POTENTIAL HEALTH CONCERNS AT FRAC SAND MINES

Minnesota Erosion Control Association Conference
March 12, 2015
Ginny Yingling, Minnesota Dept. of Health

Topics To Be Covered

- **Frac Sand in Minnesota**
  - What is it?
  - Why is it here?
  - How is it mined and processed?
  - Can't they get it somewhere else?
- **Are There Health Concerns?**
  - Air quality
  - Water quality
  - Other issues
- **What Can We Do?**

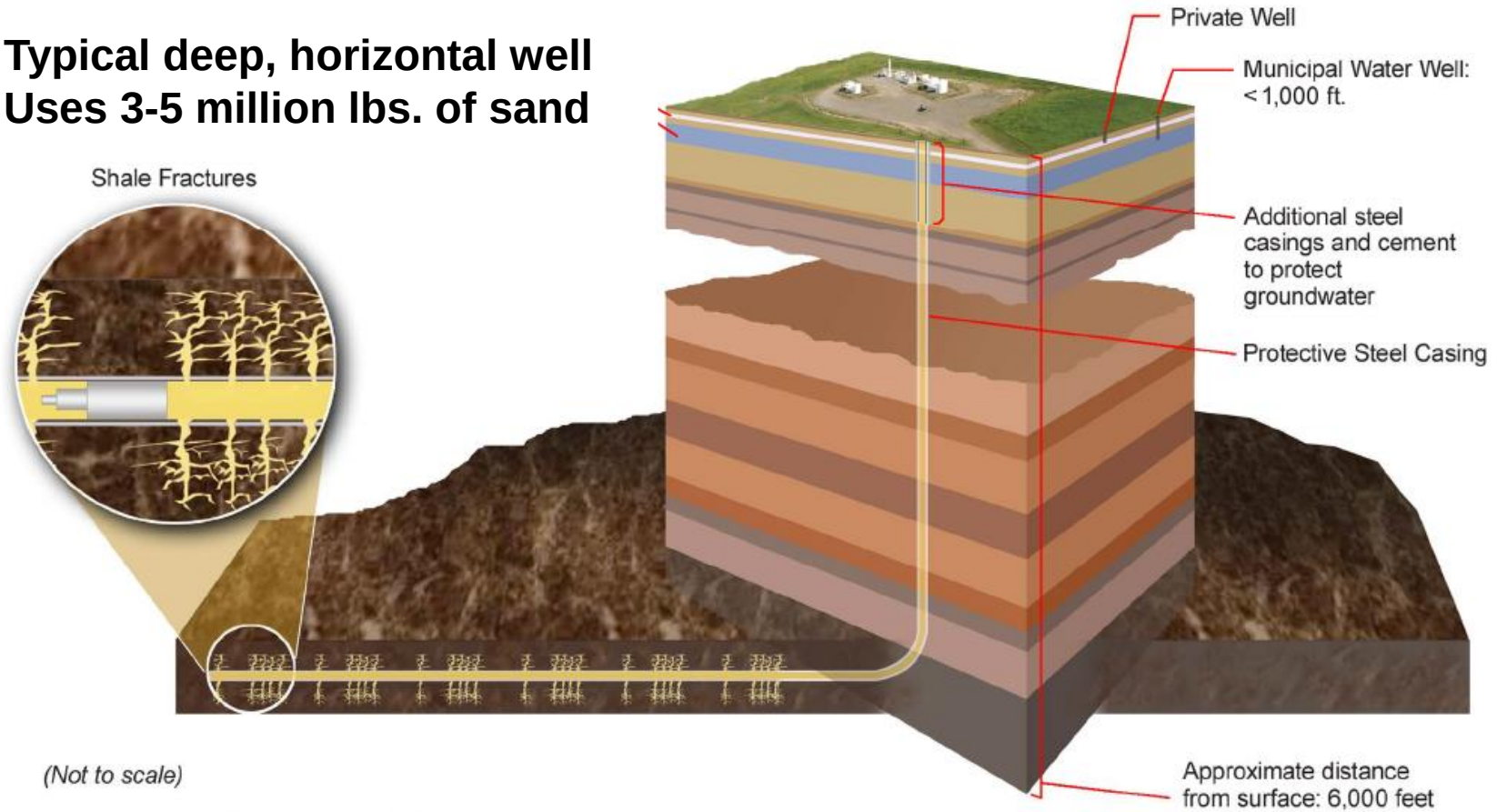
What Is Frac Sand?

- Industrial silica sand is well-rounded, well sorted sand consisting of almost pure quartz, or silicon dioxide (SiO_2)
  - "Frac" sand is a type of industrial silica sand that meets specific requirements of the oil & gas industry
- Silica is one of the most common minerals on earth
  - Major component of rocks such as granite and gneiss
- High compressive strength

Photo: Fedgazette, "Sand Surge", July 2012

Why Is Frac Sand Needed?

