



National Water-Quality Assessment (NAWQA) Program

Factors Affecting Public-Supply-Well Vulnerability to Contamination:

Understanding Observed
Water Quality and
Anticipating Future
Water Quality

USGS Circular 1385
Eberts, S.M., Thomas, M.A. and Jagucki, M.L.



OBJECTIVE

Provide Insight Into
Interpretation Of Samples From
Public-Supply Wells So That
Public-Supply-Well Monitoring
Data Can Be Better Used To Support
Decision Making

OUTLINE

Groundwater vs. Public-Supply-Well Vulnerability

Vulnerability Measures

Preferential Flow Pathways

Where to Find More Information

Groundwater Vulnerability

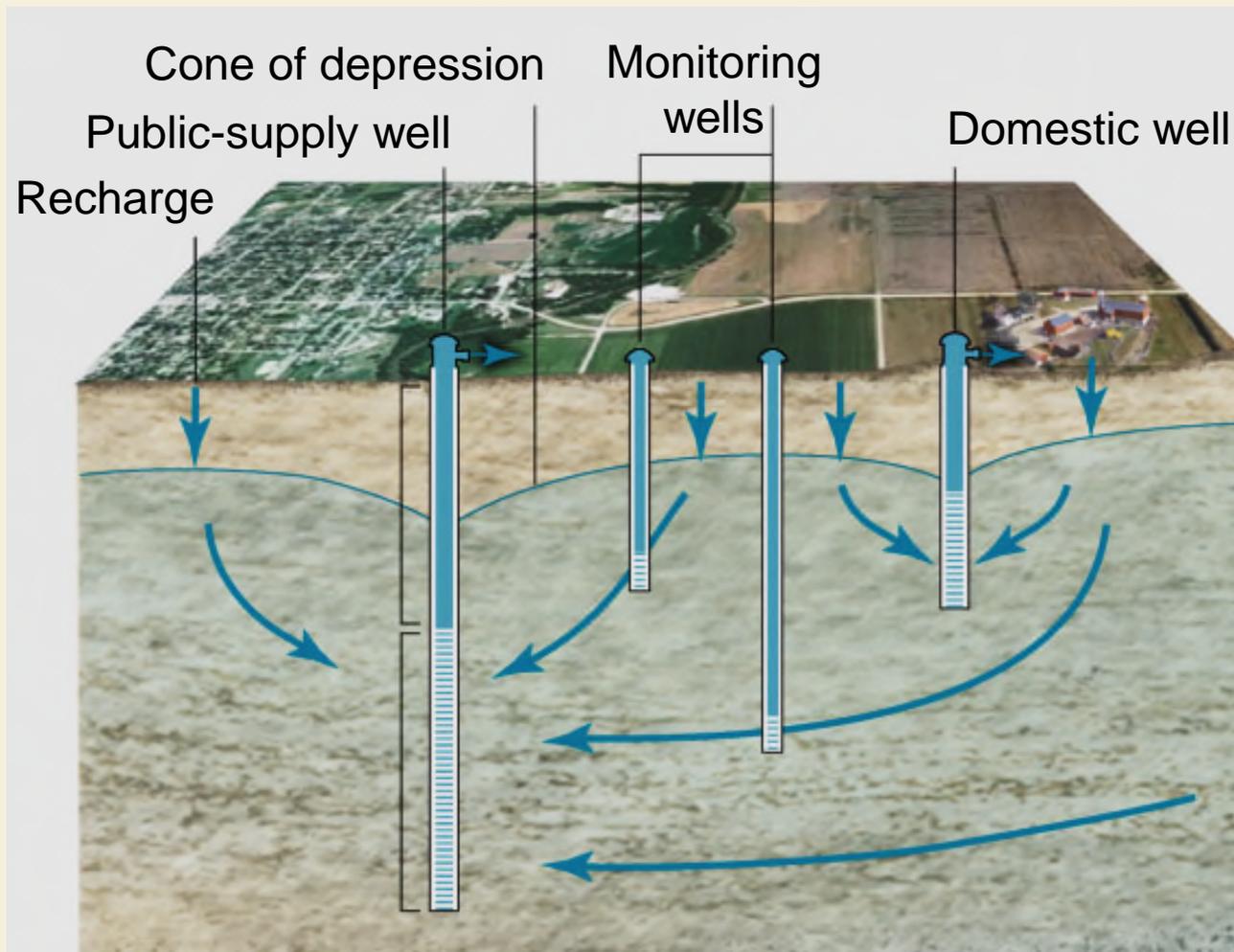
- Contaminant Input
- Contaminant Mobility & Persistence
- Intrinsic Susceptibility



