Tracking Nitrate Contamination and Septic Effluent in an Urbanizing Dryland Agricultural Watershed

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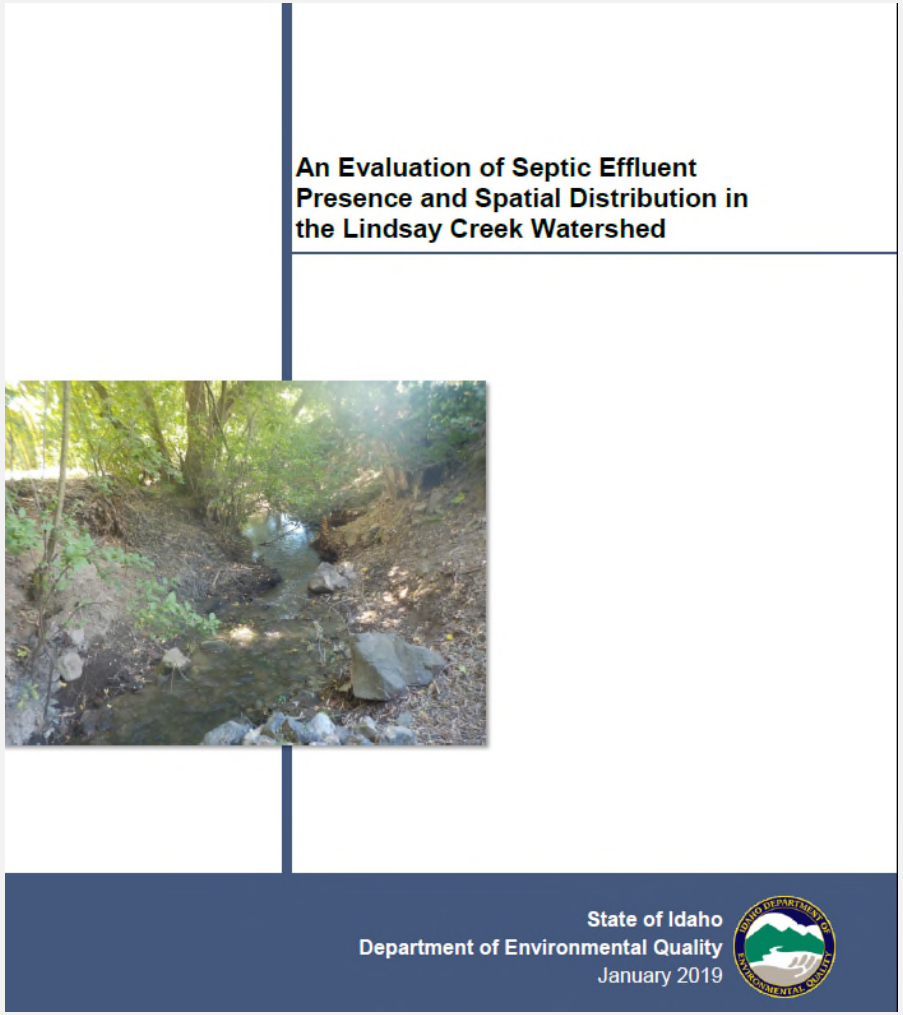

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Septic Systems

- Common in rural areas
- Treat household wastewater
- Remove pollutants or reduce their concentrations
- Discharge treated wastewater to subsurface soils

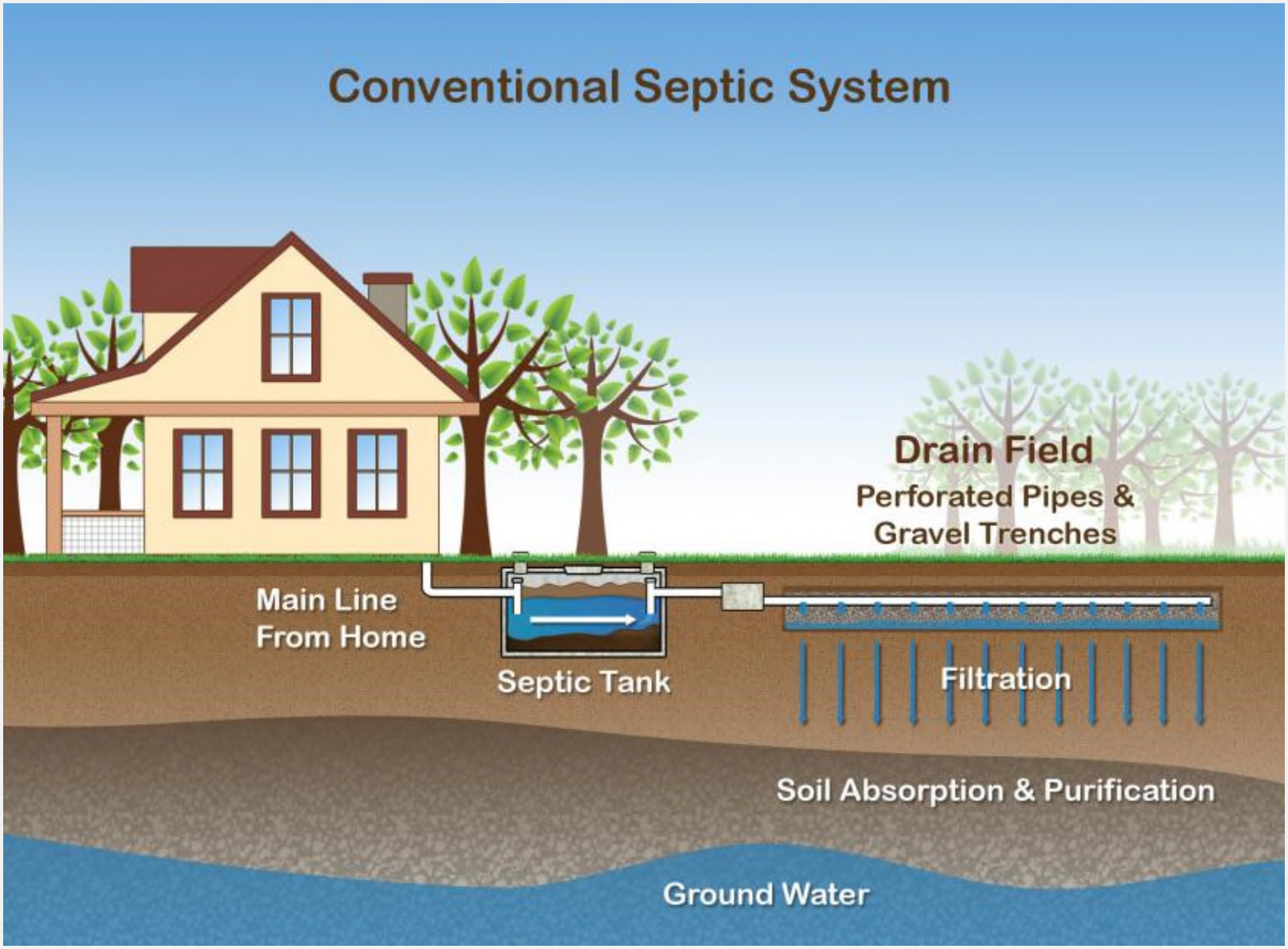

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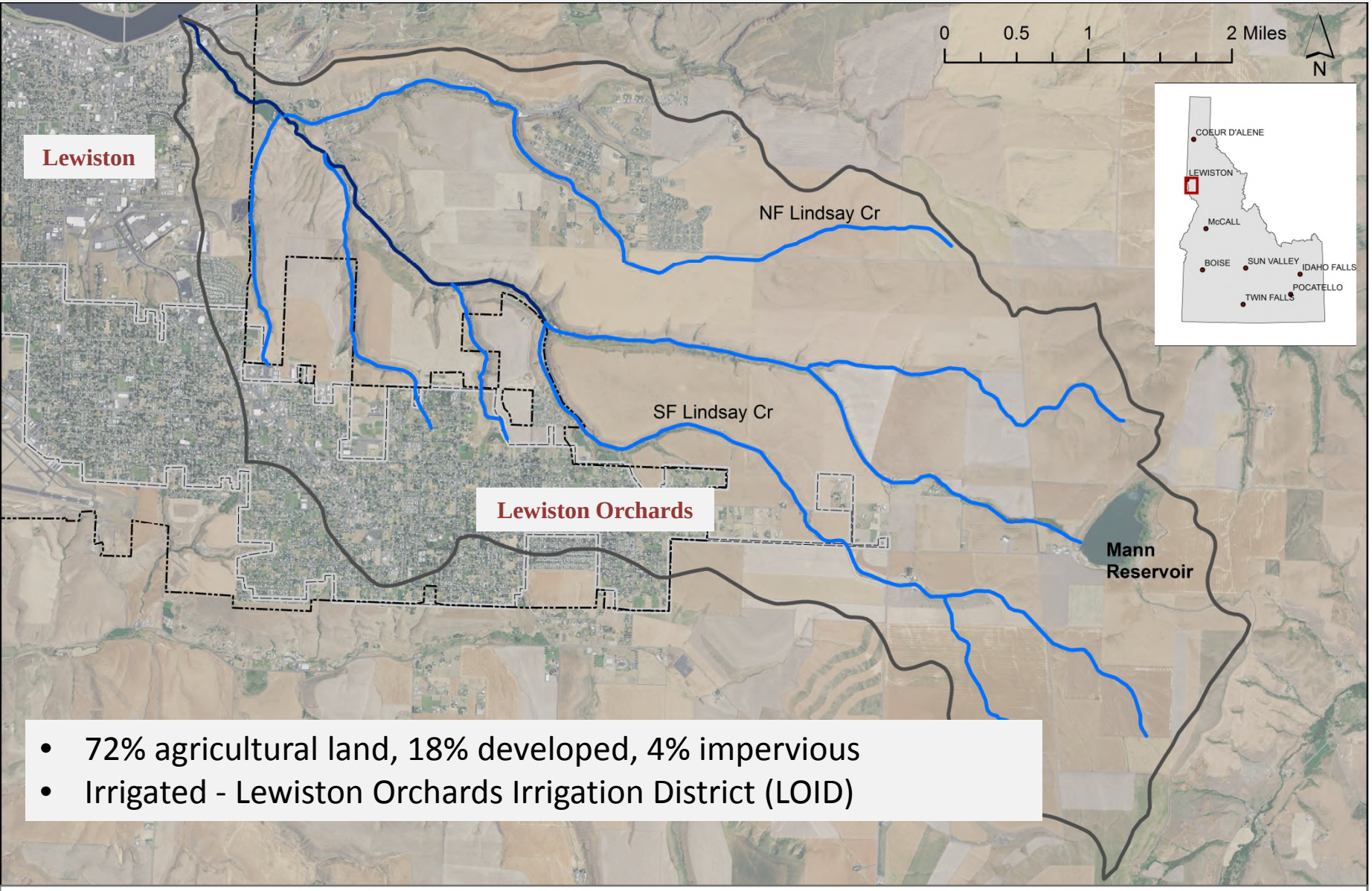
Image source: Gloucester-MA.gov