Typical deep, horizontal well
Uses 3-5 million lbs. of sand

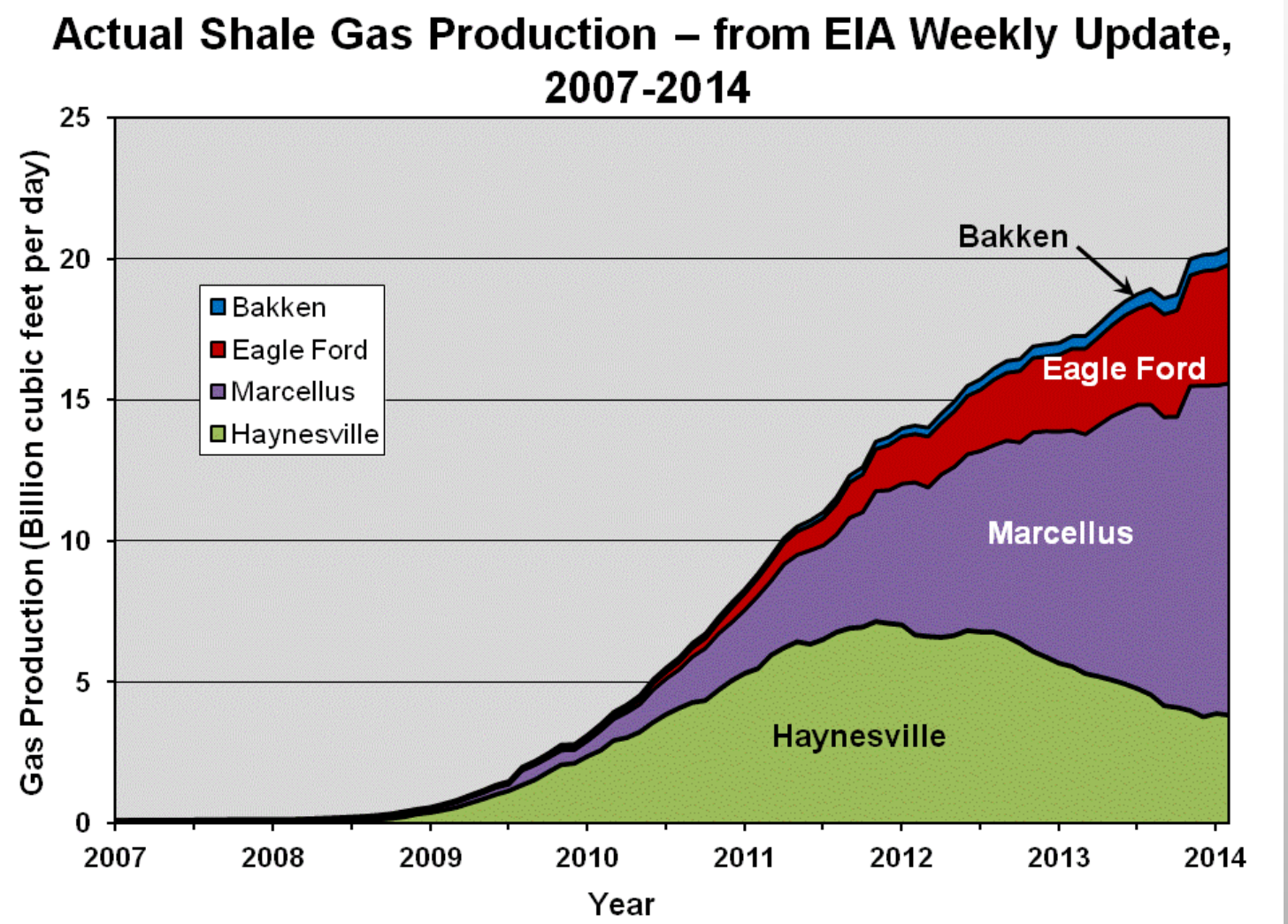


SOURCE: http://www.netl.doe.gov/technologies/oil-gas/publications/brochures/Shale_Gas_March_2011.pdf

Minnesota Department of Natural Resources, 2012

This type of oil & gas exploration is NOT happening in Minnesota

Shale Gas Production is Driving Up Demand for Frac Sand



What's So Special About Frac Sand?

Construction Sand & Gravel

Industrial Silica Sand

Unlike typical sand and gravel, it is composed of ~ 95% quartz sand that must meet very strict specifications…

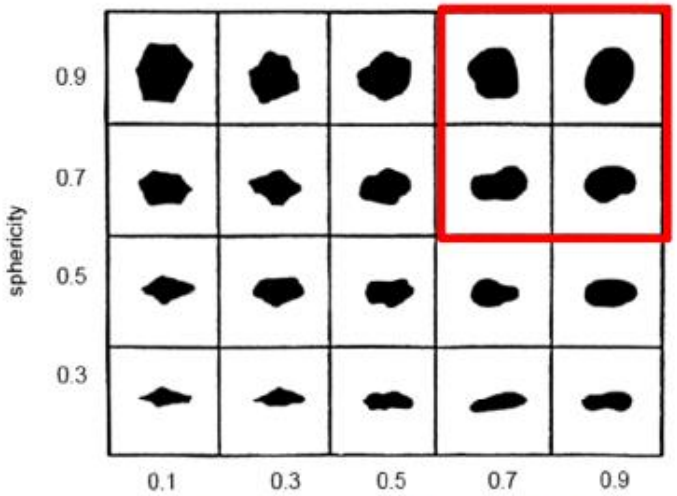
Frac Sand Must Meet Strict Specifications

GRAIN SIZE

0.15 – 0.6 millimeters

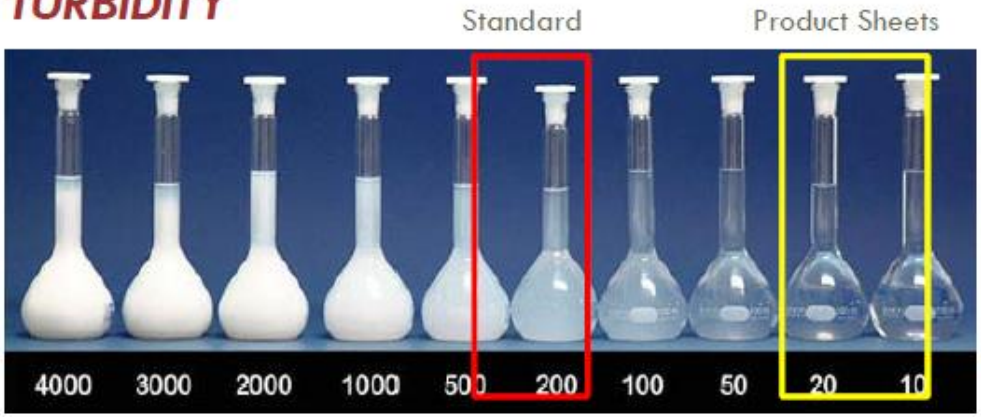
PRODUCT	8/12	10/20	20/40	70/140
Grain Size (Diameter)	2.38 to 1.68 millimeter	2.00 to 0.84 millimeter	0.84 to 0.42 millimeter	210 to 105 microns
Sediment	Fine Gravel to Coarse Sand	Very Coarse Sand to Coarse Sand	Coarse Sand to Medium Sand	Fine Sand to Very Fine Sand