Public-Supply-Well Vulnerability

PSW Vulnerability

- Contaminant Input
- Contaminant Mobility & Persistence
- Intrinsic Susceptibility
- Well Location, Design, Construction, Operation, & Maintenance



Vulnerability Measures

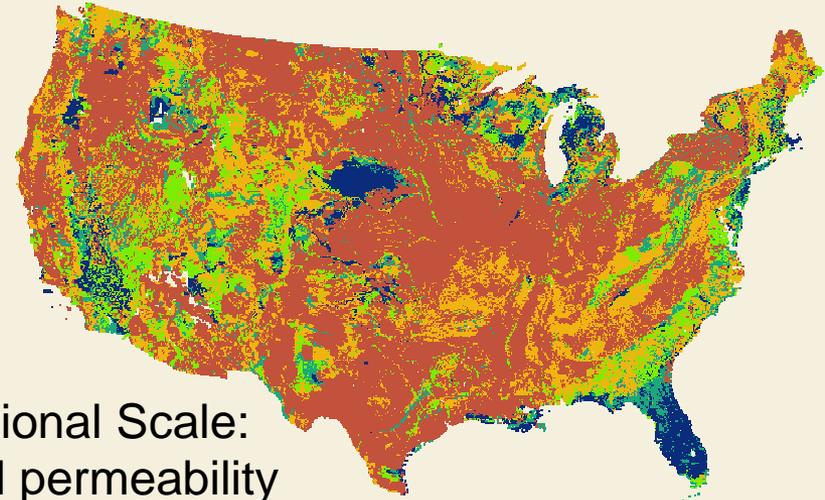


Measures differ depending on the scale of the assessment

Intrinsic Susceptibility



Individual Well Scale:
Age of water in
sample from well

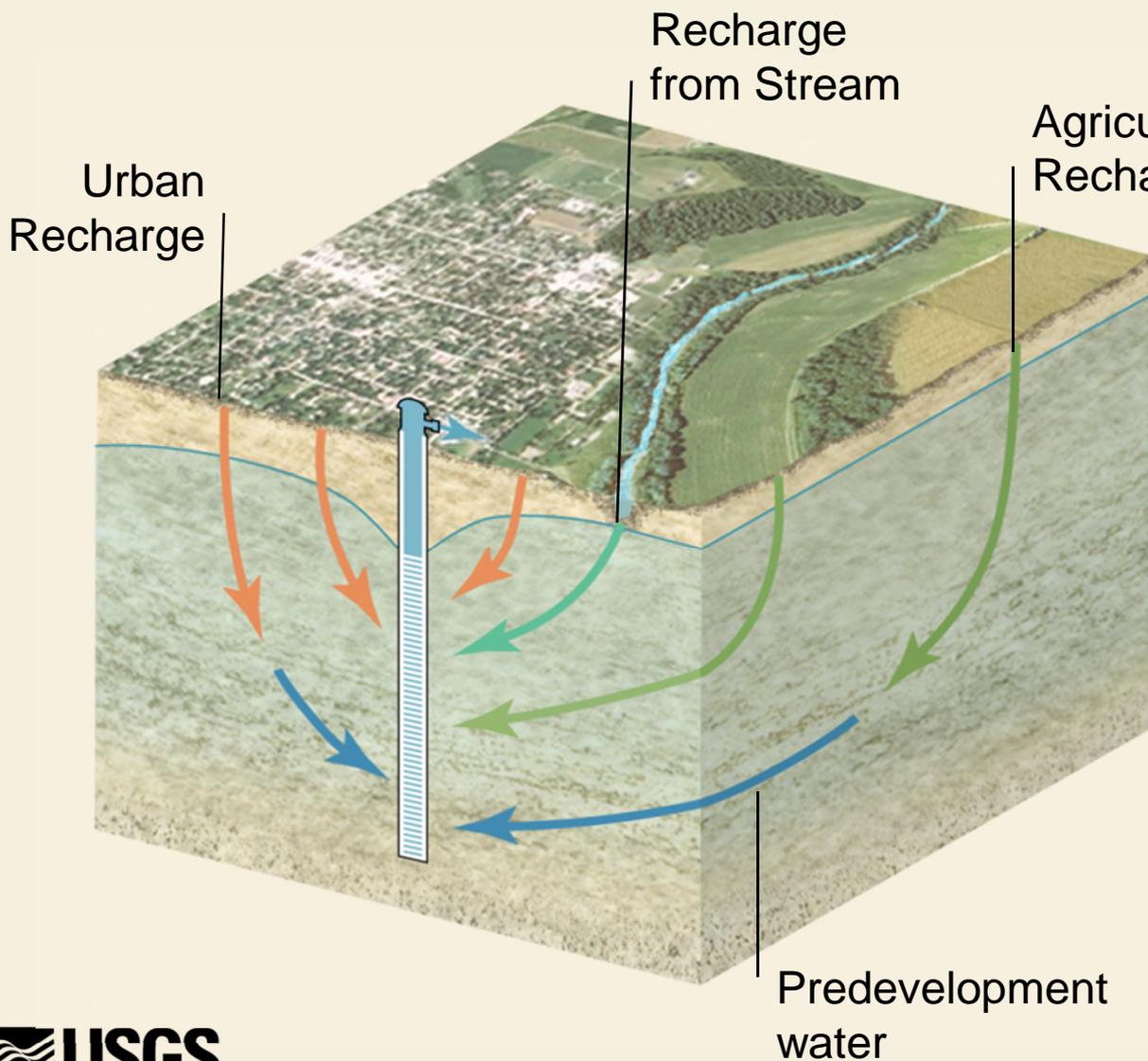