Septic Systems & Water Quality

- By design, discharge to subsurface soils
- Potential source of pollutants to ground water and surface water
- Failing systems discharge pollutants at elevated concentrations
- In high densities, collective output pollutants from septic systems can be significant

Nitrate

- Chemical of concern discharged by septic systems
- Ground water
  - well (drinking water) contamination
  - 10 mg N/L = EPA MCL & Idaho Ground Water Quality Standard
  - Blue Baby Syndrome
  - Health effects for some adults & elderly
- Surface water
  - Can contribute to nuisance algal growths
  - Aquatic life effects



- 72% agricultural land, 18% developed, 4% impervious
- Irrigated - Lewiston Orchards Irrigation District (LOID)

Lindsay Creek Watershed

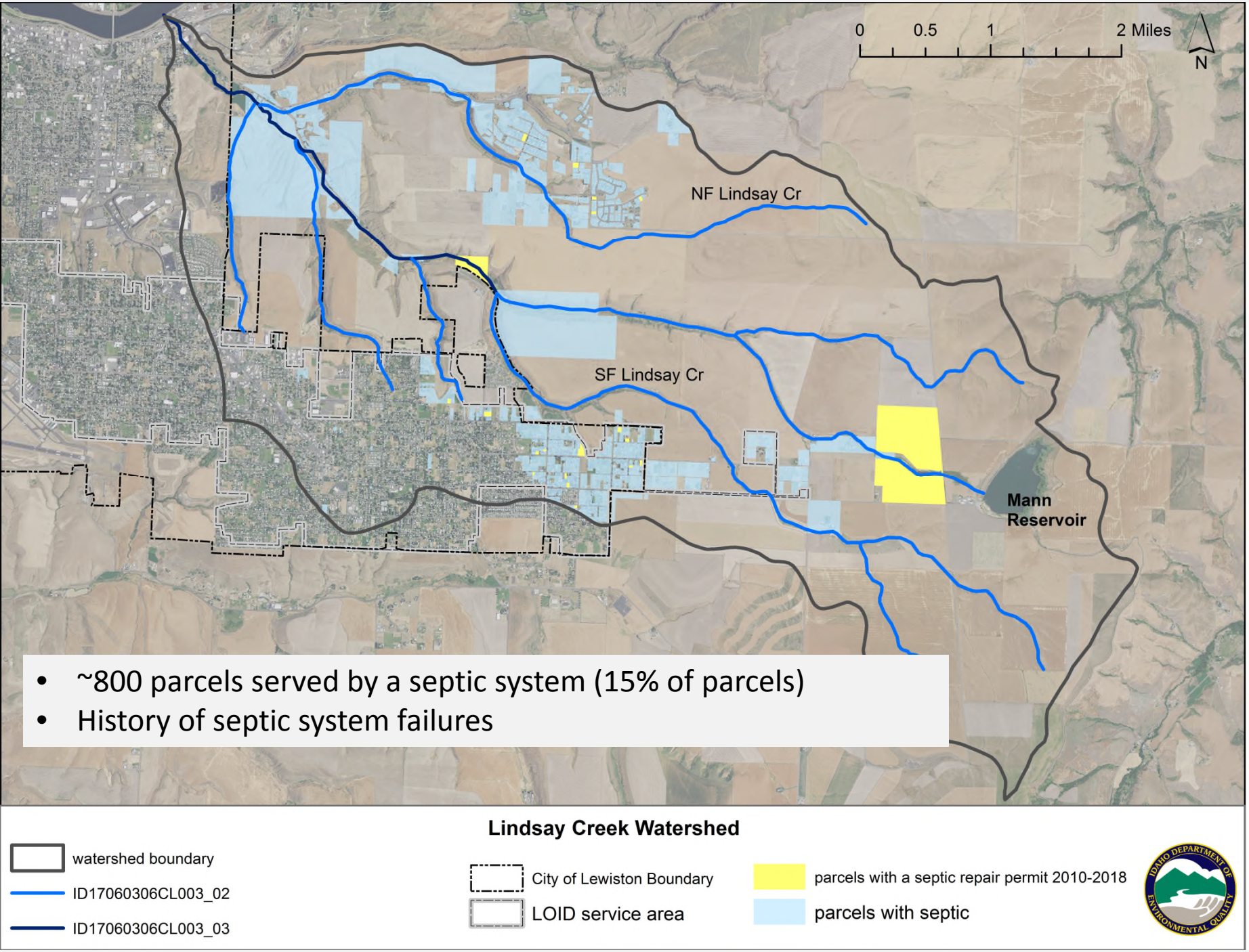
watershed boundary

ID17060306CL003_02

ID17060306CL003_03

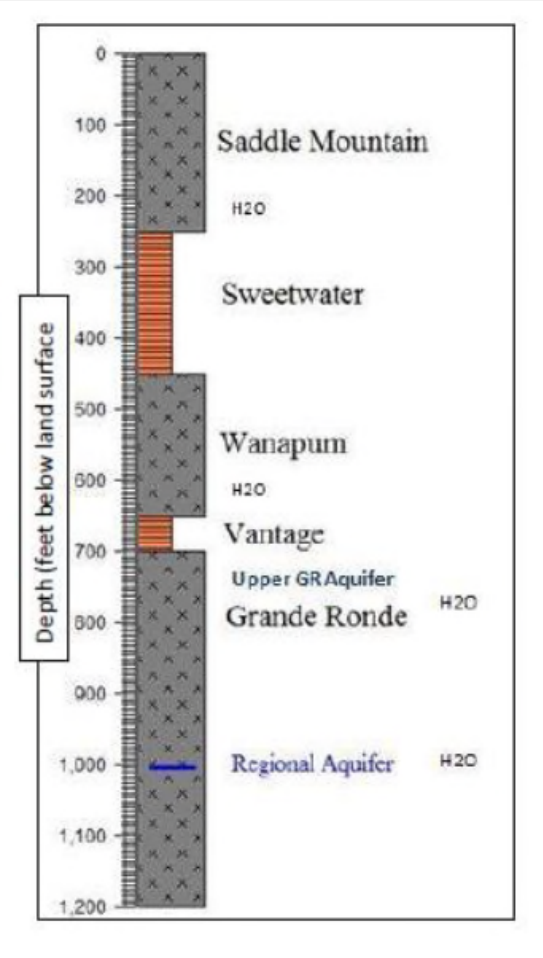
City of Lewiston Boundary

LOID service area



- ~800 parcels served by a septic system (15% of parcels)
- History of septic system failures

Aquifer Naturally Vulnerable to Nitrate Contamination



Saddle Mountains Aquifer

- Basalt begins 5-20 ft from ground surface
- Multiple layers of fractured basalt
- Unconfined aquifer
- Fractured basalt = mobile pollutants
- High dissolved oxygen limits potential for denitrification
- Used by some residents as a drinking water source
- Source of water to Lindsay Creek

High Nitrate in Saddle Mountains Aquifer (0 – 250 ft)

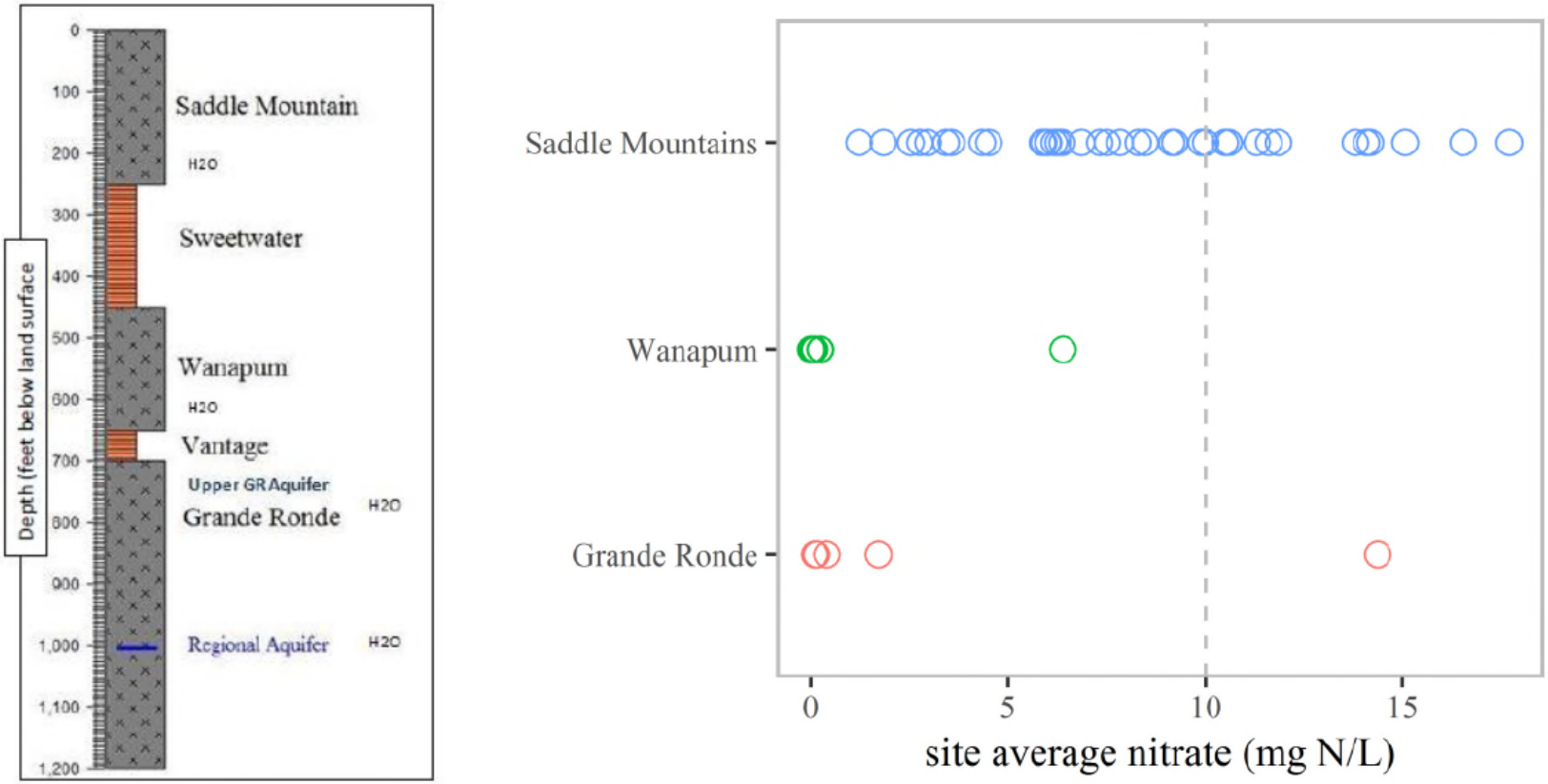


Figure 3. Geologic strata and average nitrate concentrations at wells and springs sampled by DEQ within the Lindsay Creek NPA and Lewiston plateau ground water management area (Figure 1). Geologic strata are from Neely 2018.