SHPERICITY AND ROUNDNESS



Krumbein and Sloss, 1955

TURBIDITY

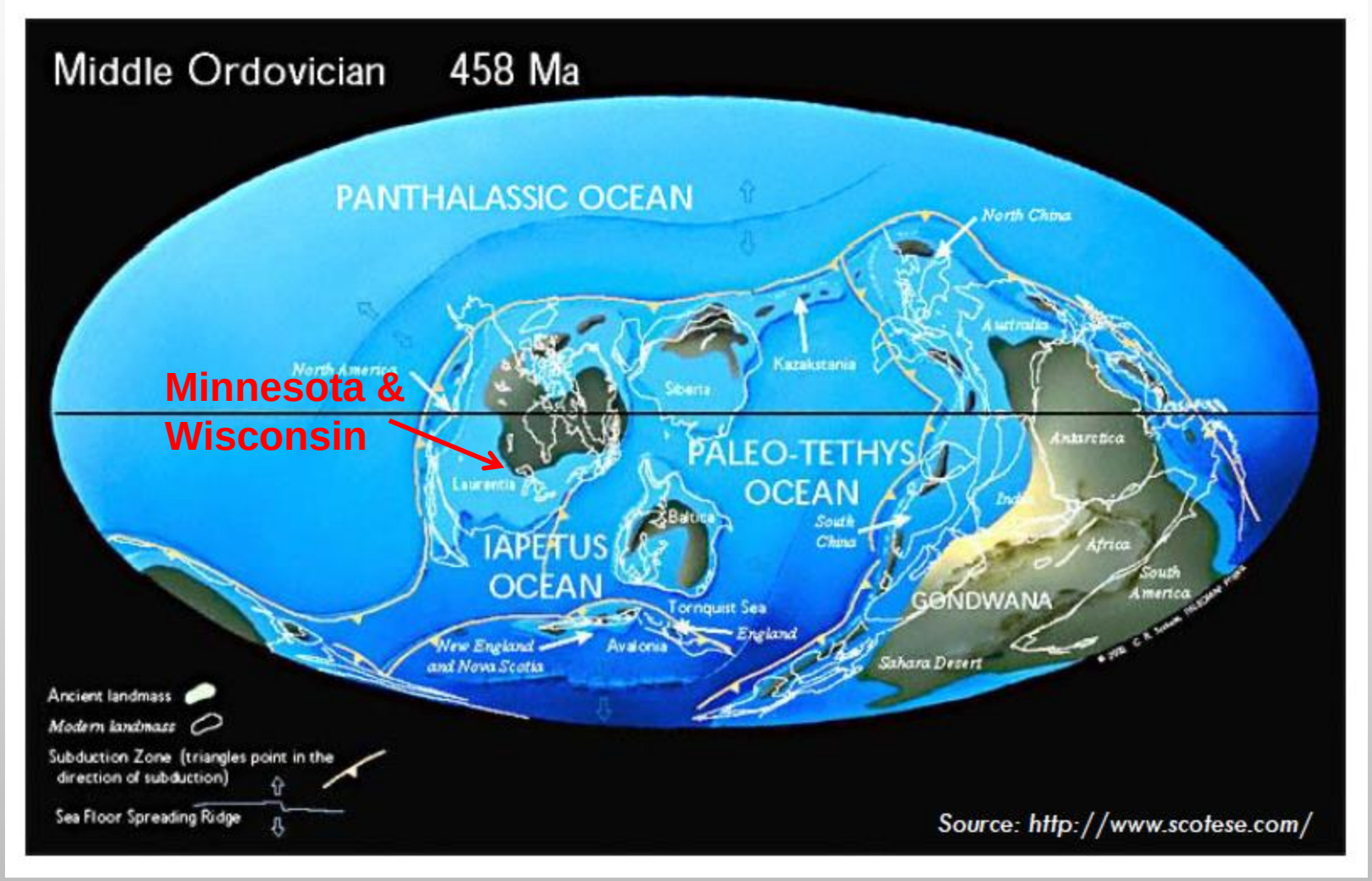


Silt and clay sized particles (<62.5 microns) must not exceed a 250 turbidity threshold of 250 FTU (Formazin Turbidity Units). However, processing significantly removes silts and clays.

Minnesota Department of Natural Resources, 2012

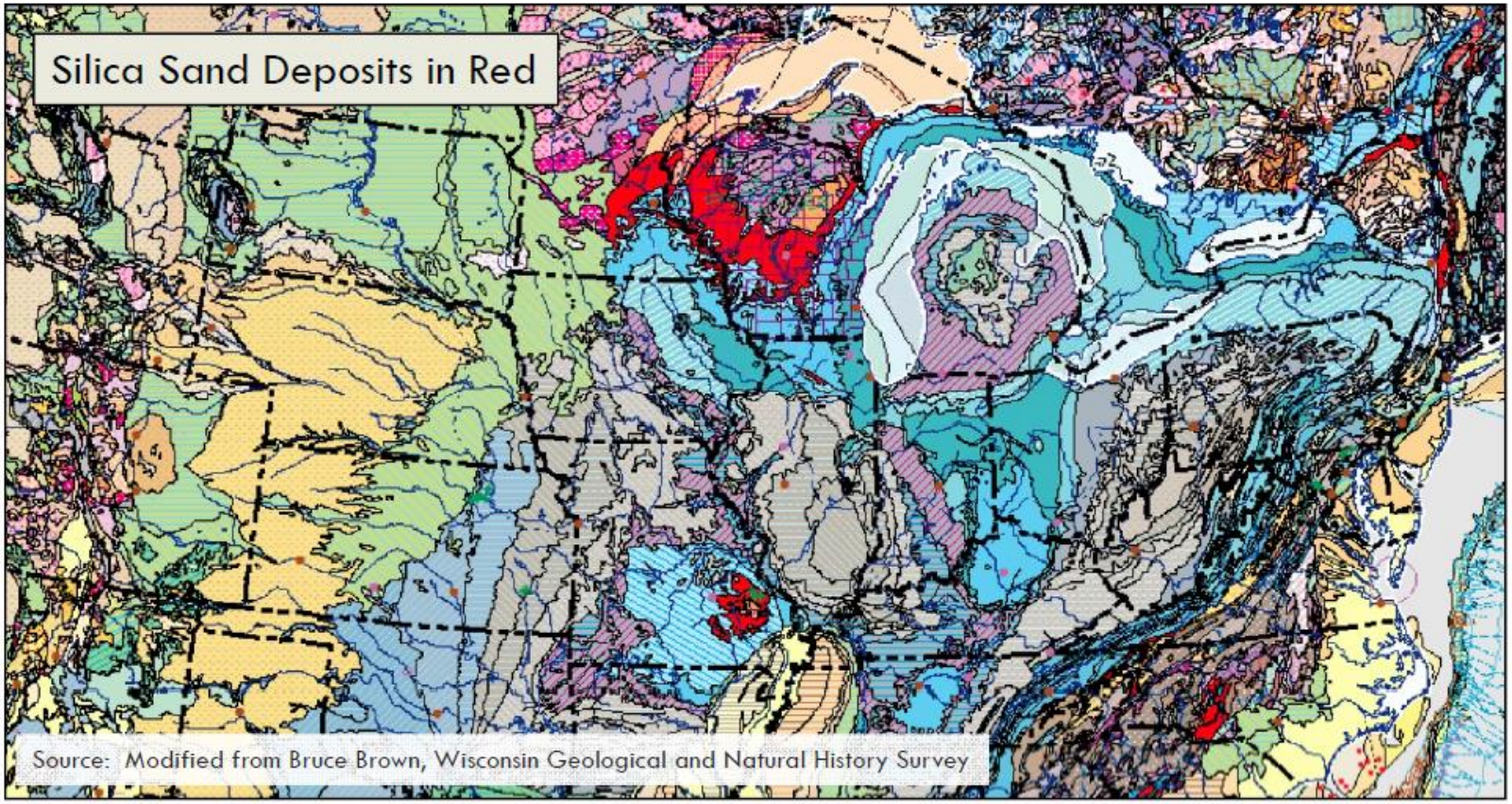
In other words – it's beach sand!

So Why Minnesota and Wisconsin?



Because 450 million years ago – this WAS the beach!

The Largest Deposits Are Here…



Minnesota Department of Natural Resources, 2012

…and they are easier to access than elsewhere in the country

Which Sandstones are of Interest?

