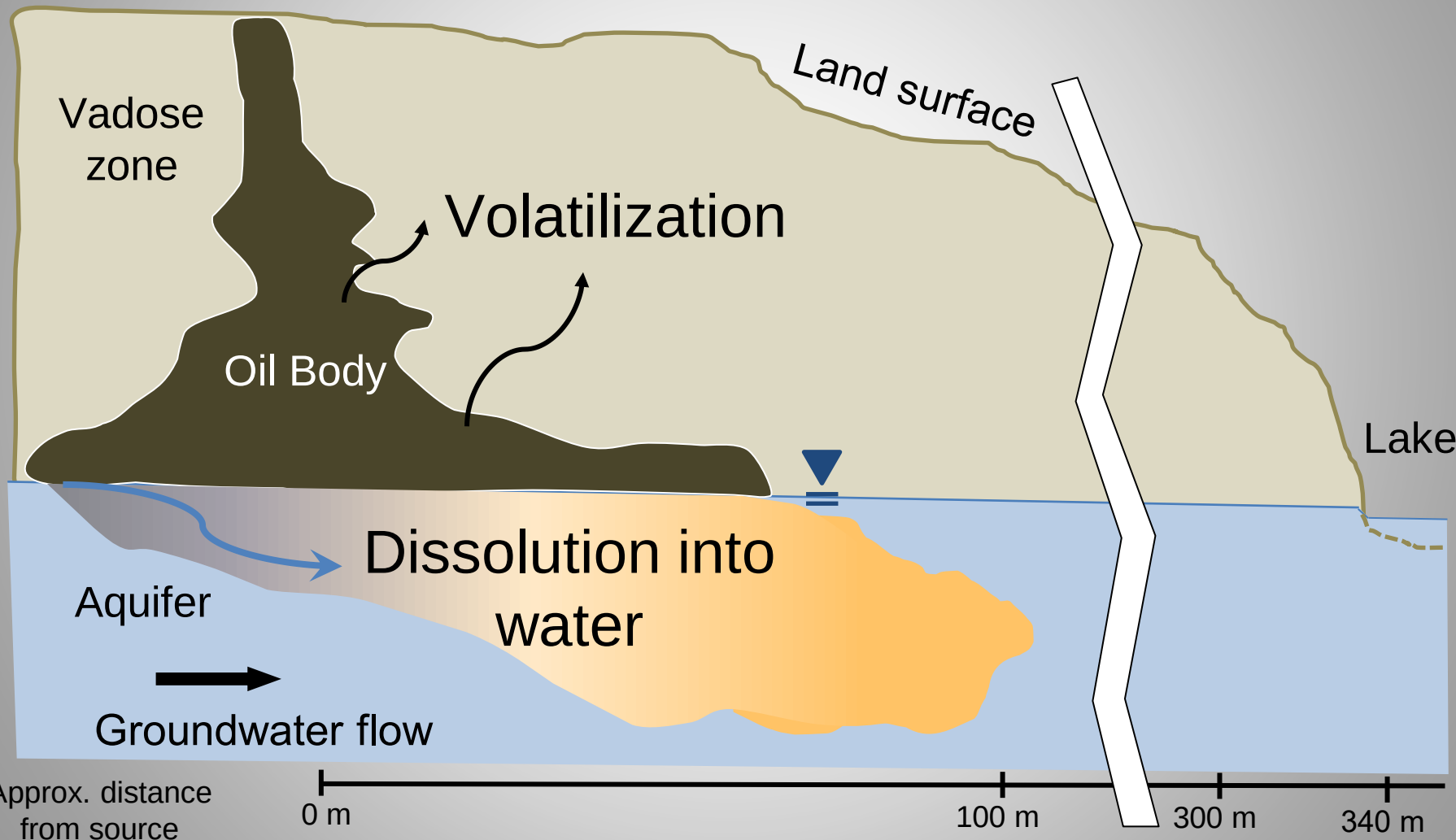


Excellent groundwater sampling coverage

http://mn.water.usgs.gov/projects/bemidji/spatial/Current/xsection.pdf

Processes by which components of the oil move away from the spill site

Biodegradation occurs on these components



Not drawn to scale

Adapted from Ng et al., 2015, DOI: 10.1002/2015WR016964

USGS science for a changing world

Bacteria transfer electrons in Redox reactions to get energy

Reduced carbon
(excess electrons)