National Scale:
Soil permeability

Useful measures for the Individual Well Scale:

- **Sources of Recharge**
—A measure of *contaminant input*
- **Geochemical Conditions** (redox, pH, alkalinity)
—A measure of *contaminant mobility and persistence*
- **Groundwater-Age Mixture**
—A measure of *intrinsic susceptibility*

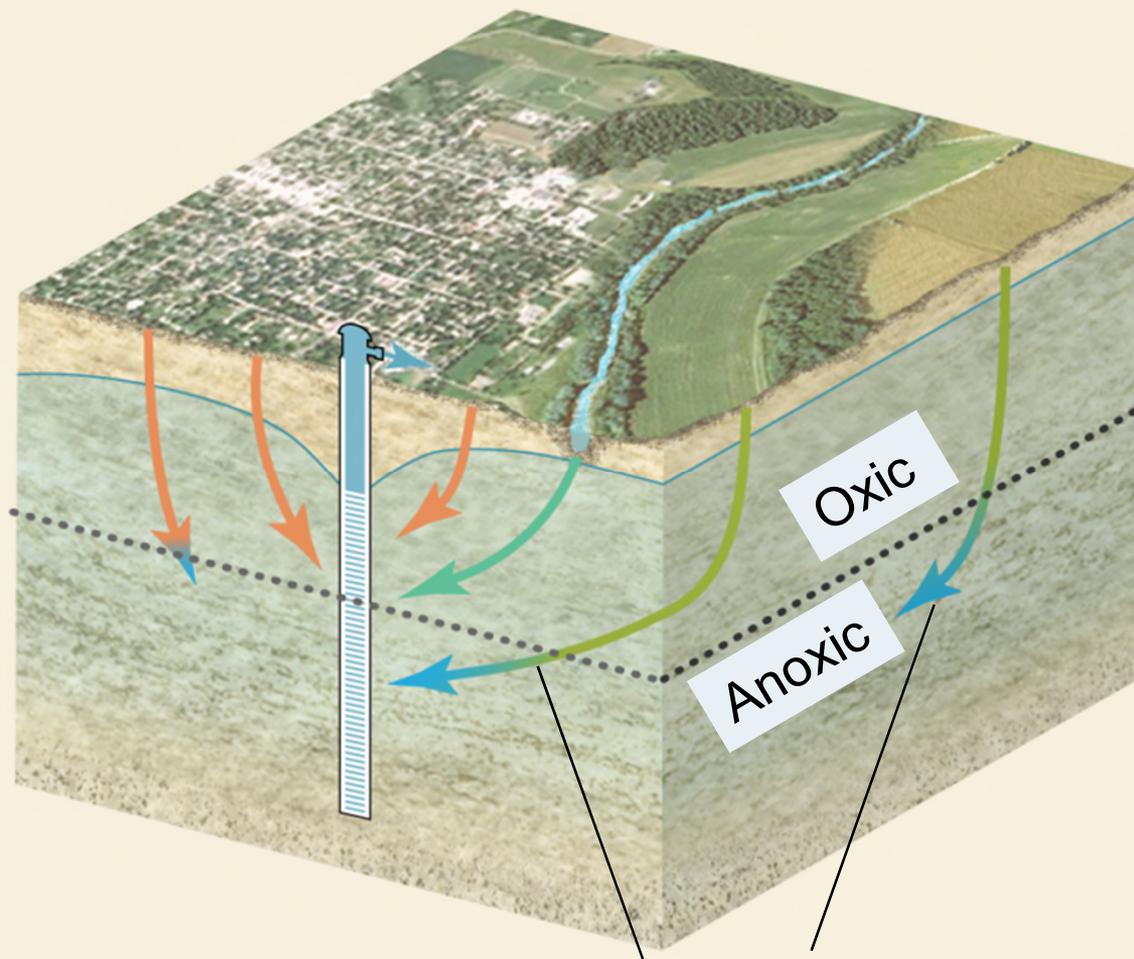
Different flow pathways bring different sources of recharge water and associated contaminants to wells