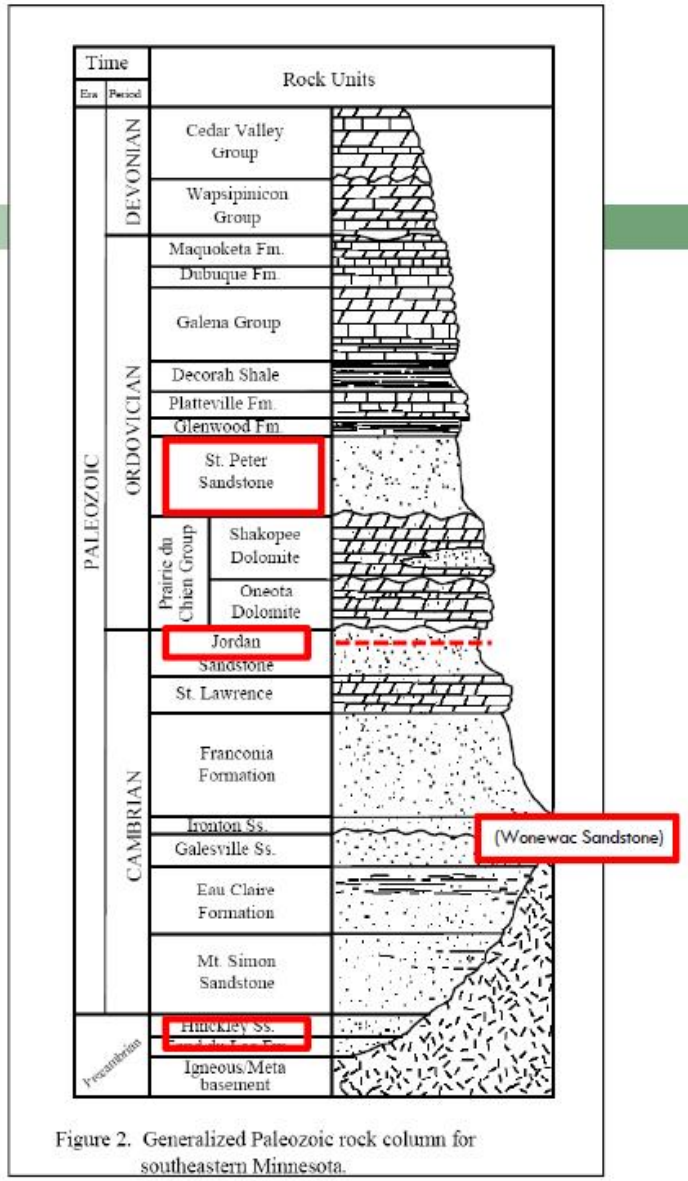
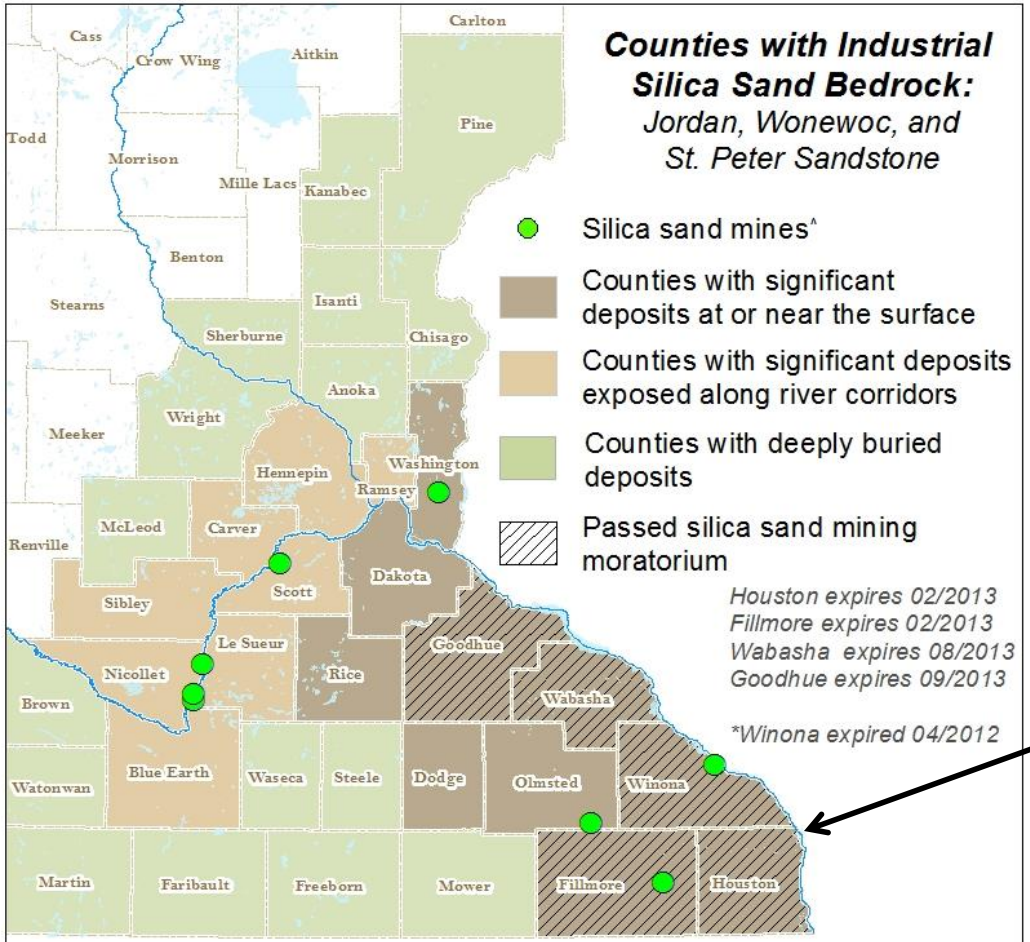


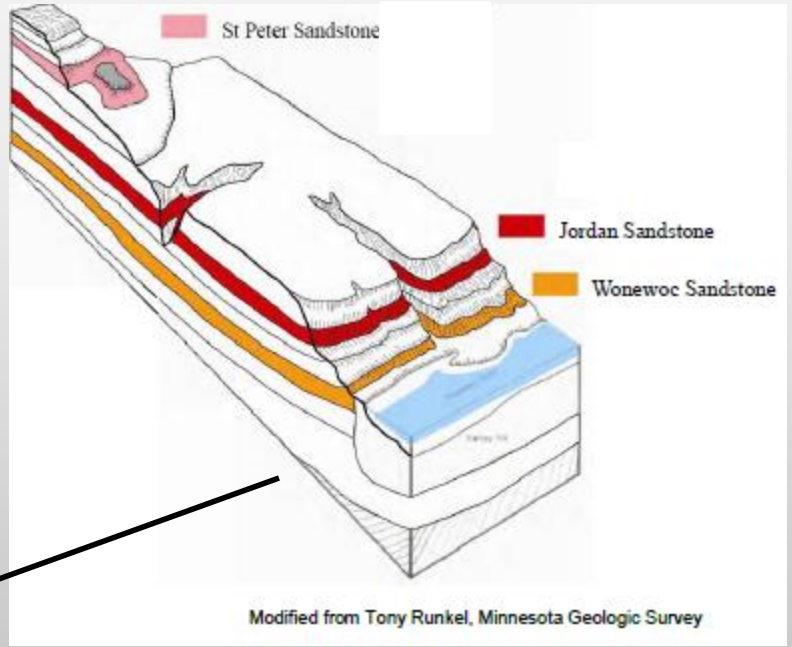
Figure 2. Generalized Paleozoic rock column for southeastern Minnesota.

Source of Stratigraphic Column: Minnesota Geological Survey

Where Is The Silica Sand In MN?