Oxidized carbon

Electrons

Oxygen

Aerobic

Nitrate

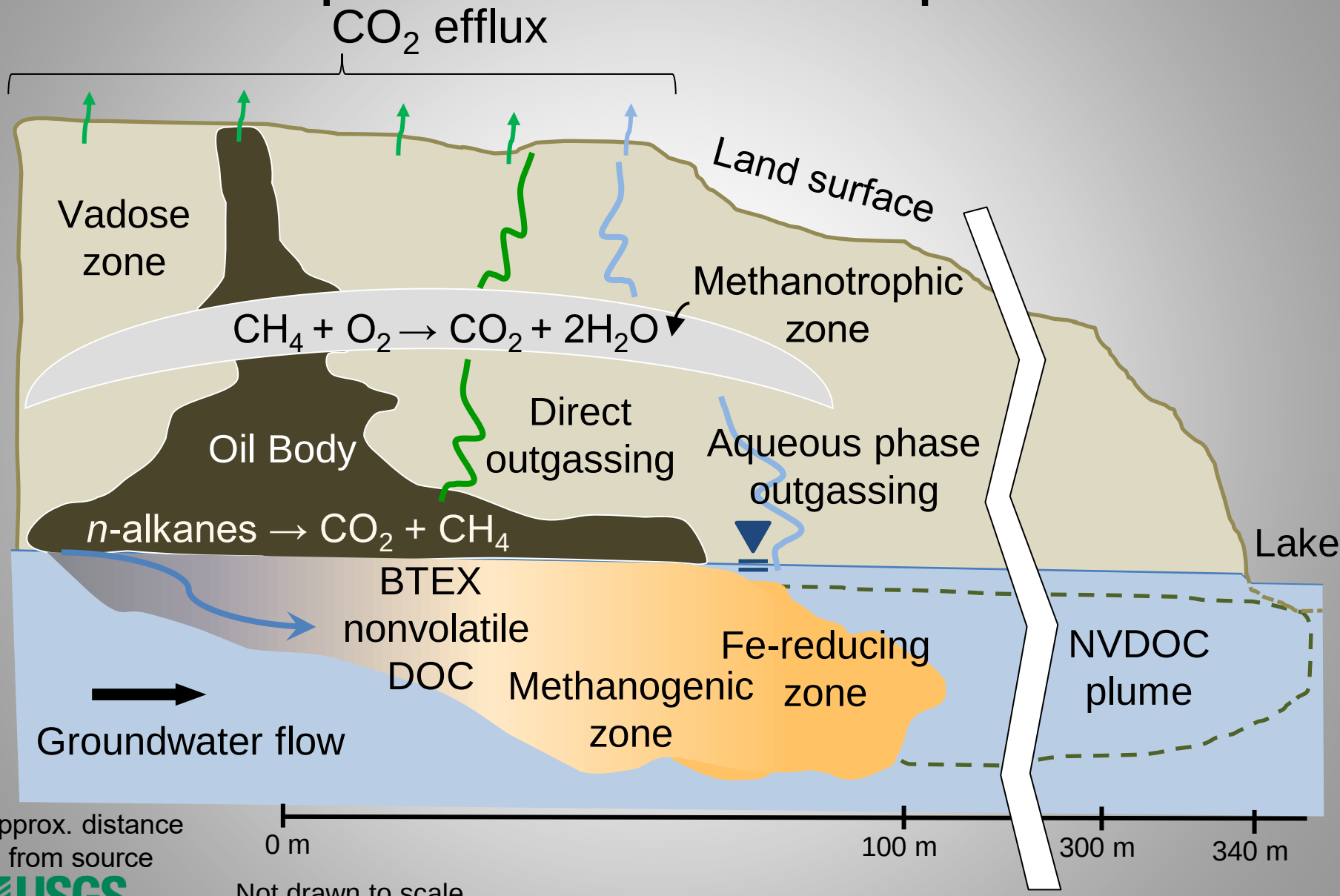
Iron

Sulfate

Anaerobic

Carbon dioxide

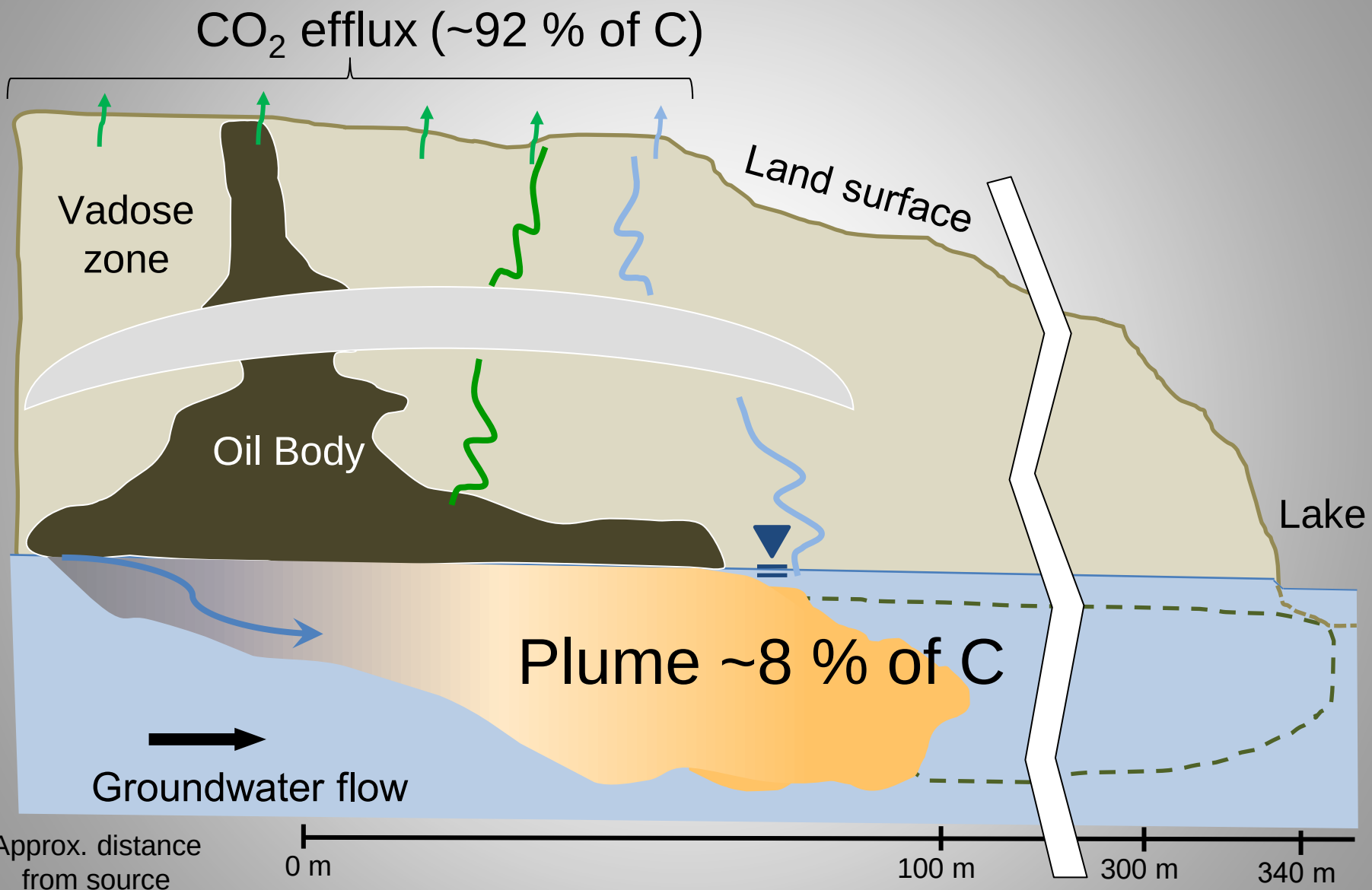
Conceptual model of site processes



Not drawn to scale

Adapted from Ng et al., 2015, DOI: 10.1002/2015WR016964

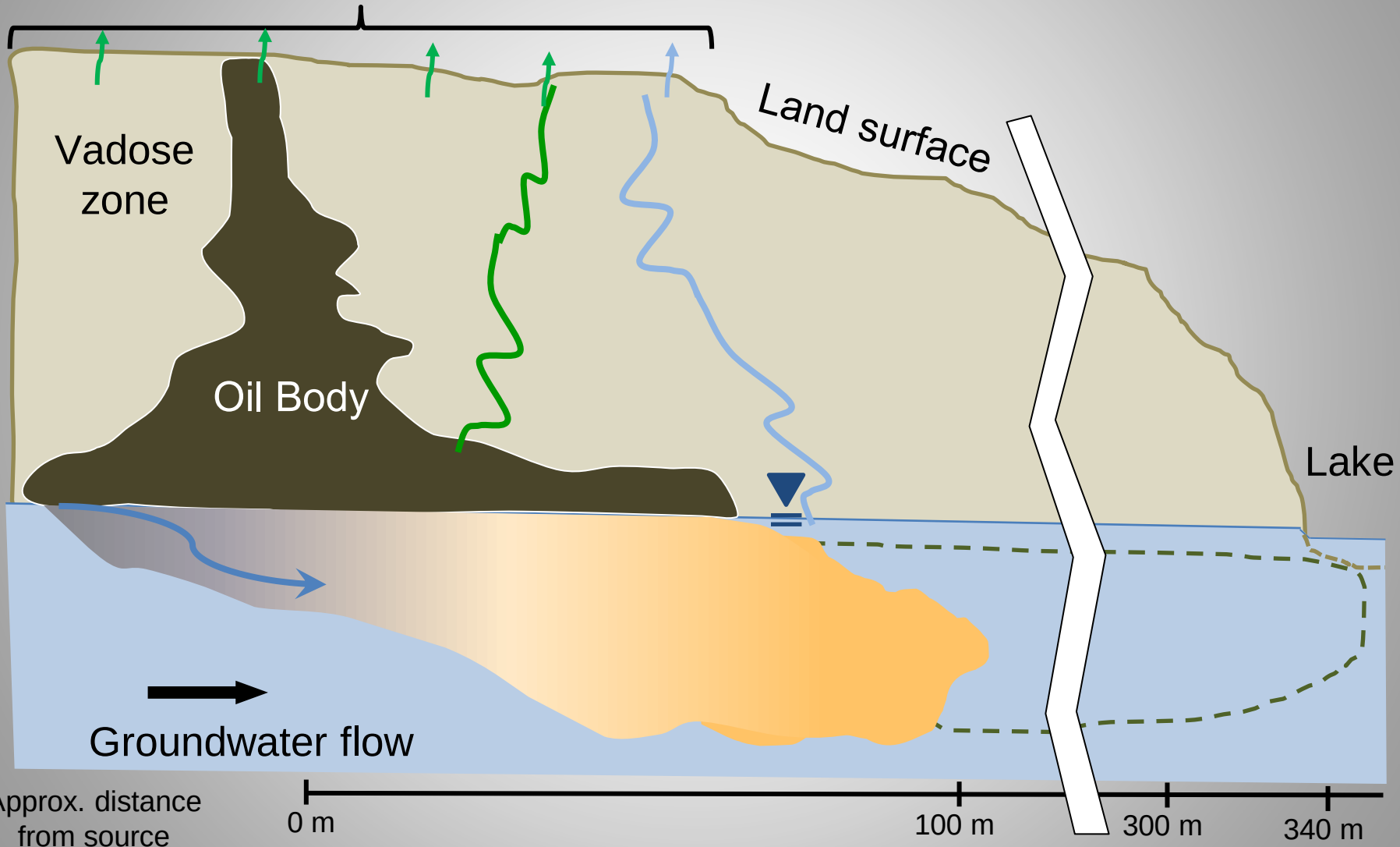
Conceptual model of site processes



Not drawn to scale

Adapted from Ng et al., 2015, DOI: 10.1002/2015WR016964