Lindsay Creek Watershed

- Ground water
  - Nitrate > 10 mg N/L in some wells
  - Nitrate Priority Area (NPA)

- Surface Water
  - Nitrate 5-15 mg N/L
  - Greater stream nitrate in wetter years
  - Nitrate Total Maximum Daily Load (TMDL)

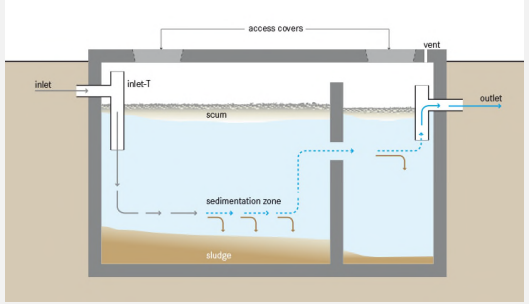
Many Potential Nitrate Sources

N fertilizer

animal manure

farm runoff

atmospheric



septic systems

storm water

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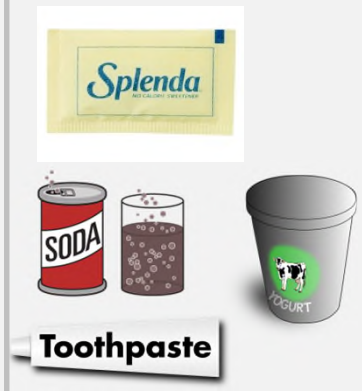
Approach

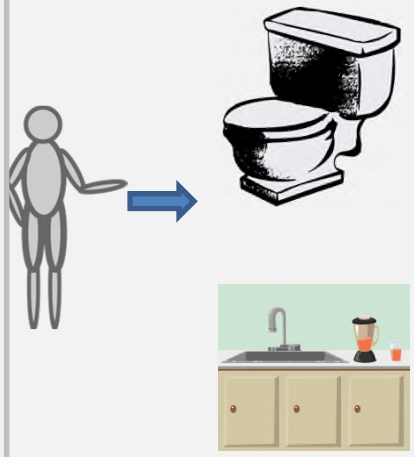
- Use artificial sweeteners as chemical markers of septic effluent
- Use caffeine as a chemical marker for effluent from poorly-functioning septic systems
- Evaluate overlap between septic indicators & nitrate

Artificial Sweeteners

Products



Human Wastewater



Sewage Treatment Plants & Septic Systems

Surface & Ground Water

FDA-approved

little or no removal in human digestive systems

Incomplete removal in wastewater treatment

chemical markers of human waste

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Table 1. Sucralose, acesulfame, and caffeine removal efficiencies reported in the literature for wastewater treatment plants (WWTP), drinking water treatment plants (DWTP) and septic systems.

			Removal (%)		
Source	Site Type	N	Sucralose	Acesulfame	Caffeine
Subedi & Kannan (2014)	WWTP	2	1.6	-54	
Li et al. (2018)	WWTP	5	-3.0 to 30		
Castronovo et al. (2017)	WWTP	13		57-97	
Qi et al. (2015)	WWTP	5	6 to 31		91-100
Schaide					
Ryu et a					
Thomas					
Scheure					
Carden					
Yang et al. (2017)	WWTP	9	< 0 to 50		> 90
Mawhinney et al. (2011)	DWTP	13	0 to 48		
Hoque et al. (2014)	aerated sewage lagoon	1	-330 to -83[b]		
Yang et al. (2016)	septic system	1	0		100
Yang et al. (2017a)	septic system	3	45-85		100
Schaider et al. (2017)	septic system	15			34-100
Robertson et al. (2016)[a]	septic system	5		-4 to 93	

[a]removal efficiencies calculated here using concentrations in tank liquid and in ground water below or downstream from infiltration beds from Table S1.
[b]values indicate range across seasons for one system
N indicates the number of sites where removal efficiencies were reported in the study.

Wastewater Treatment Removal Efficiencies:

- **Sucralose: < 50% removal**
- **Acesulfame: < 100%, variable**
- **Caffeine: near 100% removal in properly functioning septic systems**

In GW and SW:

- Artificial sweeteners indicate where septic inputs are present
- Caffeine detections further suggest inputs from one or more poorly-functioning septic systems

Objectives

1. Test for presence/absence of septic effluent using artificial sweeteners
2. Test for presence/absence of effluent from poorly-functioning septic systems using caffeine
3. Assess reliability of artificial sweeteners and caffeine as septic indicators
4. Document spatial distribution of septic indicators and their relationship to nitrate

Sampling

9/10/2018

- 5 stream sites
- 5 wells
- 1 spring
- Irrigation distribution system
- Septic indicators, NO_3+NO_2-N

Septic Indicator Sampling

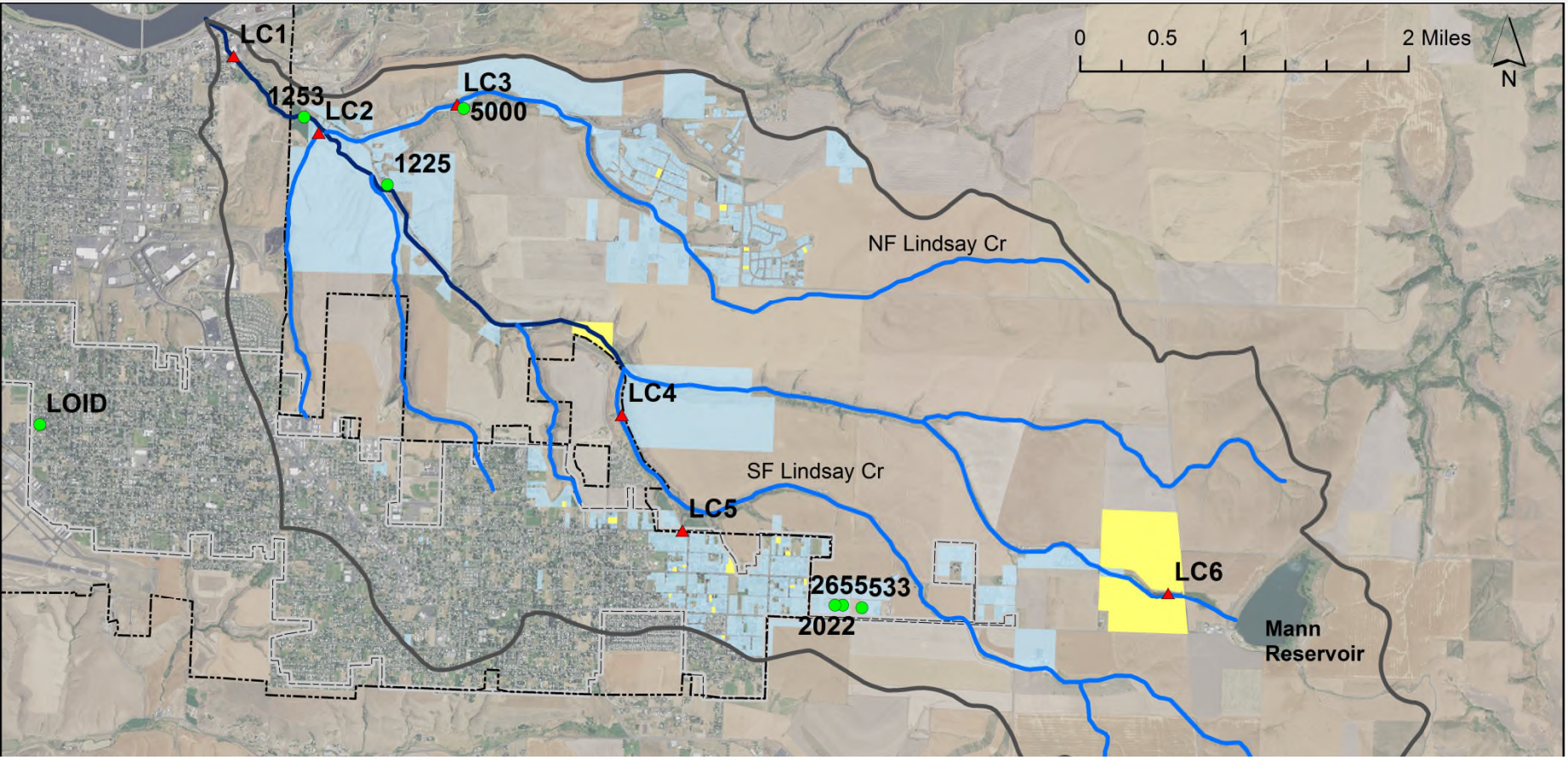
10/30/2018

- Sampled 1 septic system in Lewiston Orchards
- Septic indicators, NO_3+NO_2-N, TKN