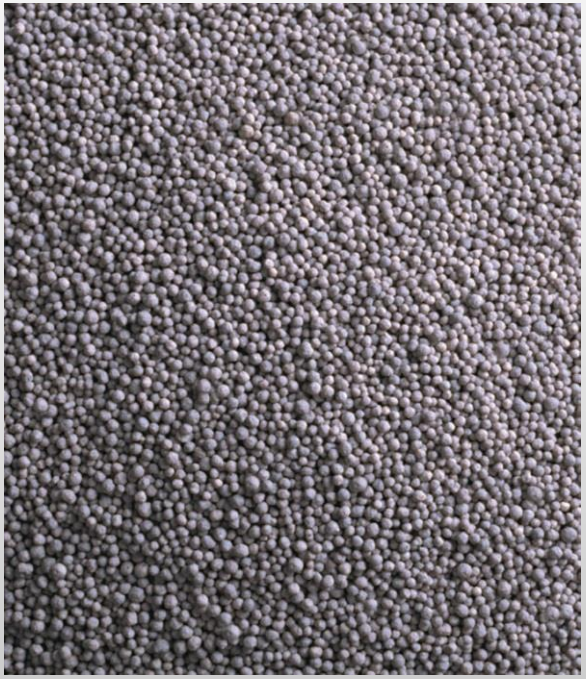


Source: Minnesota DNR



Are There Alternatives?

- **Manufactured Proppants**
  - **Ceramic beads made from:**
    - **Kaolinite**
    - **Bauxite**
    - **Recycled waste materials**
      - **glass, fly ash, mine tailings & slag**
      - **not yet commercially available**



- **Issues**
  - **Cost**
  - **Transportation (most made outside US)**
  - **Environmental impacts**
  - **Availability**

Mining Silica Sand

- Removal of overburden
- Excavation of loose sand
- Blasting and crushers used to loosen weakly cemented sandstone, but still keep individual round grains intact
- Some proposed mines will remove sandstone 50+ ft. below the water table

Photo: Lukas Keapproth, WCIJ

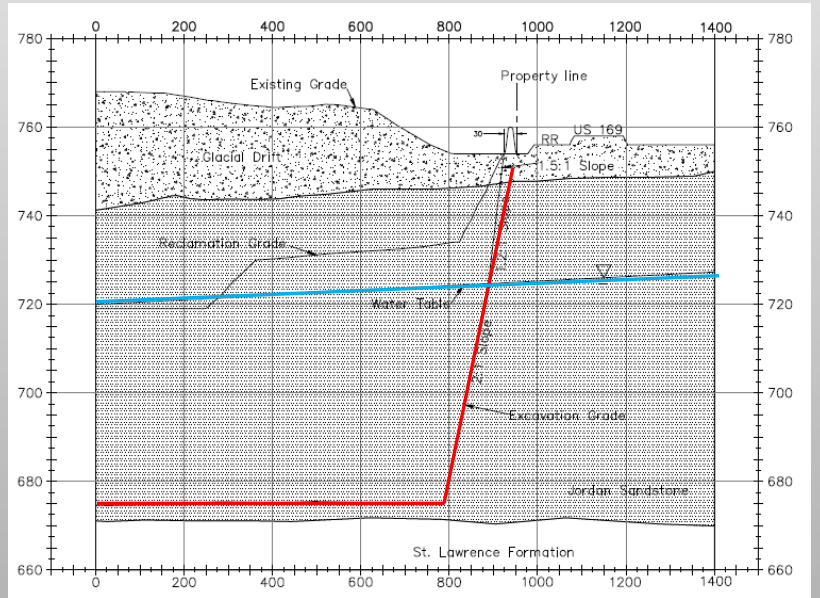


Fig. 6, Great Plains Sand EAW

Processing Frac Sand

- Sand is transported from the crusher to wash house
  - Often by conveyor belt
- Washing removes silt & clay
  - Often used in mine reclamation
  - Flocculant may be used to speed up drying → filter cake
- Sand dried and sorted by grain size
- Rinse water usually "recycled"
  - Settling ponds
  - Flocculants may be used
  - Water ultimately discharged or returned to mine

Photo: Lukas Keapproth, WCIJ

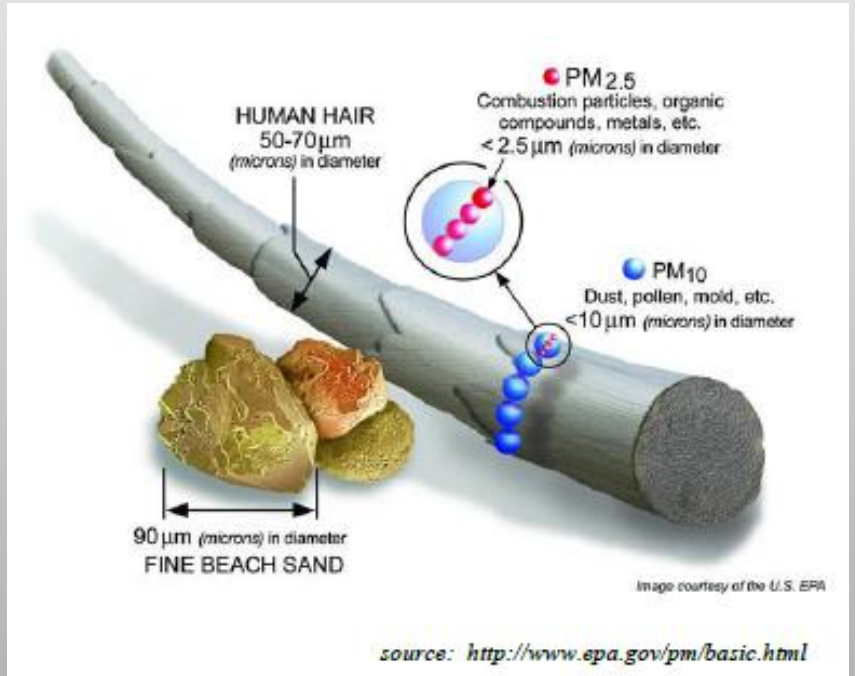
Photo: Brian Peterson, Star Tribune

Health Concerns Related to Silica Sand Mining

Air Quality Concerns

- **Two forms of silica: crystalline & amorphous**
- **Respirable crystalline silica is the main concern**
  - **Especially 4 micron or smaller (PM4)**
- **Crystalline silica has long been recognized as a major occupational hazard, causing disability and deaths in workers in several industries**
- **This problem can be controlled**

Preferred Sands, Woodbury, MN - Photo: Jim Tittle



Respirable Silica Toxicity

- **PM4 crystalline silica settles deep in lungs**
  - Then passes to other organs in the body through the blood
- **Crystalline silica exposure is associated with:**
  - **Silicosis**
  - **Lung cancer** → Especially among smokers
  - **Chronic Obstructive Pulmonary Disease**
  - **Renal disease/kidney disease**
  - **Immune system diseases**

Source: CDC

- **Disease risk is related to the level and duration of exposure**
  - **Non-linear response: risks are much more elevated at higher exposures**
- **Disease may occur long after the exposure ends**

Silica Toxicity

- **Non-workers may also be at risk**
  - **Ambient crystalline silica levels can be significantly elevated downwind of mine and quarry operations**
  - **Silicosis has been reported in highly exposed individuals in non-occupational settings**
  - **Anecdotal reports of asthma-like symptoms**
- **OSHA – Permissible Exposure Limit (PEL)**
  - **100 µg/m^3 PM4 for 8-hour time-weighted average**
  - **Adjusted to 24 hour exposure: 24 µg/m^3 PM4**
- **NIOSH – Recommend Exposure Limit (REL)**
  - **50 µg/m^3 PM4 for 8-hour time-weighted average**
  - **Adjusted to 24 hour exposure: 15 µg/m^3 PM4**