The crude oil source zone

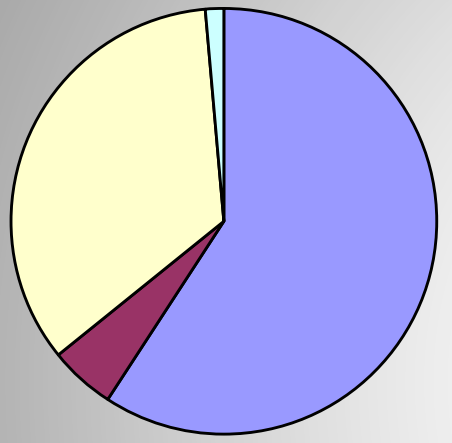


Not drawn to scale

Adapted from Ng et al., 2015, DOI: 10.1002/2015WR016964

The crude oil source

Composition

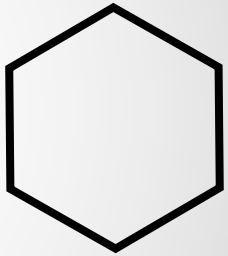


Eganhouse et al. 1993

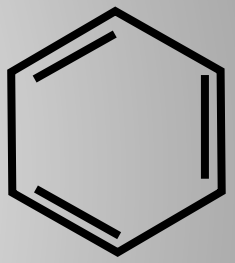
Saturates

Aliphatics

Cycloalkanes

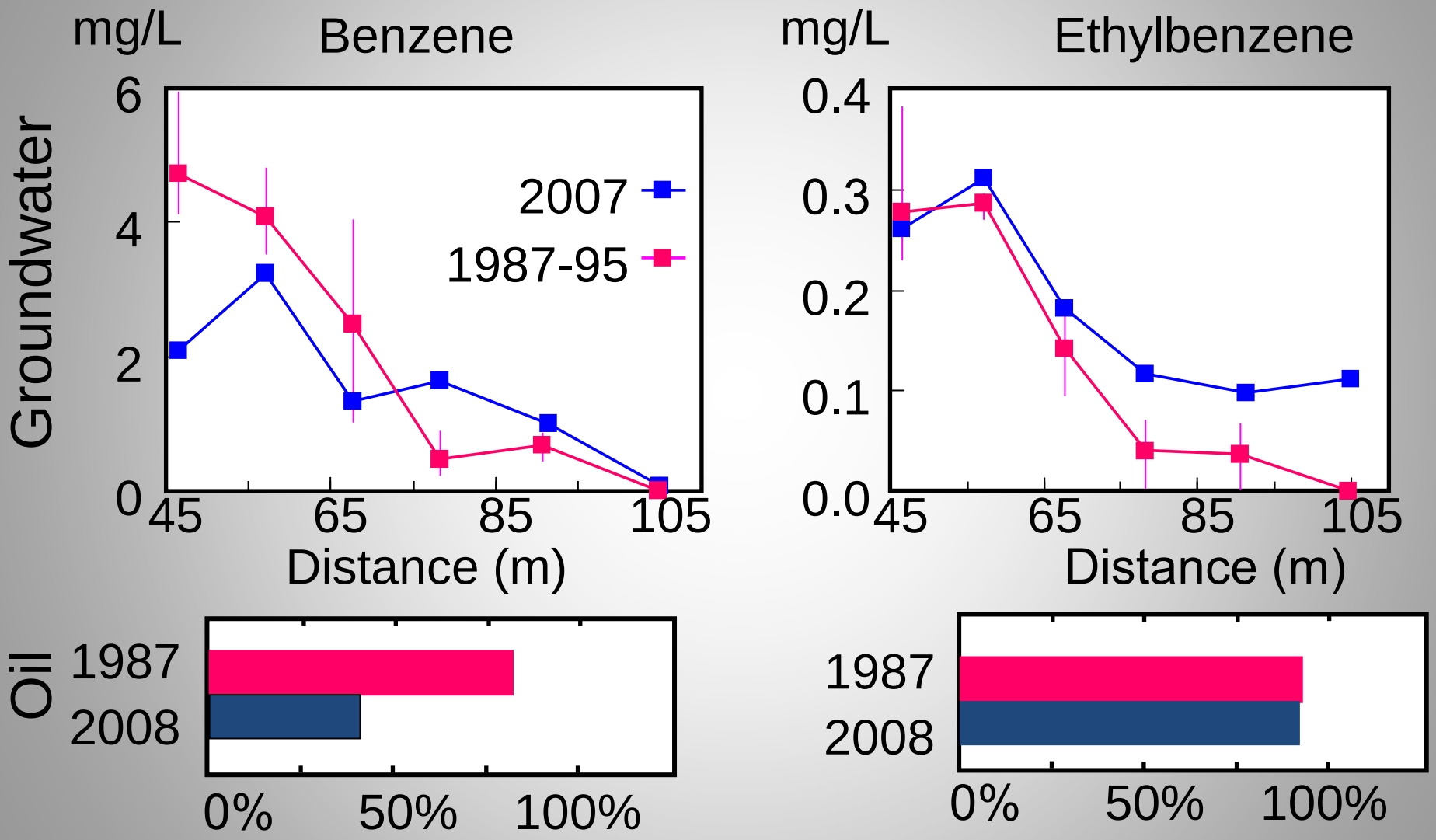


Aromatics



USGS science for a changing world

Groundwater changes reflect oil composition



