Are We There Yet?

Vermont's Experience with Time of Travel for Siting Onsite Wastewater Systems

Bruce F. Douglas, PE - Wastewater Engineering Manager

Drinking Water And Groundwater Protection Division

The materials being presented represent the opinions of the presenter, and do NOT reflect the opinions of NOWRA.

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Minimum Isolation Distances[a,b,1,*]

Item	Horizontal Distance (feet)
Drilled Well Serving 1 Home	100
Drilled Well Serving 2 or More Houses	125
Gravel Pack Well, Shallow Well, or Spring	150[1,b]
Public Water Supply	f

*Footnotes on following pages

§8-08 Isolation Distances (State of Vermont 1982)

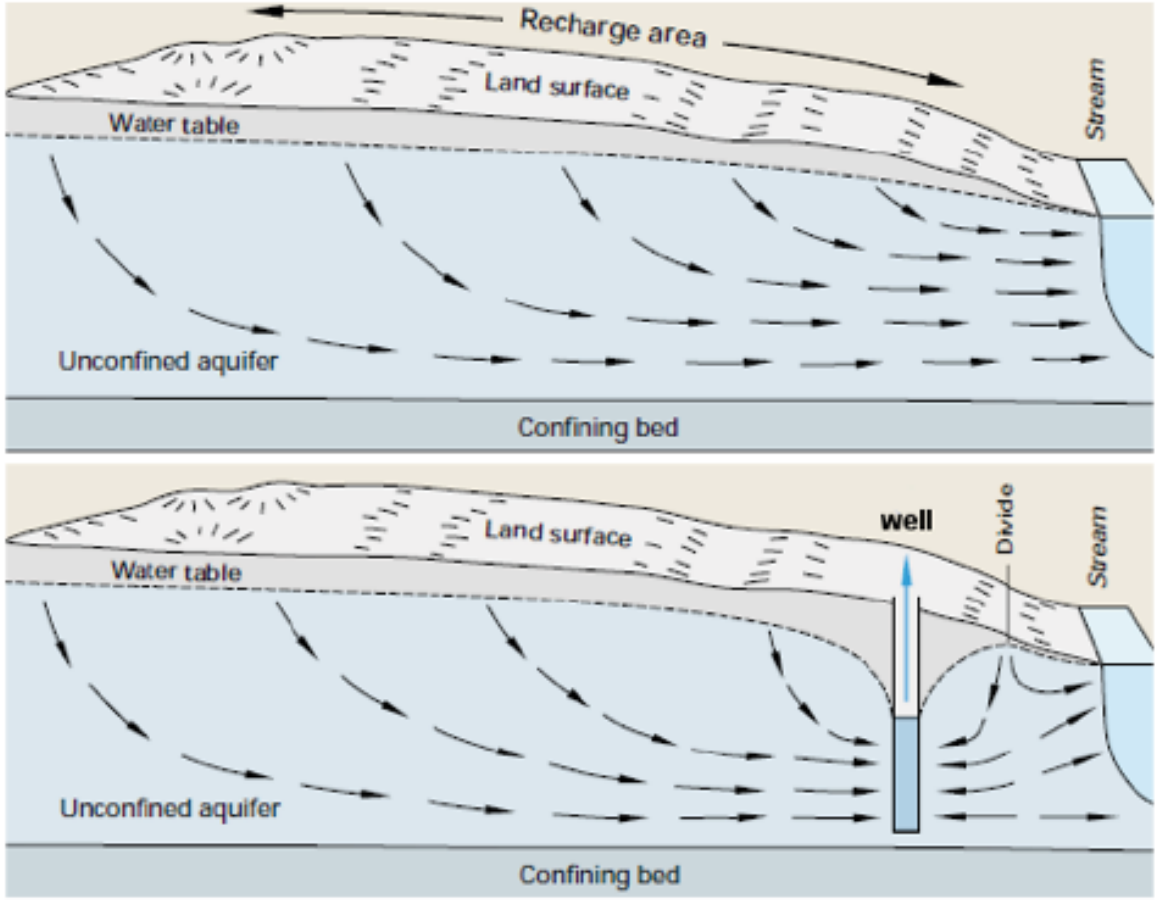
- If a hydrogeologic connection exists between a water supply and a source of contamination, the Division shall apply the following criteria which, if met will allow approval
  - 1. **A minimum residence time in saturated materials of two years** to reasonably ensure that microorganisms will be eliminated.
  - Calculation of the residence time should take into account the following:
    - a. Horizontal hydraulic conductivity in the materials with the largest hydraulic conductivity; and
    - b. the cone of influence of production wells being considered

What is the scientific and technical basis for isolation distances?

- Historic sanitary engineering design criteria, or
- Risk-based science based on attenuation of pathogens and chemical contaminants and the variability and uncertainty regarding groundwater sources

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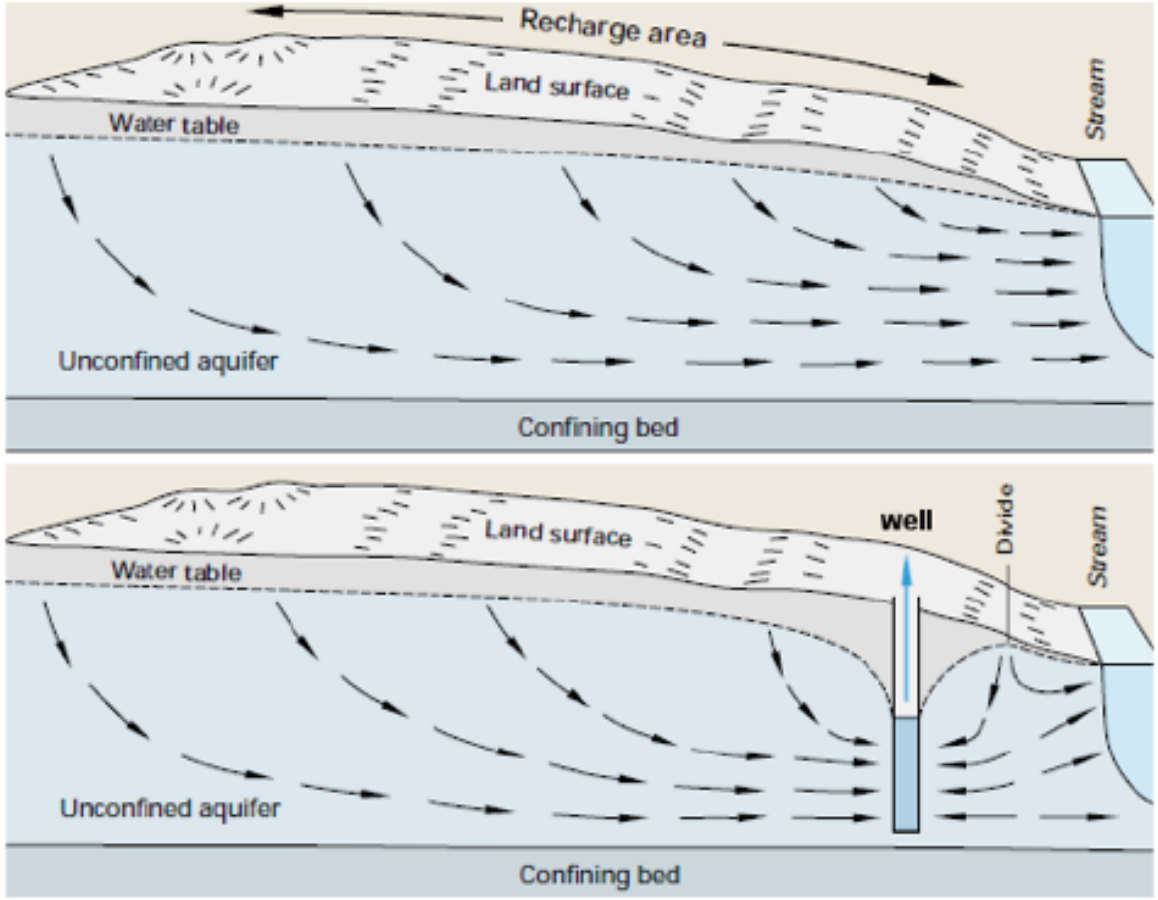
Hydrogeology 101



https://extension.okstate.edu/fact-sheets/images/introduction-to-groundwater-hydrology-and-management/2017-05-09-at-11.30.51.png

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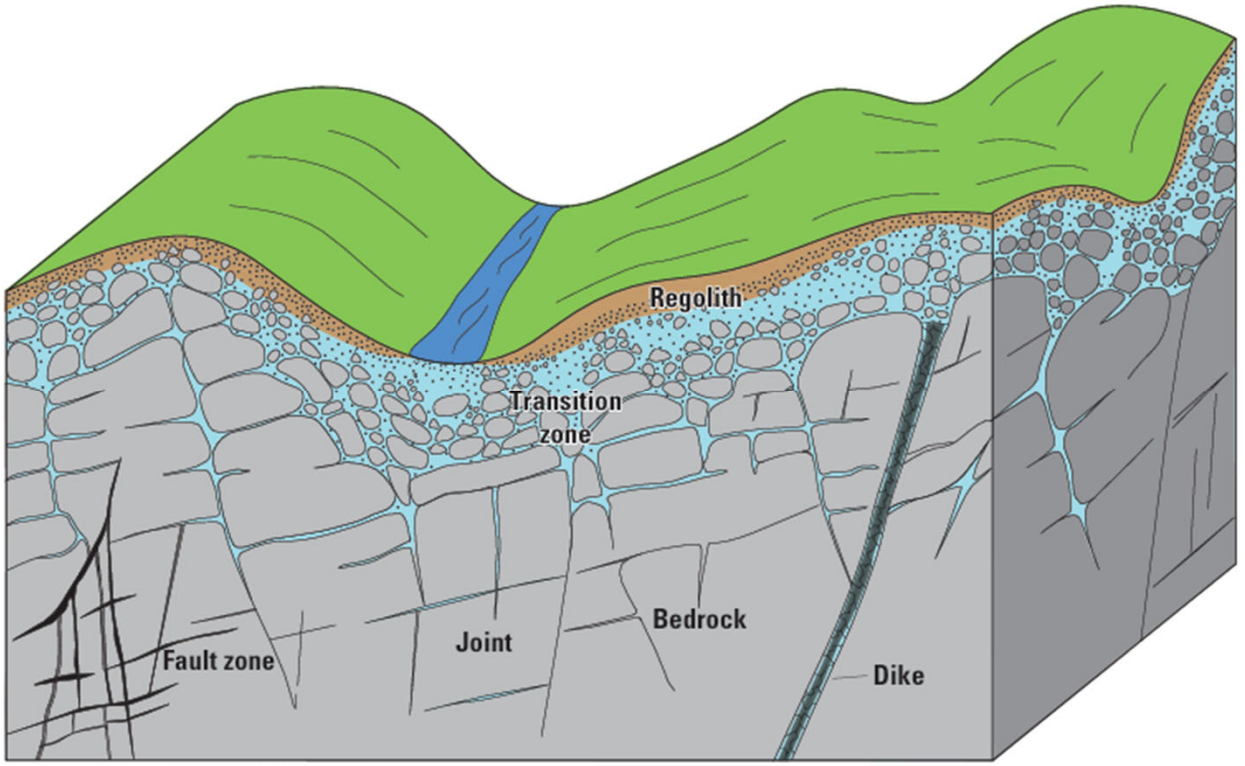
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Schematic of generalized fractured-rock aquifer system