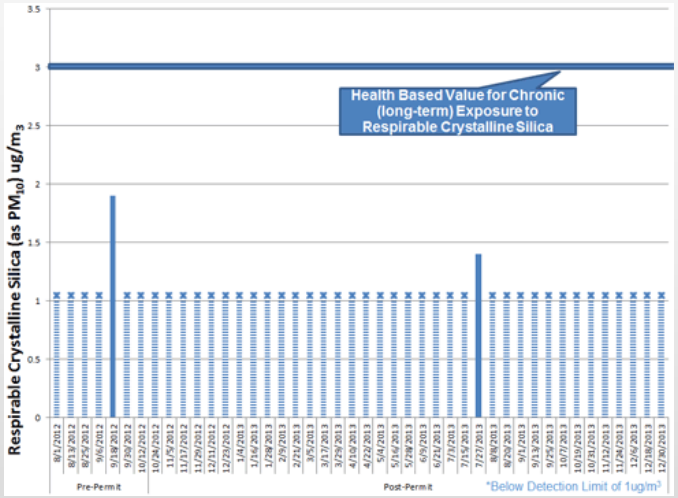
500 micrograms of frac sand looks like:

Silica Toxicity

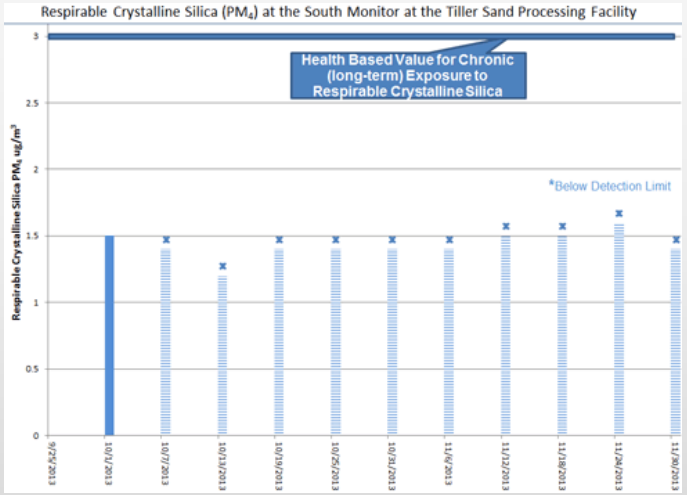
- **Minnesota**
  - **Chronic Health Based Value ($HBV_{chronic}$) = 3 µg/m^3**
  - **Protective against silicosis (and therefore, lung cancer)**
  - **www.health.state.mn.us/divs/eh/risk/guidance/air/silicasumm.pdf**
- **California EPA's OEHHA**
  - **Chronic reference exposure limit of 3 µg/m^3 PM4**
- **Little Known About Air Quality at Frac Sand Mines**
  - **No standard monitoring method for PM4**
    - **Current methods use modified PM10 monitor**
  - **Limited "real world" data (MN, WI, IA)**
  - **Risk for people near mines not well understood yet**
  - **Exposures can be controlled, but need standards**

Air Quality Data - Minnesota

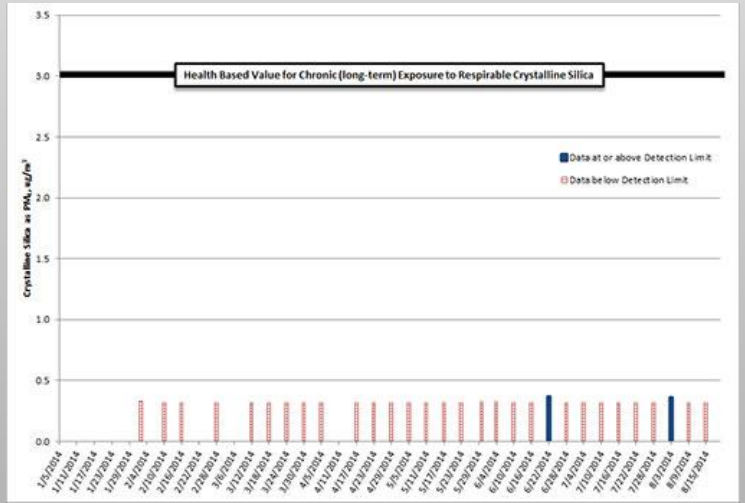
Shakopee Sands:



Tiller – North Branch:



City of Winona:



Source: MPCA website , 3/9/2015 –

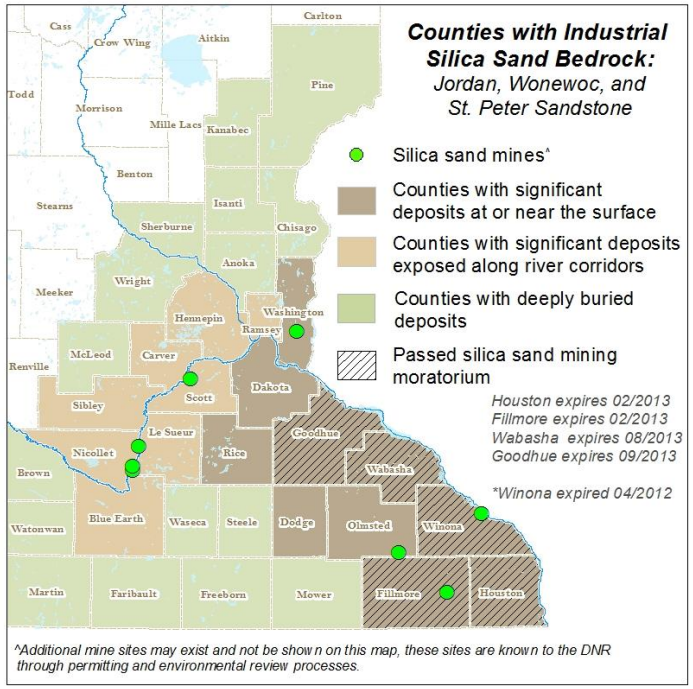
www.pca.state.mn.us/index.php/air/air-quality-and-pollutants/air-pollutants/silica-sand-mining/air-monitoring-data-at-minnesota-silica-sand-facilities.html