AN IMPLICATION

- **Changes in water quality—even temperature, pH, alkalinity, or total dissolved solids—warrant investigation so that any new source of water (and associated contaminants) for a well does not go unnoticed**

Geochemical conditions affect whether a contaminant moves with the groundwater, reacts with aquifer solids, or degrades



AN IMPLICATION

➤ **Communities that determine if their water is from oxic or anoxic zones have insight into which contaminants might reach their well**

Example – nitrate can move with the water but won't persist in anoxic conditions

Geochemical conditions – an unexpected finding

Human activities altered recharge or changed groundwater flow in ways that changed aquifer geochemical conditions in most study areas—causing naturally occurring drinking-water contaminants to dissolve into the groundwater and reach wells

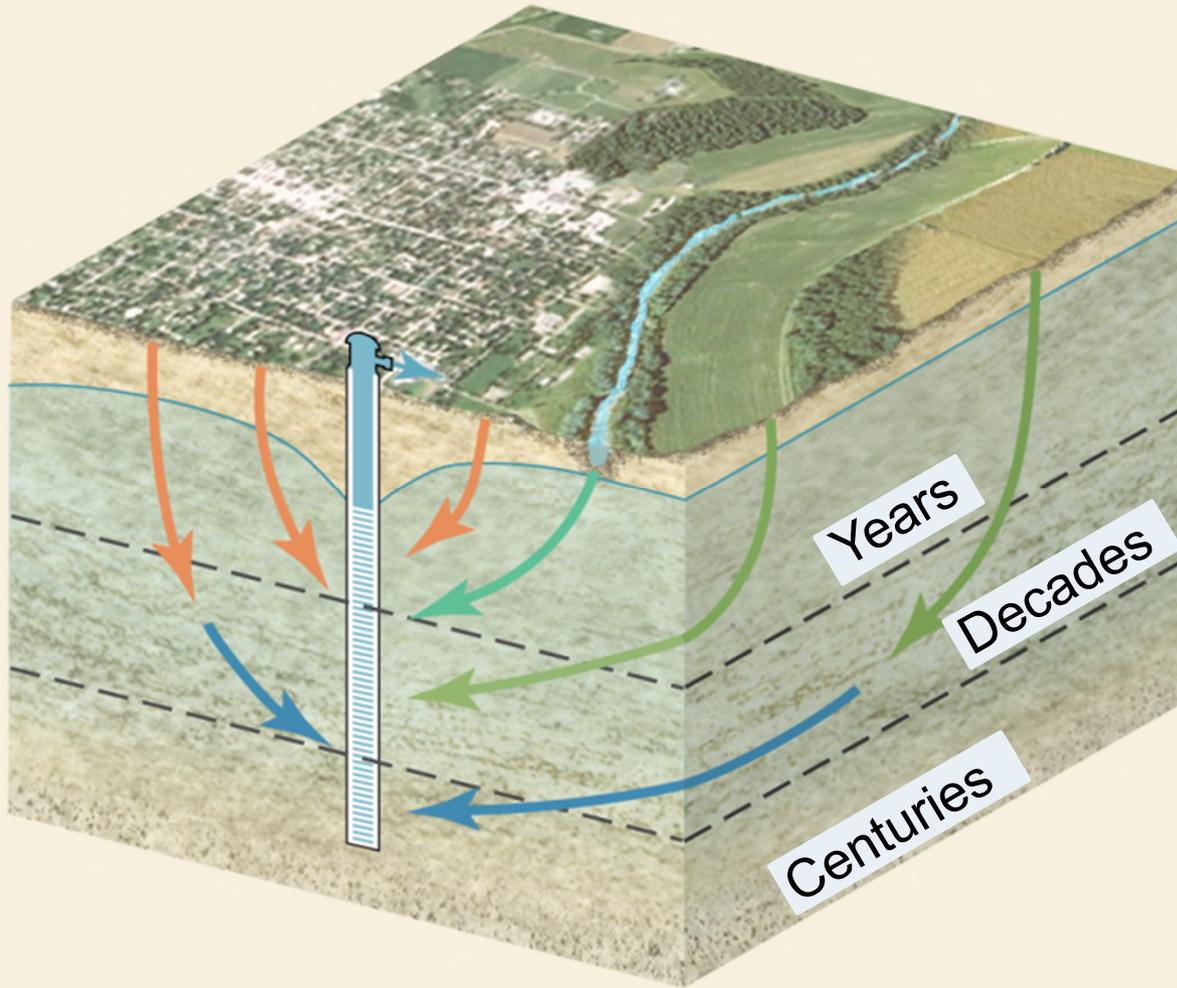


TOOL – Redox Framework

To determine redox conditions associated with water from wells