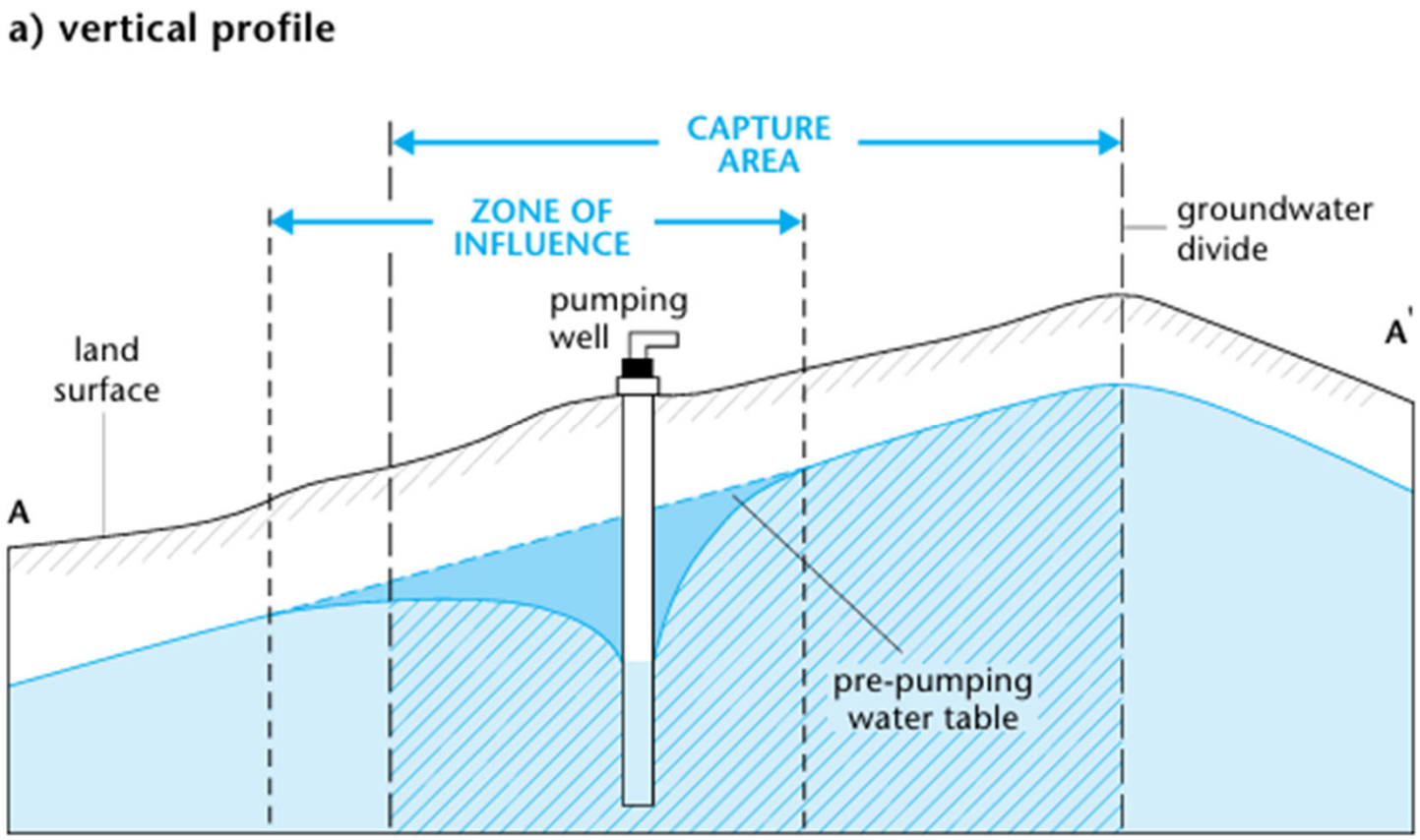


Modified from Freeze and Cherry, 1979

https://pubs.usgs.gov/publication/sir20225041/full

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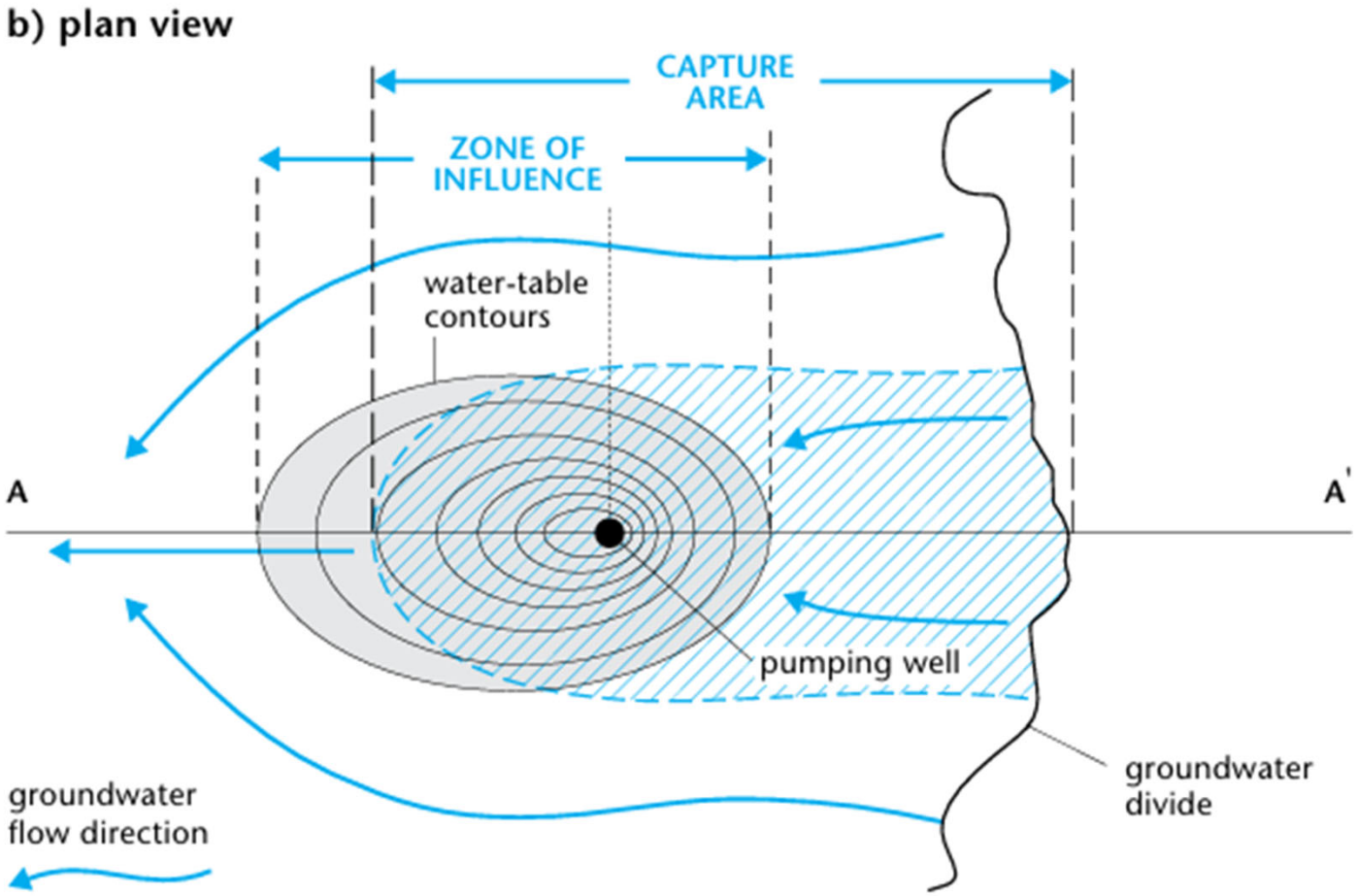
Distinction between area of capture and zone of influence of a production water well (1 of 3)



World Bank Publication : Groundwater quality protection - a guide for water utilities, municipal authorities and environment agencies

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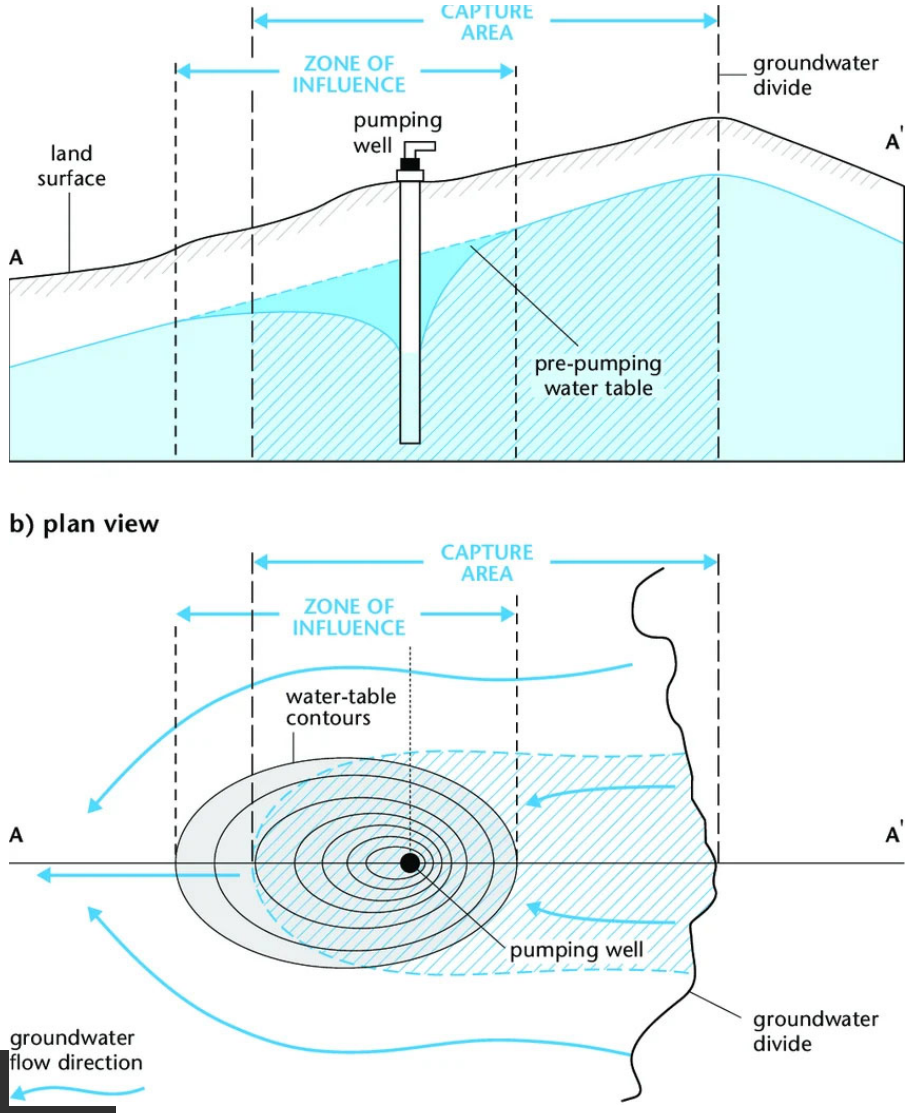
Distinction between area of capture and zone of influence of a production water well (2 of 3)



World Bank Publication : Groundwater quality protection - a guide for water utilities, municipal authorities and environment agencies

