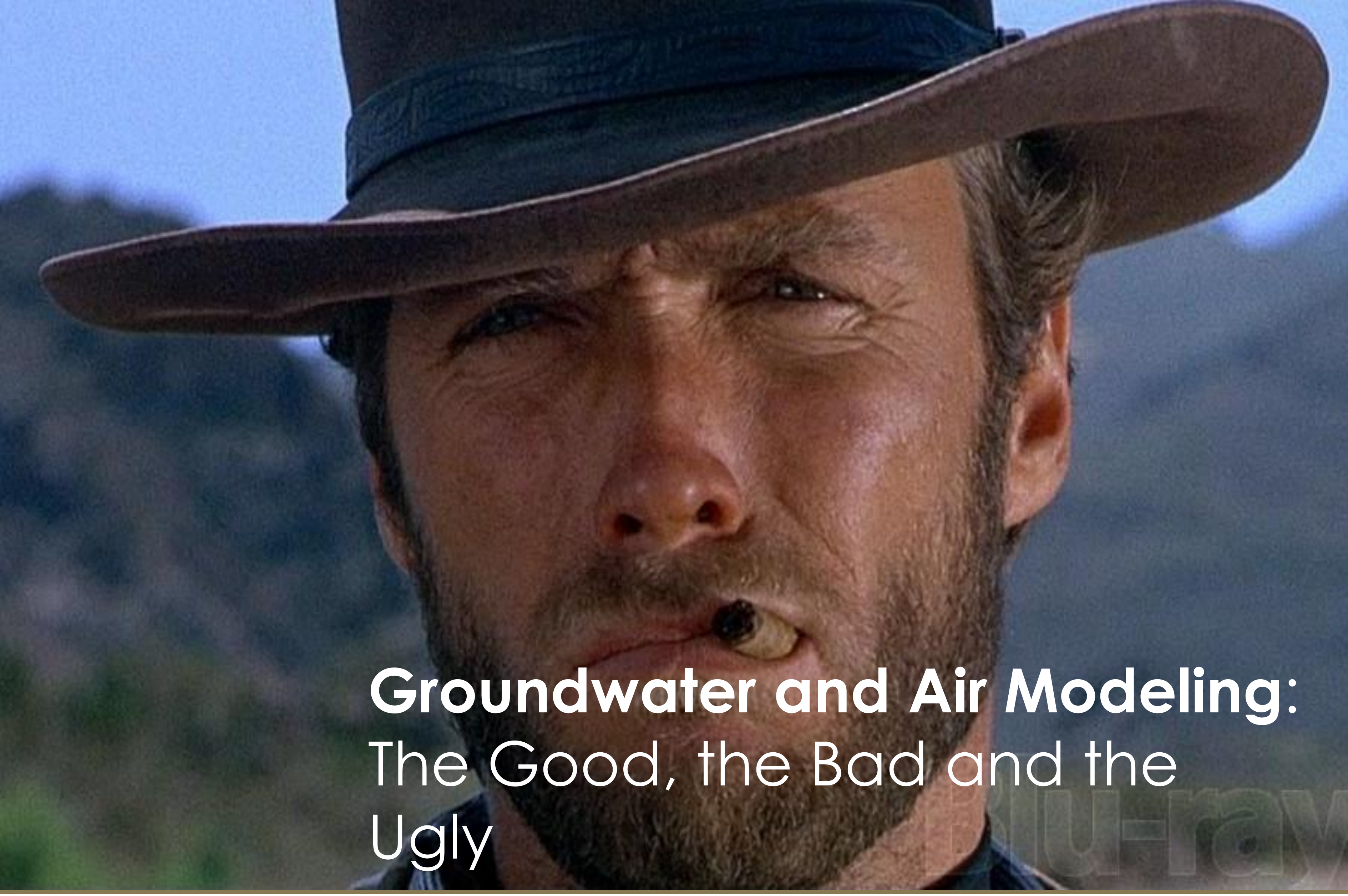

Groundwater and Air Modeling: The Good, the Bad and the Ugly

Ray Wuolo & Jennifer Koenen, Barr Engineering Co.

models are used to…

- **predict environmental impacts (**e.g. EIS**)**
- **establish regulatory compliance levels (**what, where, and how much**)**
- **allocate limited resources** (divide up a limited pie)
- **allocate liability for environmental damages**

models are simplifications of reality – but they are still very complex

- nature is complex
- the processes are complex (mathematically speaking)
- we can’t measure everything – in fact, we need to make lots of assumptions
- the price of reducing (or understanding) uncertainty is complexity

what do we mean by a "model"?

- abstract representation of reality – a simplification
- designed for a specific purpose
- to explain the present and to predict the future

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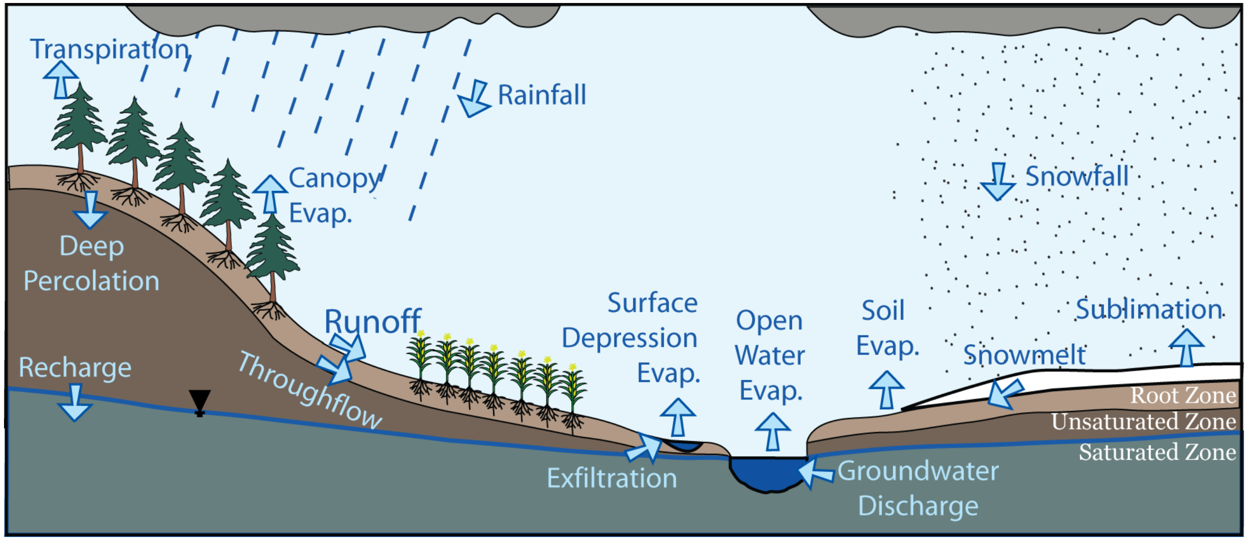
three basic kinds of models