General redox category	Predominant redox process	Threshold concentration (mg/L)					Fe ²⁺ /H ₂ S mass ratio
		O ₂	NO ₃ ⁻ -N	Mn ²⁺	Fe ²⁺	SO ₄ ²⁻	
Oxic	O ₂ reduction	≥0.5	-	<0.5	<0.1	-	-
Suboxic		<0.5	<0.5	<0.5	<0.1	-	-
Anoxic	NO ₃ ⁻ reduction	<0.5	≥0.5	<0.5	<0.1	-	-
	Mn(IV) reduction	<0.5	<0.5	≥0.5	<0.1	-	-
	Fe(III) or SO ₄ ²⁻ reduction	<0.5	<0.5	-	≥0.1	≥0.5	-
	Fe(III) reduction	<0.5	<0.5	-	≥0.1	≥0.5	>10
	Mix Fe(III) and SO ₄ ²⁻ reduction	<0.5	<0.5	-	≥0.1	≥0.5	≥0.3 and ≤10
	SO ₄ ²⁻ reduction	<0.5	<0.5	-	≥0.1	≥0.5	<0.3
	Methanogenesis	<0.5	<0.5	-	≥0.1	<0.5	-
Mixed	Criteria for more than one redox process are met						

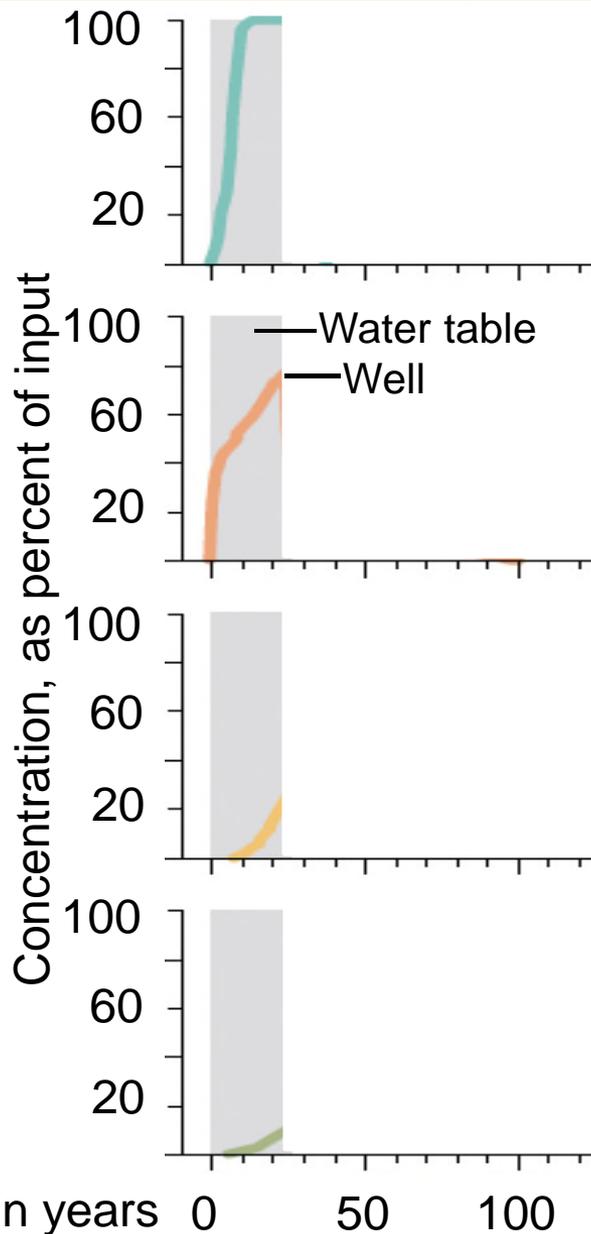
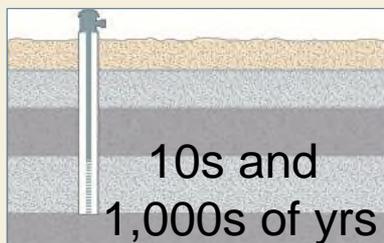
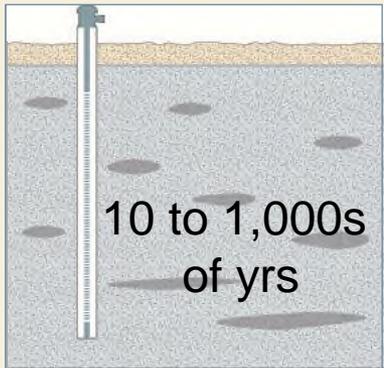
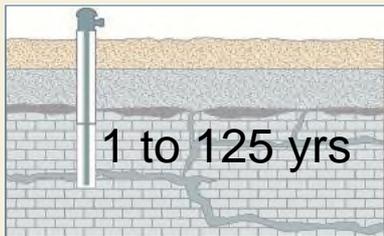
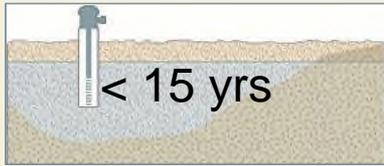
The groundwater-age mixture for a well characterizes the complete range of time it can take contaminants to arrive