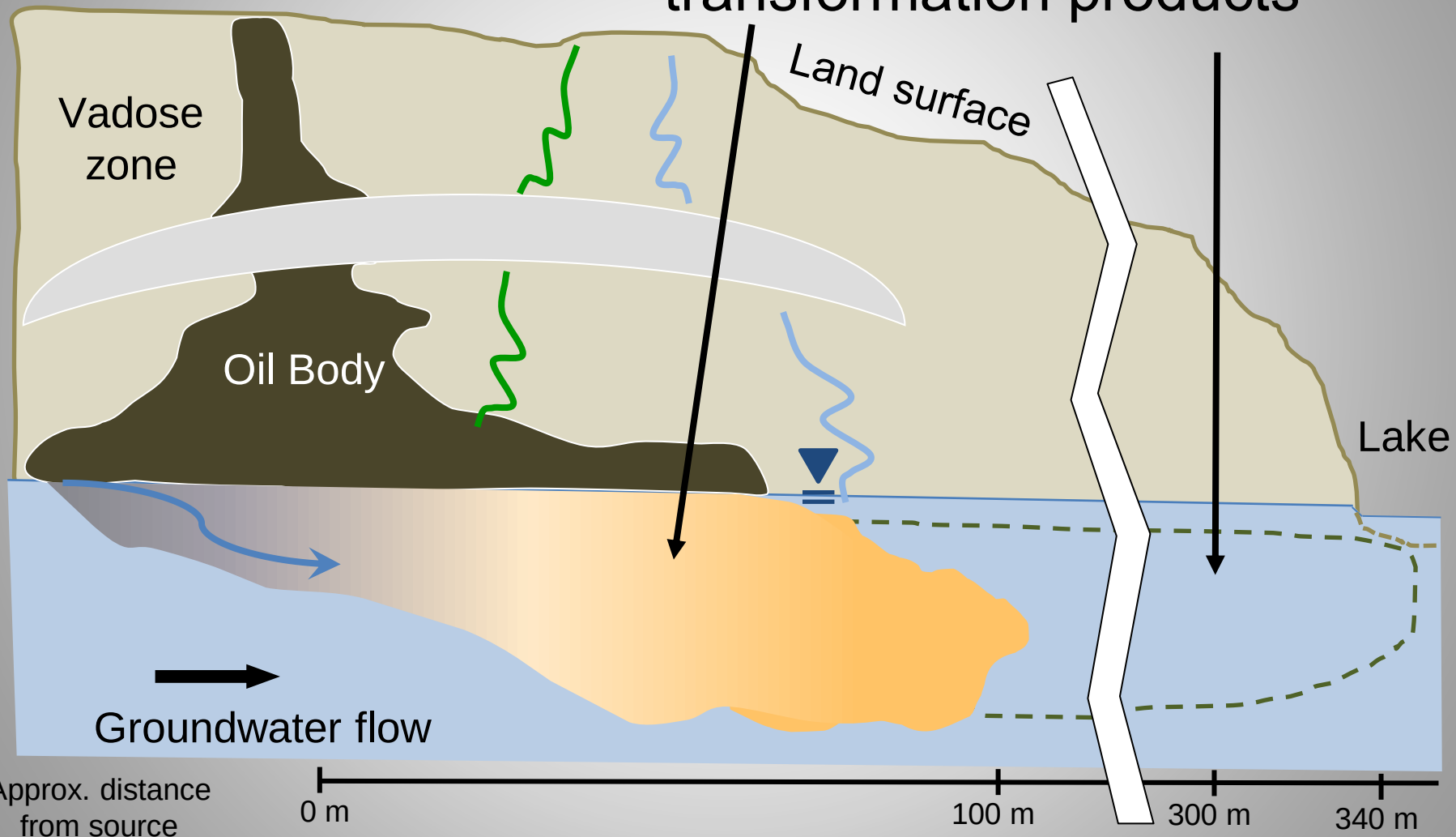
USGS science for a changing world

Bekins et al., 2011

Oil Source Longevity

- Oil mass loss can be calculated by using conservative compound concentration changes in oil through time (Douglas et al., 1996)
- Baedecker et al. (2018) estimated 23.4 – 36.7% mass loss at the north oil pool after 31 years.
- Better conservative compounds have been identified and indicate a higher mass loss (Bekins et al., in prep)