physical model



conceptual model

$$Y = Ax + b$$

mathematical model

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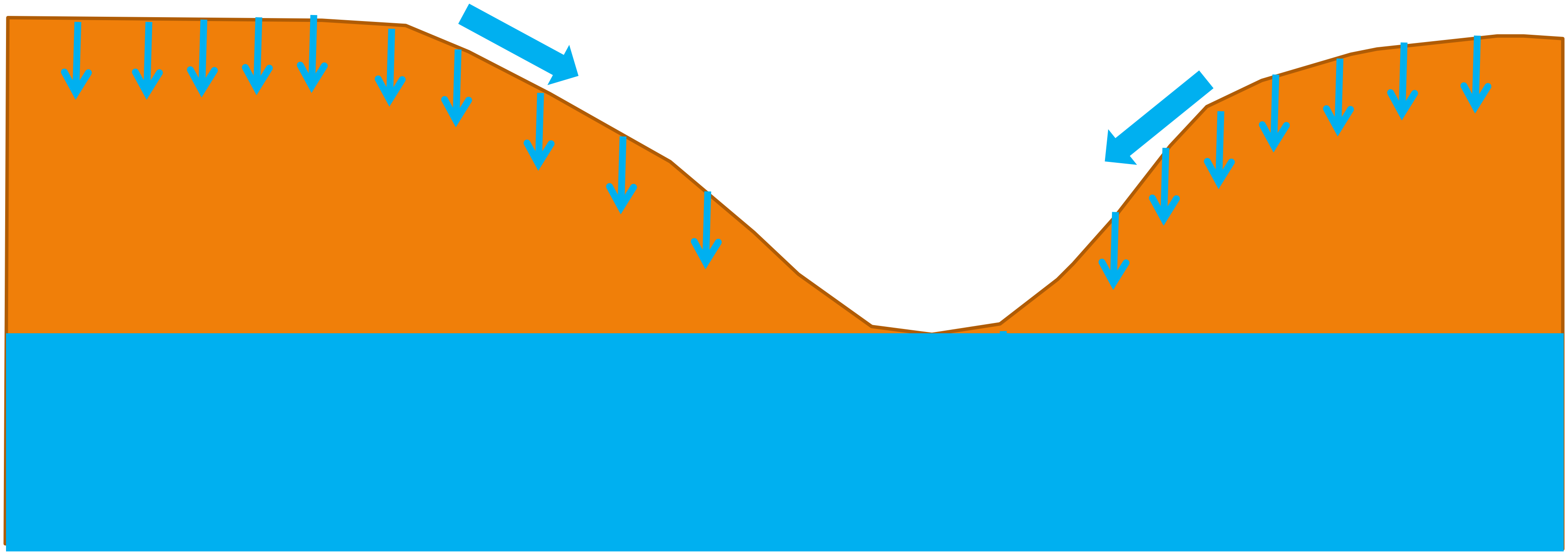
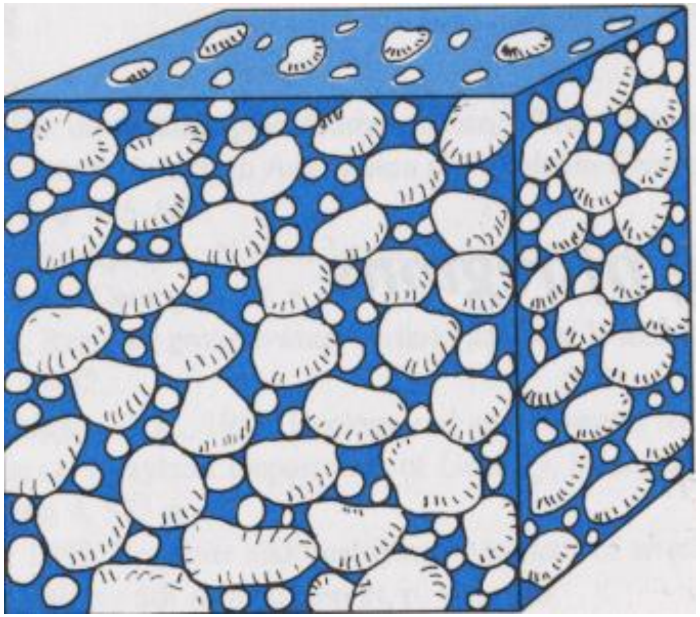
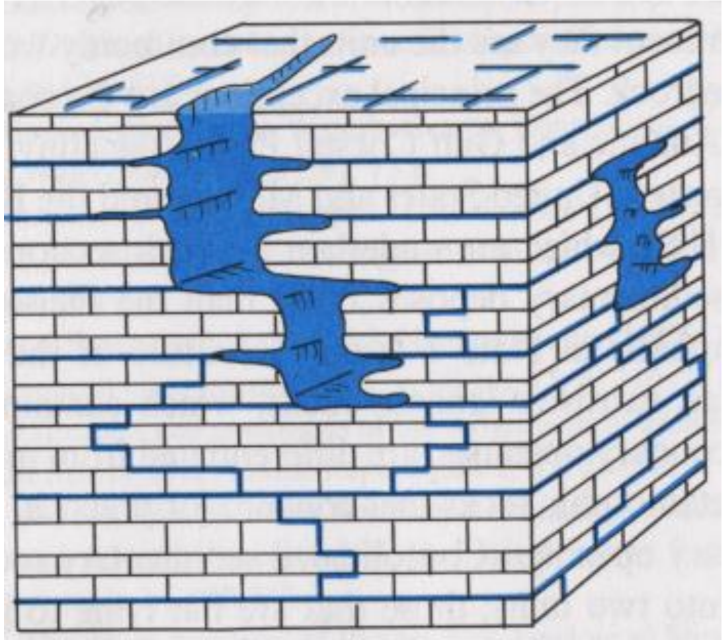
groundwater hydrology in 60 seconds…