AN IMPLICATION

- Several years or even decades of monitoring will not be enough to characterize water-quality changes in wells that produce a substantial amount of old water— a combined monitoring and modeling approach is needed for such wells

Groundwater-age mixtures – unexpected findings



- A wide range of groundwater ages provides some protection against high levels of nonpoint-source contamination
- A lack of young water can cause concentrations to continue to go up long after source reduction

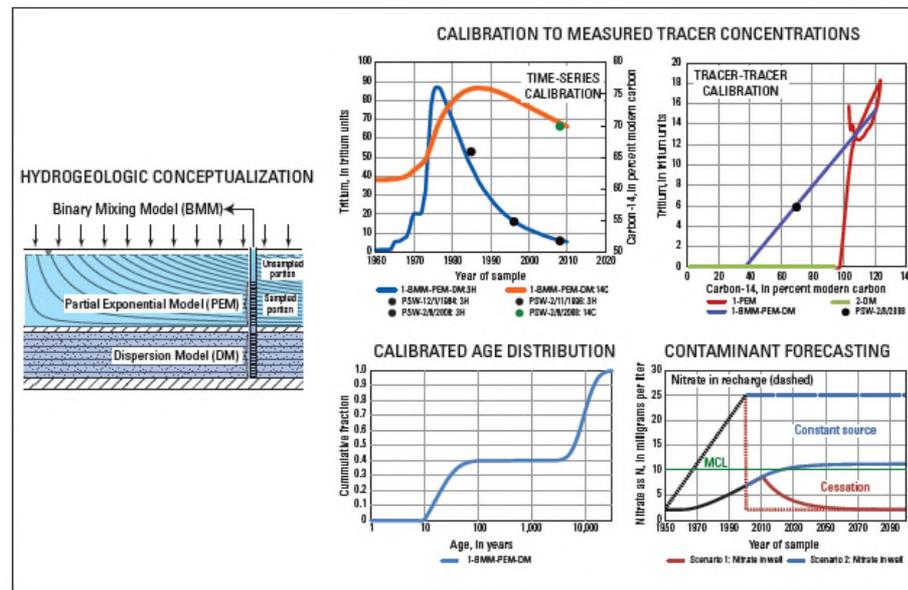
TOOL – Lumped-Parameter Mixing Models

To estimate the groundwater-age mixture for a well from tracer data



National Water-Quality Assessment Program
National Research Program

TracerLPM (Version 1): An Excel® Workbook for Interpreting Groundwater Age Distributions from Environmental Tracer Data