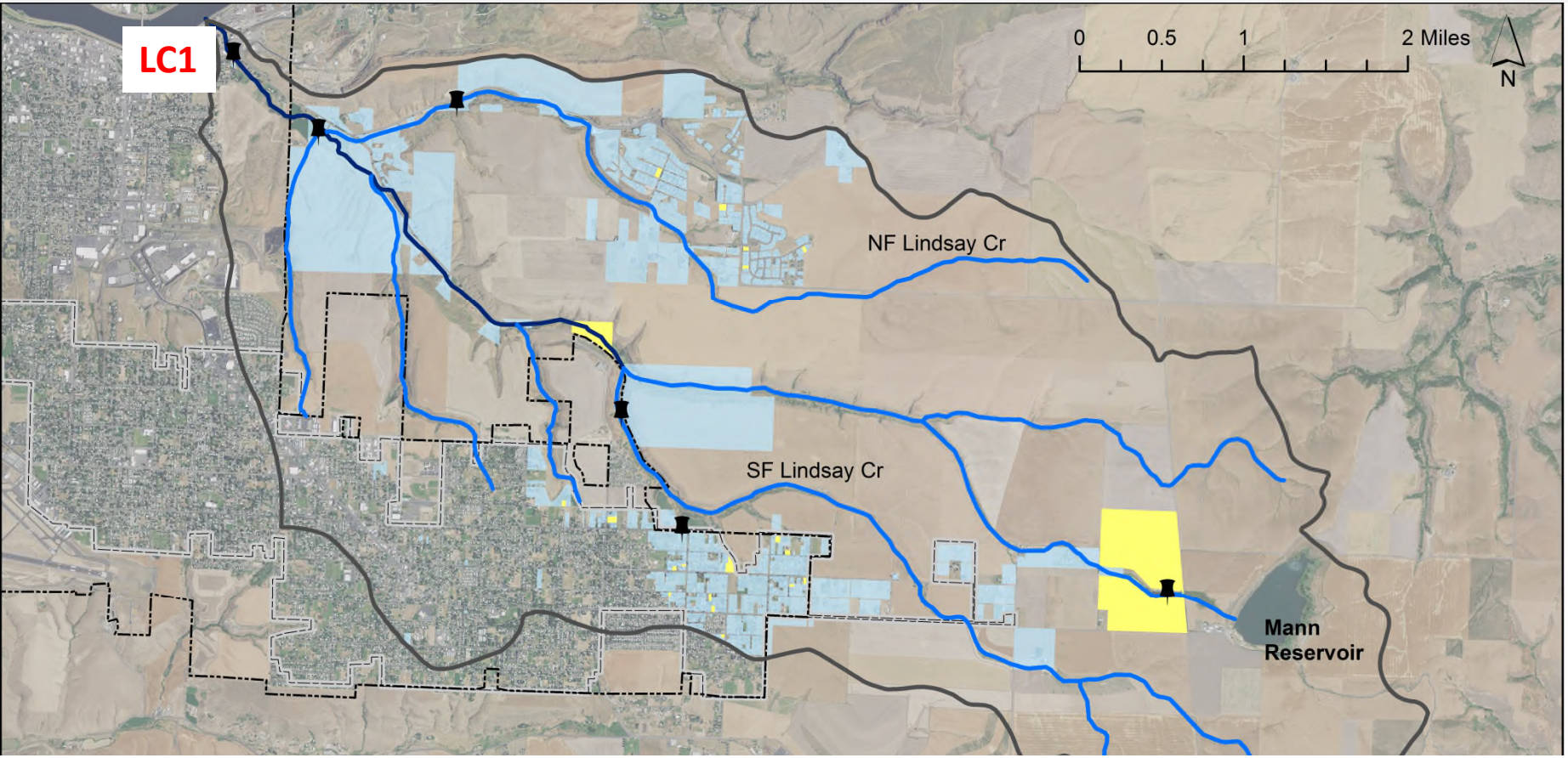
Goal: confirm septic indicator compounds present in typical septic systems

Analytical Methods

- Anatek Labs (Moscow, ID)
- NO_3+NO_2-N
  - EPA 353.2
- Sweeteners & Caffeine
  - EPA 8321A (HPLC coupled to MS/MS)
  - Solid-phase extraction
  - Isotopically-labeled internal standards to address matrix effects
- *E. coli*
  - SM 9223B
  - GW only



Site	Upstream Septics (#, density mi^2)	Depth (ft)	NO_3+NO_2-N (mg N/L)	Caffeine (µg/L)	Sucralose (µg/L)	Acesulfame (µg/L)
Surface Water						
LC1 (mouth)	800, 3.6	--	8.24	ND	ND	0.141
LC2 (Gun Club Creek)	5, 4.3	--	8.92	ND	ND	0.0535
LC3 (NF Lindsay Creek)	271, 69	--	9.8	0.0167	1.32	0.265
LC4 (SF Lindsay Creek)	360, 70	--	10	0.0132	7.56	0.0644
LC5 (Burrell Ave culvert)	--	--	--	--	--	--
LC6 (headwaters)	0	--	1.14	ND	ND	ND
LOID distribution system	0	--	0.185	ND	ND	ND



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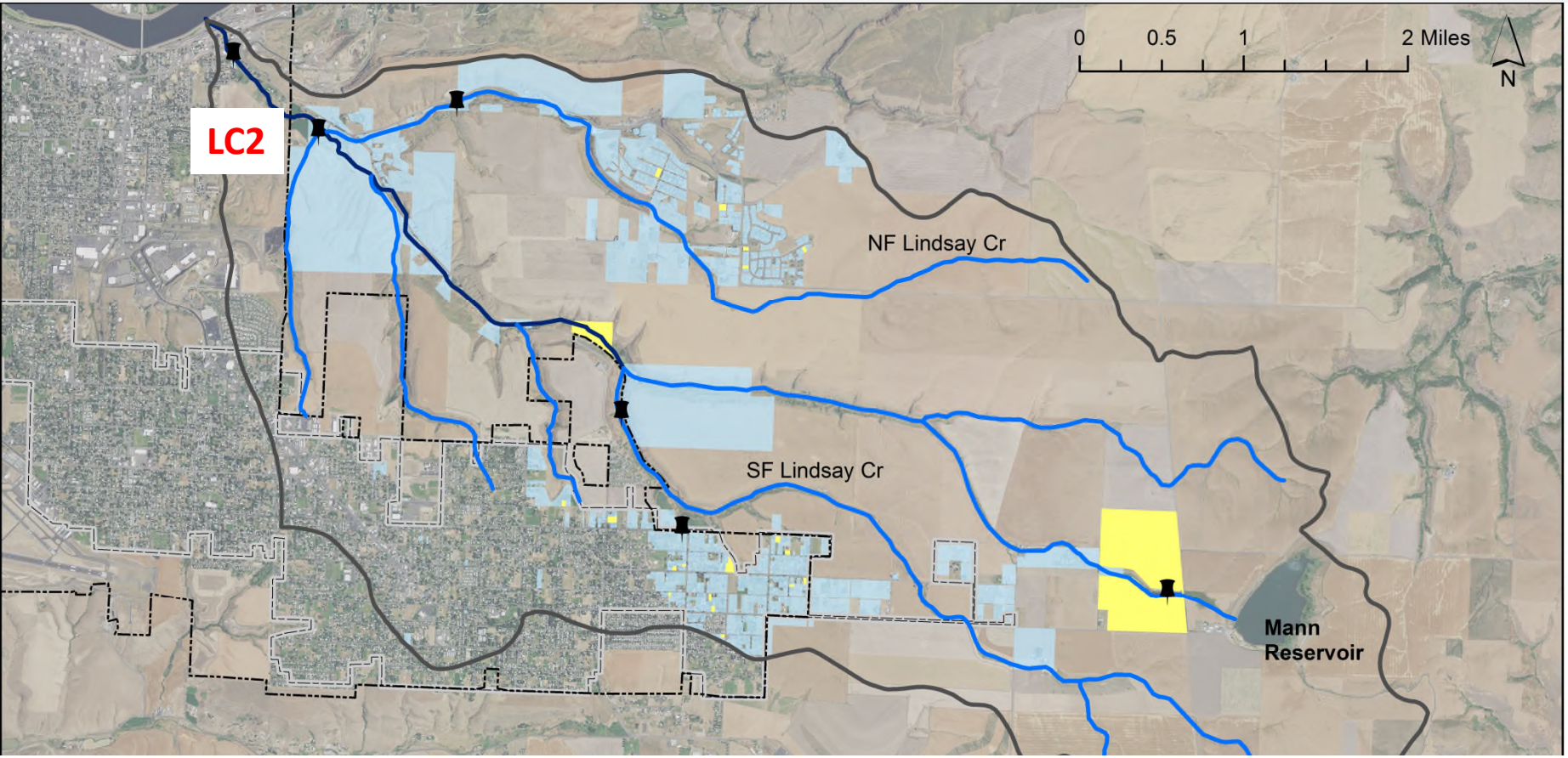

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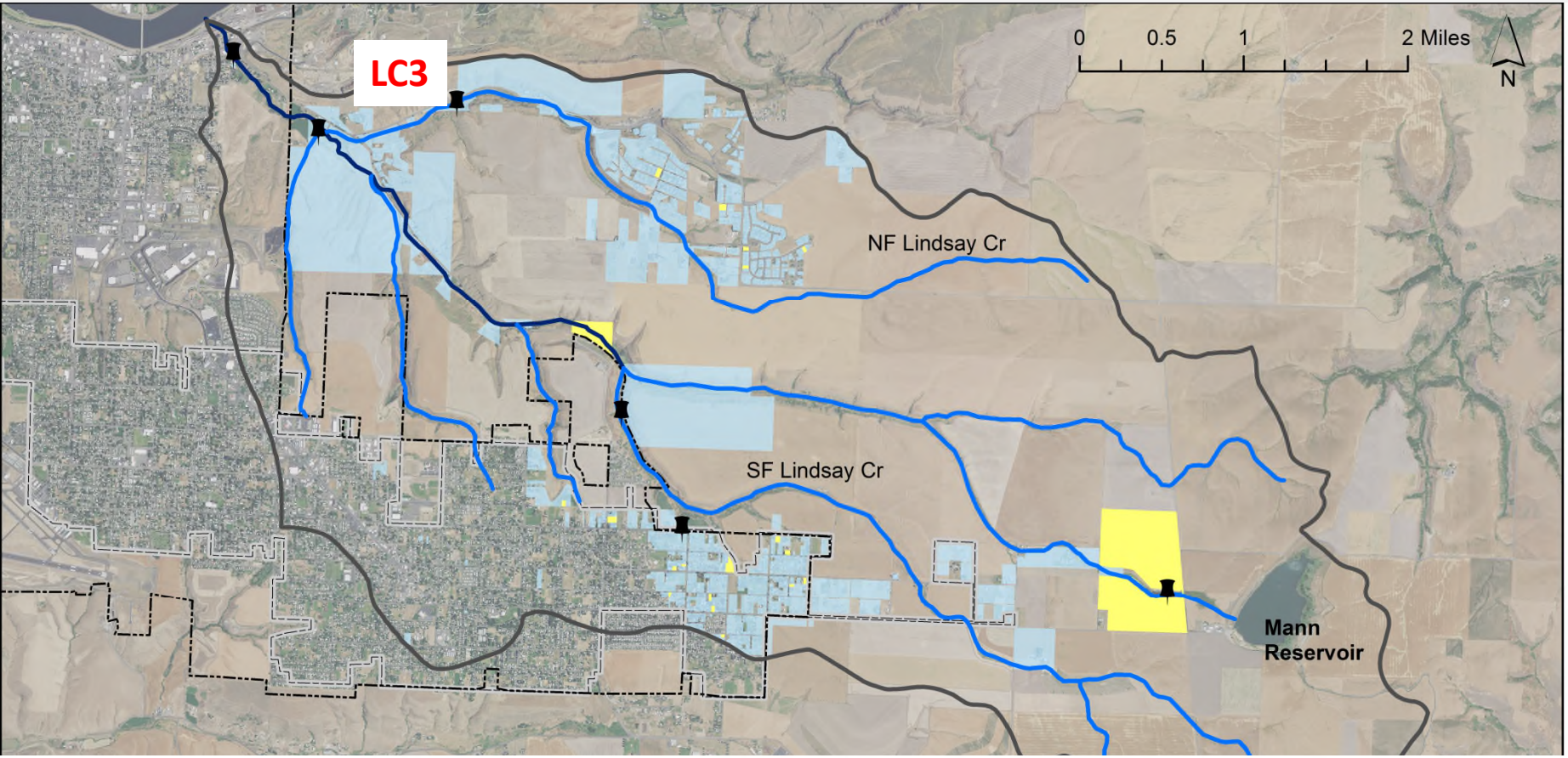

