Emerging Risks Responder Awareness Training

Bakken Crude Oil

FEMA USDA GSA

NRT-RRT

Bakken Crude Oil

DEVELOPED BY NRT TRAINING SUBCOMMITTEE,
JUNE 2014

Content

- Where is Bakken oil coming from?
- How is it being transported?
- Bakken chemistry
- Response issues
- Recent incidents
- Question & Answer Session

Objectives

- Provide background information on Bakken crude oil production and transportation methods
- Provide information on recent regulatory efforts to deal with Bakken crude oil transportation methods and routes
- Provide an overview of Health and Safety issues facing first responders
- Provide case studies of recent incidents

Speakers

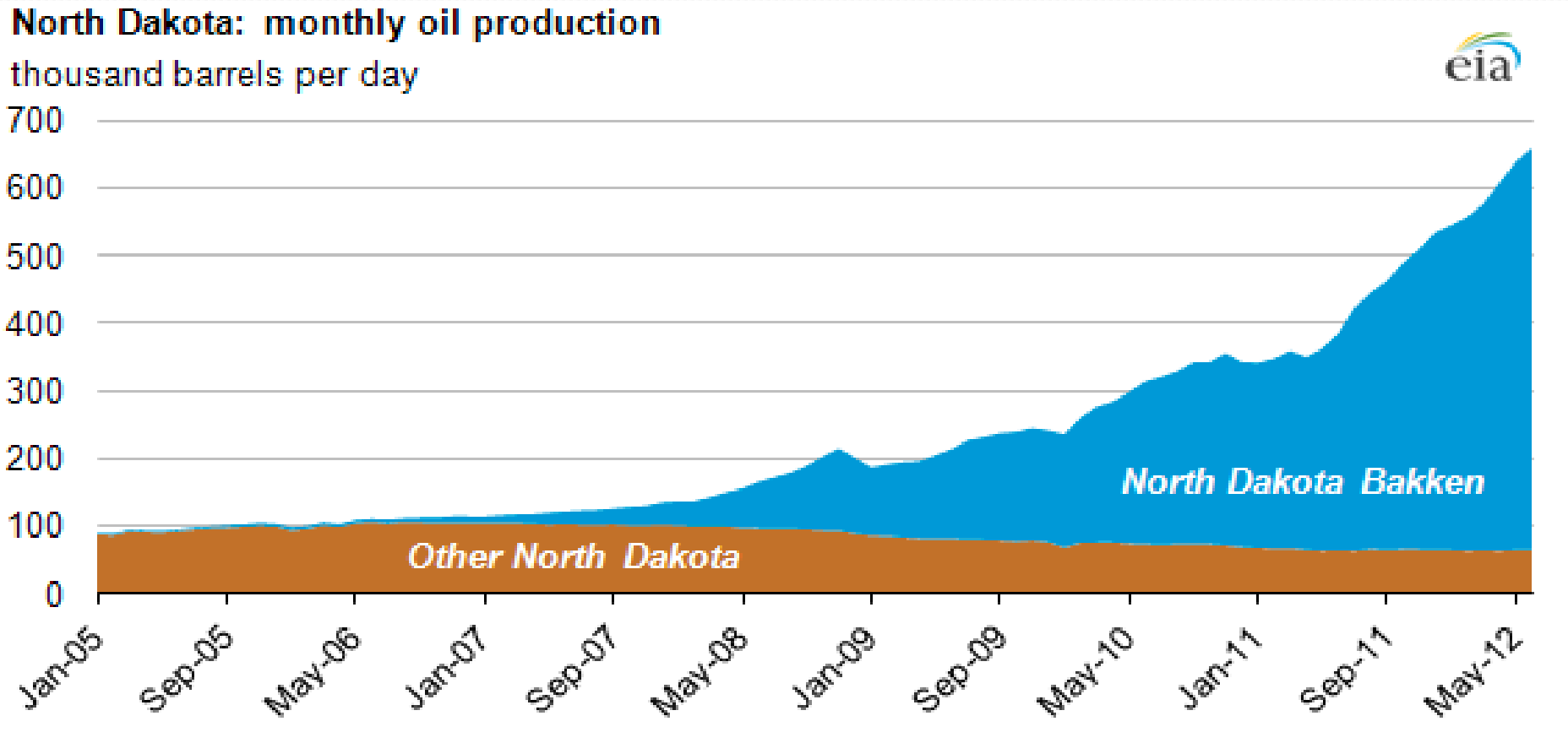
- Mike Faulkner, U.S. EPA
- Ed Levine, NOAA
- Brian Schleiger, U.S. EPA
- TBD, U.S. DOT
- Josee Boudreau, Environment Canada
- Christine Petitti, OSHA
- Brian Kovack, U.S. EPA
- Greg Powell, U.S. EPA
- Patrick Lambert, Environment Canada
- Jordan Garrard, U.S. EPA