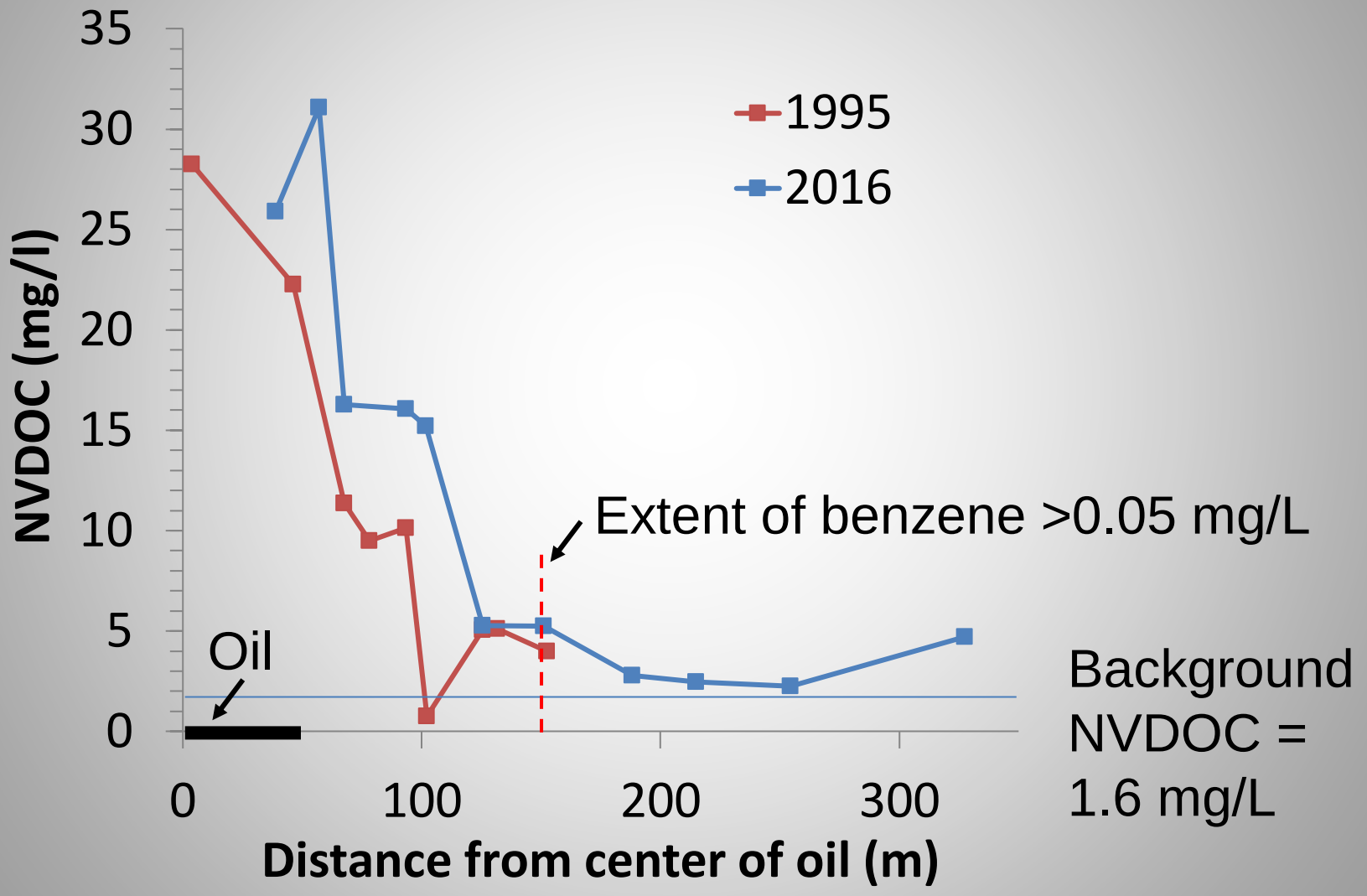
Nature, potential toxicity and prevalence of partial hydrocarbon transformation products



Not drawn to scale

Adapted from Ng et al., 2015, DOI: 10.1002/2015WR016964

A nonvolatile organic carbon (NVDOC) plume grew by about 1m/year and has a refractory component