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Distinction between area of capture and zone of influence of a production water well (3 of 3)



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General Results from Unpublished Study of N in Private Wells in Permitted Subdivisions, with 1-2 acre lot size (1987)

	FH	W	H	P	FA	M
Monitoring Wells	6	6	-	-	-	-
Up-gradient NO3-N (mg/L)	<1	<1[2]	-	-	-	-
Down-gradient NO3-N (mg/L)	5-10[1]	1-4	-	-	-	-
Bedrock Wells	-	7	10	8	12	9
Bedrock Well N03-N (mg/L)	-	6 @ <0.1 & 1 @ <2	9 @ <0.5 & 1 @ 0.5 - 1	2 @ <2 4 @ 2- 3.9 2 @ 4-6	6@ <2 4 @ 2-4.9 2 @ 5-14	3 @ <2 3 @ 2 – 4.9 3 @ 5 - 12

1. For five or more months in one year
2. After relocating upgradient well further from development

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Revision of Private Water Supply Rules (1988 – 1992)

- Evaluate Risk
- Identify
  - Potential Source Of Contamination
  - Limiting Contaminant from Source
  - Model of Attenuation
- Set Isolation Distance or Methodology to Define Isolation Area

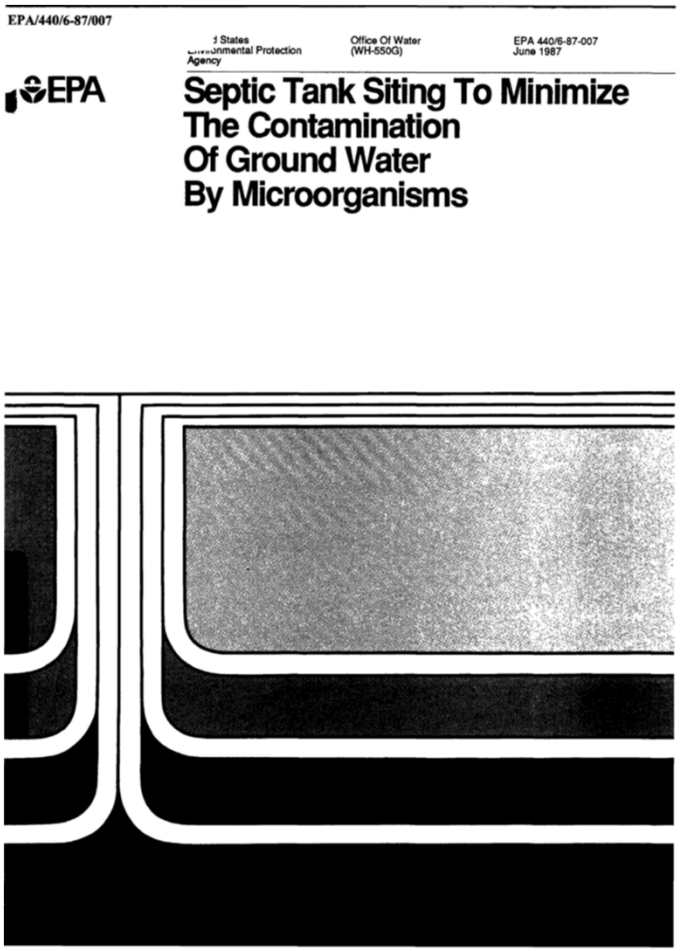
What is the Appropriate Limiting Contaminant for Private Water Sources?





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Literature Review and Conversations with Microbiologists



https://nepis.epa.gov/

- Application Rate
- Net Recharge Rate
- Soil Texture
- Depth to Groundwater
- Hydraulic Conductivity
- Aquifer Media
- Groundwater Temperature
- Distance to Point of Use

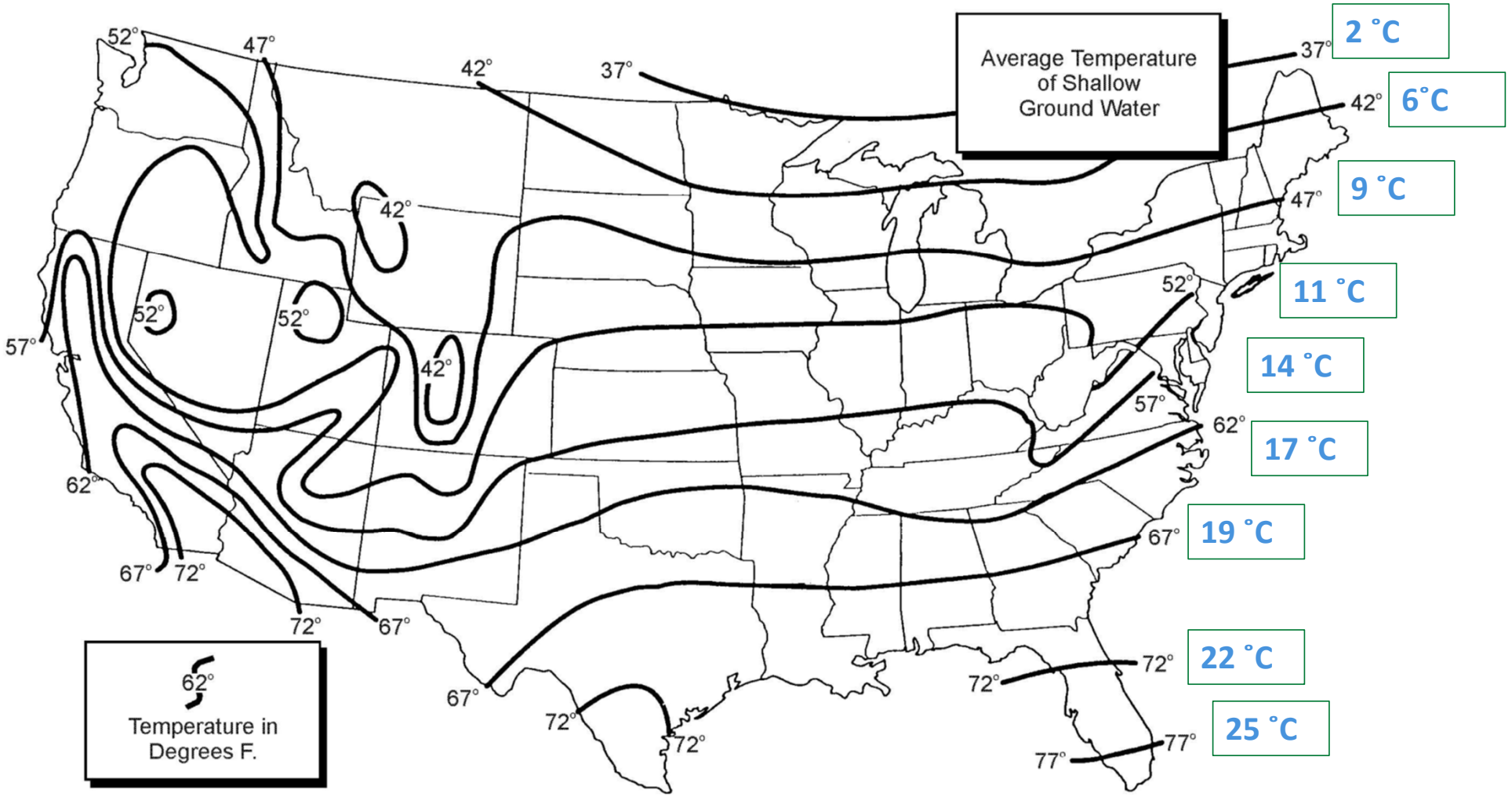
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What is the Appropriate Limiting Contaminant for Private Water Sources?





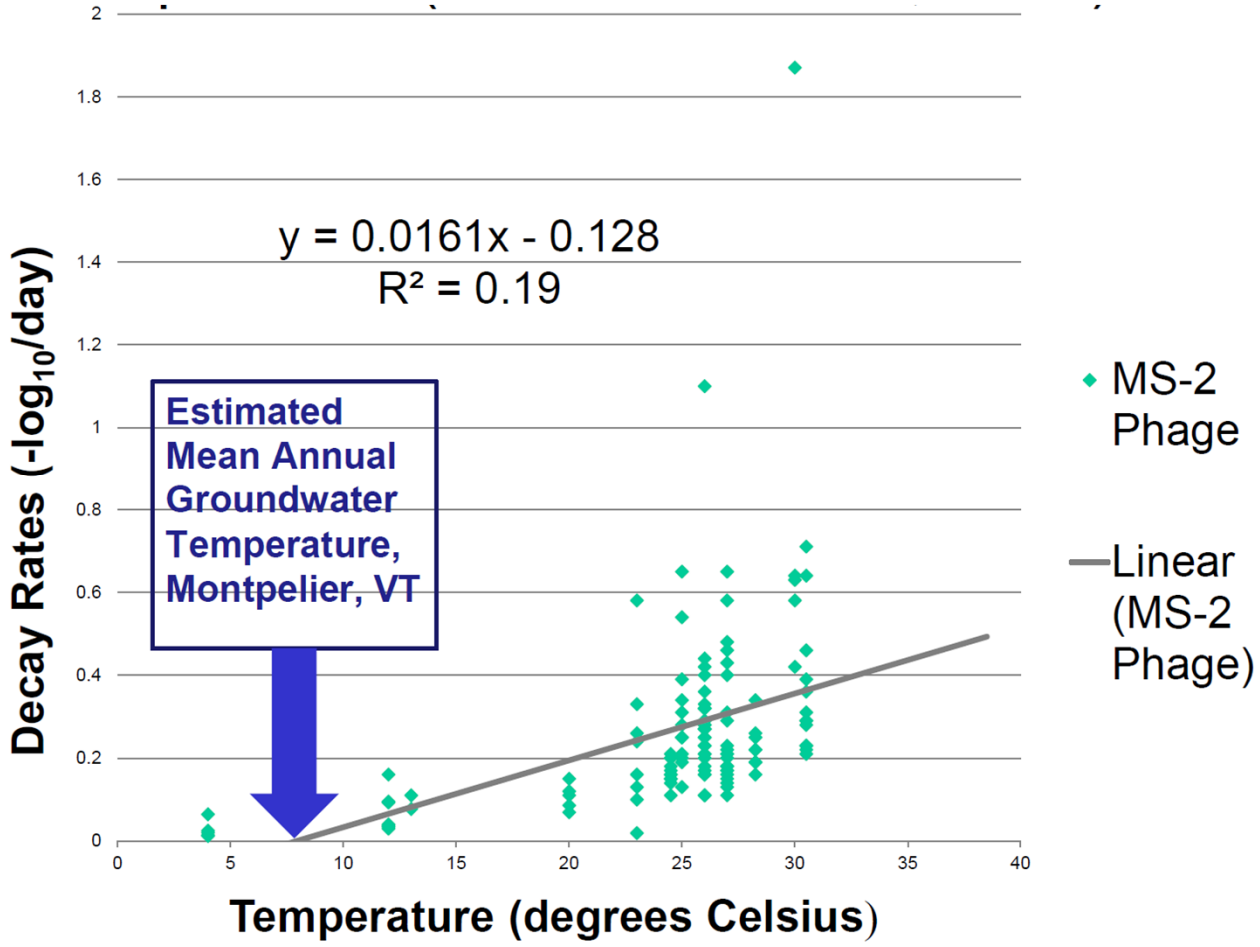
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(Source: USEPA, 2004)