Ed Levine

NOAA

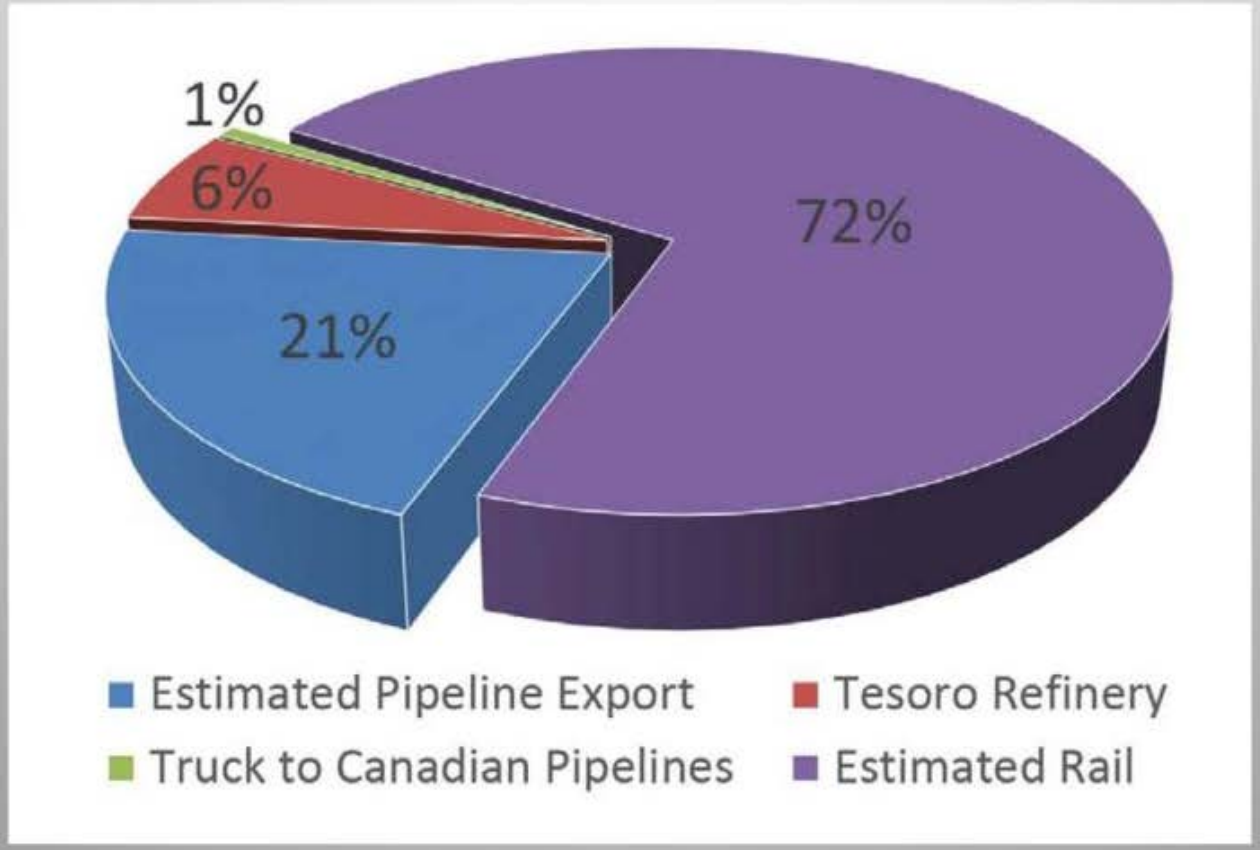
Bakken Oil Formation

Bakken Oil Production



Jim Gehrz/The Columbian

Bakken Oil Transportation



Monthly Production (bbls)	Pipeline Export (bbls/month)	Rail Export (bbls/month)	Rail Export (cars/month)
28.9M	6M	~21M	~30,000

There are other oil sands products you need to be aware of transported by rail and pipeline:

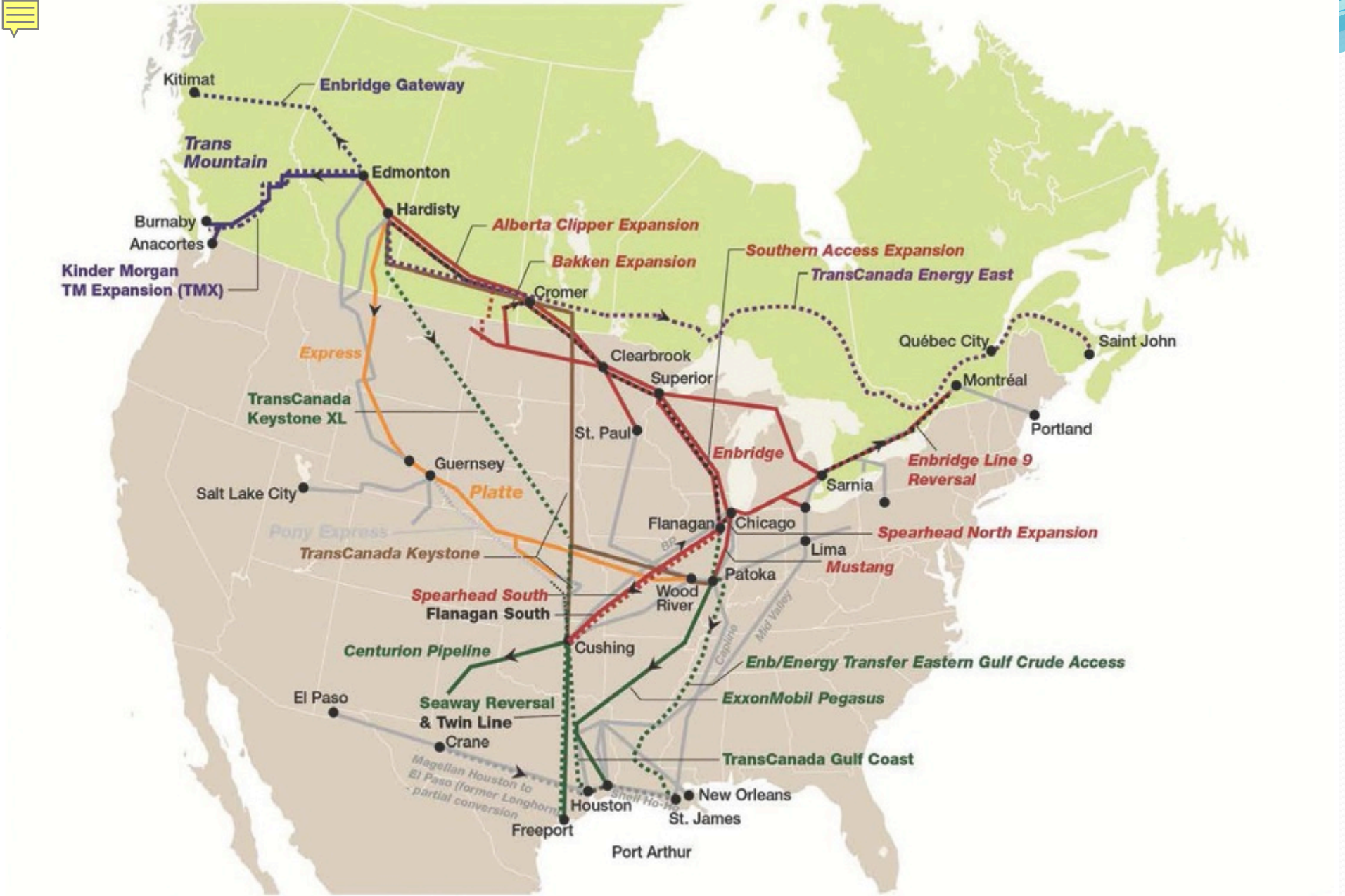
- Oil sands (tar sands): Naturally-occurring combination of bitumen, clay, sand, and water
- Bitumen: Semi-solid raw petroleum product resulting from in-situ partial biodegradation of crude oil reserve
- Diluent: Any lighter viscosity petroleum product used to dilute bitumen for transportation
- Dilbit: Diluted bitumen, bitumen mixed with any diluent for transport
- Synbit: Bitumen combined with synthetic crude oil
- Dilsynbit: Synbit combined with a diluent