Techniques and Methods 4-F3



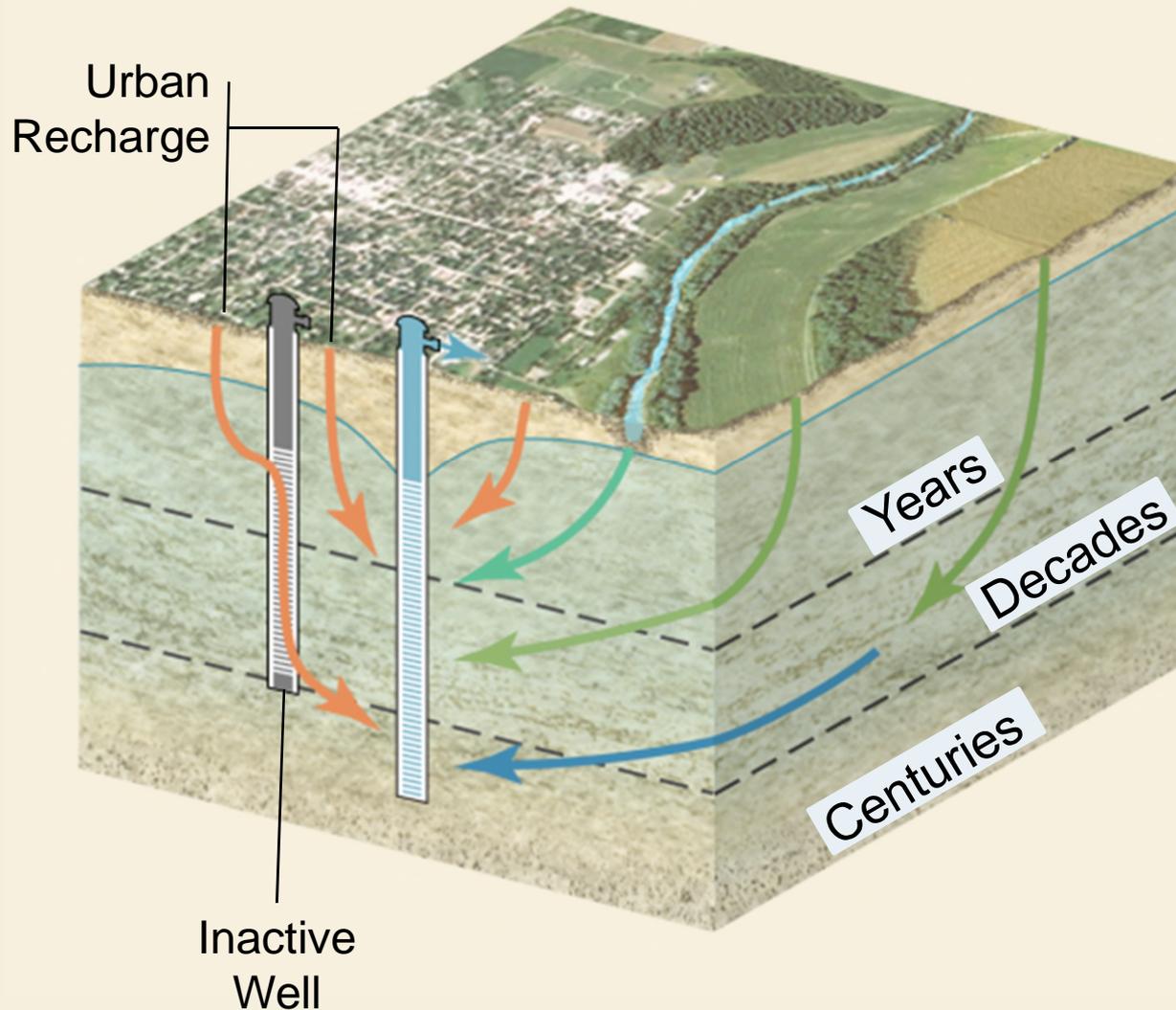
U.S. Department of the Interior
U.S. Geological Survey