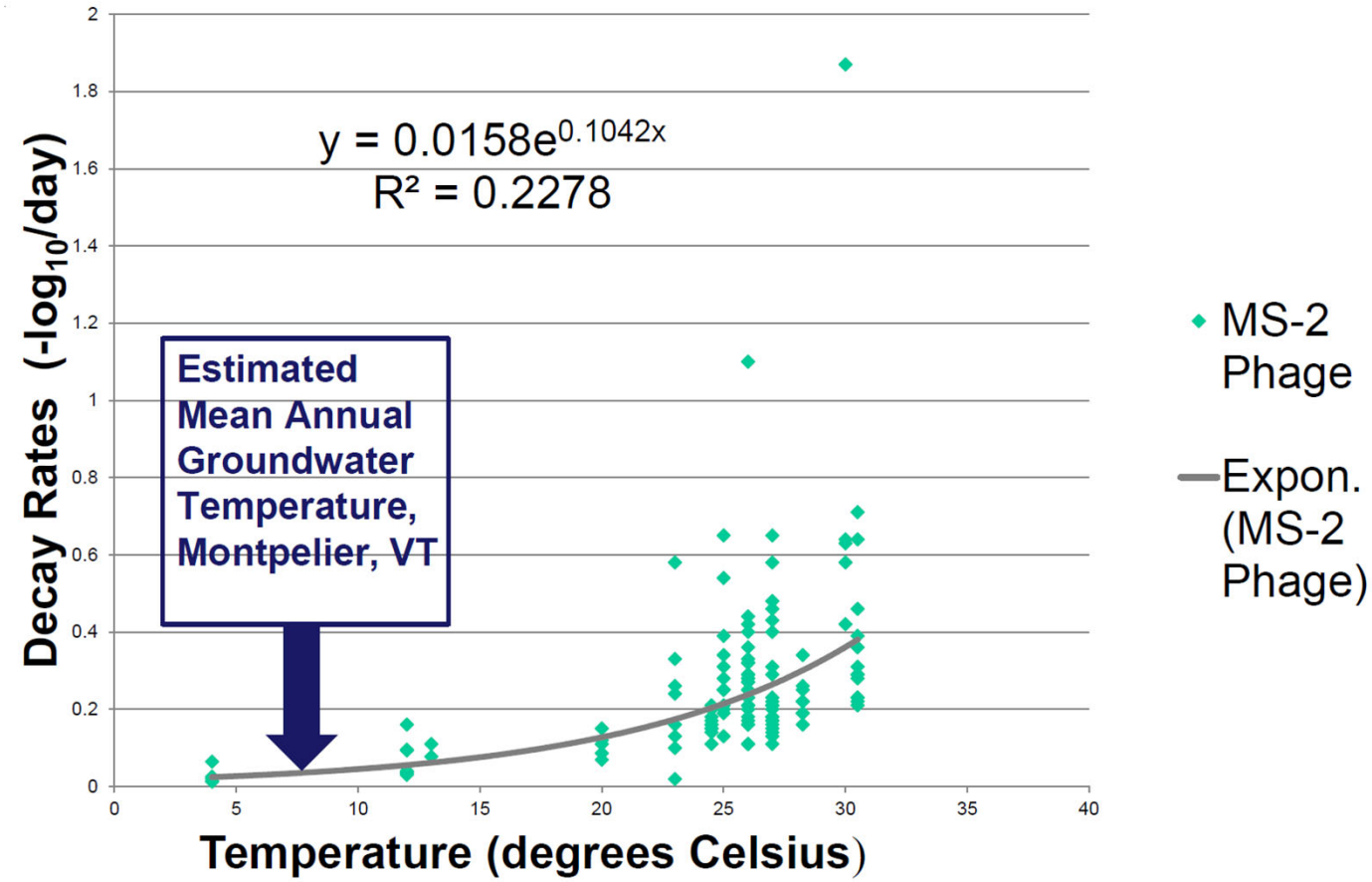
https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/ex/HenrysMap.gif

Linear Virus Decay Rates as a Function of Temperature (Data from Yates, 1987)



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Logarithmic Virus Decay Rates as a Function of Temperature (Data from Yates, 1987)



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Applying Results of Literature Review to Virus Attenuation Goal

- Viruses
  - Feces: 10^6 to 10^{10} plaque forming units (pfu) per gram
  - Wastewater 10^6 pfu per liter
- Unsaturated Soil
  - 99.9% or three logs of removal
  - 10^3 pfu/liter
- Goal: 1 pfu per 10^5 liter
  - 99.9% or three logs of removal
  - Requires an 8-log reduction

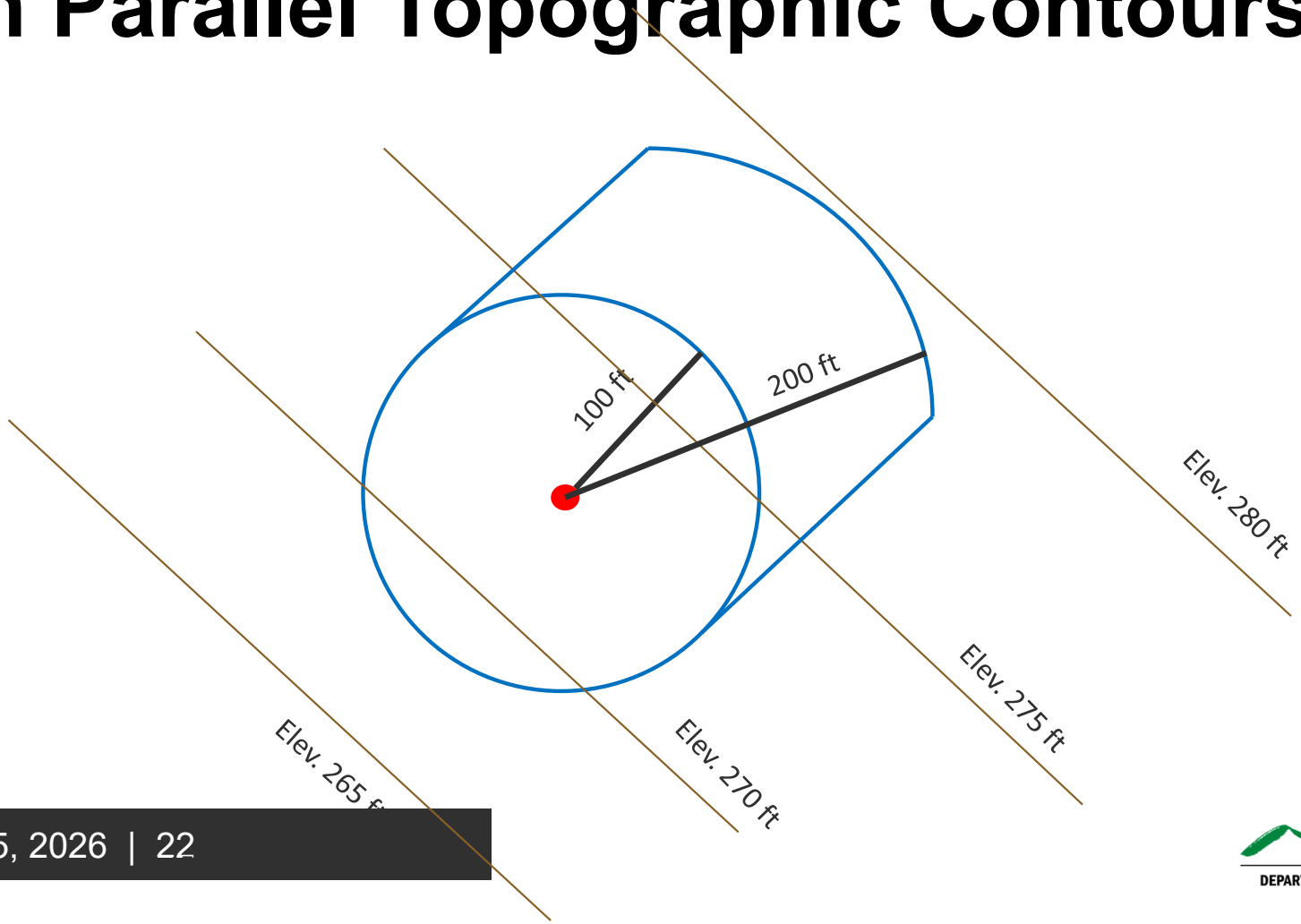
Temperature-based Inactivation Model

- Logarithmic (log) Reduction / Decay Rate = Travel Time
  - Recommended Reduction = 7 to 10 logs
  - Decay Rate = 0.014 log PFU/day
- Example Calculations
  - 7 log reduction/0.014 log PFU = 500 days
  - 10 log reduction/0.014 log PFU= 714 days
- Thus confirming 2-year Time of Travel is a reasonable order of magnitude estimate

Building a New Approach from the Ground Up

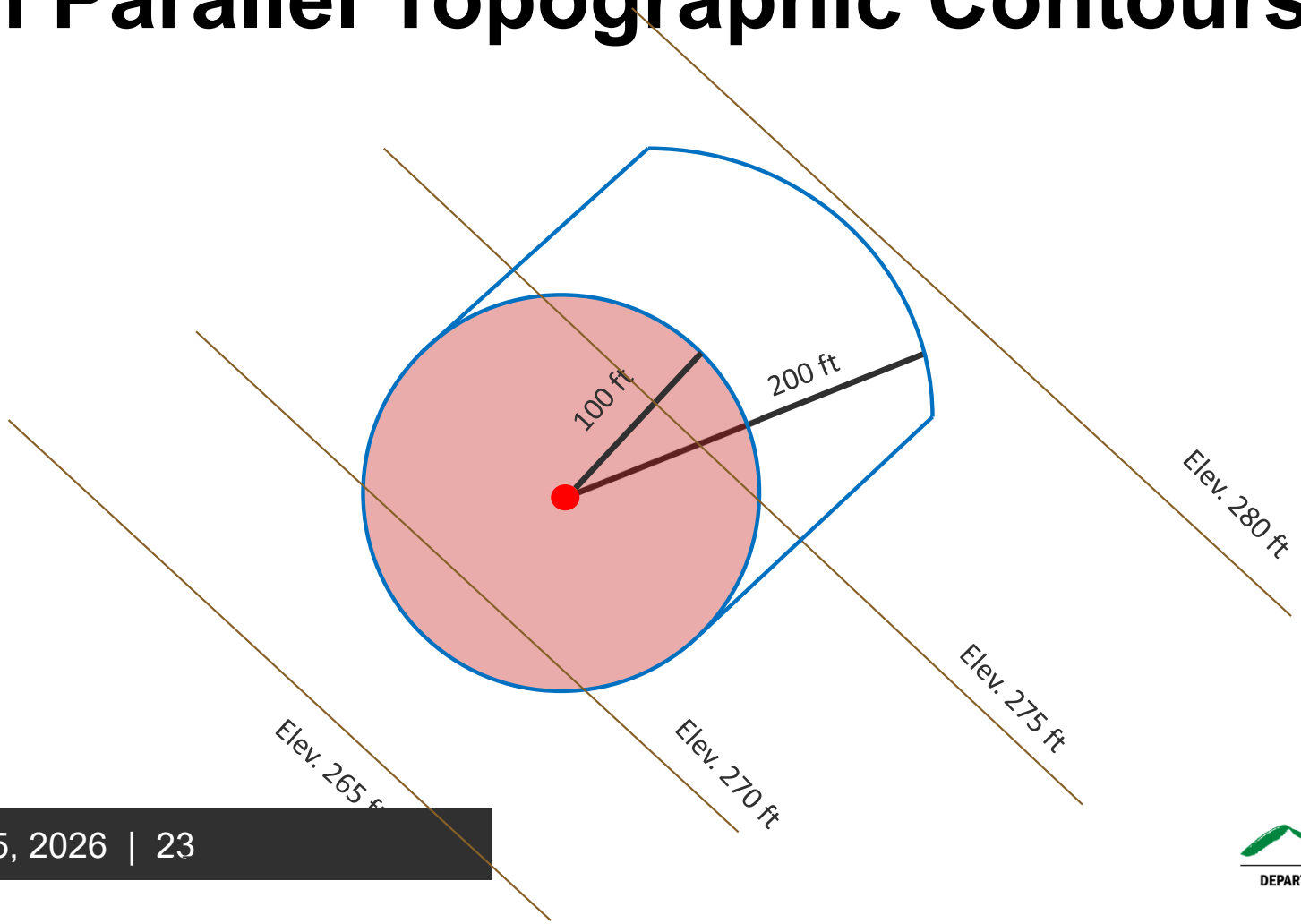
- Series of workshops with consulting engineers and hydrogeologists
  - Obtain general agreement on the rationale
  - Rough-out the methodology
    - Use minimum isolation radius of circle
    - Include area upslope of the circle to 2x isolation distance for drilled wells and 500 feet for shallow sources
    - Time of travel based on Darcy's Law
- Present literature review findings & draft method to Department of Health Epidemiologist and Toxicologist, Water Supply Division