Brian Schlieger

U.S. EPA

By Pipeline….

Photo: Huffington Post


Kitimat
Enbridge Gateway
Trans Mountain
Edmonton
Hardisty
Burnaby
Anacortes
Kinder Morgan TM Expansion (TMX)
Alberta Clipper Expansion
Bakken Expansion
Southern Access Expansion
TransCanada Energy East
Cromer
Express
Clearbrook
Superior
Québec City
Saint John
Montréal
Portland
TransCanada Keystone XL
St. Paul
Enbridge
Enbridge Line 9 Reversal
Guernsey
Salt Lake City
Platte
Sarnia
Flanagan
Chicago
Spearhead North Expansion
Pony Express
TransCanada Keystone
Lima
Mustang
Patoka
Spearhead South
Flanagan South
Wood River
Centurion Pipeline
Cushing
Enb/Energy Transfer Eastern Gulf Crude Access
Capline
Mid Valley
El Paso
Seaway Reversal & Twin Line
ExxonMobil Pegasus
Crane
TransCanada Gulf Coast
Houston
New Orleans
St. James
Freeport
Port Arthur

Pipeline Break

Photo: NTSB

Josee Boudreau

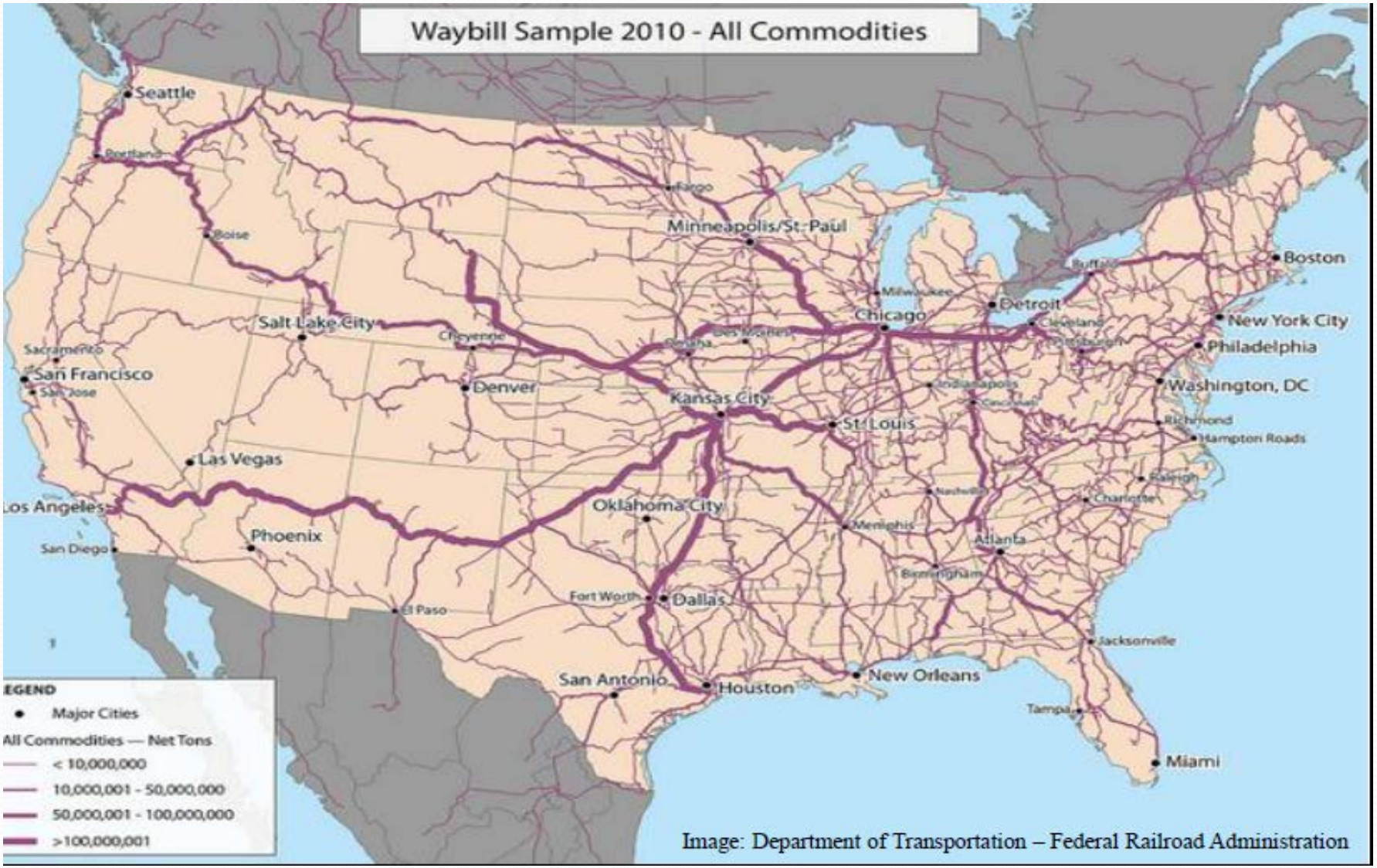
Environment Canada

By Rail….