groundwater fills the pores in soil and rock





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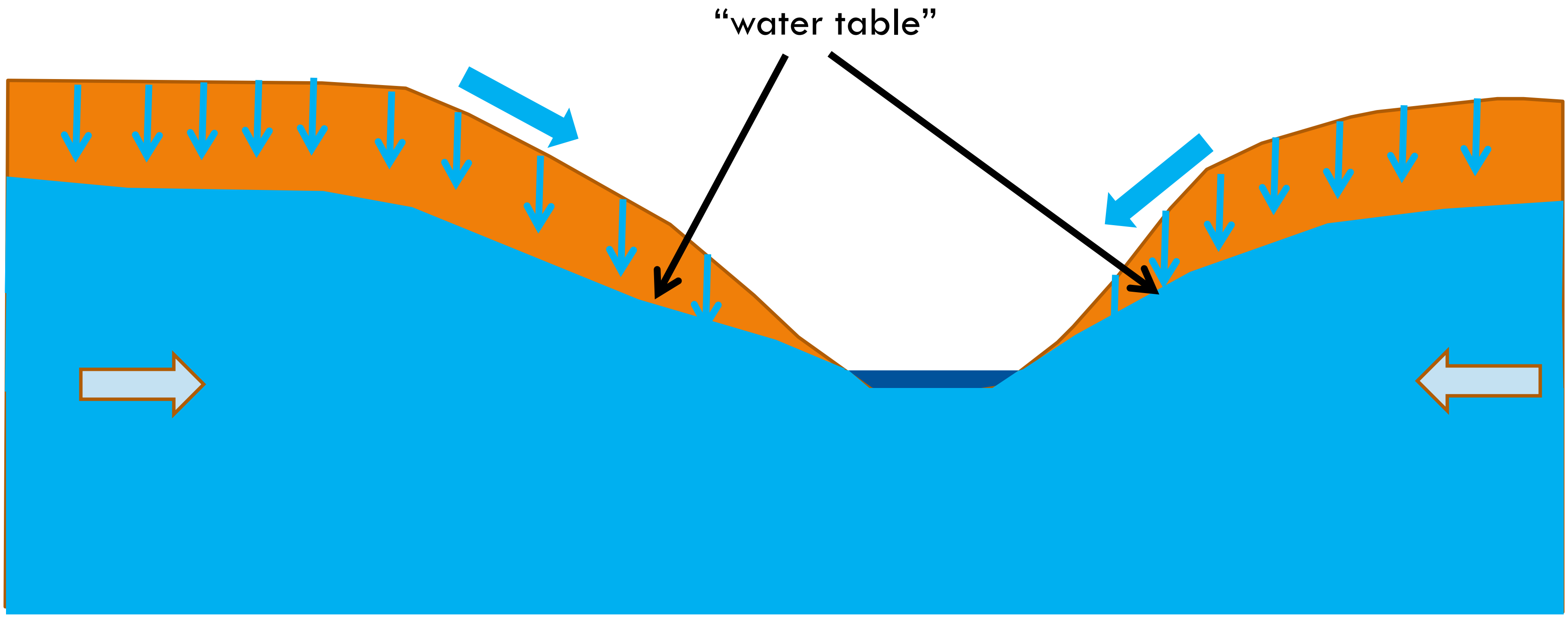
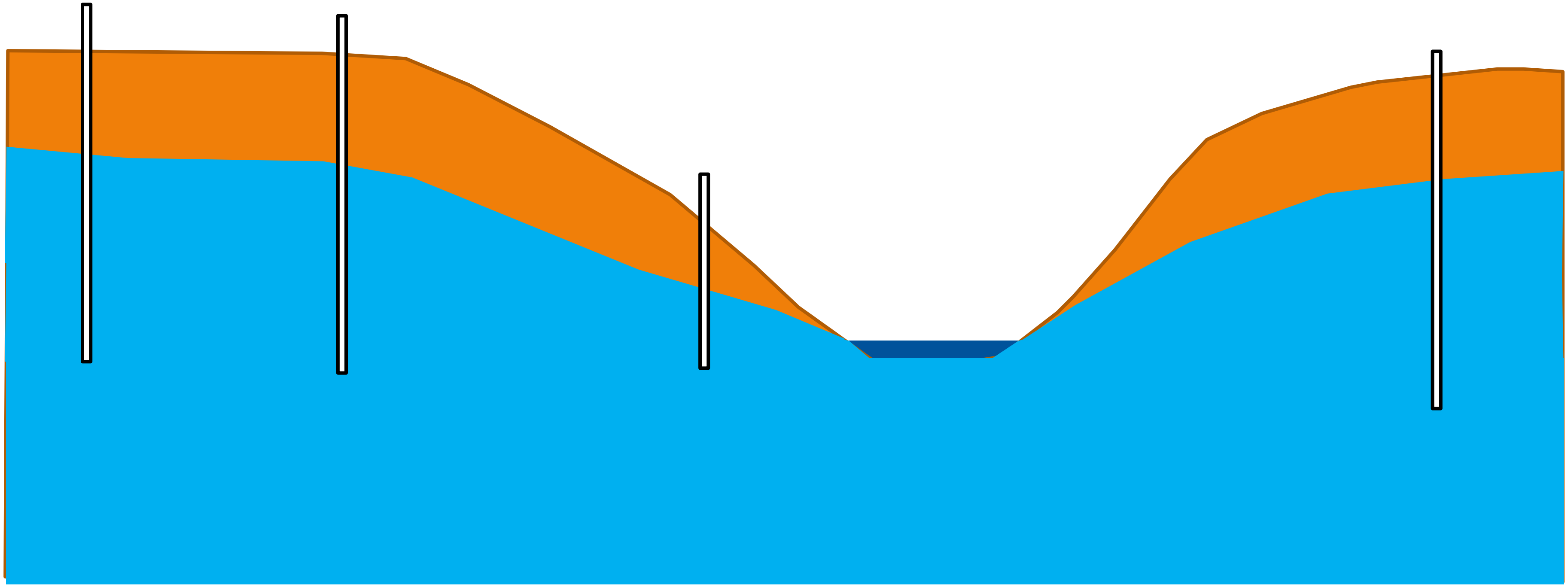
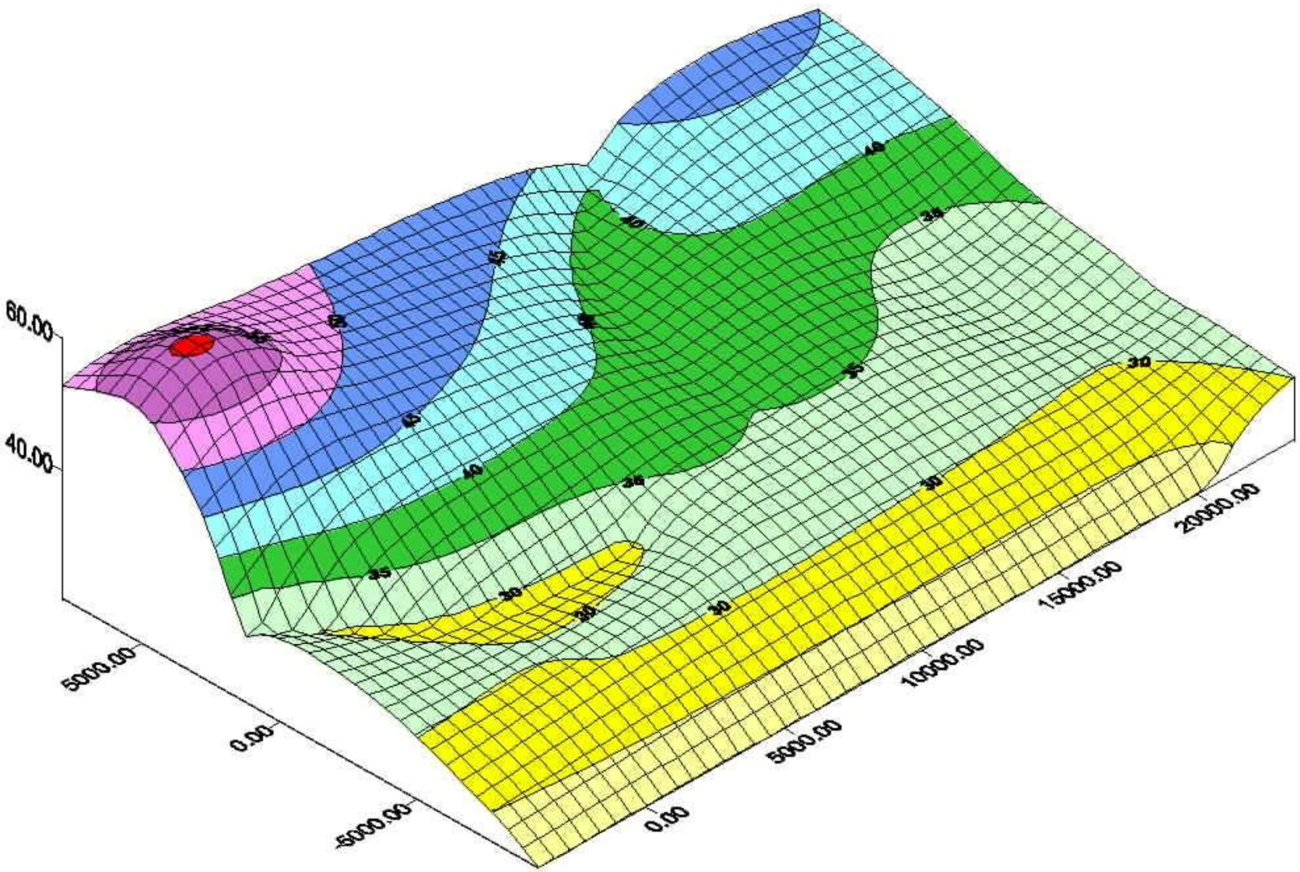
groundwater hydrology in 60 seconds…



the water table is measured using "monitoring wells"