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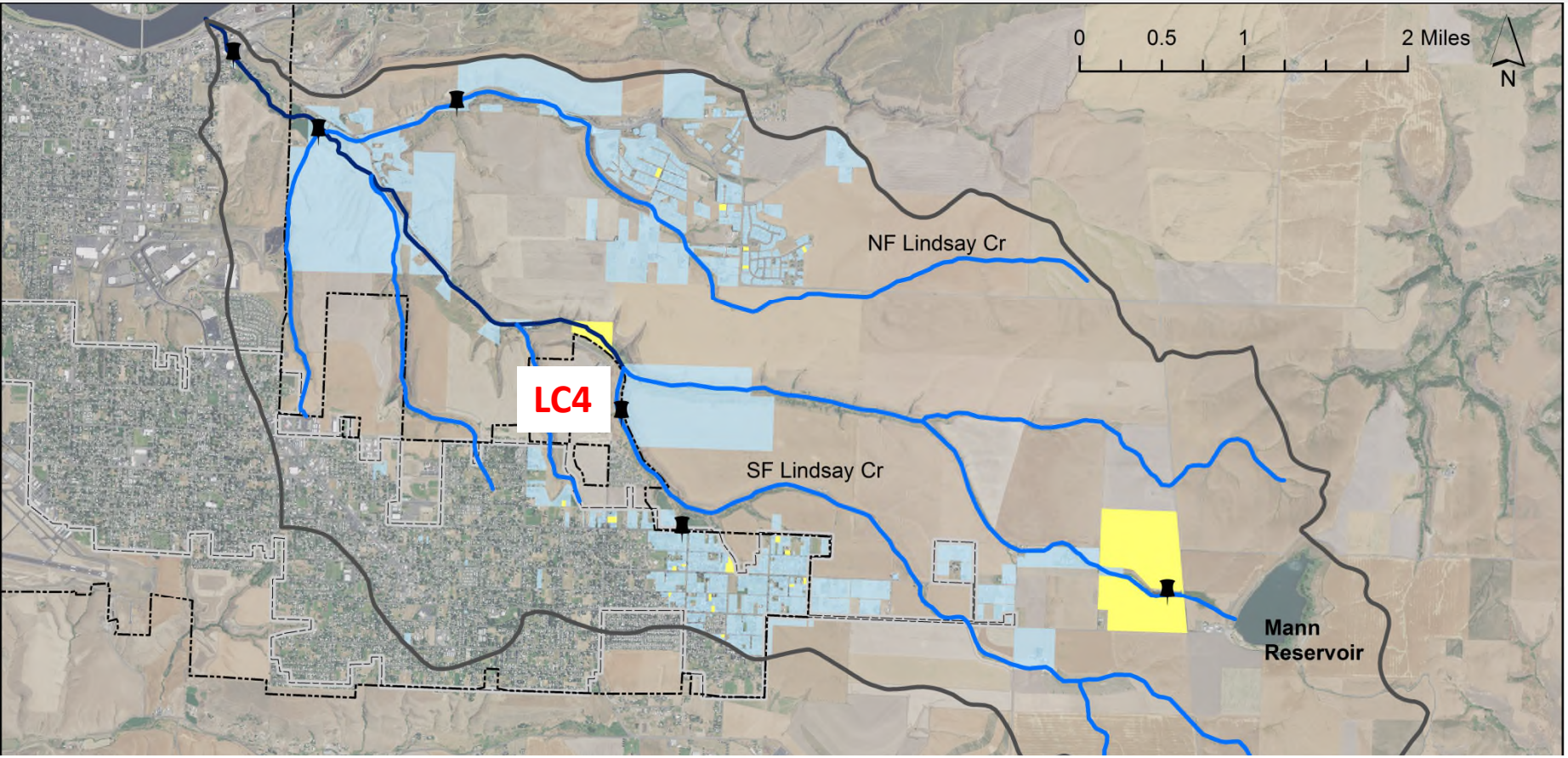

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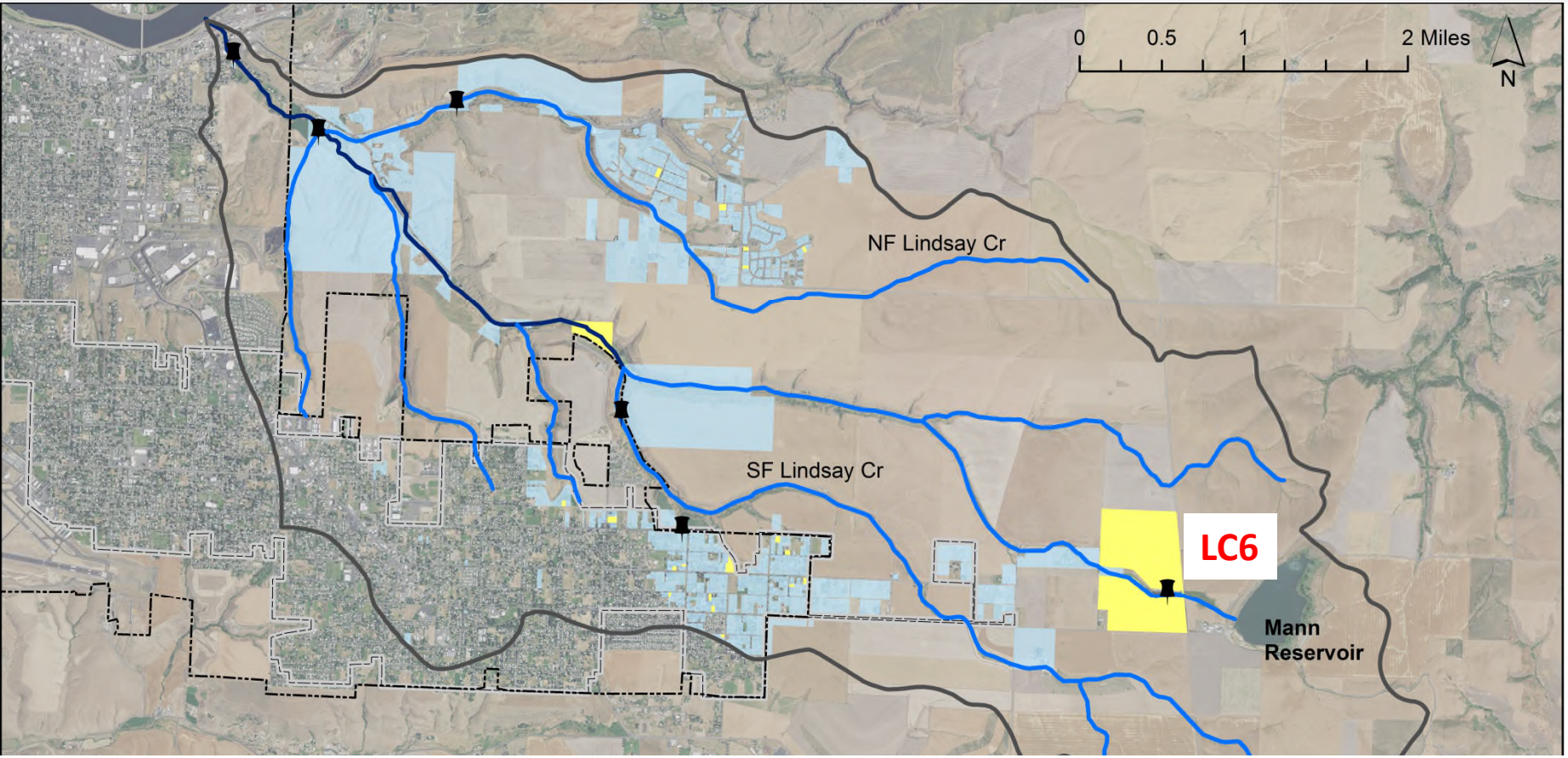