TBD

U.S. DOT

U.S. Oil Transport by Rail



New tank cars are being built to meet shipping demands

Image Credit: American Railcar Industries

A railroad oil tanker car is parked along Interstate 787 in downtown Albany, N.Y., on Friday, Feb. 7, 2014. The Port of Albany has become a hub for the U.S. oil business, taking shipments from North Dakota's Bakken shale daily by mile-long trains and shipping it in tankers down the Hudson River to refineries. Opponents of a proposal to build boilers to liquefy heavy crude passing through Albany by rail are drawing attention to the capital's emergence as a major hub for the transport of oil that's widely considered risky from an environmental and safety standpoint. (AP Photo/Mike Groll)

PHMSA Safety Alert

- Emergency responders should remember that light sweet crude oil, such as that coming from the Bakken region, is typically assigned a packing group (PG) I or II
- The PGs mean that the material's flashpoint is below 73 degrees Fahrenheit and, for PG I materials, the boiling point is below 95 degrees Fahrenheit
- This means the materials pose significant fire risk if released from the package in an accident

DOT Emergency Order

- Trains carrying large amounts of crude oil from the Bakken region are required to notify State Emergency Response Commissions (SERCs) of their trains' operation through their states, if the trains are carrying more than 1 million gallons of Bakken crude, or about 35 tank cars
- This notification must include estimated volumes of Bakken crude oil, frequency of anticipated train traffic, and the route the train is taking
- The railroad must provide contact information for at least one responsible party at the railroads to the SERCs

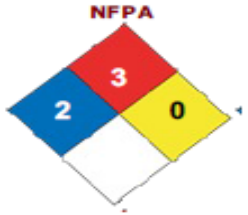
Christine Petitti

OSHA

Bakken Crude Oil Safety Data Sheet (SDS)

SECTION 1 : IDENTIFICATION

Product Name:	**Bakken Crude Oil, Sweet**
SDS Manufacturer Number:	825378
Synonyms:	Crude Oils, Desalted, Sweet, Field Crude, Petroleum Crude, Petroleum Oil, Rock Oil, Separator Crude, Sweet Crude, Crude Oils
Product Use/Restriction:	Refinery Feed
Manufacturer Name:	ConocoPhillips
Address:	600 N. Dairy Ashford Houston, Texas 77079-1175
General Phone Number:	855-244-0762
Health Issues Information:	SDS@conocophillips.com
Emergency Phone Number:	Chemtrec: 800-424-9300 (24 Hours)
Website:	www.conocophillips.com
SDS Creation Date:	May 19, 2014
SDS Revision Date:	May 19, 2014



HMIS

Health Hazard	2*
Fire Hazard	3
Reactivity	1
Personal Protection	X

* Chronic Health Effects

SECTION 3 : COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	CAS#	Ingredient Percent	EC Num.
Crude Oil (Petroleum)	8002-05-9	100 by weight	
N-Hexane	110-54-3	<5 by Volume	
Ethyl Benzene	100-41-4	<3 by weight	
Xylenes	1330-20-7	<1 by weight	
Benzene	71-43-2	<1 by weight	
Hydrogen Sulfide	7783-06-4	<0.2 by Volume	
Naphthalene	91-20-3	0 - 0.9 by weight	

Total Sulfur: < 0.5 wt%

Crude oil, natural gas and natural gas condensate can contain minor amounts of sulfur, nitrogen and oxygen containing organic compounds as well as trace amounts of heavy metals like mercury, arsenic, nickel, and vanadium. Composition can vary depending on the source of crude.

SECTION 5 : FIRE FIGHTING MEASURES

Flammable Properties:	Extremely flammable.
Flash Point:	<-20°F (<-29°C)
Flash Point Method:	Manual ASTM D53
Auto Ignition Temperature:	Not determined.
Lower Flammable/Explosive Limit:	Not determined.
Upper Flammable/Explosive Limit:	Not determined.
Fire Fighting Instructions:	Long-duration fires involving crude or residual fuel oil stored in tanks may result in a boilover. The contents of the tank may be expelled beyond the containment dikes or ditches. All personnel should be kept back a safe distance when a boilover is anticipated (reference NFPA 11 or API 2021). For fires beyond the initial stage, emergency responders in the immediate hazard area should wear protective clothing. When the potential chemical hazard is unknown, in enclosed or confined spaces, a self contained breathing apparatus should be worn. In addition, wear other appropriate protective equipment as conditions warrant (see Section 8). Isolate immediate hazard area and keep unauthorized personnel out. Stop spill/release if it can be done safely. Move undamaged containers from immediate hazard area if it can be done safely. Water spray may be useful in minimizing or dispersing vapors and to protect personnel. Cool equipment exposed to fire with water, if it can be done safely. Avoid spreading burning liquid with water used for cooling purposes.
Extinguishing Media:	Dry chemical, carbon dioxide, or foam is recommended. Water spray is recommended to cool or protect exposed materials or structures. Carbon dioxide can displace oxygen. Use caution when applying carbon dioxide in confined spaces. Simultaneous use of foam and water on the same surface is to be avoided as water destroys the foam. Water may be ineffective for extinguishment, unless used under favorable conditions by experienced fire fighters.
Protective Equipment:	As in any fire, wear Self-Contained Breathing Apparatus (SCBA), MSHA/NIOSH (approved or equivalent) and full protective gear.
Unusual Fire Hazards:	This material can be ignited by heat, sparks, flames, or other sources of ignition (e.g., static electricity, pilot lights, mechanical/electrical equipment, and electronic devices such as cell phones, computers, calculators, and pagers which have not been certified as intrinsically safe). Vapors may travel considerable distances to a source of ignition where they can ignite, flash back, or explode. May create vapor/air explosion hazard indoors, in confined spaces, outdoors, or in sewers. This product will float and can be reignited on surface water. Vapors are heavier than air and can accumulate in low areas. If container is not properly cooled, it can rupture in the heat of a fire.
Hazardous Combustion Byproducts:	Combustion may yield smoke, carbon monoxide, and other products of incomplete combustion. Hydrogen sulfide and oxides of nitrogen and sulfur may also be formed. Hazardous combustion/decomposition products, including hydrogen sulfide, may be released by this material when exposed to heat or fire. Use caution and wear protective clothing, including respiratory protection.