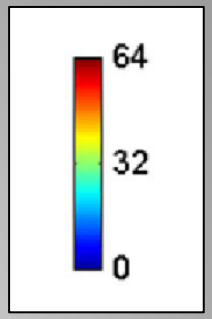


Bekins et al. 2016

Photo credit: Barbara Bekins, USGS

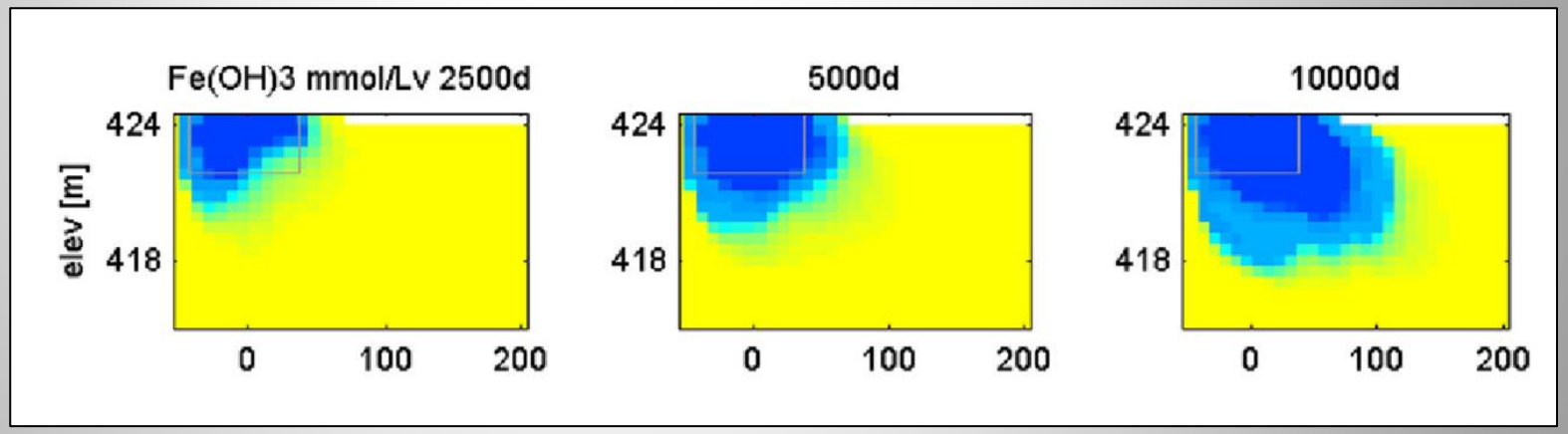
The electron acceptor Fe^{3+} is a coating of iron oxyhydroxide on the clean aquifer sediments