the groundwater levels in wells are contoured, much like a topographic map



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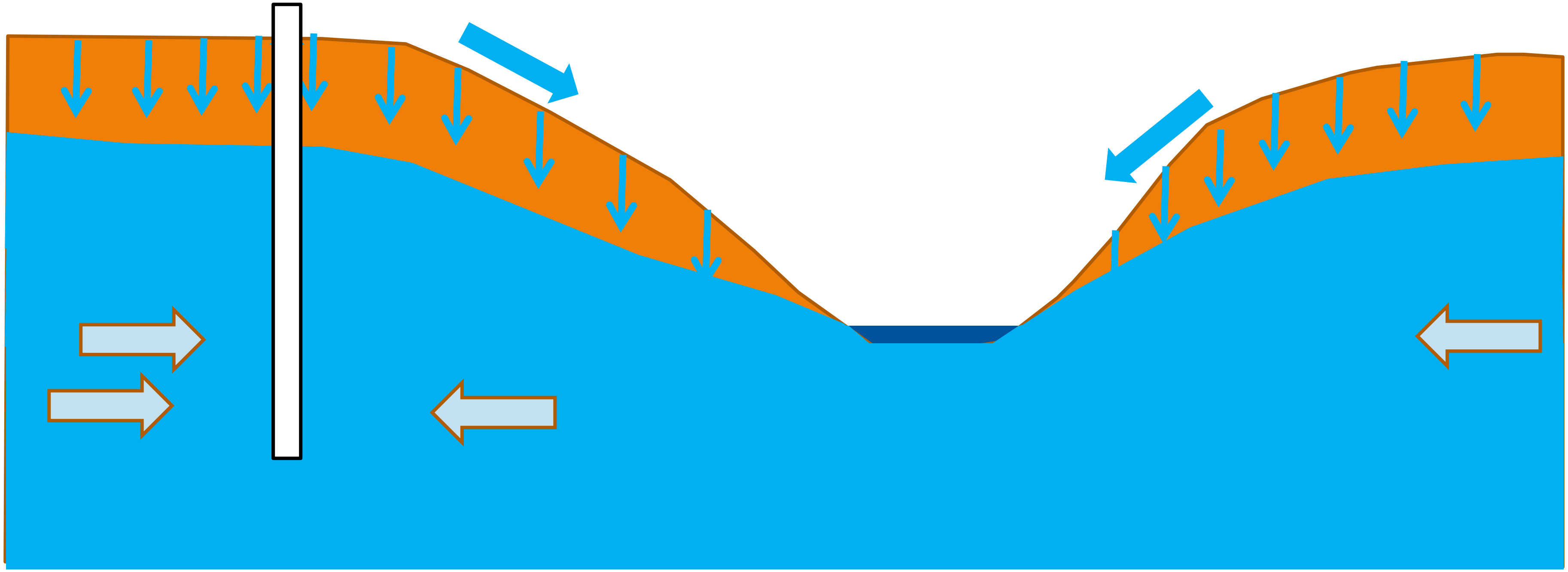
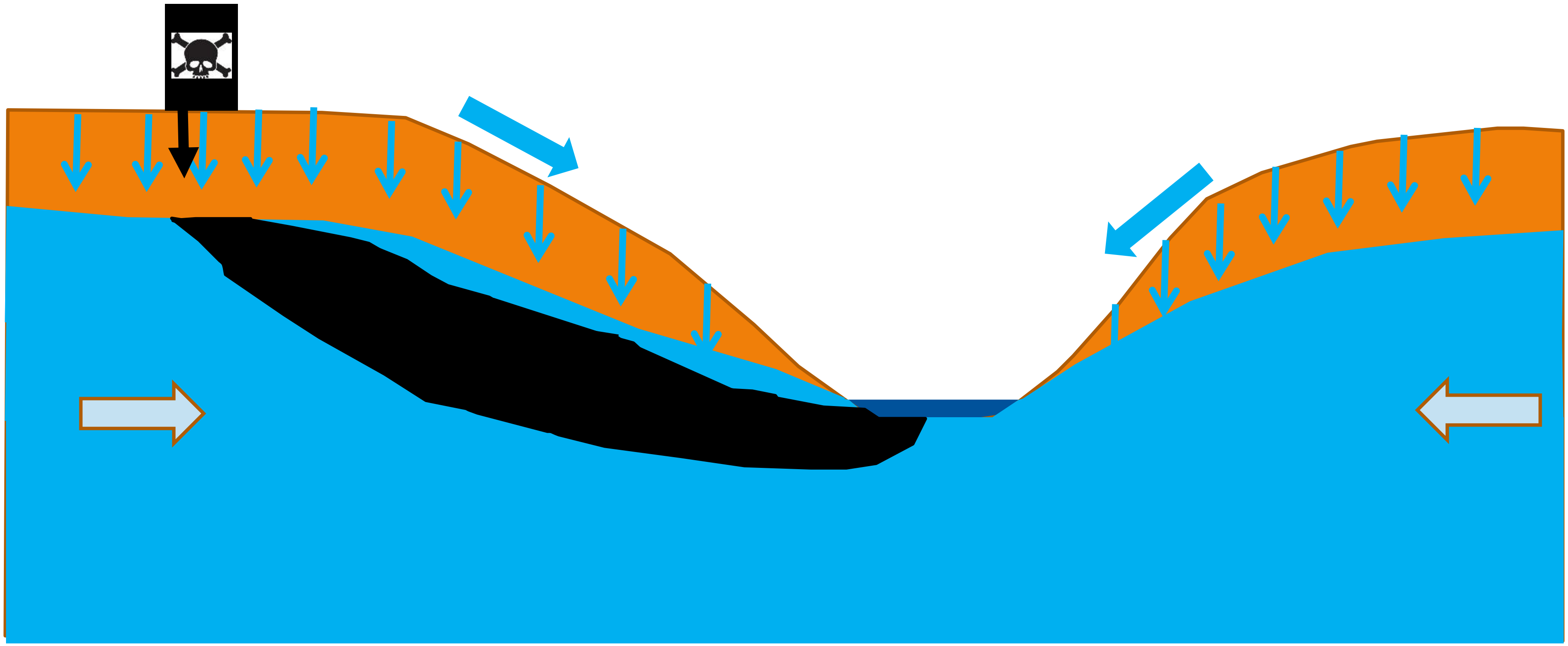
groundwater hydrology in 60 seconds…



groundwater hydrology in 60 seconds…



groundwater is replenishment (recharge) is controlled by:

- rainfall (how much and when)
- temperature & wind
- land use & cover (impervious area)
- vegetation
- topography
- geology (soil type)

groundwater levels and pumping rates are controlled by:

- type of rock or soil (permeability)
- location of lakes and rivers
- other pumping wells

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equations that describe groundwater flow can be complex

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t}$$

parameters vary in space and time

computer modeling codes for groundwater flow are (almost standardized)

- MODFLOW (USGS code) for flow is now the standard of the profession
- Automated "calibration" performed using PEST
- Contaminant transport using MT3D
- Some standardization of methods

The modeling process:

- data compiled and organized
- conceptual model developed
- computer model built
- model is “calibrated” (history matching) by varying unknown or uncertain parameters within expected ranges
- predictions are made

"All models are wrong, but some are useful" - George Box (statistician)

- Why are they wrong? Because they don't equal reality?
  - Why do we want them to equal reality? – We already **HAVE** reality.
- A model is a **<u>simplification</u>**
  - To gain an *understanding* of how reality works
  - To make *prediction*<u>**s**</u> about phenomena *that cannot be tested* at full-scale
- All models have "defects" – get over it

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categories of the sources of uncertainty in groundwater models

- How we conceptualize and simulate groundwater flow
- "Calibration"/Observation Target Values – the byproducts of groundwater flow (what we can measure)
- Parameter Values – the "container" of groundwater flow(what we can measure and infer)
- The "null space"

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ultimate source of uncertainty: the "null space"

"There are the 'known knowns', the 'known unknowns' and then there are the 'unknown unknowns'".