NFPA Ratings:

NFPA Health:	2
NFPA Flammability:	3
NFPA Reactivity:	0

SECTION 8 : EXPOSURE CONTROLS, PERSONAL PROTECTION - EXPOSURE GUIDELINES

Engineering Controls:	Use appropriate engineering control such as process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits. Good general ventilation should be sufficient to control airborne levels. Where such systems are not effective wear suitable personal protective equipment, which performs satisfactorily and meets OSHA or other recognized standards. Consult with local procedures for selection, training, inspection and maintenance of the personal protective equipment.
Eye/Face Protection:	Wear appropriate protective glasses or splash goggles as described by 29 CFR 1910.133, OSHA eye and face protection regulation, or the European standard EN 166.
Skin Protection Description:	Wear appropriate protective gloves and other protective apparel to prevent skin contact. Consult manufacturer's data for permeability data.
Hand Protection Description:	Suggested protective materials: Nitrile
Respiratory Protection:	Where there is potential for airborne exposure to hydrogen sulfide (H2S) above exposure limits, a NIOSH approved, self-contained breathing apparatus (SCBA) or equivalent operated in a pressure demand or other positive pressure mode should be used. Under conditions where hydrogen sulfide (H2S) is NOT detected, a NIOSH certified air purifying respirator equipped with organic vapor cartridges/canisters may be used. A respiratory protection program that meets or is equivalent to OSHA 29 CFR 1910.134 and ANSI Z88.2 should be followed whenever workplace conditions warrant a respirator's use. Air purifying respirators provide limited protection and cannot be used in atmospheres that exceed the maximum use concentration (as directed by regulation or the manufacturer's instructions), in oxygen deficient (less than 19.5 percent oxygen) situations, or under conditions that are immediately dangerous to life and health (IDLH). If benzene concentrations equal or exceed applicable exposure limits, OSHA requirements for personal protective equipment, exposure monitoring, and training may apply (29CFR1910.1028 - Benzene). Workplace monitoring plans should consider the possibility that heavy metals such as mercury may concentrate in processing vessels and equipment presenting the possibility of exposure during various sampling and maintenance operations. Implement appropriate respiratory protection and the use of other protective equipment as dictated by monitoring results (See Sections 2 and 7).
Other Protective:	Facilities storing or utilizing this material should be equipped with an eyewash and a deluge shower safety station.
PPE Pictograms:	

EXPOSURE GUIDELINES

Crude Oil (Petroleum) :

Guideline User Defined:	ConocoPhillips Guidelines TWA:100 mg/m3 - 8 hr

N-Hexane :

Guideline ACGIH:	Skin: Yes. TLV-TWA: 50 ppm
Guideline OSHA:	PEL-TWA: 500 ppm

Ethyl Benzene :

Guideline ACGIH:	TLV-TWA: 20 ppm
Guideline OSHA:	PEL-TWA: 100 ppm

Xylenes :

Guideline ACGIH:	TLV-STEL: 150 ppm TLV-TWA: 100 ppm

Benzene :

Guideline ACGIH:	Skin: Yes. TLV-STEL: 2.5 ppm TLV-TWA: 0.5 ppm
Guideline OSHA:	PEL-TWA: 1 ppm PEL-STEL: 5 ppm
Guideline User Defined:	ConocoPhillips Guidelines

Hydrogen Sulfide :

Guideline ACGIH:	TLV-STEL: 5 ppm TLV-TWA: 1 ppm TLV-TWA: 1 ppm TLV-STEL: 5 ppm
Guideline OSHA:	PEL-Ceiling/Peak: 20 ppm PEL-Ceiling/Peak: 50 ppm Peak
Guideline User Defined:	ConocoPhillips Guidelines TWA: 5 ppm 8hr TWA: 2.5 ppm 12hr STEL: 15 ppm

Naphthalene :

Guideline ACGIH:	Skin: Yes. TLV-STEL: 15 ppm TLV-TWA: 10 ppm
Guideline OSHA:	PEL-TWA: 10 ppm

Note: Suggestions provided in this section for exposure control and specific types of protective equipment are based on readily available information. Users should consult with the specific manufacturer to confirm the performance of their protective equipment. Specific situations may require consultation with industrial hygiene, safety, or engineering professionals.

State, local or other agencies or advisory groups may have established more stringent limits. Consult an industrial hygienist or similar professional, or your local agencies, for further information.

SECTION 9 : PHYSICAL and CHEMICAL PROPERTIES

Physical State:	Liquid.
Color:	Amber to Black
Odor:	Petroleum. Rotten egg / sulfurous
Odor Threshold:	Not determined.
Boiling Point:	70 to 110 °F (21 to 43 °C)
Melting Point:	Not determined.
Density:	5.83-8.58 lbs/gal Bulk
Specific Gravity:	0.7-1.03 @ 60°F (15.6°C) Reference water = 1
Solubility:	Negligible solubility in water.
Vapor Density:	>1 (air = 1)
Vapor Pressure:	8.5-15 psia (Reid VP) @ 100°F (37.8°C)
Percent Volatile:	Not determined.
Evaporation Rate:	Not determined.
pH:	Not applicable.
Viscosity:	Not determined.
Coefficient of Water/Oil Distribution:	Not determined.
Flash Point:	<-20°F (<-29°C)
Flash Point Method:	Manual ASTM D53
Auto Ignition Temperature:	Not determined.
Note:	Unless otherwise stated, values are determined at 20°C (68°F) and 760 mm Hg (1 atm). Data represent typical values and are not intended to be specifications.