Well Isolation Area for Drilled Well with Parallel Topographic Contours



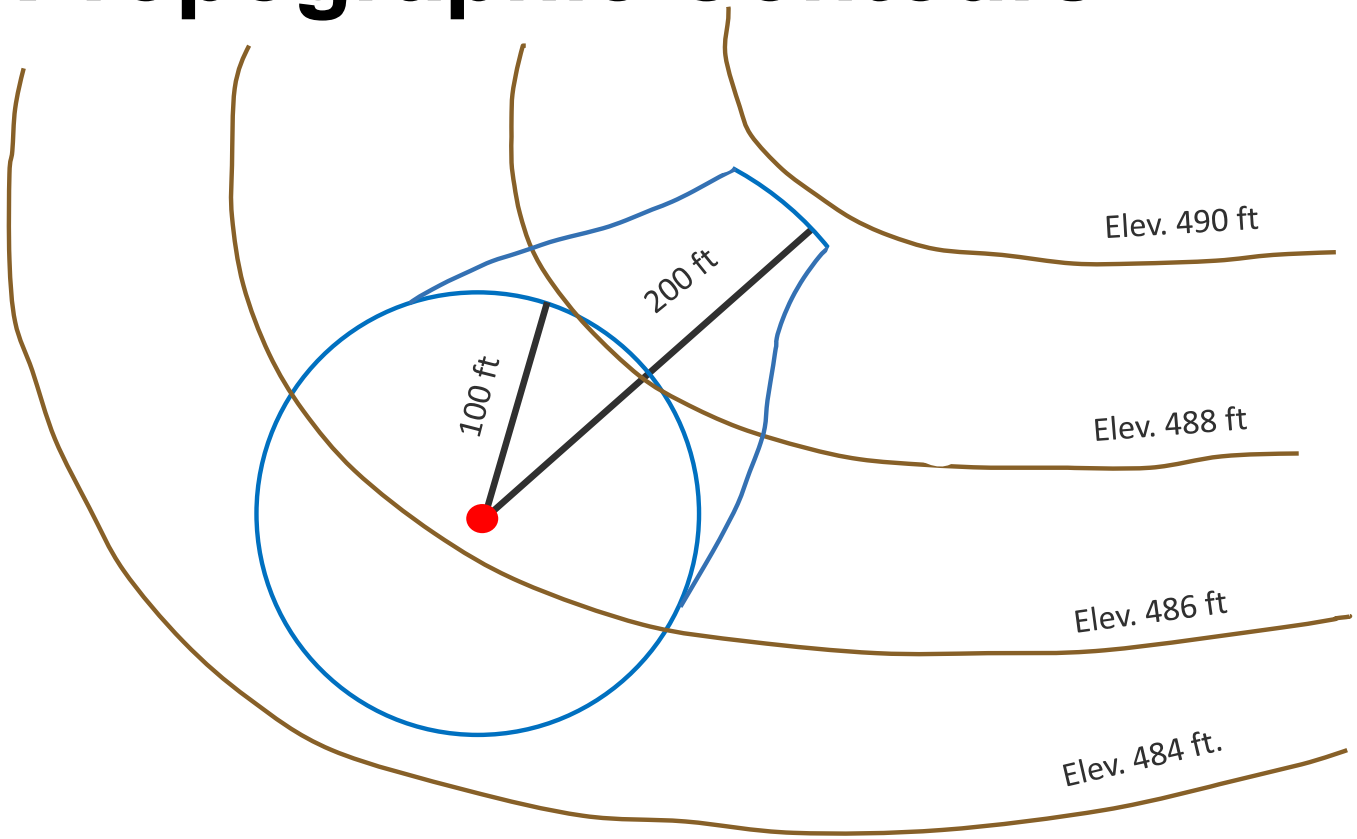
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Well Isolation Area for Drilled Well with Parallel Topographic Contours



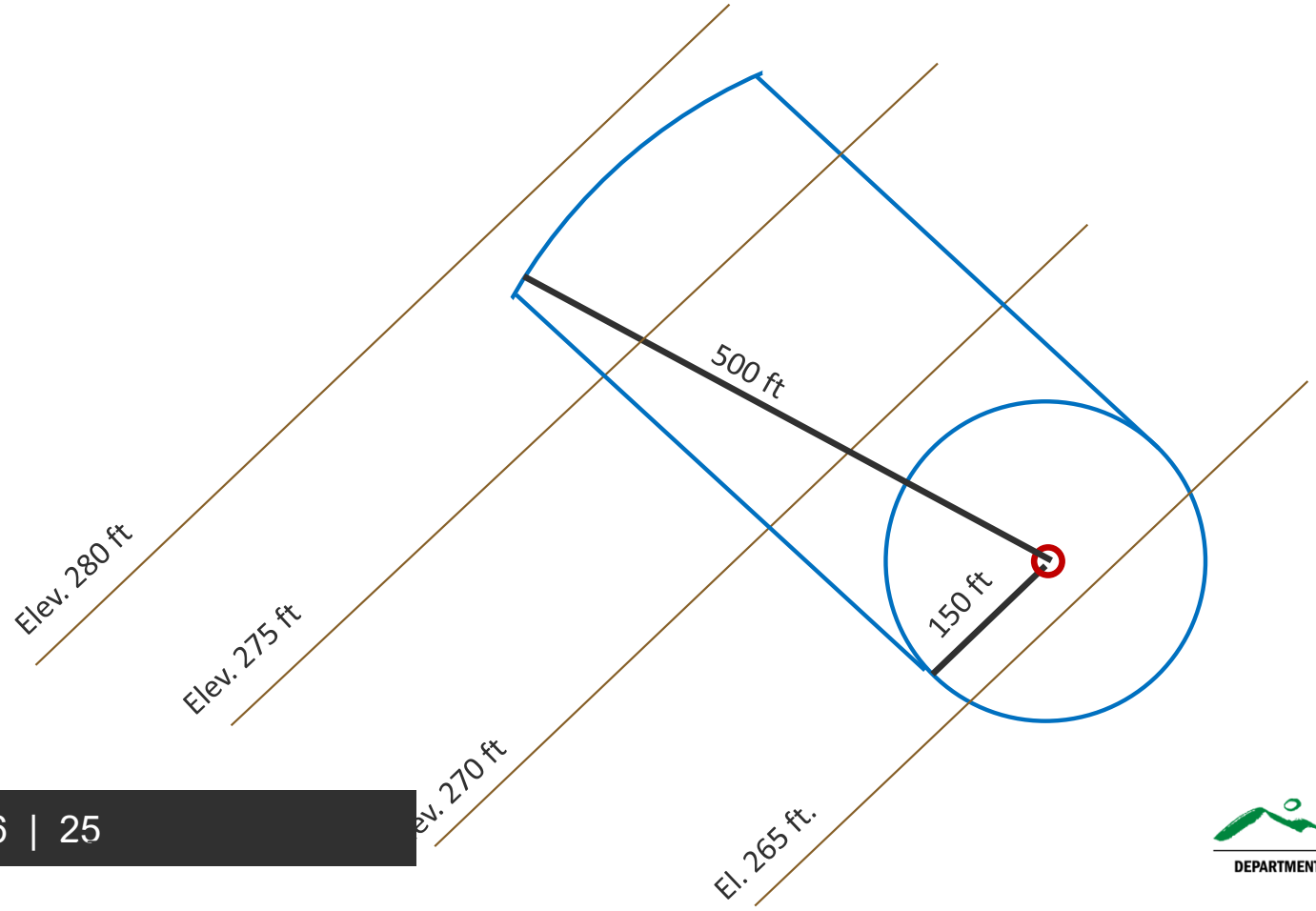
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Well Isolation Area for Drilled Well with Convex Topographic Contours



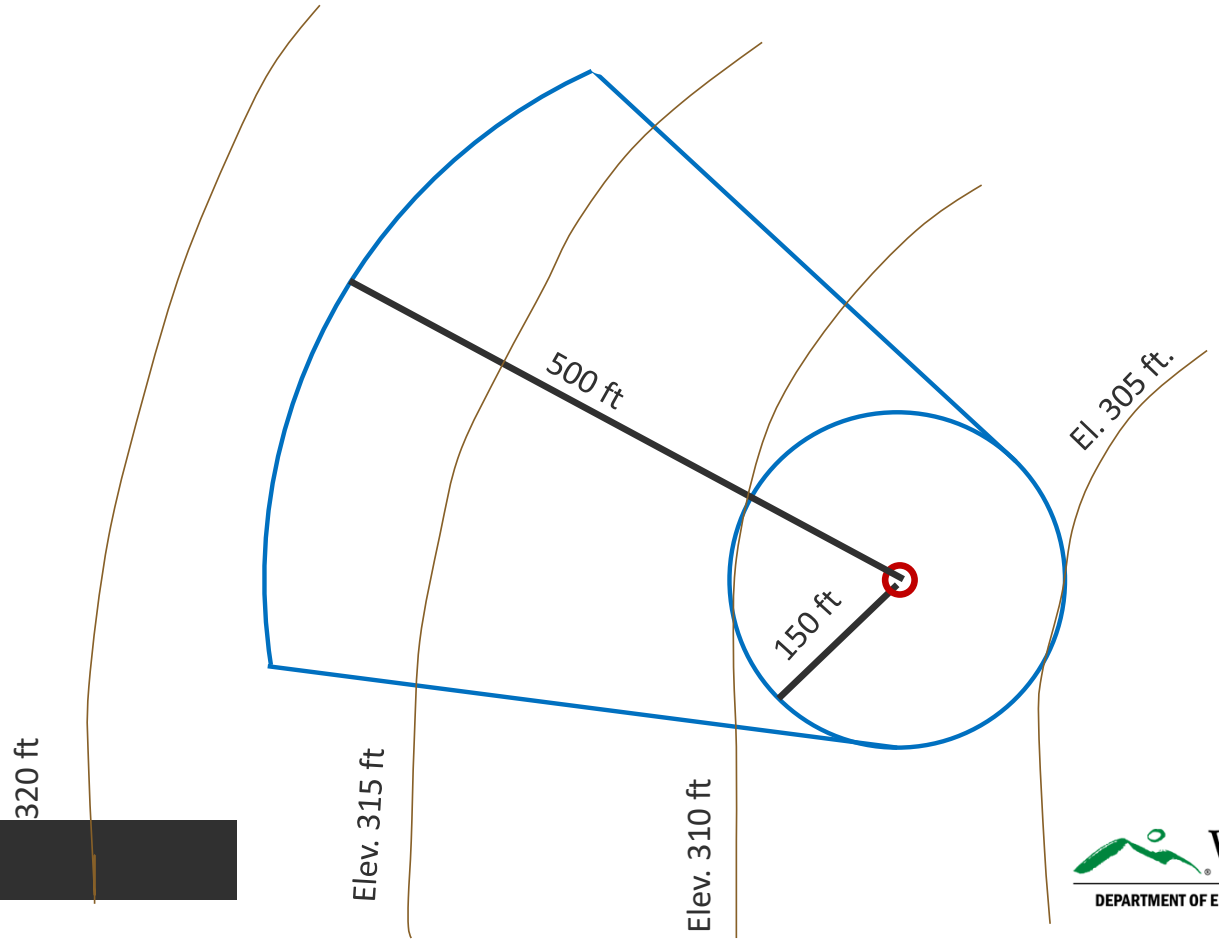
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Shallow Well on Slope with Parallel Topographic Contours