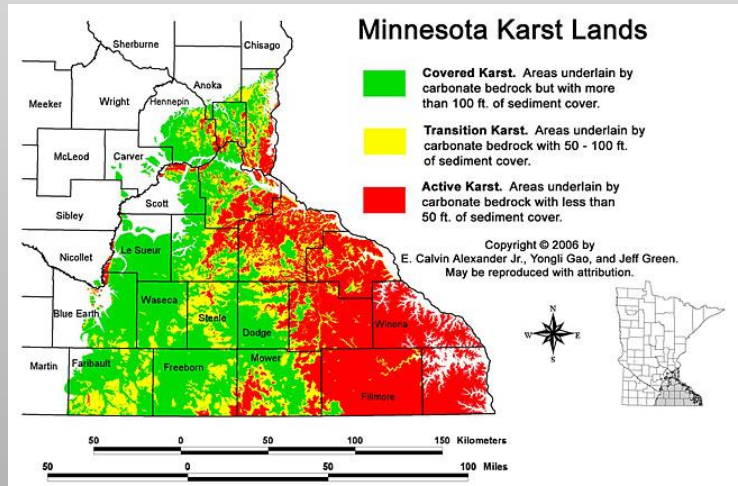
Water Quality Concerns

- All mines pose some potential risk to water quality
- Removal or reduction of cover above aquifers
- Chemicals used within the mining area
  - Fuel and other automotive liquids
  - Explosives & mineral processing chemicals
- Contaminated runoff entering the mine
  - Bacteria & viruses
  - Pesticides & nutrients
  - Other contaminants
- Illegal waste disposal in mine
- Improper reclamation & future land use
- www.health.state.mn.us/divs/eh/water/swp/mining.pdf

Water Issues Unique to Frac Sand Mines

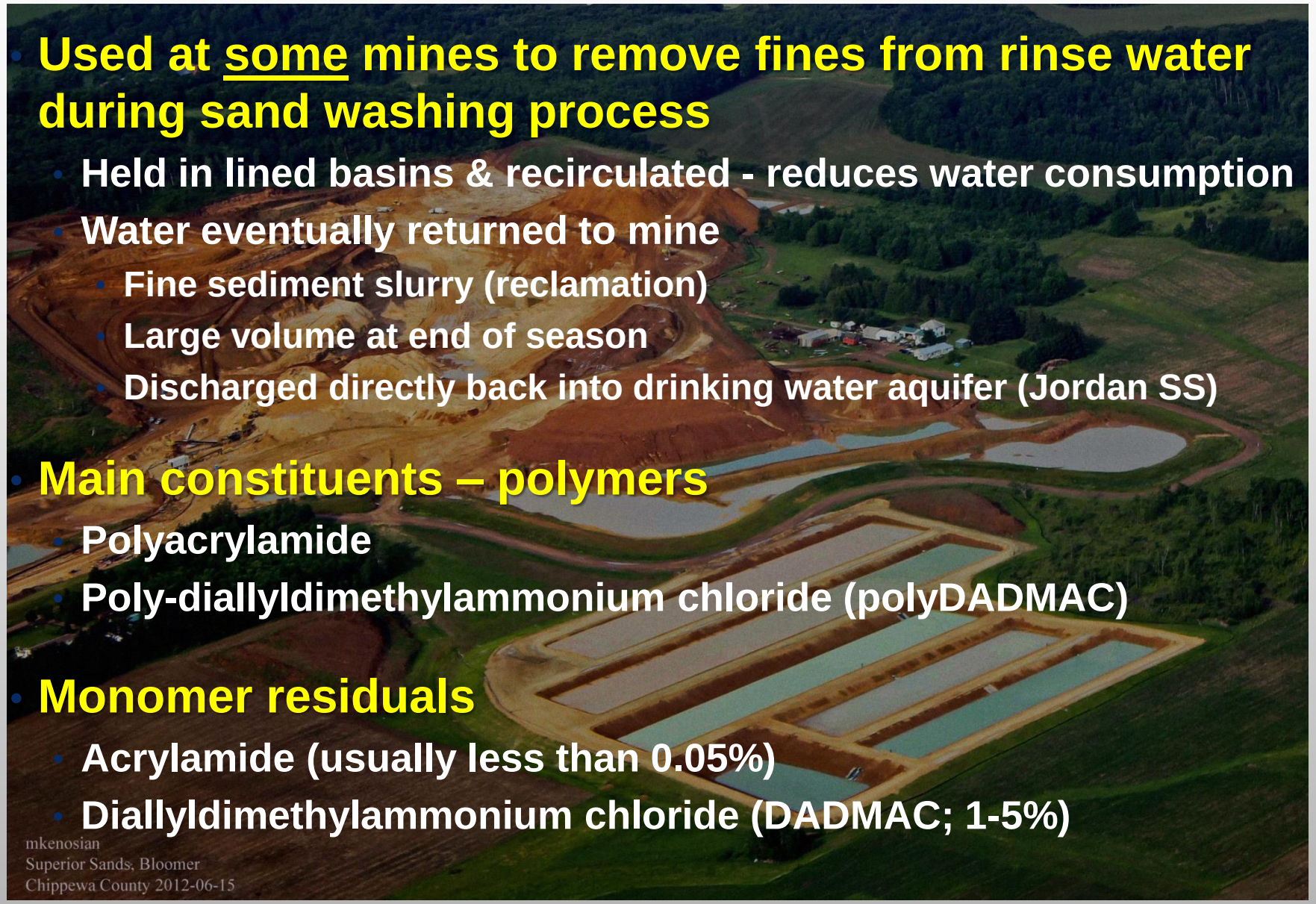
- **Frac sand areas are co-located with some of Minnesota's most vulnerable groundwater**
- **Jordan Sandstone mines may remove local/regional aquitards (shales) that protect the main drinking water aquifer for east-central Minnesota**
- **St. Peter Sandstone mines may remove cover over bedrock where karst exists or readily forms; when this happens…**
- **The backfilled mine remains as a depression in the surface of the bedrock that may:**
  - **focus infiltration**
  - **accelerate karst formation**
  - **create/enlarge contaminant pathways**





Flocculants at Frac Sand Mines

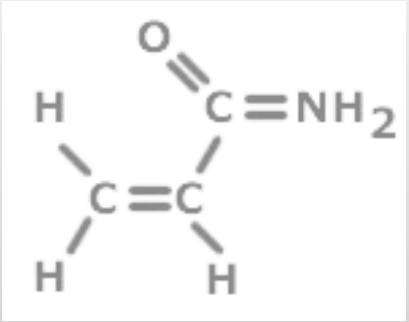
- **Used at some mines to remove fines from rinse water during sand washing process**
  - Held in lined basins & recirculated - reduces water consumption
  - Water eventually returned to mine
    - Fine sediment slurry (reclamation)
    - Large volume at end of season
    - Discharged directly back into drinking water aquifer (Jordan SS)
- **Main constituents – polymers**
  - Polyacrylamide
  - Poly-diallyldimethylammonium chloride (polyDADMAC)
- **Monomer residuals**
  - Acrylamide (usually less than 0.05%)
  - Diallyldimethylammonium chloride (DADMAC; 1-5%)



mkenosian
Superior Sands, Bloomer
Chippewa County 2012-06-15

Acrylamide – Health Concern

- **EPA classifies as a "likely carcinogen"**
  - Also a neurotoxin
  - National Primary Drinking Water Regulation: 0.5 µg/L
- **Concentrations in rinse water:**
  - Belvidere, NJ (measured): 1.19 µg/L
  - Chippewa Co., WI (estimate): 5.57 µg/L
  - Shakopee Sands, Scott Co., MN (estimate): 1.3–9.1 µg/L
  - Sand and gravel mine, MN (measured): 0.28 µg/L
- **May be present in some blasting agents:**
  - Shakopee Sands, Scott Co., MN: 2.2 – 7.4 µg/L - ???