SECTION 10 : STABILITY and REACTIVITY

Chemical Stability:	Stable under normal ambient and anticipated conditions of use.
Hazardous Polymerization:	Hazardous Polymerization does not occur.
Conditions to Avoid:	Avoid high temperatures and all sources of ignition. Prevent vapor accumulation.
Incompatible Materials:	Avoid contact with strong oxidizing agents and strong reducing agents.
Special Decomposition Products:	Thermal decomposition or combustion may liberate carbon oxides, aldehydes, and other toxic gases or vapors

SECTION 14 : TRANSPORT INFORMATION

DOT Shipping Name:	Petroleum crude oil
DOT UN Number:	UN1267
DOT Hazard Class:	3
DOT Packing Group:	I
IATA Shipping Name:	Petroleum crude oil
IATA UN Number:	UN1267
IATA Hazard Class:	3
IATA Packing Group:	I
IMDG UN NUmber :	UN1267
IMDG Shipping Name :	Petroleum crude oil
IMDG Hazard Class :	3
IMDG Packing Group :	I
Notes :	U.S. DOT compliance requirements may apply. See 49 CFR 171.22, 23 & 25. If transported in bulk by marine vessel in international waters, product is being carried under the scope of MARPOL Annex I.

Bakken Crude Oil Properties

(@60° F)

- Specific Gravity 0.7 – 0.8 : **floats on water**
- Vapor Density 2.5 – 5.0: **heavier than air**
- Vapor Pressure, 280-360 mmHg: **moderate volatility**
  - Water 12.5 mmHg
  - Gasoline 400 mmHg

Bakken Crude Oil Properties

Gases (Light Crude)

- Higher concentrations of light end petroleum hydrocarbons (i.e., methane, ethane, propane and butanes)

- The dissolved gases and light ends:
  - Increase the vapor pressure
  - Lower the flashpoint
  - Lower the initial boiling point

- H_2S may be present in high concentrations (vapor)

Bakken Crude Oil Properties

Flammability

- NFPA Flammability = 3-4 (sample -3)
  - Sensitive to static discharge
- Explosive Limits variable:
  - LEL 0.4% (sample - 0.1%)
  - UEL 15.0% (sample – 4.5%)
- Flash point : - 40°to 212° F
  - - 74° to 122° F (AFPM data)
  - Recent sample < 74° F

Brian Kovack

U.S. EPA

Health & Safety – H_2S

- Colorless, flammable, toxic gas, rotten egg odor, quick olfactory fatigue
- Heavier than air, soluble in water and oil
- Explosive in air: 4.3 - 45.5% concentration (volume)
- Auto ignition at 500°F
- Odor threshold 0.13 ppm

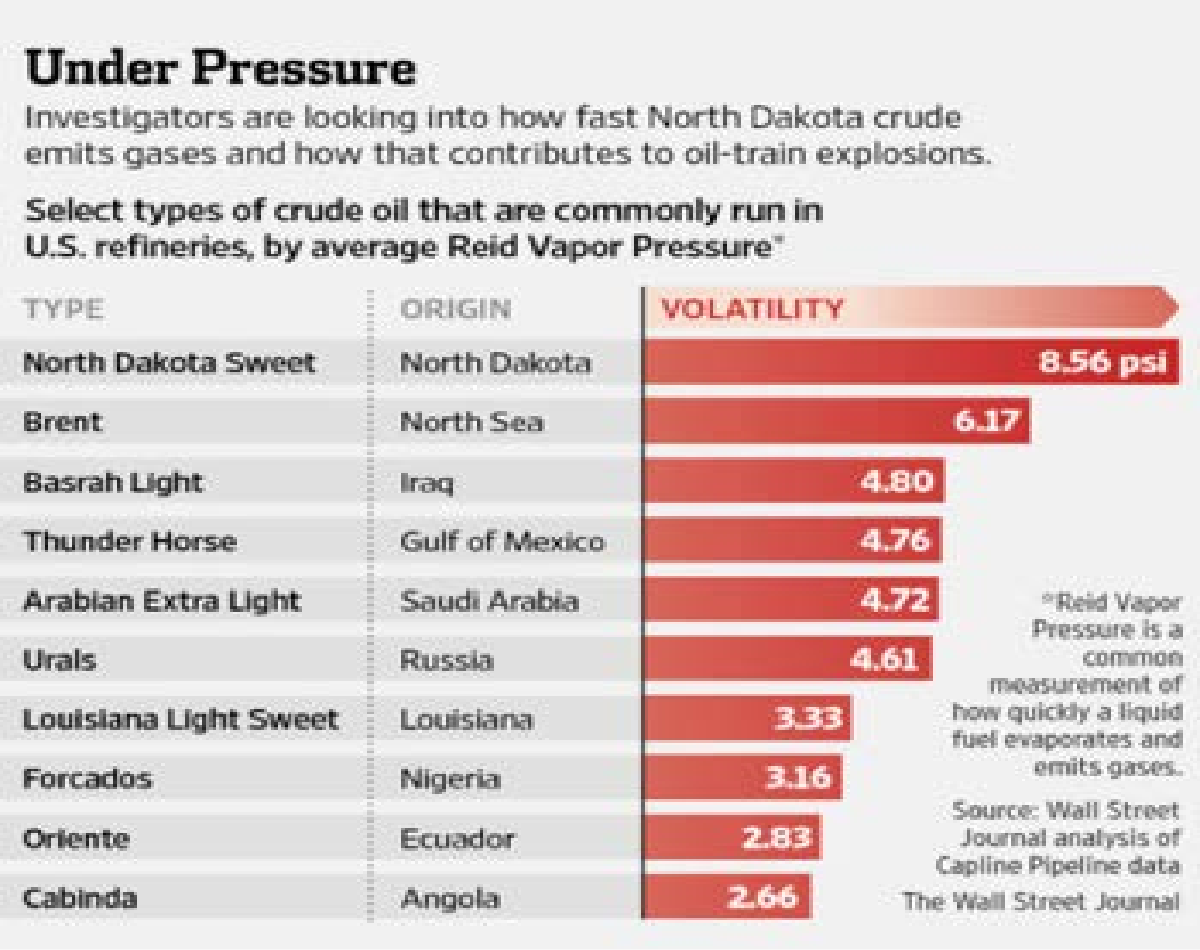
H_2S Concentration & Health Effects

Concentration (ppm)	Health Effect
0.01 – 0.3	Odor threshold (variable)
1.0 – 5.0	Odor, nausea, eye irritation, headache
20 - 50	Keratoconjuctivitis, lung irritation
100 - 150	Eye & lung irritation, olfactory paralysis
250 - 500	Pulmonary edema, convulsions, risk of "knockdown"
500 - 1000	Unconsciousness, risk of respiratory paralysis
> 1000	Respiratory paralysis, death