Jurgens et al., 2012

Preferential Flow Pathways



Preferential flow pathways are pathways that provide little resistance to flow

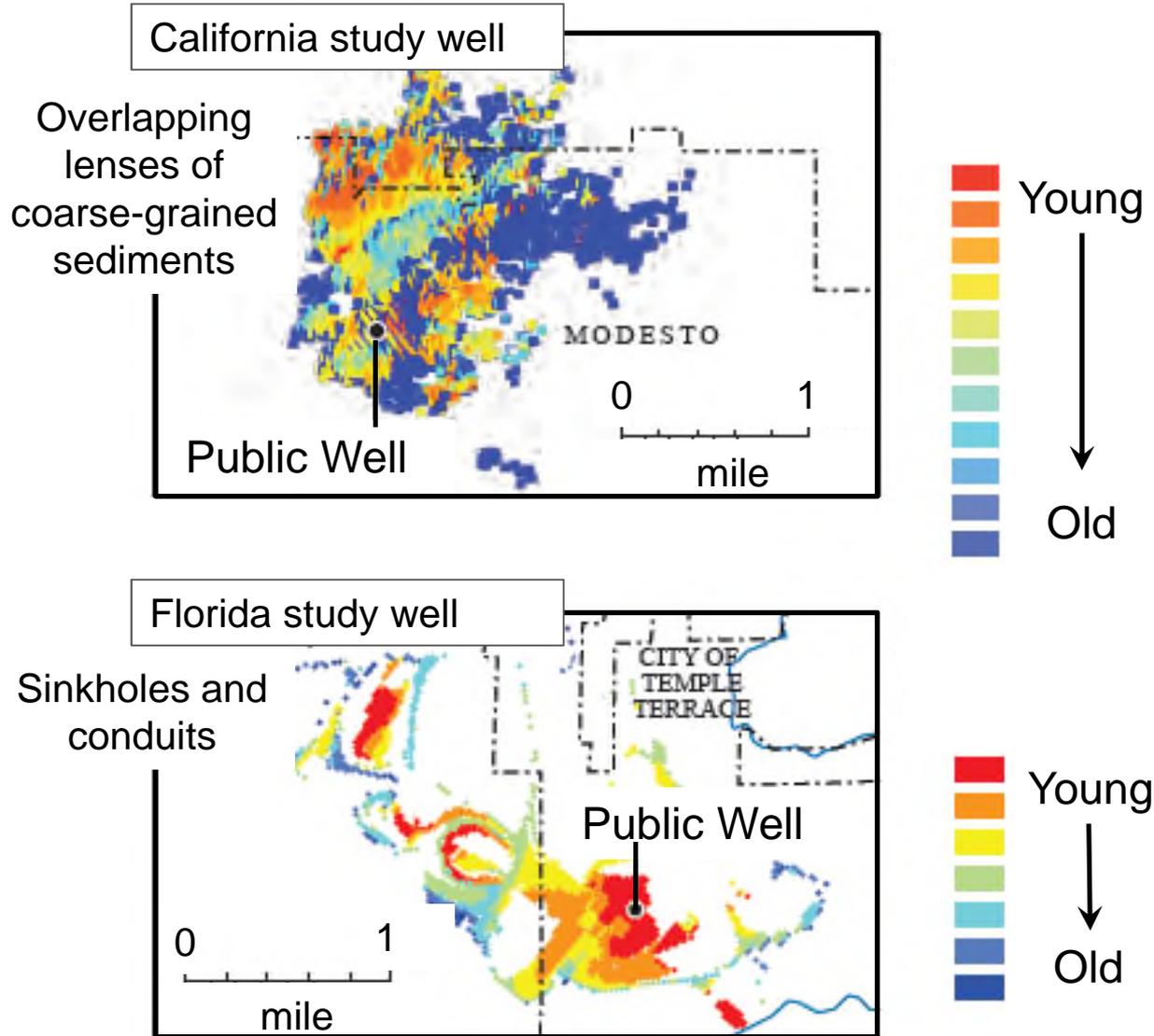


AN IMPLICATION

- A general campaign to engage everyone in groundwater protection is worthwhile because preferential flow pathways are frequently present but difficult to locate, making it difficult to know where the most vulnerable waters originate

Preferential flow pathways – an unexpected finding

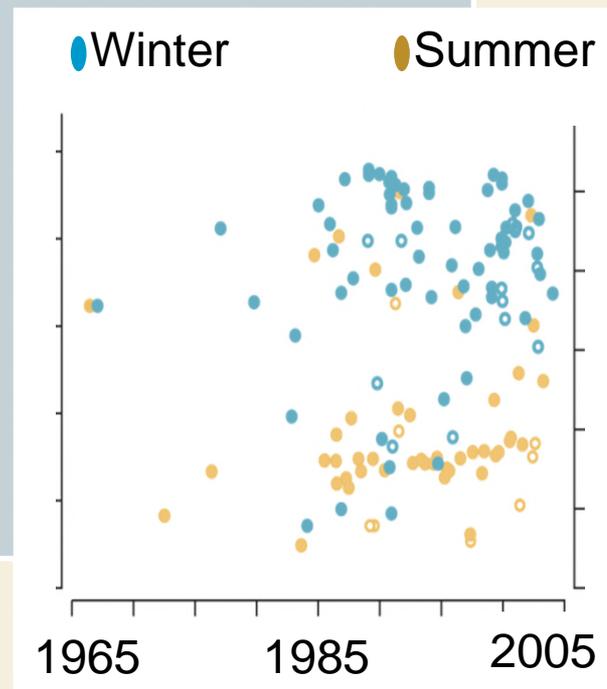
Preferential flow pathways affected public-supply-well water quality in every study area and resulted in recharge areas in which the youngest water did not necessarily enter the aquifer in the areas closest to the wellhead



Tools – Ways to Collect, Analyze and Interpret Data

To recognize the influence of preferential flow pathways on water quality

- Are public-supply-well samples similar to monitoring-well samples in an overlying aquifer?
- Do historic water quality records show unexpected water quality patterns?
- Does young water exist where it is unexpected?
- Do flow and transport models need to include preferential flow pathways to match field conditions?



More Information ...