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Shallow Well on Concave Slope



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Implementation

- Part of overall revision of private water supply rule chapter
- Workshops with regulatory staff, consulting engineers, and licensed designers
- Concurrent with revision of public water supply rule chapter
- Became part of drinking water supply rule, not wastewater rule

Well Isolation Area Example



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Quadplex on Two Acre Lot





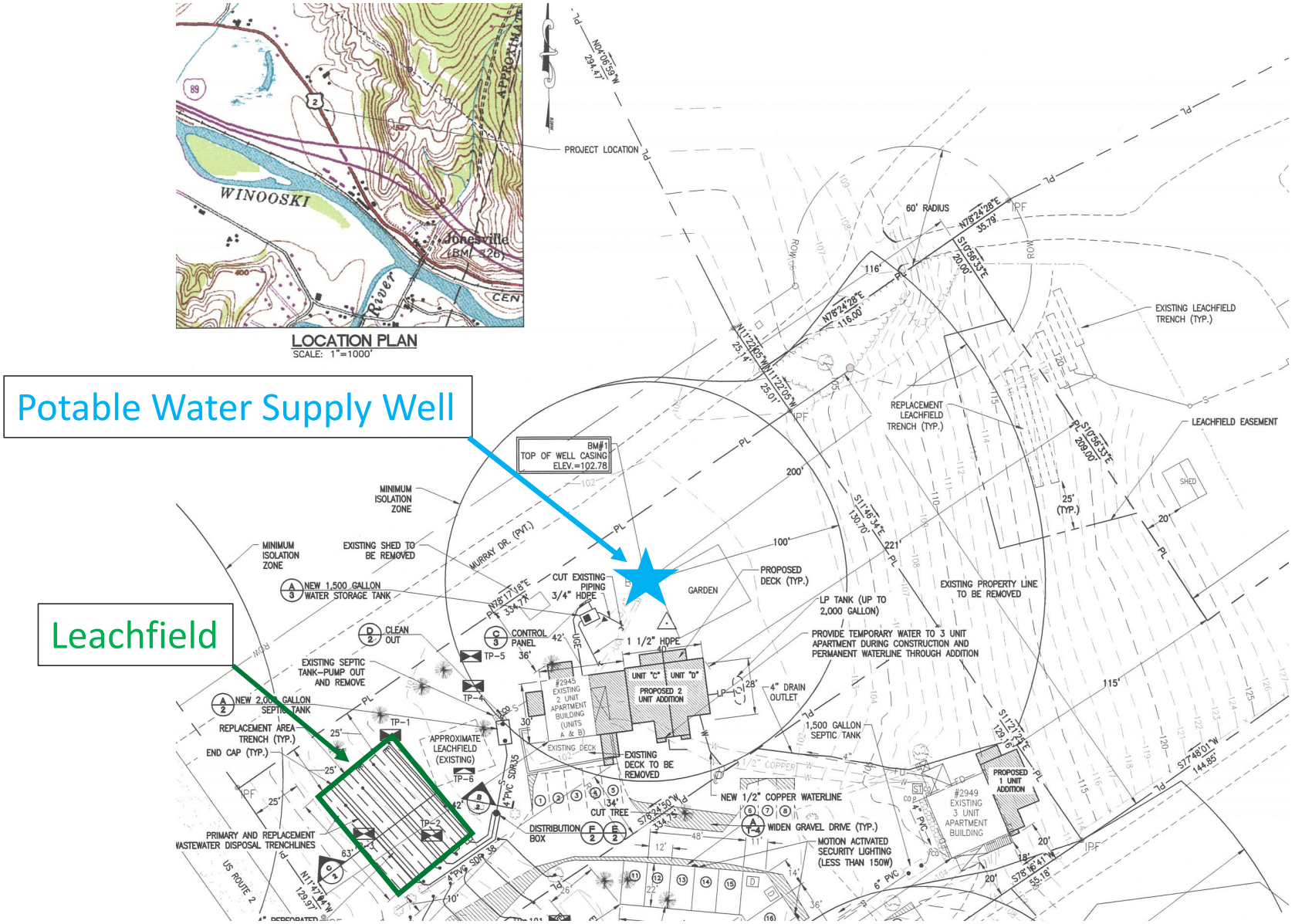
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Look Up-gradient from Well



Look Down-gradient from Leachfield

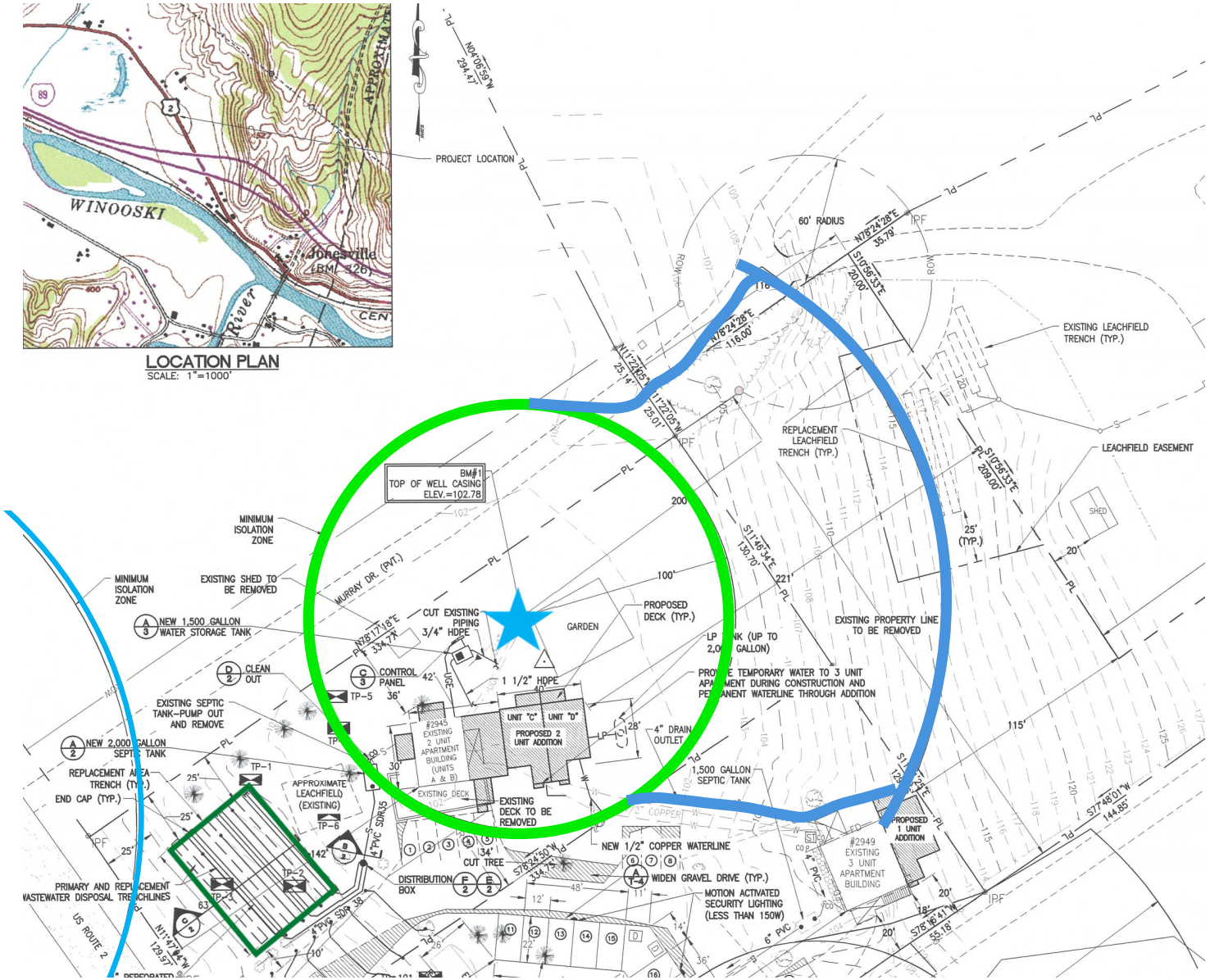



Potable Water Supply Well
Leachfield
LOCATION PLAN
SCALE: 1"=1000'
WINOOSKI
Jonesville
PROJECT LOCATION
N04°06'59"W 294.47'
60' RADIUS
N78°24'28"E 35.79'
S10°58'33"E 20.00'
N78°24'28"E 116.00'
EXISTING LEACHFIELD TRENCH (TYP.)
REPLACEMENT LEACHFIELD TRENCH (TYP.)
LEACHFIELD EASEMENT
S11°46'34"E 130.70'
S10°58'33"E 209.00'
BM#1 TOP OF WELL CASING ELEV.=102.78
MINIMUM ISOLATION ZONE
EXISTING SHED TO BE REMOVED
MURRAY DR. (PVT.)
NEW 1,500 GALLON WATER STORAGE TANK
CUT EXISTING PIPING 3/4" HDPE
N78°17'18"E 334.74'
GARDEN
PROPOSED DECK (TYP.)
LP TANK (UP TO 2,000 GALLON)
EXISTING PROPERTY LINE TO BE REMOVED
CLEAN OUT
CONTROL PANEL
TP-5
1 1/2" HDPE
PROVIDE TEMPORARY WATER TO 3 UNIT APARTMENT DURING CONSTRUCTION AND PERMANENT WATERLINE THROUGH ADDITION
EXISTING SEPTIC TANK--PUMP OUT AND REMOVE
NEW 2,000 GALLON SEPTIC TANK
TP-4
TP-1
#2945 EXISTING 2 UNIT APARTMENT BUILDING (UNITS A & B)
UNIT "C"
UNIT "D"
PROPOSED 2 UNIT ADDITION
4" DRAIN OUTLET
REPLACEMENT AREA TRENCH (TYP.)
END CAP (TYP.)
APPROXIMATE LEACHFIELD (EXISTING)
TP-6
EXISTING DECK
EXISTING DECK TO BE REMOVED
1,500 GALLON SEPTIC TANK
NEW 1/2" COPPER WATERLINE
CUT TREE
S78°24'50"W 334.75'
TP-2
DISTRIBUTION BOX
WIDEN GRAVEL DRIVE (TYP.)
MOTION ACTIVATED SECURITY LIGHTING (LESS THAN 150W)
#2949 EXISTING 3 UNIT APARTMENT BUILDING
PROPOSED 1 UNIT ADDITION
PRIMARY AND REPLACEMENT WASTEWATER DISPOSAL TRENCHLINES
US ROUTE 2
N11°47'34"W 129.97'
S17°27'34"E 129.52'
S77°48'01"W 144.85'
S78°16'41"E 55.18'
6" PVC
4" PVC SDR 35