The null space: where the unknown sources of uncertainty congregate – where mathematical models are denied entry

most of us have an unusually high tolerance for model uncertainty

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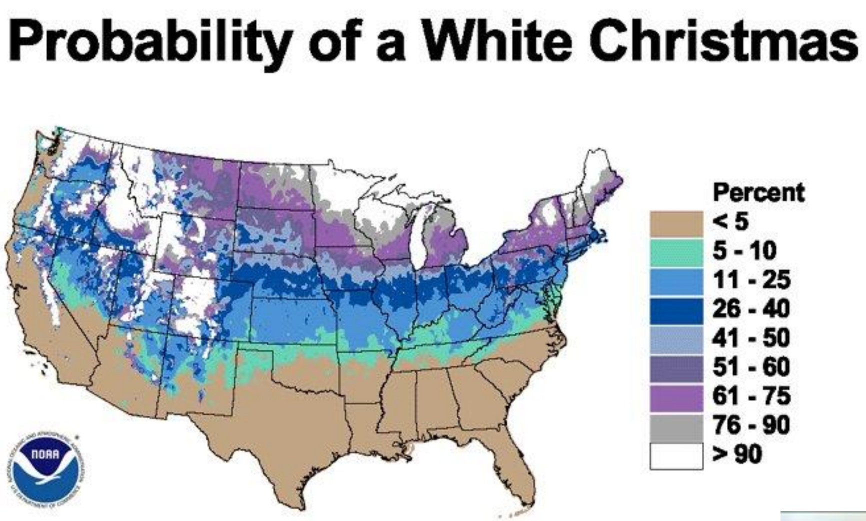
most of us are conditioned to accept model inaccuracies (and their usefulness)



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uncertainty is one key element in understanding risk (the other is consequence)

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the take home message: be wary of any model that does not address uncertainty

- no model can possibly provide a unique answer or prediction
- uncertainty should be described in terms of a range of possible outcomes
- “worst-case scenarios” often are not worst-case
- beware of the modeler with a super computer for he/she will find uncertainty where others cannot

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air dispersion modeling triggers as part of regulatory framework

- Federal New Source Review (NSR) Prevention of Significant Deterioration (PSD) permitting program
- Environmental Review (EAW/EIS)
  - Environmental Justice
- MN Title V Permitting Program
- Permit condition

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air dispersion modeling according to EPA

- “Dispersion models are source-oriented models that characterize atmospheric processes by dispersing a directly emitted pollutant to predict concentrations at selected downwind receptor locations.”
- regulatory model of choice is AERMOD
  - AMS/EPA Regulatory Model

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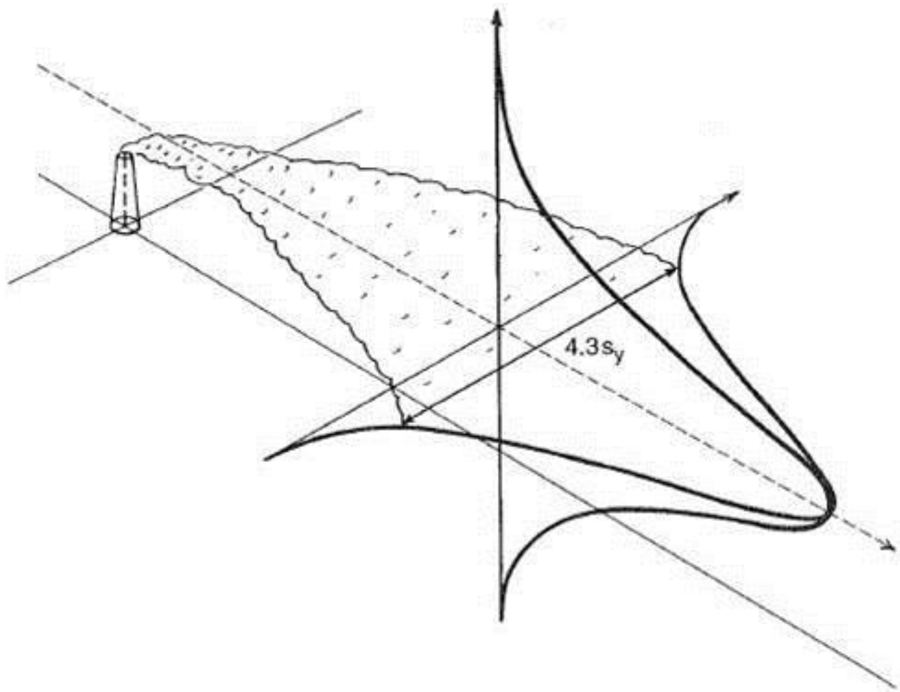
air dispersion modeling is…

FIGURE 9.3-2
SCHEMATIC OF GAUSSIAN PLUME MODEL



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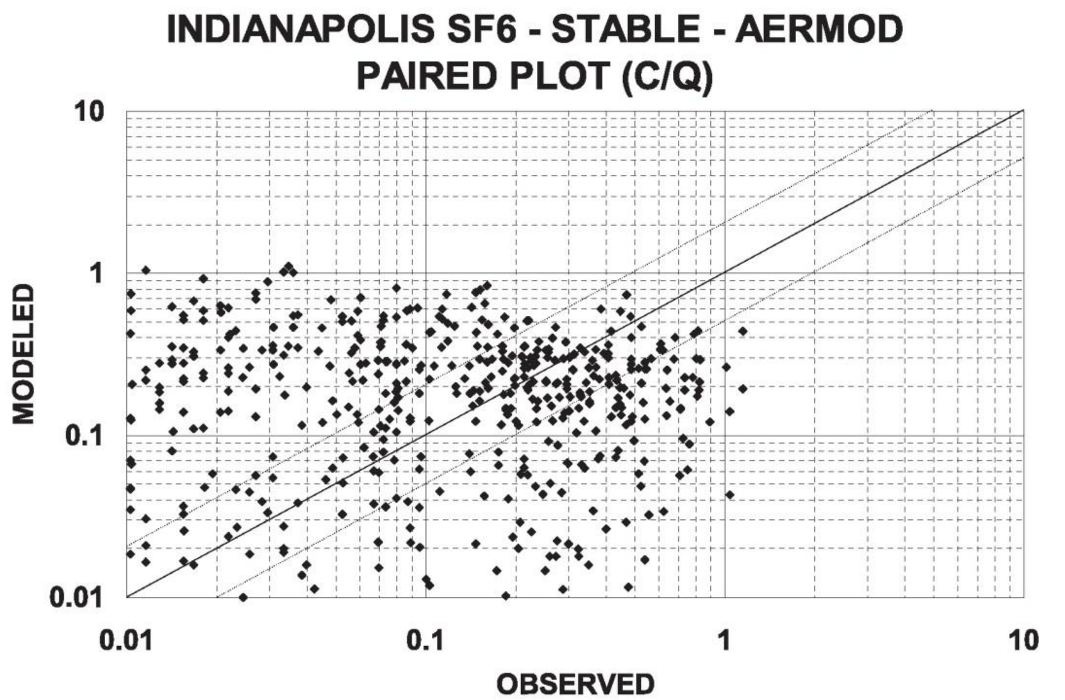
air dispersion modeling requires…