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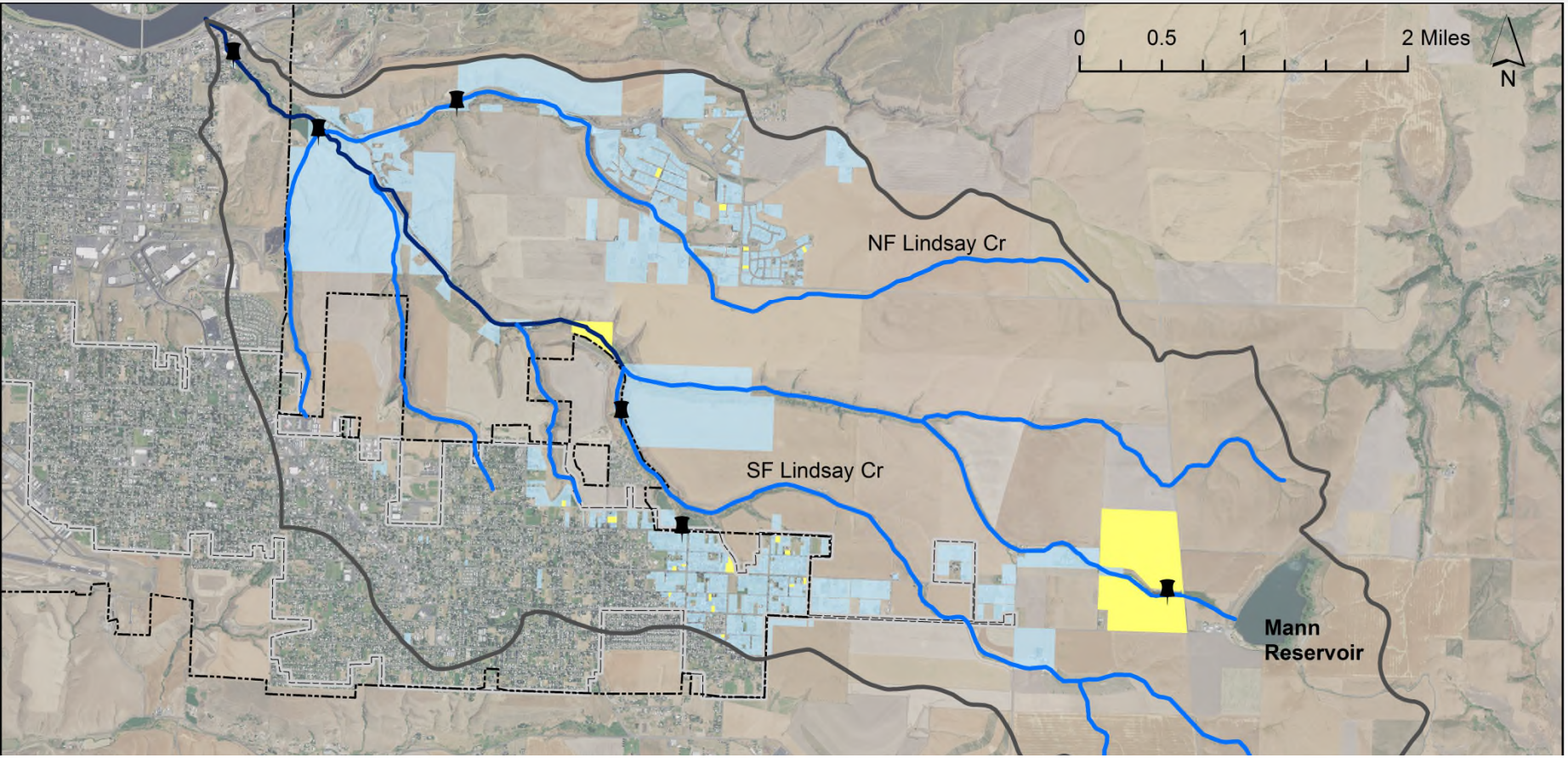

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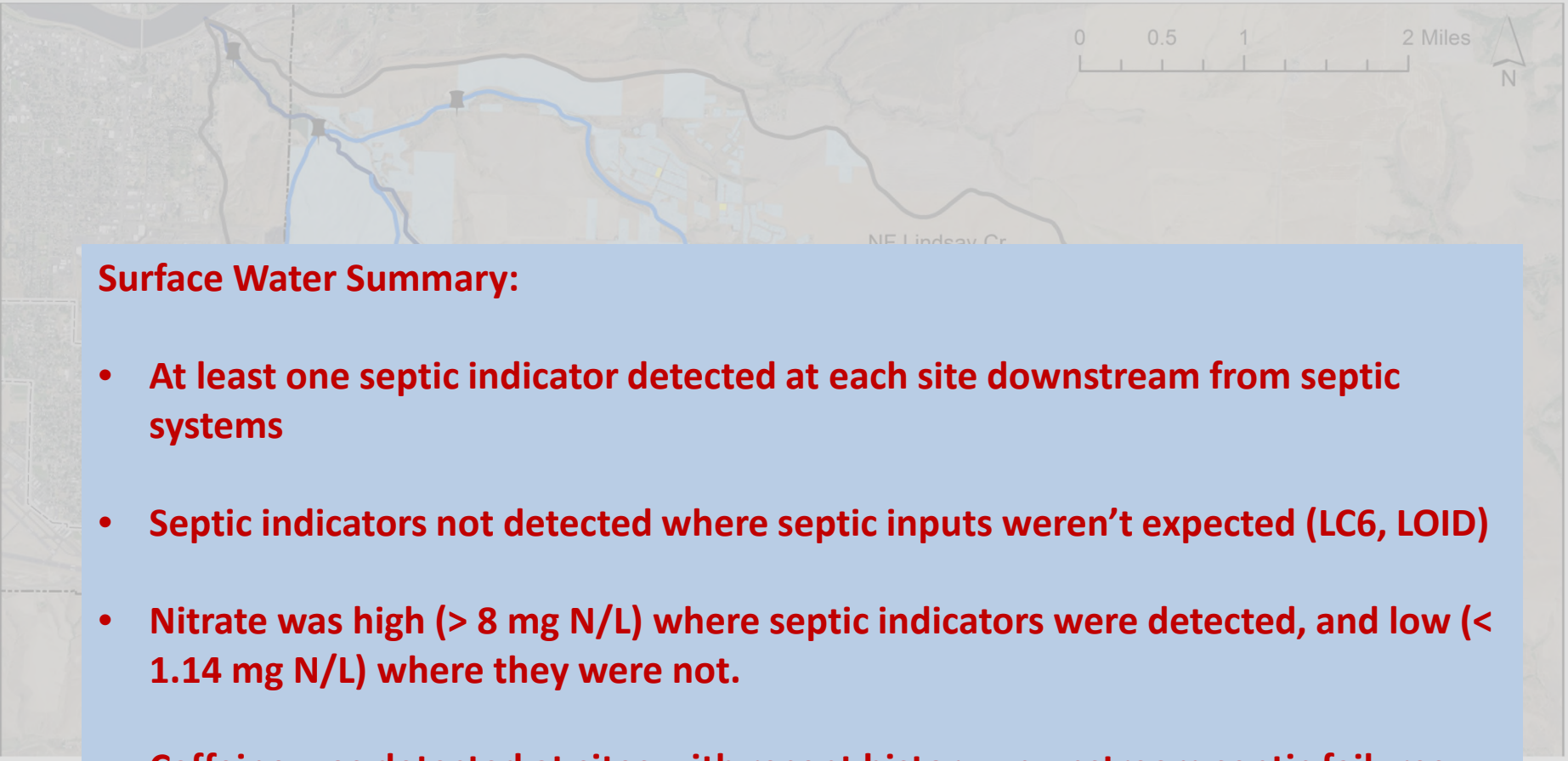

Surface Water Summary:

- At least one septic indicator detected at each site downstream from septic systems
- Septic indicators not detected where septic inputs weren't expected (LC6, LOID)
- Nitrate was high (> 8 mg N/L) where septic indicators were detected, and low (< 1.14 mg N/L) where they were not.
- Caffeine was detected at sites with recent history up upstream septic failures
- Caffeine was not detect at sites without upstream septic repair permits