Acrylamide – Fate & Transport

- **Mobility:**
  - Very soluble
  - Poorly adsorbed to mineral or organic matter
- **Degradation:**
  - Readily degrades in soil and surface water
  - Degradation rates decrease <u>significantly</u> at lower temperatures (10º C) and in saturated soils[1]
    - i.e. groundwater conditions
  - Polyacrylamide DOES NOT degrade to acrylamide in any appreciable amounts

[1] Abdelmagid and Tabataba (1982) Journal of Env. Qual., 11:701-704

MDH Activities

- **Acrylamide added to "Chemicals of Emerging Concern" list → toxicological evaluation**
- **Health Based Value (HBV): 0.2 µg/L**
  - **Based on cancer risk (i.e. long-term exposure)**
- **Public Health Laboratory**
  - **Developed analytical method in 2013**
  - **Evaluated acrylamide degradation rates**
- **Environmental Review**
  - **Review EAWs and EISs for proposed mines**
  - **Assist MPCA in permitting review process**

Preliminary Water Quality Data

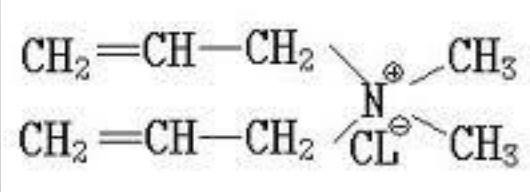
- **Shakopee Sands (frac sand mine)**
  - **2.2 – 7.4 µg/L in pit water (possibly from blasting agent?) – 2012**
  - **0.15 – 0.17 µg/L in pit water – 2014**
  - **Not detected in groundwater monitoring wells**
- **Sand and gravel mine**
  - **0.26 – 0.28 µg/L in pit water**
    - **Corresponds with MPCA permitted application rate estimates**
  - **0.047 µg/L in recirculating water**
  - **Not detected (<0.017 µg/L) after 4 days in holding pond**
- **Taconite mine**
  - **0.018 µg/L in nearby surface water**
  - **<0.017 µg/L in mine pits**
  - **<0.017 – 0.033 µg/L in groundwater monitoring wells**

Preliminary Water Quality Data

- **Drinking water treatment plants**
  - **0.021 – 0.04 µg/L in process water**
  - **0.046 – 0.056 µg/L in finished water**

DADMACs: Health Concern

- **polyDADMAC & DADMAC**
  - **Precursors to the formation of N-nitrosodimethylamine (NDMA) in the presence of some water disinfectants [2,3]**
  - **NDMA:**
    - **EPA - "reasonably anticipated human carcinogen"**
    - **On EPA's Unregulated Chemicals Monitoring Regulation List 2 and Contaminant Candidate List 3 (CCL3)**
    - **No federal or MN drinking water standards**
      - **IRIS: 10^{-5} cancer risk: 0.7 µg/L**
      - **California DPH response level: 0.3 µg/L**



- **Concentrations in frac sand rinse water unknown**
  - **Scott Co., MN (est.): pDADMAC – mg/L?; DADMAC – "sub mg/L"**

[2]Mitch & Sedlak (2004) ES&T, 38:1445-1454
[3]Kemper (2009) PhD thesis, Yale

DADMACs – Fate & Transport

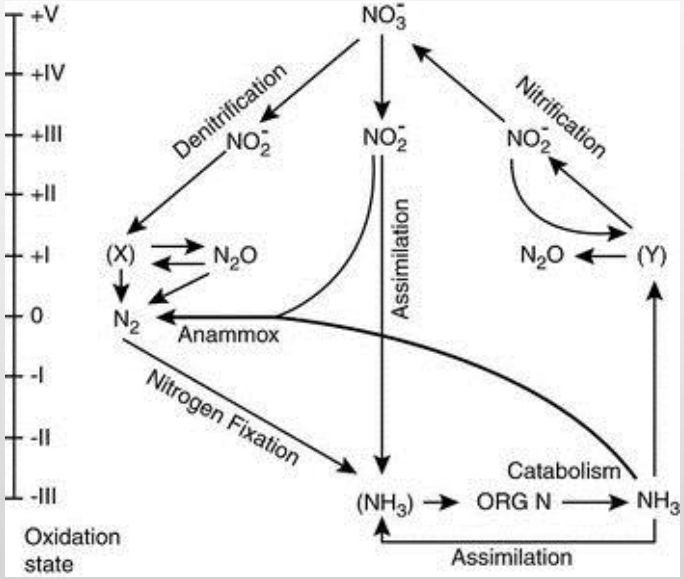
- **Mobility:**
  - Very soluble
  - pDADMAC readily adsorbed to soil and sediment
  - DADMAC poorly adsorbed to mineral or organic matter
- **Degradation:**
  - Both biodegrade under aerobic conditions
    - DADMAC half-life in aerobic soil reported 30 days
  - Neither degrades under anaerobic conditions

MDH Activities

- **DADMAC and NDMA added to "Chemicals of Emerging Concern" list**
  - **Available information will be reviewed to determine if Health Based Values can be established**
- **Public Health Laboratory**
  - **NDMA on priority list for method development**
- **Environmental Review**
  - **Review EAWs and EISs for proposed mines**
  - **Assist MPCA in permitting review process**
  - **Currently controlling through filter cake management**

Other Water Quality Issues?

- **Oxidation of groundwater**
  - **Convert ammonia to nitrate**
- **Change pH of groundwater?**
  - **Mobilize metals in aquifer**



Other Health Issues?

- **Truck traffic 24/7**
  - **Dust**
  - **Noise**
  - **Risk of accidents**
  - **Engine exhaust**
    - **Diesel particulates**

- **Acrylamide & DADMAC in air?**
  - **Does drying of sands or filter cake processed with flocculants release acrylamide and/or DADMAC?**
  - **Seems unlikely – but no data available**

An Ounce of Prevention….

- **Planning**
  - Identify, evaluate and address risks before digging
  - Minimize activities in vulnerable areas
  - Require appropriate flocculant addition rates
  - Establish air and water monitoring networks

- **Management**
  - Engineer site & process to control runoff and dust
  - Proper handling, storage, & disposal of chemicals
  - Monitor water and air quality
  - Confirm acrylamide degradation

- **Reclamation**
  - Divert surface drainage from former mine area
  - Re-vegetate with native plants to minimize or eliminate need for fertilizers and pesticides

MN 2013 Legislative Action

- **State agencies directed to develop:**
  - Particulate emissions control rules (MPCA)
  - Mine reclamation rules (DNR)
  - Respirable silica sand health-based value (MDH)

- **Mines within 1 mile of a trout stream require:**
  - In-depth hydrological study
  - DNR permit

- **State "technical assistance team" established to aid local governments with:**
  - Ordinance development and zoning
  - Environmental review and permitting
  - Monitoring

What Is Needed?

- **Air quality**
  - **PM4 standard monitoring methodology**
  - **Air monitoring data from areas near silica sand mines**
  - **More information about flocculants in air from drying sands**
- **Water quality**
  - **Standard analytical methods and drinking water criteria for DADMAC and NDMA**
  - **More monitoring data from groundwater and holding ponds at frac sand mines and processing facilities**

Acknowledgements

- Heather Arends, MN Dept. of Natural Resources
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Questions?