- source parameter characteristics
- identifying structures influencing the source plume
- defined ambient air boundary (AAB)
- receptor grid starting at the AAB and extending beyond
- 5 years of representative meteorological surface and upper air data
  - typically from a nearby airport
- representative background monitor concentrations

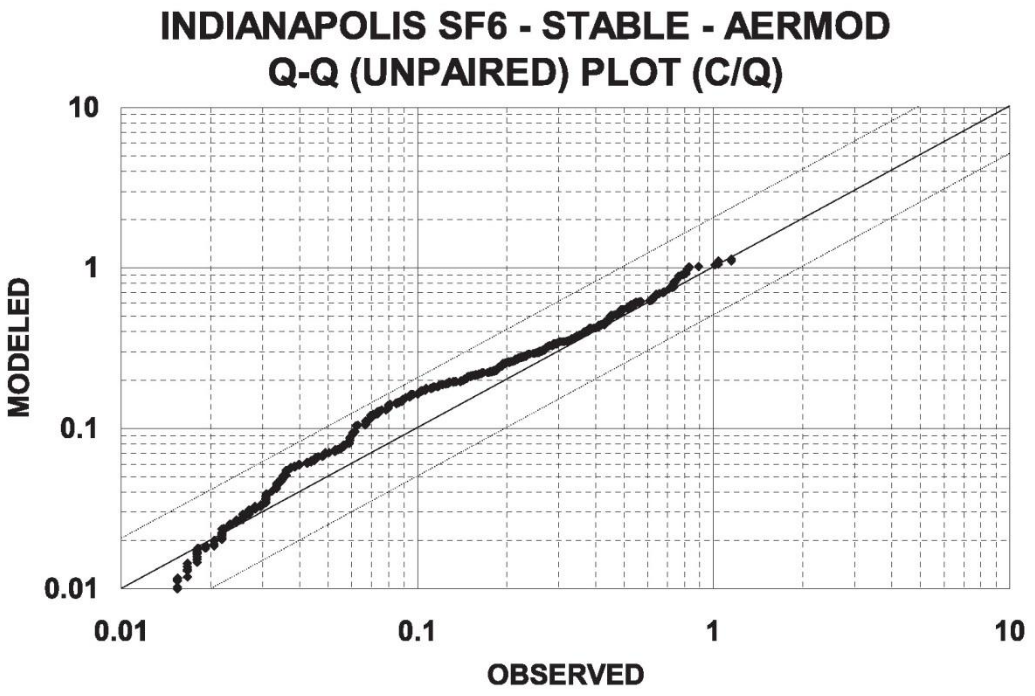
how well does the model predict concentrations?

Previous Example Showing Results Paired in Time and Space



however, comparing only the magnitude of the values, performance improves

Example of Operational Regulatory Dispersion Model Evaluation – Urban Case



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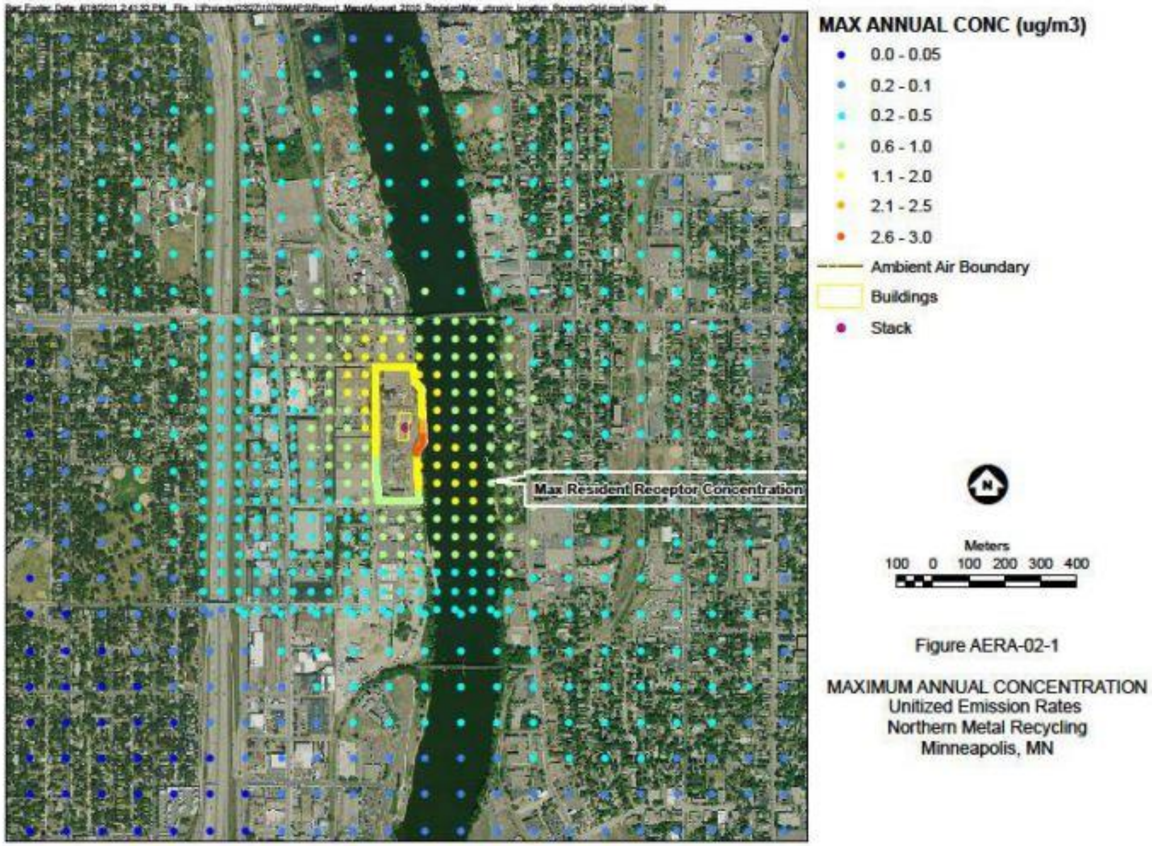
despite issues, models provide more information since we are limited by monitors

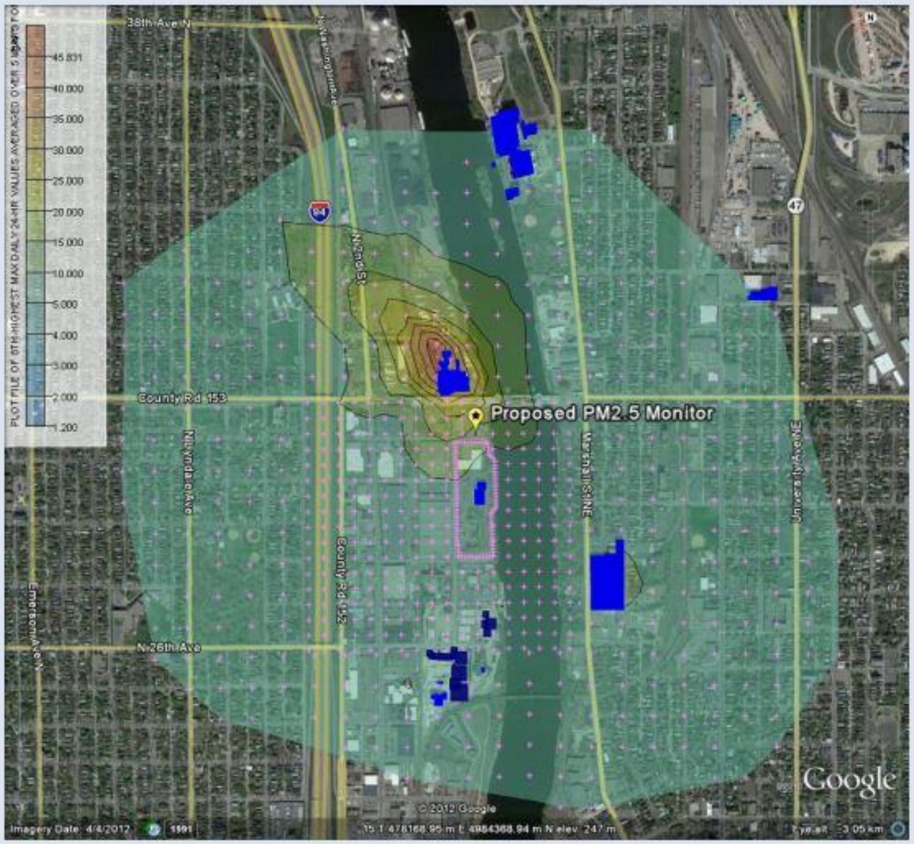
Appendix A Figure 2 Maximum Annual Unitized Emission Rates