Sur						
LC1						
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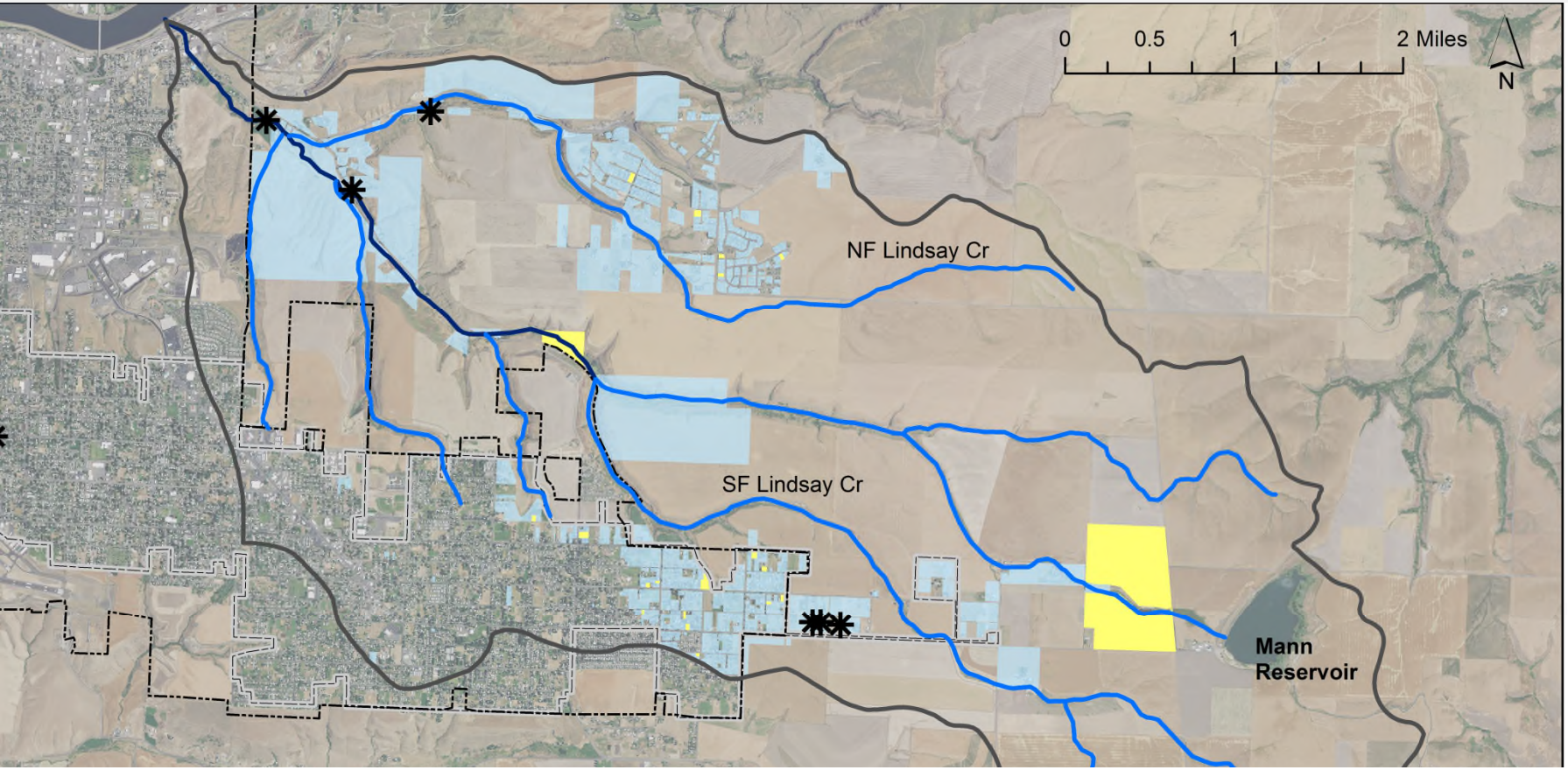
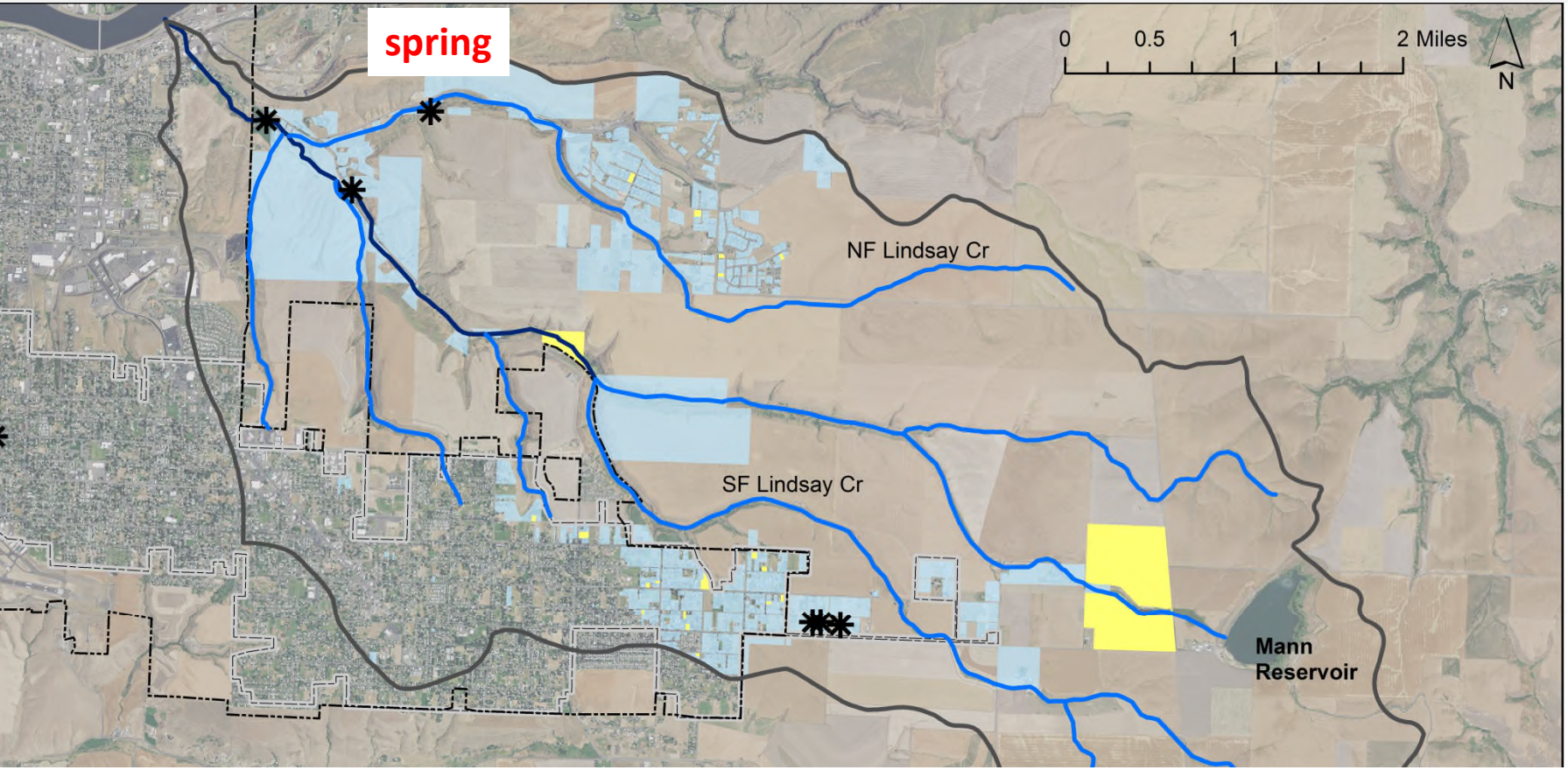


Site	Aquifer	Depth (ft)	NO_3+NO_2-N (mg N/L)	Caffeine (µg/L)	Sucralose (µg/L)	Acesulfame (µg/L)
Ground Water						
5000 (spring)	Saddle Mountains	0	9.26	ND	ND	0.506
1225 (well)	Saddle Mountains	16	7.15	ND	ND	0.404
1253 (well)	Saddle Mountains	56	10.3	0.0189	ND	0.0857
2655 (well)	Saddle Mountains	200	10.2	ND	1.15	1.22
533 (well)	Saddle Mountains	225	9.88	ND	ND	0.202
2022 (well)	Grande Ronde	950	ND	ND	ND	ND
Septic System	--	--	ND*	119	80	51.3



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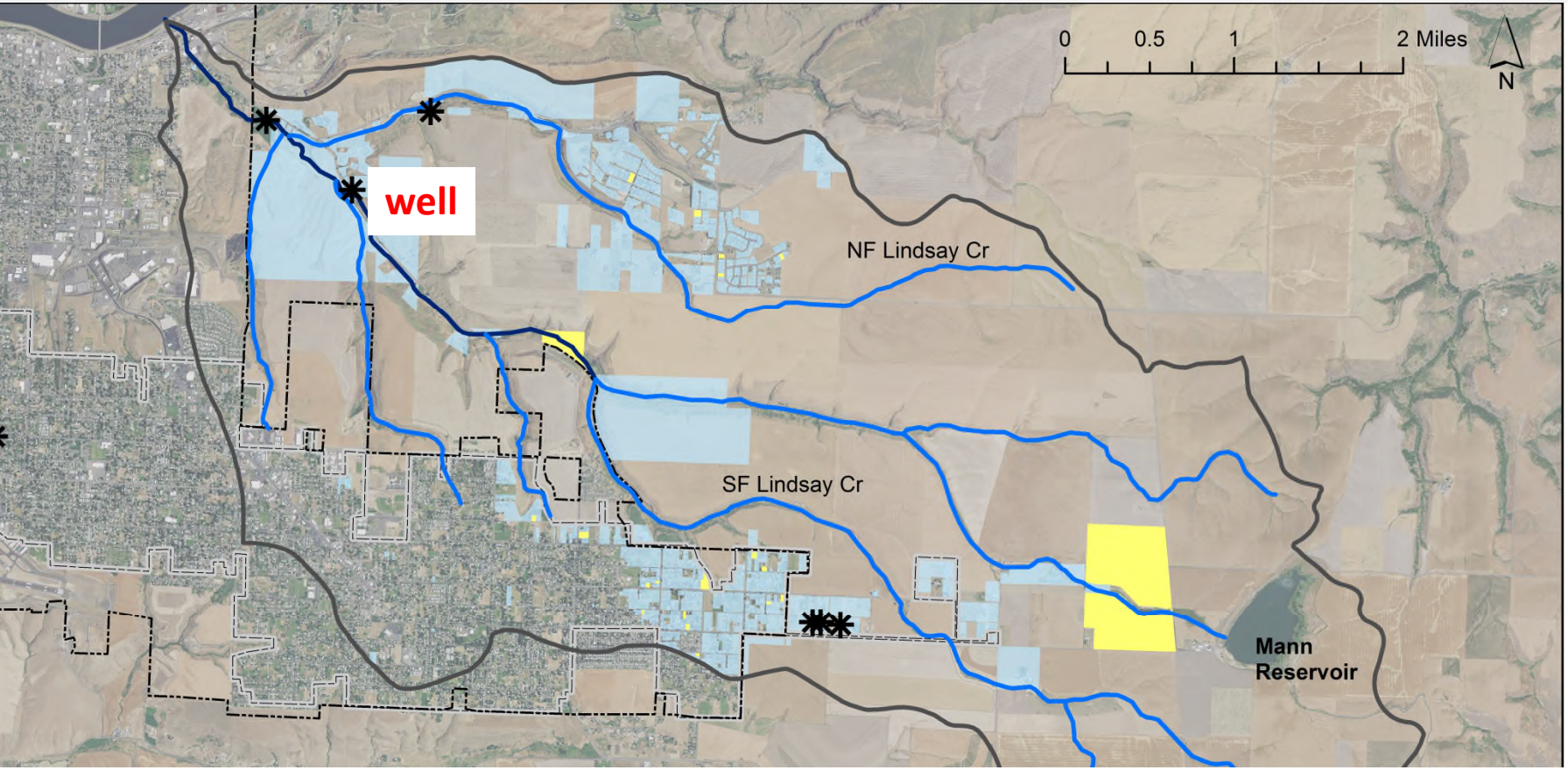