WINOOSKI
Jonesville
(BM 320')
River
PROJECT LOCATION
LOCATION PLAN
SCALE: 1"=1000'
N04°05'59"W 294.47'
60' RADIUS
N78°24'28"E 35.79'
S10°56'33"E 20.00'
N78°24'28"E 116.00'
N11°22'05"W 25.14'
N11°22'05"W 25.01'
EXISTING LEACHFIELD TRENCH (TYP.)
REPLACEMENT LEACHFIELD TRENCH (TYP.)
LEACHFIELD EASEMENT
S10°56'33"E 209.00'
SHED
25' (TYP.)
BM#1 TOP OF WELL CASING ELEV.=102.78
MINIMUM ISOLATION ZONE
MURRAY DR. (PVT.)
EXISTING SHED TO BE REMOVED
NEW 1,500 GALLON WATER STORAGE TANK
N78°17'18"E 334.74'
CUT EXISTING PIPING 3/4" HDPE
GARDEN
PROPOSED DECK (TYP.)
LP TANK (UP TO 2,000 GALLON)
S11°45'34"E 130.70'
EXISTING PROPERTY LINE TO BE REMOVED
CLEAN OUT
CONTROL PANEL
TP-5
1 1/2" HDPE
PROVIDE TEMPORARY WATER TO 3 UNIT APARTMENT DURING CONSTRUCTION AND PERMANENT WATERLINE THROUGH ADDITION
EXISTING SEPTIC TANK-PUMP OUT AND REMOVE
TP-4
#2945 EXISTING 2 UNIT APARTMENT BUILDING (UNITS A & B)
UNIT "C"
UNIT "B"
PROPOSED 2 UNIT ADDITION
4" DRAIN OUTLET
NEW 2,000 GALLON SEPTIC TANK
TP-1
REPLACEMENT AREA TRENCH (TYP.)
END CAP (TYP.)
APPROXIMATE LEACHFIELD (EXISTING)
TP-6
EXISTING DECK
EXISTING DECK TO BE REMOVED
1,500 GALLON SEPTIC TANK
PROPOSED 1 UNIT ADDITION
S17°12'34"E 129.16'
S77°48'01"W 144.85'
4" PVC SDR35
34" CUT TREE
NEW 1/2" COPPER WATERLINE
S78°24'35"W 334.72'
DISTRIBUTION BOX
WIDEN GRAVEL DRIVE (TYP.)
#2949 EXISTING 3 UNIT APARTMENT BUILDING
MOTION ACTIVATED SECURITY LIGHTING (LESS THAN 150W)
PRIMARY AND REPLACEMENT WASTEWATER DISPOSAL TRENCHLINES
TP-2
TP-3
US ROUTE 2
N11°47'14"W 129.97'
S78°16'41"W 55.18'
6" PVC


WINOOSKI
Jonesville
(RM. 226)
PROJECT LOCATION
LOCATION PLAN
SCALE: 1"=1000'
BM#1
TOP OF WELL CASING
ELEV.=102.78
MINIMUM ISOLATION ZONE
EXISTING SHED TO BE REMOVED
MURRAY DR. (PVT.)
NEW 1,500 GALLON WATER STORAGE TANK
CLEAN OUT
CONTROL PANEL
CUT EXISTING PIPING 3/4" HDPE
1 1/2" HDPE
GARDEN
PROPOSED DECK (TYP.)
LP TANK (UP TO 2,000 GALLON)
PROVIDE TEMPORARY WATER TO 3 UNIT APARTMENT DURING CONSTRUCTION AND PERMANENT WATERLINE THROUGH ADDITION
EXISTING PROPERTY LINE TO BE REMOVED
EXISTING SEPTIC TANK–PUMP OUT AND REMOVE
NEW 2,000 GALLON SEPTIC TANK
REPLACEMENT AREA TRENCH (TYP.)
END CAP (TYP.)
APPROXIMATE LEACHFIELD (EXISTING)
#2945 EXISTING 2 UNIT APARTMENT BUILDING (UNITS A & B)
UNIT "C"
UNIT "D"
PROPOSED 2 UNIT ADDITION
EXISTING DECK
EXISTING DECK TO BE REMOVED
4" DRAIN OUTLET
1,500 GALLON SEPTIC TANK
NEW 1/2" COPPER WATERLINE
CUT TREE
DISTRIBUTION BOX
WIDEN GRAVEL DRIVE (TYP.)
MOTION ACTIVATED SECURITY LIGHTING (LESS THAN 150W)
PRIMARY AND REPLACEMENT WASTEWATER DISPOSAL TRENCHLINES
US ROUTE 2
#2949 EXISTING 3 UNIT APARTMENT BUILDING
PROPOSED 1 UNIT ADDITION
EXISTING LEACHFIELD TRENCH (TYP.)
REPLACEMENT LEACHFIELD TRENCH (TYP.)
LEACHFIELD EASEMENT
60' RADIUS
SHED
TP-1
TP-2
TP-5
TP-6
N04°06'59"W 294.47'
N78°24'28"E 35.79'
S10°58'33"E 20.00'
N78°24'28"E 116.00'
N11°22'05"W 25.14'
N11°22'05"W 25.01'
S11°46'34"E 130.70'
S10°58'33"E 209.00'
N78°17'18"E 334.74'
S78°24'50"W 334.75'
S11°27'34"E 129.52'
S77°48'01"W 144.85'
N11°47'24"W 129.97'
S78°16'41"E 55.18'


WINOOSKI
Jonesville
PROJECT LOCATION
LOCATION PLAN
SCALE: 1"=1000'
BM#1
TOP OF WELL CASING
ELEV.=102.78
MINIMUM ISOLATION ZONE
EXISTING SHED TO BE REMOVED
NEW 1,500 GALLON WATER STORAGE TANK
CLEAN OUT
CONTROL PANEL
EXISTING SEPTIC TANK-PUMP OUT AND REMOVE
NEW 2,000 GALLON SEPTIC TANK
REPLACEMENT AREA TRENCH (TYP.)
END CAP (TYP.)
APPROXIMATE LEACHFIELD (EXISTING)
PRIMARY AND REPLACEMENT WASTEWATER DISPOSAL TRENCHLINES
DISTRIBUTION BOX
CUT EXISTING PIPING 3/4" HDPE
1 1/2" HDPE
GARDEN
PROPOSED DECK (TYP.)
#2945 EXISTING 2 UNIT APARTMENT BUILDING (UNITS A & B)
PROPOSED 2 UNIT ADDITION
UNIT "C"
UNIT "D"
EXISTING DECK TO BE REMOVED
4" DRAIN OUTLET
1,500 GALLON SEPTIC TANK
NEW 1/2" COPPER WATERLINE
CUT TREE
WIDEN GRAVEL DRIVE (TYP.)
MOTION ACTIVATED SECURITY LIGHTING (LESS THAN 150W)
#2949 EXISTING 3 UNIT APARTMENT BUILDING
PROPOSED 1 UNIT ADDITION
EXISTING PROPERTY LINE TO BE REMOVED
EXISTING LEACHFIELD TRENCH (TYP.)
REPLACEMENT LEACHFIELD TRENCH (TYP.)
LEACHFIELD EASEMENT
60' RADIUS
MURRAY DR. (PVT.)
US ROUTE 2
TP-1
TP-2
TP-3
TP-4
TP-5
TP-6
N04°06'59"W 294.47'
N78°24'28"E 35.79'
S10°58'33"E 20.00'
N78°24'28"E 116.00'
N11°22'05"W 25.14'
N11°22'05"W 25.01'
S11°46'34"E 130.70'
S10°58'33"E 209.00'
S78°24'50"W 334.75'
S77°48'01"W 144.85'
S78°16'41"E 55.18'
N78°17'18"E 334.77'
N11°47'18"W 129.57'


WINOOSKI
Jonesville
(BM 426)
PROJECT LOCATION
LOCATION PLAN
SCALE: 1"=1000'
N04°06'59"W 294.47'
60' RADIUS
N78°24'28"E 35.79'
S10°58'33"E 20.00'
N78°24'28"E 116.00'
N11°22'05"W 25.14'
S11°22'05"E 25.01'
EXISTING LEACHFIELD TRENCH (TYP.)
REPLACEMENT LEACHFIELD TRENCH (TYP.)
LEACHFIELD EASEMENT
S10°58'33"E 209.00'
25' (TYP.)
SHED
S11°46'34"E 130.70'
EXISTING PROPERTY LINE TO BE REMOVED
BM#1
TOP OF WELL CASING
ELEV.=102.78
MINIMUM ISOLATION ZONE
MURRAY DR. (PVT.)
EXISTING SHED TO BE REMOVED
NEW 1,500 GALLON WATER STORAGE TANK
CUT EXISTING PIPING 3/4" HDPE
N78°17'18"E 334.74'
GARDEN
PROPOSED DECK (TYP.)
CLEAN OUT
CONTROL PANEL
TP-5
1 1/2" HDPE
PROVIDE TEMPORARY WATER TO 3 UNIT APARTMENT DURING CONSTRUCTION AND PERMANENT WATERLINE THROUGH ADDITION
EXISTING SEPTIC TANK-PUMP OUT AND REMOVE
#2945 EXISTING 2 UNIT APARTMENT BUILDING (UNITS A & B)
UNIT "C"
UNIT "D"
PROPOSED 2 UNIT ADDITION
4" DRAIN OUTLET
NEW 2,000 GALLON SEPTIC TANK
REPLACEMENT AREA TRENCH (TYP.)
END CAP (TYP.)
TP-1
TP-6
APPROXIMATE LEACHFIELD (EXISTING)
EXISTING DECK
EXISTING DECK TO BE REMOVED
1,500 GALLON SEPTIC TANK
PROPOSED 1 UNIT ADDITION
#2949 EXISTING 3 UNIT APARTMENT BUILDING
NEW 1/2" COPPER WATERLINE
CUT TREE
S78°24'50"W 334.75'
DISTRIBUTION BOX
WIDEN GRAVEL DRIVE (TYP.)
MOTION ACTIVATED SECURITY LIGHTING (LESS THAN 150W)
PRIMARY AND REPLACEMENT WASTEWATER DISPOSAL TRENCHLINES
TP-2
TP-3
TP-4
4" PVC SDR 35
6" PVC
US ROUTE 2
N11°47'18"W 129.57'
S77°48'01"W 144.85'
S78°16'41"E 55.18'

Significant Developments in the Vermont Legislature and the Vermont Supreme Court (1 of 2)