Source: Northern Metals LLC AQ Permit 05300480-003 (http://www.pca.state.mn.us/index.php/topics/environmental-review/environmental-review-and-draft-air-permit-amendment-for-northern-metals.html)

remember earlier slide of model vs monitor paired in space and time?

Fine Particle Modeling Results



The proposed monitor location is in the area of highest modeled $PM_{2.5}$ levels identified in the Northern Metals Environmental Assessment Worksheet.

The colored contours on the map describe the gradient of modeled $PM_{2.5}$ concentrations and the blue shaded areas identify the facilities that were included in the model.

The MPCA proposal to begin monitoring at this location will tell us whether the modeling results are realistic and measure the fine particle levels in this industrial part of North Minneapolis.

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current modeling issues facing industry and regulators

- new short term (1-hour) NAAQS for SO_2 and NO_2 and $PM_{2.5}$ (24-hour)
  - tighter standards and percentile based
- background concentration monitor availability
  - lack of monitoring outside of Twin Cities
- increasingly refined modeling needed to address first two issues usually requires EPA approval

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current table of National Ambient Air Quality Standards (NAAQS)

Table 3. National ambient air quality standards, PSD increments, and significant impact levels

Pollutant	Averaging Period	Primary NAAQS (µg/m³)	Secondary NAAQS (µg/m³)	PSD Class II Increment (µg/m³)	PSD Class I Increment (µg/m³)	Significant Impact Level (µg/m³)
SO_2	1-Hour	196	To be determined	To be determined	To be determined	7.86 (USEPA interim value)
	3-Hour	None	1,300[B]	512	25	25
	24-Hour	365	None	91	5	5
	Annual	60[A]	None	20	2	1
PM_{10}	24-Hour	150	150	30	8	5
	Annual	50[C]	50[4]	17	4	1
$PM_{2.5}$	24-Hour	35	35	9	2	1.2[D]
	Annual	15	15	4	1	0.3
NO_2	1-Hour	188	To be determined	To be determined	To be determined	7.52 (USEPA interim value)
	Annual	100	100	25	2.5	1
CO	1-Hour	40,000	40,000	None	None	2,000
	8-Hour	10,000	10,000	None	None	500
O_3	1-Hour	235	235	None	None	None
	8-Hour	157	None	None	None	None
Pb	Rolling 3-Months	0.15	0.15	None	None	None

[A] Minnesota state annual SO_2 standard. Federal annual standard is 80 µg/m³.
[B] Minnesota state 3-hour SO_2 standard for Northern Minnesota is 915 µg/m³.
[C] Minnesota state annual PM_{10} standard (EPA revoked the federal annual PM_{10} NAAQS).
[D] This value has been vacated by the Federal Court. EPA is in the process of evaluating new SIL strategy for this pollutant.
Note: PSD Class I Area 24-Hour value is generally 1 µg/m³ [$PM_{2.5}$ is 0.07 µg/m³] (MPCA interim value is 0.2 percent of NAAQS).

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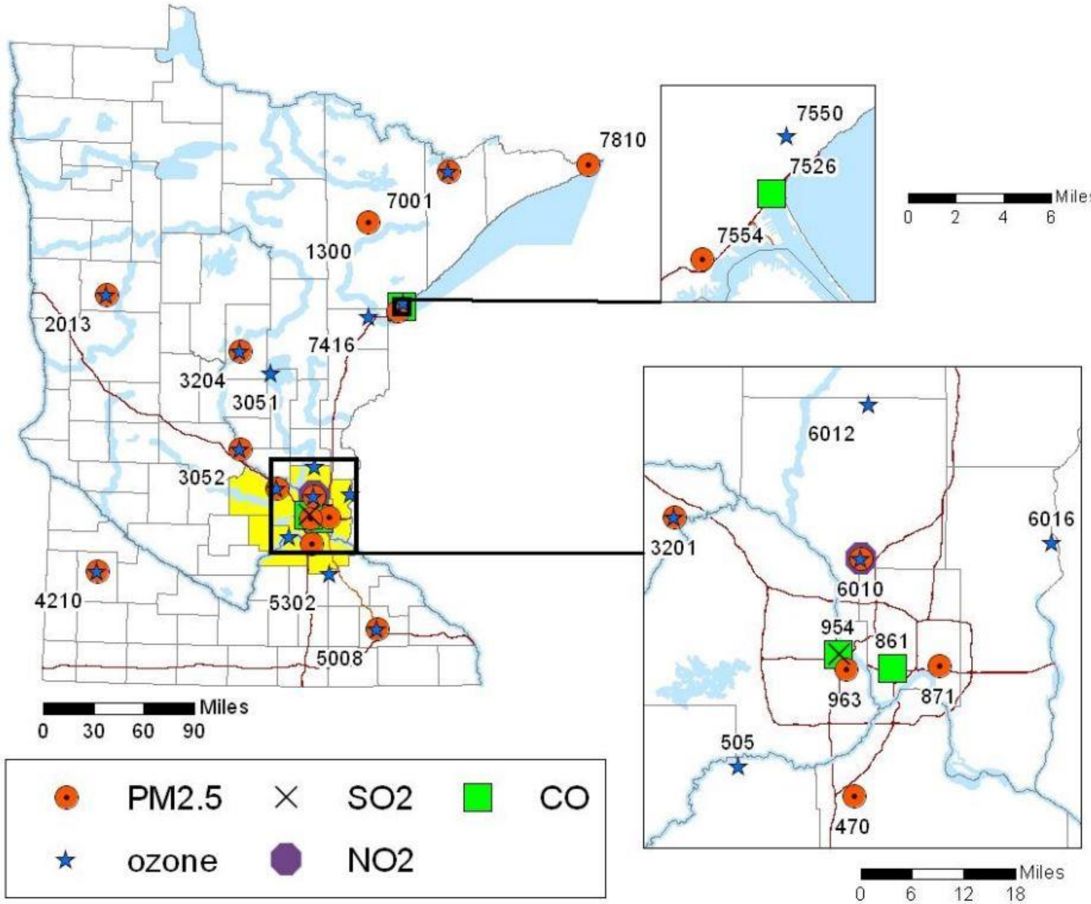
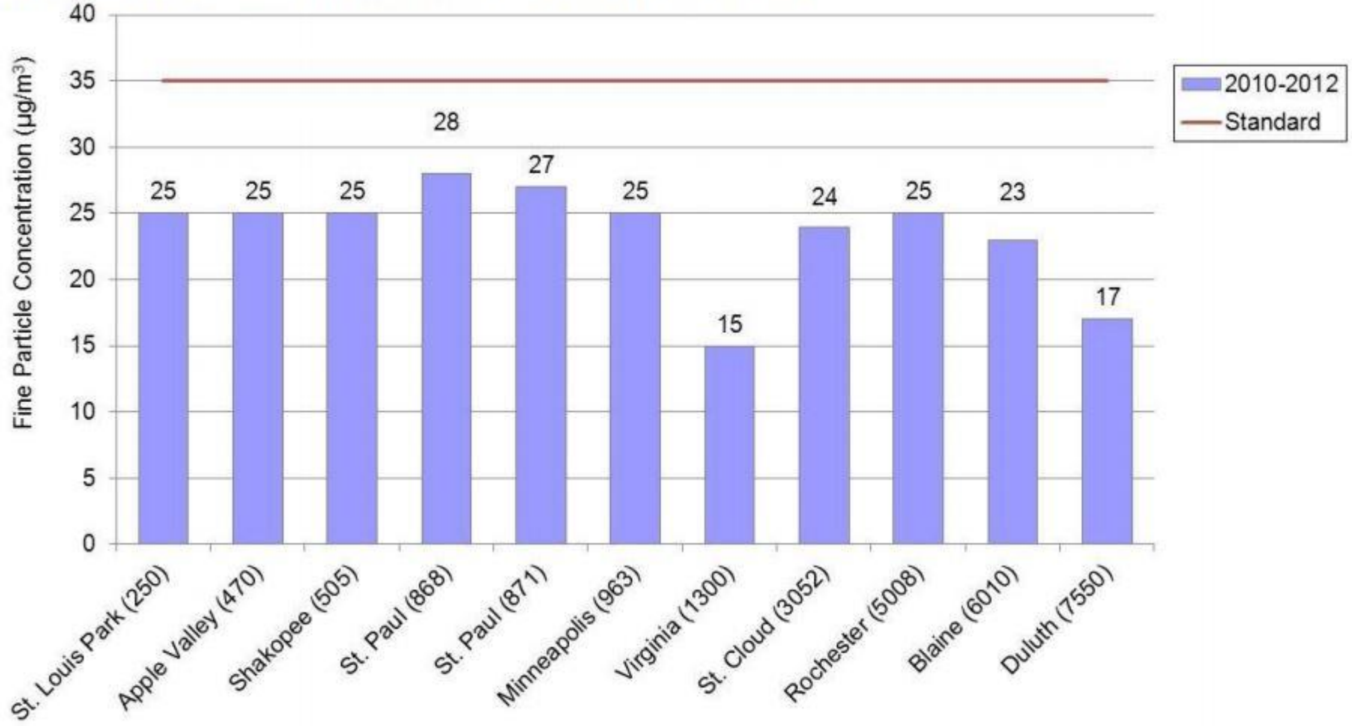
projects outside the metro end up using higher background concentrations from the