Health & Safety – H_2S

- **Olfactory fatigue** – Sense of smell becomes rapidly fatigued and can not be relied upon to detect H_2S
- **100 ppm, IDLH** – Olfactory fatigue in 3-5 minutes; altered respiration, coughing, drowsiness
- **200 ppm** – Olfactory fatigue shortly; stinging eyes and throat, death after 1-2 hours exposure
- **500 ppm** – Dizziness, stinging eyes and throat, self rescue impossible, loss of muscle control, death
- **1000 ppm** – Unconscious at once, death within minutes

Why is Bakken oil dangerous?



Bakken Crude Oil Properties

Component Comparison with Fuels

	Oil Type	Bakken Crude		Gasoline		Diesel		WTI Crude	
SVOCS	**Napthalene**	**340**	ppm	**20,000**	ppm	/	/	/	/
	2-Methylnapthalene	**860**	ppm	/	/	/	/	/	/
	Phenanthrane	**150**	ppm	/	/	/	/	/	/
	1-Methylnapthalene	**630**	ppm	/	/	/	/	/	/
VOCS	**Benzene**	**1,400**	ppm	**49,000**	ppm	/	/	**1,380**	ppm
	Toluene	**3,100**	ppm	**250,000**	ppm	/	/	**2,860**	ppm
	Ethylbenzene	**740**	ppm	**30,000**	ppm	/	/	**1,120**	ppm
	m,p-Xylene	**3,600**	ppm	/	/	/	/	**4,290**	ppm
	o-Xylene	**1,200**	ppm	/	/	/	/	/	/
	1,3,5-Trimethylbenzene	**870**	ppm	/	/	/	/	/	/
	1,2,4-Trimethylbenzene	**2,700**	ppm	/	/	/	/	/	/
	Isopropylbenzene	**200**	ppm	/	/	/	/	/	/
	n-Butylbenzene	**170**	ppm	/	/	/	/	/	/
	Napthalene	**275**	ppm	/	/	/	/	/	/

Greg Powell

U.S. EPA

Spill Response Considerations

Monitoring Equipment

- For Spill:
  - 4 or 5 gas monitors for O_2, LEL, H_2S
  - PID/FID for VOCs (FIDs may be more sensitive)
  - Chemical-specific monitors for benzene
    - Colorimetric tubes
    - PID with benzene tube
- Additionally, for fire:
  - Particulate monitors for Polynuclear Aromatic Hydrocarbons (PAHs) sampling
  - Monitors or sampling equipment for particulates (smoke)

Spill Response Considerations

Safety

Safety

- Air monitoring - Spill
  - O_2
  - Explosive Levels – LEL/UEL
  - H_2S
  - Benzene
  - Organic vapors (VOCs)

Spill Response Considerations

Safety

Safety

- Air monitoring - Fire
  - O_2
  - CO
  - Explosive Levels – LEL/UEL
  - H_2S
  - Benzene
  - Organic vapors (VOCs)
  - Sulfur and Nitrogen Oxides
  - Particulates - smoke

Exposure Guidelines

Component	ACGIH	NIOSH	OSHA
Petroleum (8002-05-9)	Not established	CEIL: 1800 mg/m3 TWA: 350 mg/m3	Not established
Hydrogen sulfide (7783-06-4) [Oregon <1]	TWA: 1 ppm STEL: 5 ppm	CEIL: 10 ppm	CEIL: 20 ppm
Benzene (71-43-2) [Oregon 0.25 ppm]	TWA: 0.5 ppm STEL: 2.5 ppm	TWA: 0.1 ppm STEL: 1 ppm	TWA: 1 ppm STEL: 5 ppm
Ethylbenzene (100-41-4)	TWA: 20 ppm	TWA: 100 ppm STEL: 125 ppm	TWA: 100 ppm
Toluene (108-88-3)	TWA: 20 ppm	TWA: 100 ppm STEL: 150 ppm	TWA: 200 ppm CEIL: 500 ppm

Patrick Lambert

Environment Canada

Lac-Megantic, Quebec

Photo: Michael Forlan/Twitter

AP Photo: The Canadian Press, Paul Chiasson

Lac-Megantic, Quebec

- Lac-Megantic, Quebec
  - Sherbrooke, Quebec is the closest large city
  - The State of Maine border is approximately 12 miles away
  - On-site response by many agencies during the incident
  - No local infrastructure existed to support the response
  - The oil spill response Emergency Operations Center was located in community of St. George

- The incident at Lac-Megantic possessed all the traditional health and safety concerns of working at an emergency plus a number of other issues.