It is depleted as it is used by the bacteria



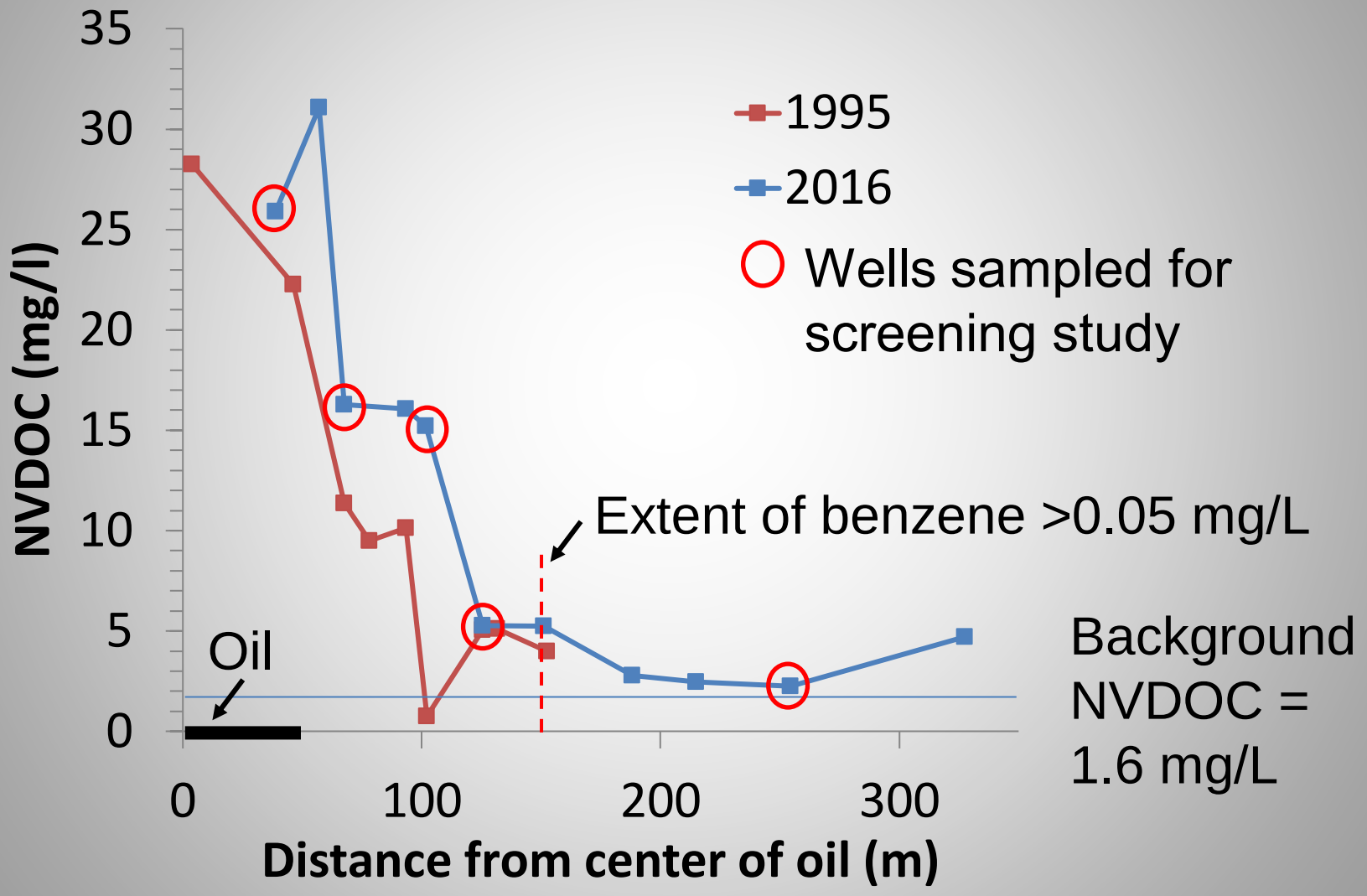
mmol/L volume

7 years | 14 years | 28 years



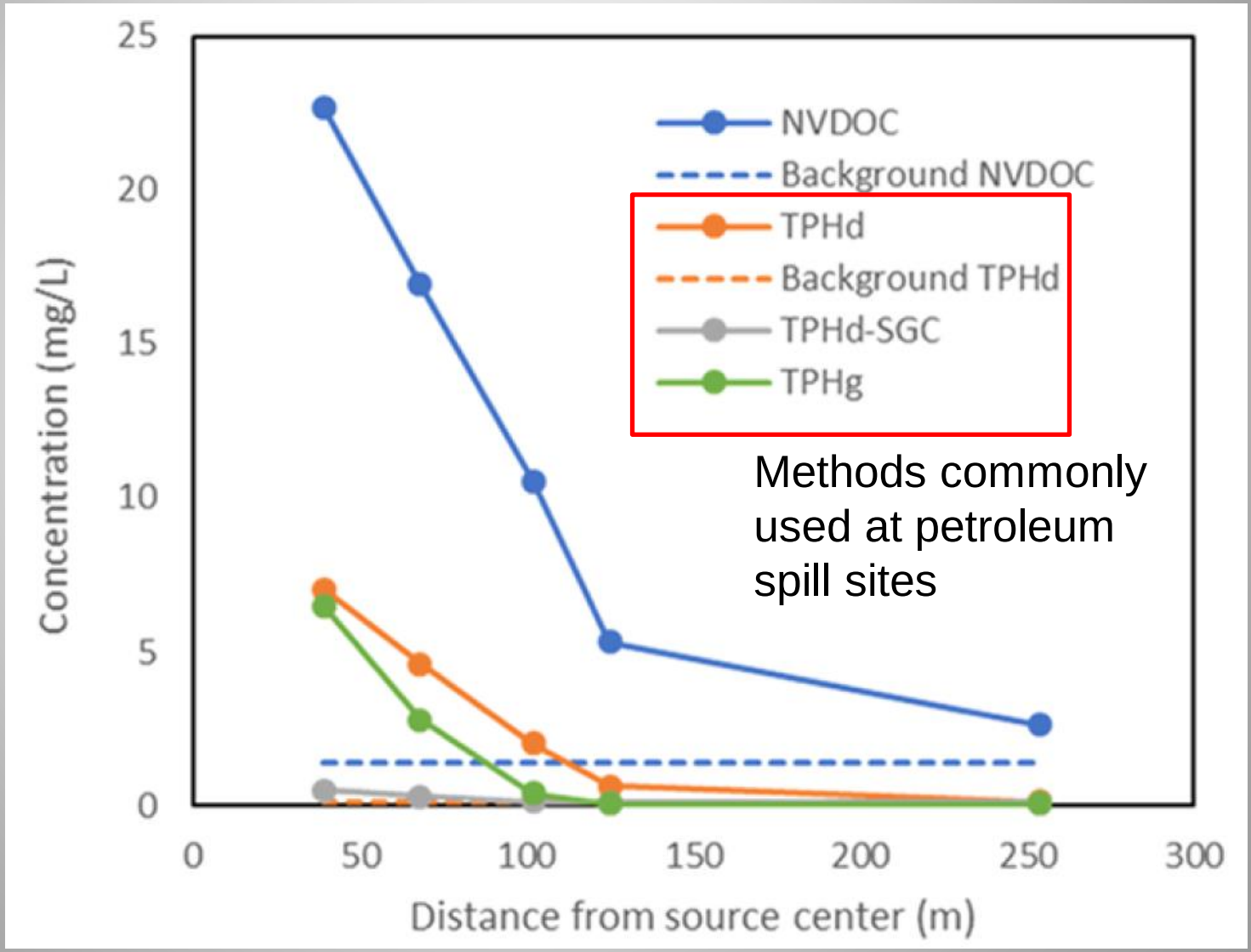
Ng et al. , 2015, DOI: 10.1002/2015WR016964

NVDOC plume and sampling locations for bioeffects screening



Bekins et al. 2016

NVDOC methods (containing partial transformation products) contain a higher mass of carbon than more "selective" routine measurements



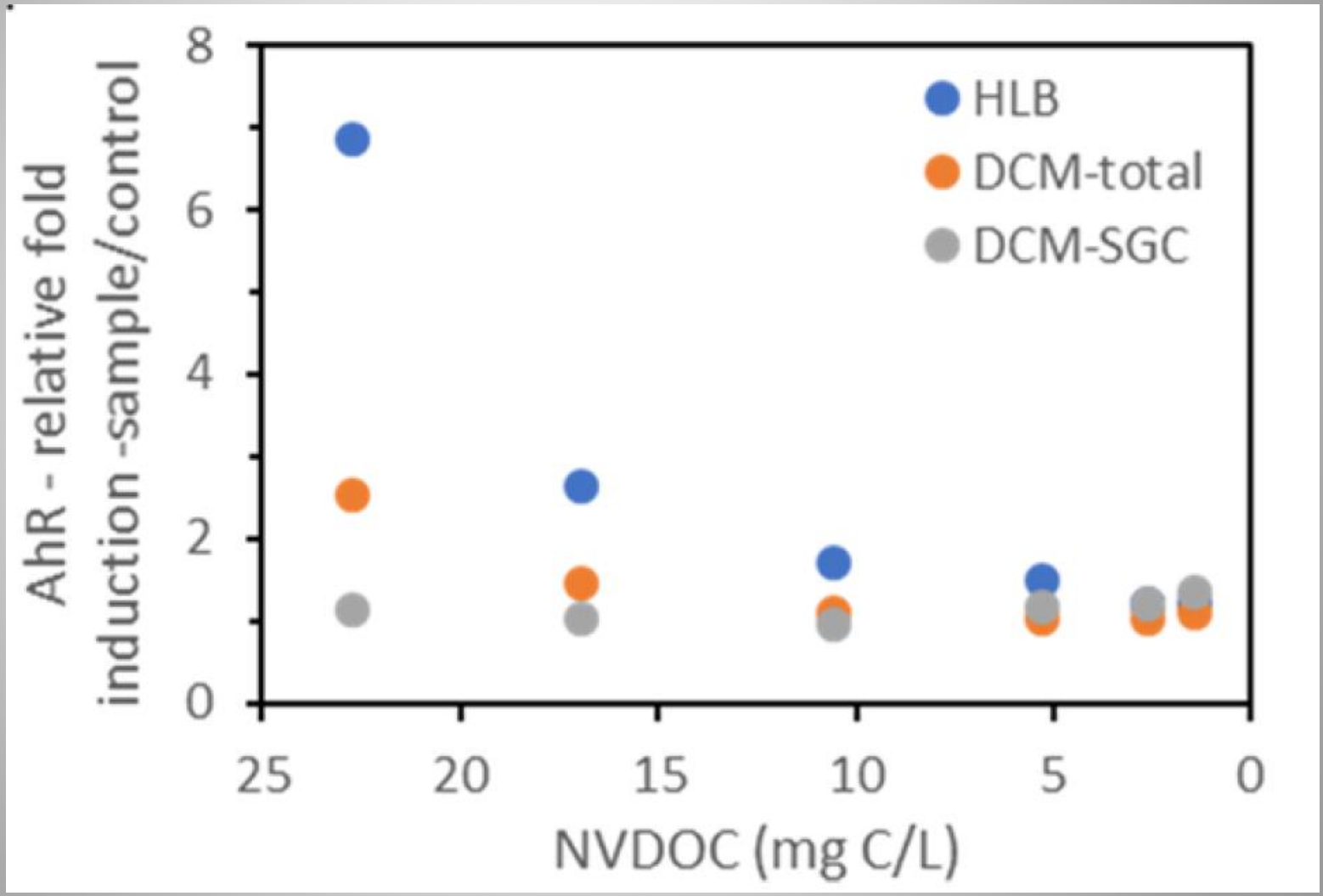
Bekins et al. 2020

USGS science for a changing world

Bioeffects screening (Attagene assays)