Figure 3: 2013 AQI Sites



tighter standards plus higher background means less room for model impacts

Figure 8: 24-hour $PM_{2.5}$ concentrations compared to the NAAQS



* The monitoring site did not meet the minimum completeness criteria for design value calculations. A site meets the completeness requirement if 75% of required sampling days are valid for each calendar quarter included in the design value calculation.

2014 Annual Air Monitoring Network Plan • July 2013 *Minnesota Pollution Control Agency*
aq10-08a

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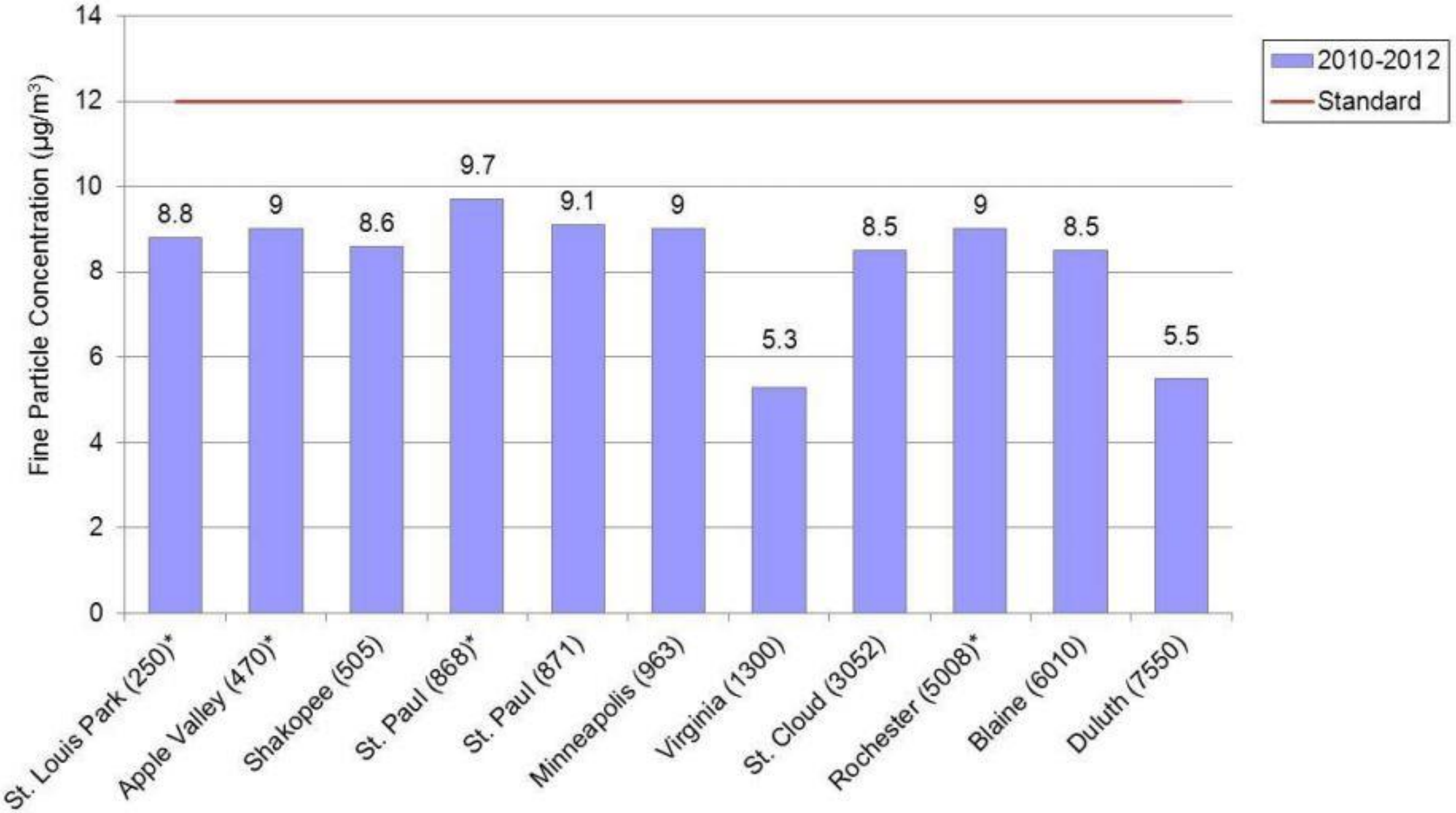
on an annual basis, there is even less room to show model compliance

Figure 7: Annual $PM_{2.5}$ concentrations compared to the NAAQS



the tighter the limits get, the more clients have to suck it in

- limits on emissions
- operation limits
- increase property
- increase recordkeeping
- <u>any refined modeling input will become a permit condition</u>

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“you know, I learned something today”

- don’t expect the same decisions/outcomes for two projects even if they are similar
- air models are a tool, not necessarily a crystal ball
- as long as ambient air standards continue to decrease, there will be increasing pressure on facilities and more permit limits/requirements

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