Lac-Mégantic oil spill, Source: Montreal Gazette

Chaudière River oil spill, Source: Sun News Network

Cleanup operations on Chaudière River, Source: CTVNew.ca

Lac-Megantic, Quebec

- Examples of specific H&S concerns were as follows:
  - Intense, sustained fire and numerous explosions during the initial days as well as risk of the further fire and explosions throughout recovery operations until all derailed railcars and crude oil were addressed
  - The presence of volatile organic compounds (VOCs), especially benzene, as well as particulates from the burning crude oil
  - Forensic investigation and evidence collection

Lac-Mégantic recovery operations, Source: Macleans.ca

Lac-Mégantic recovery operations, Source: LeDevoir.com

Lac-Mégantic recovery operations, Source: Cnews.canoe.ca

Jordan Garrard

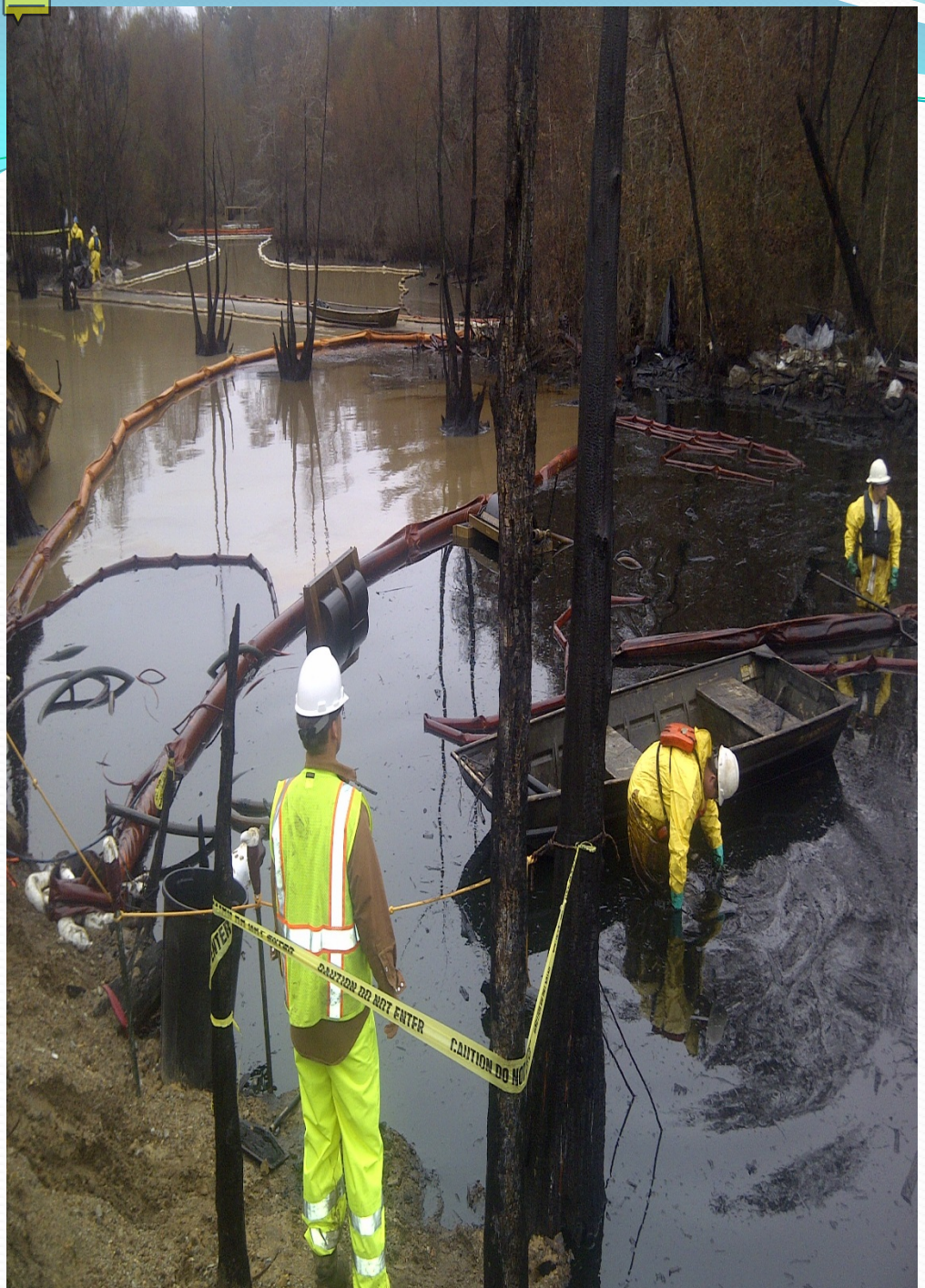
U.S. EPA

Aliceville, Alabama

Photo: Bill Castle/Associated Press

Night Operations

Containment



Extent of Contamination

Photos: John Wathen

Mike Faulkner

U.S. EPA

Bakken Oil Summary

- Flammable and more volatile than other crude oils because of dissolved gases and other petroleum hydrocarbon light ends
- May contain hydrogen sulfide in high concentrations
- Transported by rail and pipeline, in addition to trucks and vessels
- New regulations are being developed to deal with the volatility of this flammable oil
- Emergency personnel need to be aware of the chemical and physical characteristics as well as the health and safety issues associated with a Bakken oil spill response

Reference Material

- "Railway Investigation Report, R13D0054", Transportation Safety Board of Canada, ISBN 978-1-100-24860-8, August 19, 2014, *http://tsb.gc.ca/eng/enquetes-investigations/rail/2013/r13d0054/r13d0054.asp*.
- "Preliminary Findings and Recommendations", State of California, Interagency Rail Safety Working Group, June 10, 2014.
- Association of American Railroads, Movement of Bakken Crude by Rail, July 11, 2014 meeting minutes.
- "Properties, Composition and Marine Spill Behaviour, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands", Environment Canada, ISBN 978-1-100-23004-7, November 30, 2013, *http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=D6AB8B67-73F5-48B6-B3D1-AAE1B06FF9A2*.
- "Bakken Petroleum: The Substance of Energy Independence", Written Statement of Timothy P. Butters, Deputy Administrator, The Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Before the Subcommittees on Energy and Oversight, Committee on Science, Space, and Technology, U.S. House of Representatives, September 9, 2014.
- Banerjee, Dwijen K., OIL SANDS, HEAVY OIL, & BITUMEN: From Recovery to Refinery. ISBN 978-1-59370-260-1; PennWell Corp., Oct 22, 2012

Questions?