- Human liver cells (HepG2) are used as a model of liver metabolism
- To accommodate a changing environment, cells alter their gene expression (to metabolize chemicals, for example).
- Signaling pathways communicate with DNA by using transcription factors
- Quantifying transcription factor activities helps us understand cellular responses to complex mixtures of chemicals.
- Activities are reported as the ratio of induction values to unexposed cells.
- For example , a “ 5-fold induction” means a sample caused a 5-fold increase in transcription factor activity compared to a control

Bioeffects responses vary by fraction and concentration of dissolved organic carbon



Bekins et al. 2020

The long-term crude oil study shows…

Oil Source

- In 2010 still contained about 40% of the original benzene
- In 2010 an estimated 30% of the oil was degraded (but improvements are underway toward this estimate)

Groundwater Plume

- benzene plume is stable at ~150 m
- partial transformation products of oil dominate the DOC
- DOC plume is expanding as Fe^{3+} (iron oxy-hydroxide) is depleted by anaerobic biodegradation
- The partial transformation products activate a known hydrocarbon detoxification pathway in human liver cells

Jared Trost
Bemidji Site Coordinator
jtrost@usgs.gov
http://mn.water.usgs.gov/projects/bemidji/index.html

Photo credit: Jared Trost, USGS

Bemidji field site, October 2012

USGS science for a changing world

References

Adams, R.H., Cerecedo-López, R.A., Alejandro-Álvarez, L.A., Domínguez-Rodríguez, V.I., and Nieber, J.L., 2016, Treatment of water-repellent petroleum-contaminated soil from Bemidji, Minnesota, by alkaline desorption: International Journal of Environmental Science and Technology, v. 13, no. 9, p. 2249-2260, doi:10.1007/s13762-016-1058-4.

Baedecker, M.J., Eganhouse, R.P., Qi, H., Cozzarelli, I.M., Trost, J.J., and Bekins, B.A., 2018, Weathering of oil in a surficial aquifer: Groundwater, v. 56, no. 5, p. 797-809, doi:10.1111/gwat.12619.

Bekins, B.A., Baedecker, M.J., Eganhouse, R.P., and Herkelrath, W.N., 2011, Long-term natural attenuation of crude oil in the subsurface, in Schirmer, M., Hoehn, E., and Vogt, T., eds., GQ10--Groundwater Quality Management in a Rapidly Changing World--Procedings of the 7th International Groundwater Quality Conference, Zurich, Switzerland, June 13-18, 2010: International Association of Hydrologic Sciences Publication 342, p. 123-127, ISBN:978-1-907161-16-2.

Bekins, B.A., Cozzarelli, I.M., Erickson, M.L., Steenson, R.A., and Thorn, K.A., 2016, Crude oil metabolites in groundwater at two spill sites: Groundwater, v. 54, no. 5, p. 681-691, doi:10.1111/gwat.12419.

Bekins, B. A., Brennan, J. C., Tillitt, D. E., Cozzarelli, I. M., Illig, J. M., & Martinović-Weigelt, D. (2020). Biological Effects of Hydrocarbon Degradation Intermediates: Is the Total Petroleum Hydrocarbon Analytical Method Adequate for Risk Assessment?. Environmental Science & Technology, 54(18), 11396-11404.

Cozzarelli, I.M., Schreiber, M.E., Erickson, M.L., and Ziegler, B.A., 2016, Arsenic cycling in hydrocarbon plumes--Secondary effects of natural attenuation: Groundwater, v. 54, no. 1, p. 35-45, doi:10.1111/gwat.12316.

References continued

Delin, G.N., Essaid, H.I., Cozzarelli, I.M., Lahvis, M.H., and Bekins, B.A., 1998, Ground water contamination by crude oil near Bemidji, Minnesota: U.S. Geological Survey Fact Sheet FS-084-98, 4 p.

Douglas, G.S., A.E. Bence, R.C. Prince, S.J. McMillen, and E.L. Butler. 1996. Environmental stability of selected petroleum hydrocarbon source and weathering ratios. Environmental Science and Technology 30: 2332–2339.

Eganhouse, R.P., Baedecker, M.J., Cozzarelli, I.M., Aiken, G.R., Thorn, K.A., and Dorsey, T.F., 1993, Crude oil in a shallow sand and gravel aquifer--II, Organic Geochemistry: Applied Geochemistry, v. 8, no. 6, p. 551-567, doi:10.1016/0883-2927(93)90013-7.

MPCA, 2021, Petroleum Tanks and Leaks Site Search Tool, accessed March 19,202 at https://www.pca.state.mn.us/waste/petroleum-tanks-and-leaks-site-search.

Natural Resources Engineering Company, 1998, Remedial investigation and corrective action design report milepost 926.53: Pinewood, Minnesota, Prepared for Lakehead Pipe Line Company, August 1998, 86 p.

Ng, G.H.C., Bekins, B.A., Cozzarelli, I.M., Baedecker, M.J., Bennett, P.C., Amos, R.T., and Herkelrath, W.N., 2015, Reactive transport modeling of geochemical controls on secondary water quality impacts at a crude oil spill site near Bemidji, MN: Water Resources Research, v. 51, no. 6, p. 4156-4183, doi:10.1002/2015WR016964.

USEPA, 2021, Semiannual Report of UST Performance Measures End of Fiscal Year 2020, accessed March 19, 2021 at https://www.epa.gov/sites/production/files/2020-11/documents/ca-20-34.pdf