- 2002 Universal Jurisdiction
  - All Wastewater Systems and Potable Water Supplies regulated by Vermont Department of Environmental Conservation
  - Established Technical Advisory Committee
- 2010 Notification Requirement
  - Request for Evaluation Overshadowing
- 2011 Notification Requirement
  - Presumptive Isolation Zones for Potable Water Sources and Leachfields

Significant Developments in the Vermont Legislature and the Vermont Supreme Court (2 of 2)

- 2023 Vermont Supreme Court Upholds Permit that includes Presumptive Isolation Zone Against Appeal that it is a Regulatory Taking
- 2026 Overshadowing Report Requested by Legislature

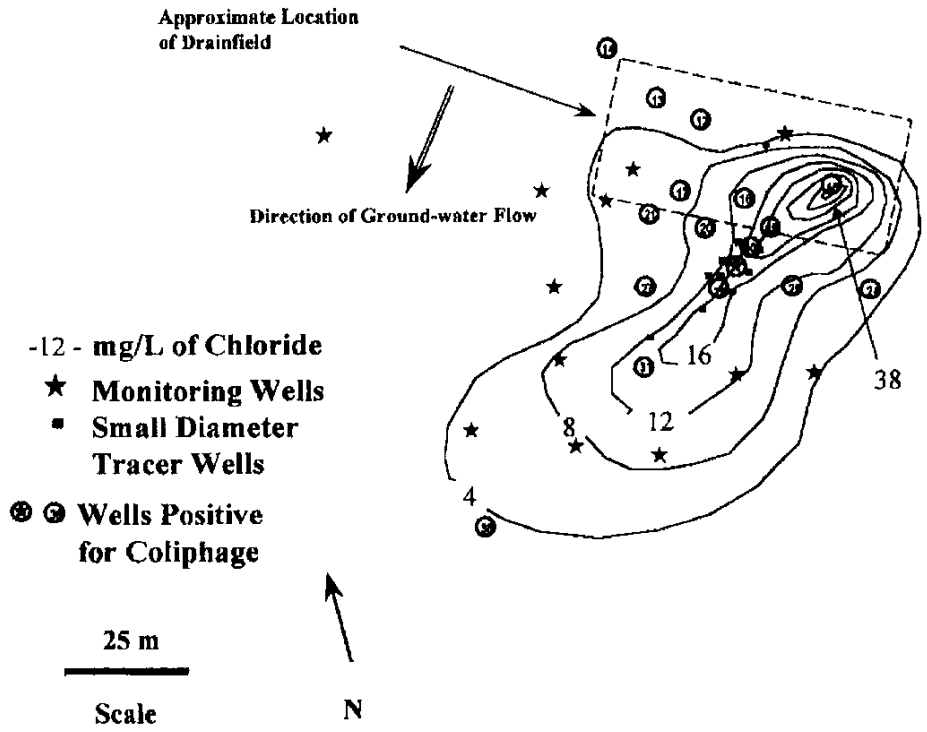
Research Needs

- Pathogen survival studies. (protozoa, bacteria and viruses)
- Additional field studies on transport and fate of pathogens and tracers
- Development of predictive models for pathogenic transport in multiple groundwater settings.

(adapted from W. Woessner, 2004)

Revisit the Literature - Montana

Virus Occurrence and Transport in a School Septic System and Unconfined Aquifer (DeBord, et. al., 1998)



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Revisit the Literature - California

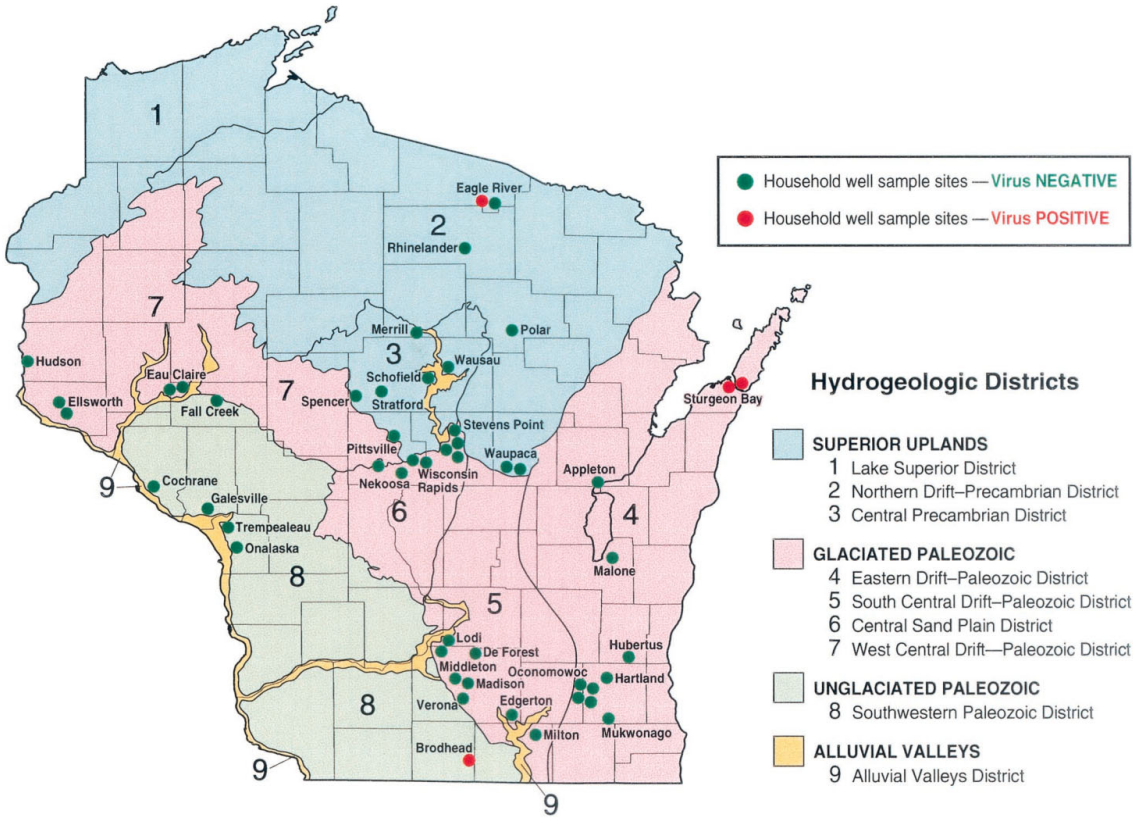
A Field Study of Water Flow and Virus Transport in Weathered Granitic Bedrock (Frazier, et. al., 2002)



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Revisit the Literature - Wisconsin

Incidence of Enteric Viruses in Groundwater from Household Wells in Wisconsin (Borchardt, et. al., 2002)



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Bacteria Sampling in England

A survey of the microbiological quality of private water supplies in England (Rutter, et al 2000)

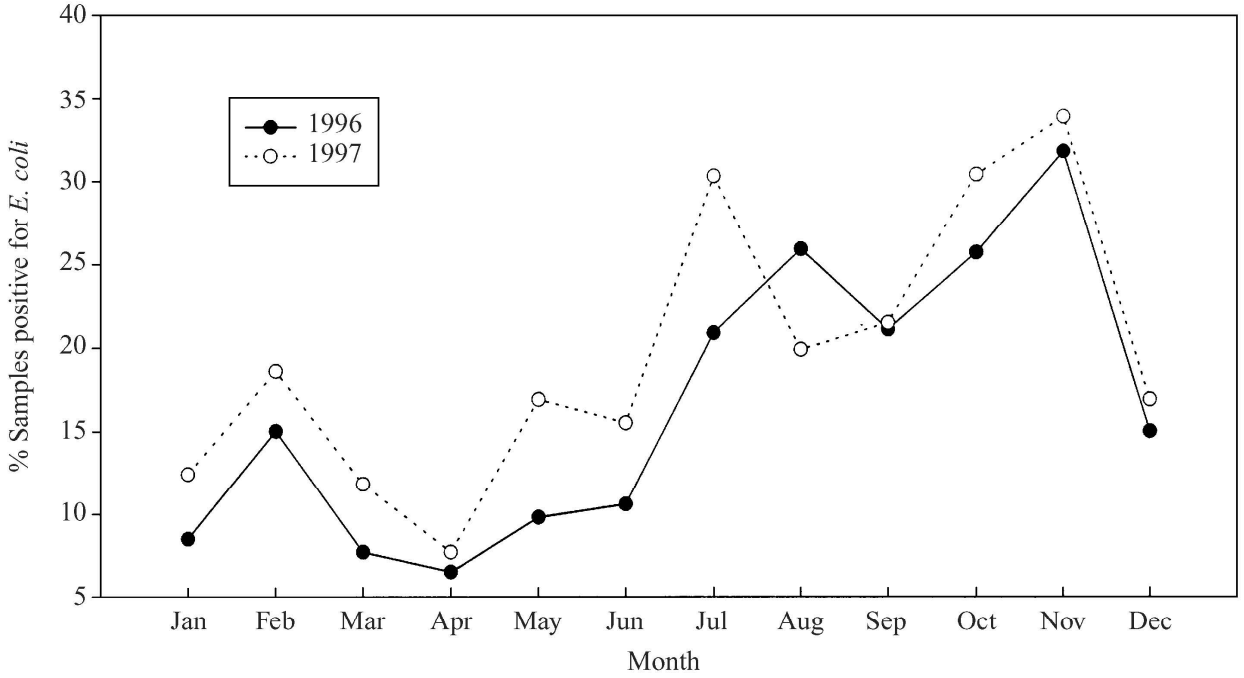


Fig. 1. Monthly % of samples from private water supplies positive for *E. coli*.

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Next Steps

- Complete Overshadowing Report
  - Technical and Scientific basis of Overshadowing
  - Human Health and Environmental Benefits of Overshadowing
  - Alternatives to Overshadowing and Potential Outcomes
  - Recommendations for Regulatory or Legislative Changes
  - Other Pertinent Issues
- Review and revise communication template for notifying neighbors of overshadowing

Research & Regulatory Needs – OWTS Site Evaluation and Design

- Synthesis of scientific literature to update impacts of:
  - Unsaturated flow
    - Methods of distribution
    - Long Term Acceptance Rates
    - Vertical separation to seasonal high groundwater,
    - Soil particle size distribution,
  - Saturated (groundwater) flow
    - temperature
    - hydraulic conductivity
    - Talk to other states about overshadowing and the siting of leachfields relative to potable water supplies, and vice versa

Research & Regulatory Needs - Characterization of Risk of Water Born Diseases in US

- Apply Quantitative Microbial Risk Assessment Methods to Designing Onsite Water Treatment Systems[1]
- Establish of Logarithmic Reduction Values for Unit Processes in Onsite Wastewater Treatment Systems
  - Septic Tanks
  - Advanced Treatment Units
  - Disinfection Processes
  - Distribution Systems
  - Unsaturated flow
  - Saturated Flow

1. Haas, Rose & Gerba, 2014, Quantitative Microbial Risk Assessment, 2nd ed.

Research & Regulatory Needs (Potable Water Supply Design and Construction

- More testing of viruses in private wells during water borne pathogenic disease occurnaces
- Characterize Water Supply Construction Methods to minimize susceptibility of source to pathogens
- Talk to other states about overshadowing and the placement of potable water supplies

Acknowledgements

- State of Vermont Department of Environmental Conservation
  - Drinking Water and Groundwater Protection Division
  - Groundwater Quality Section of Water Quality Division
- Stone Environmental
- State of Vermont Technical Advisory Committee

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Thank you!

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