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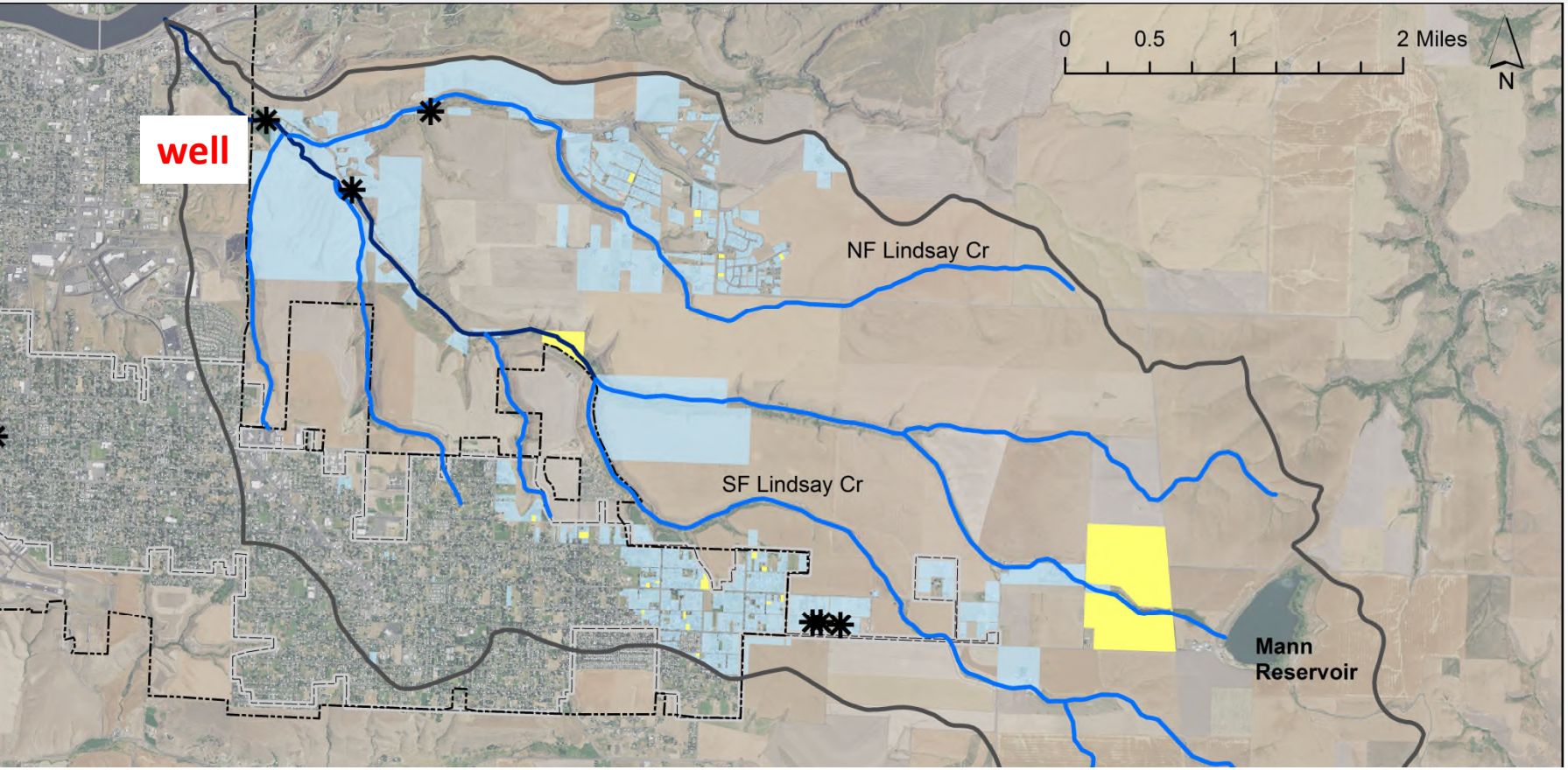

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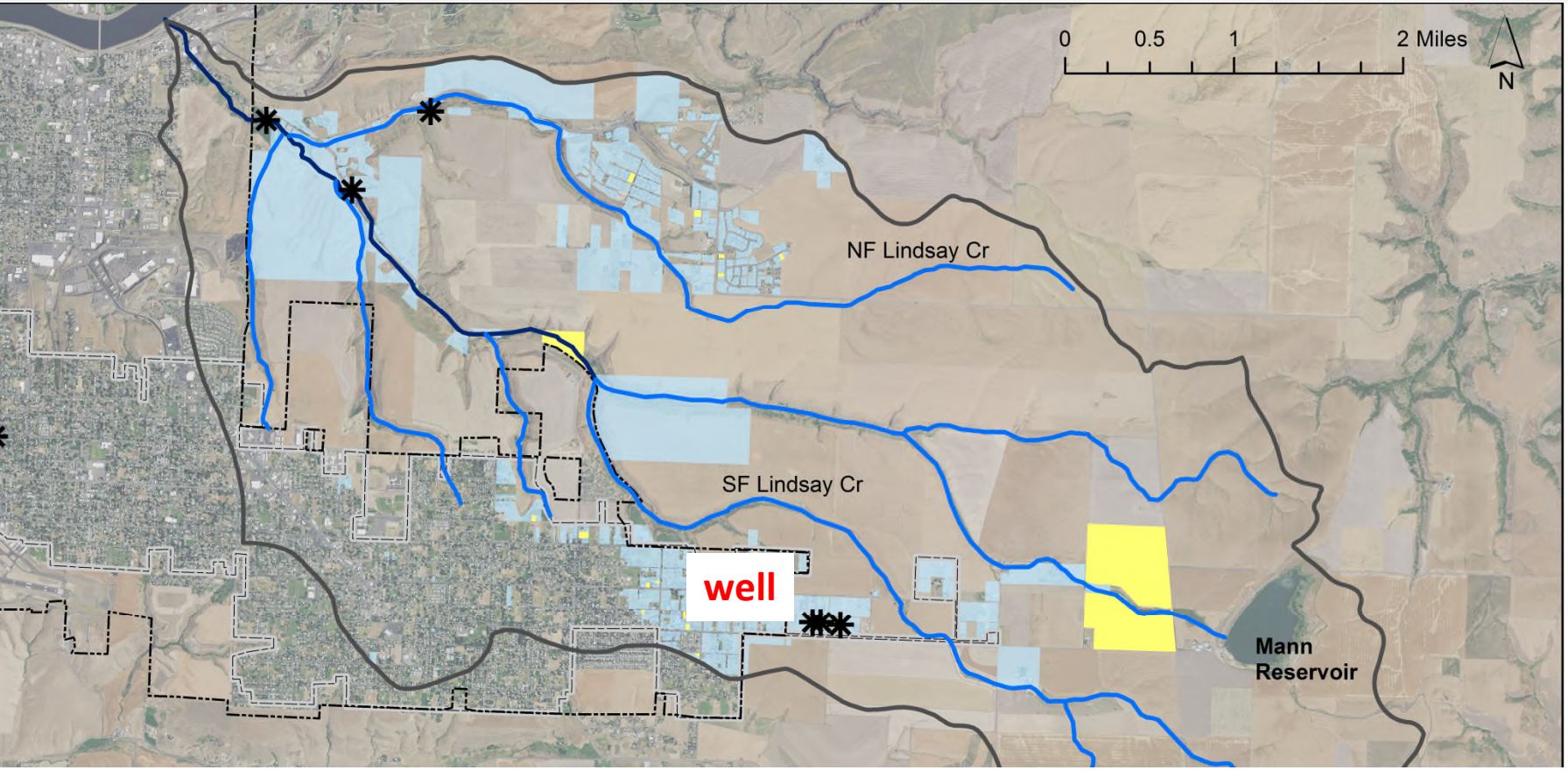

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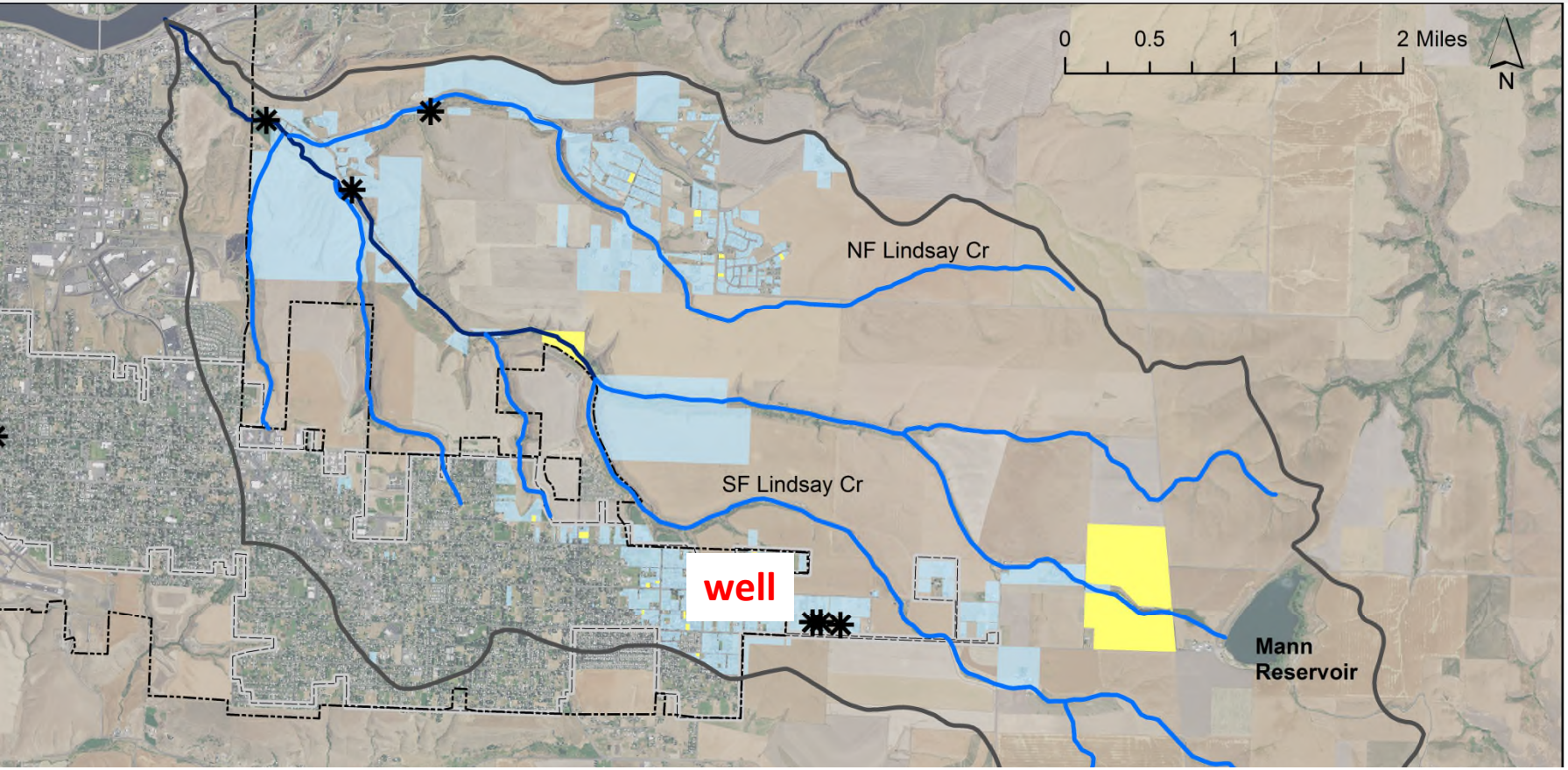

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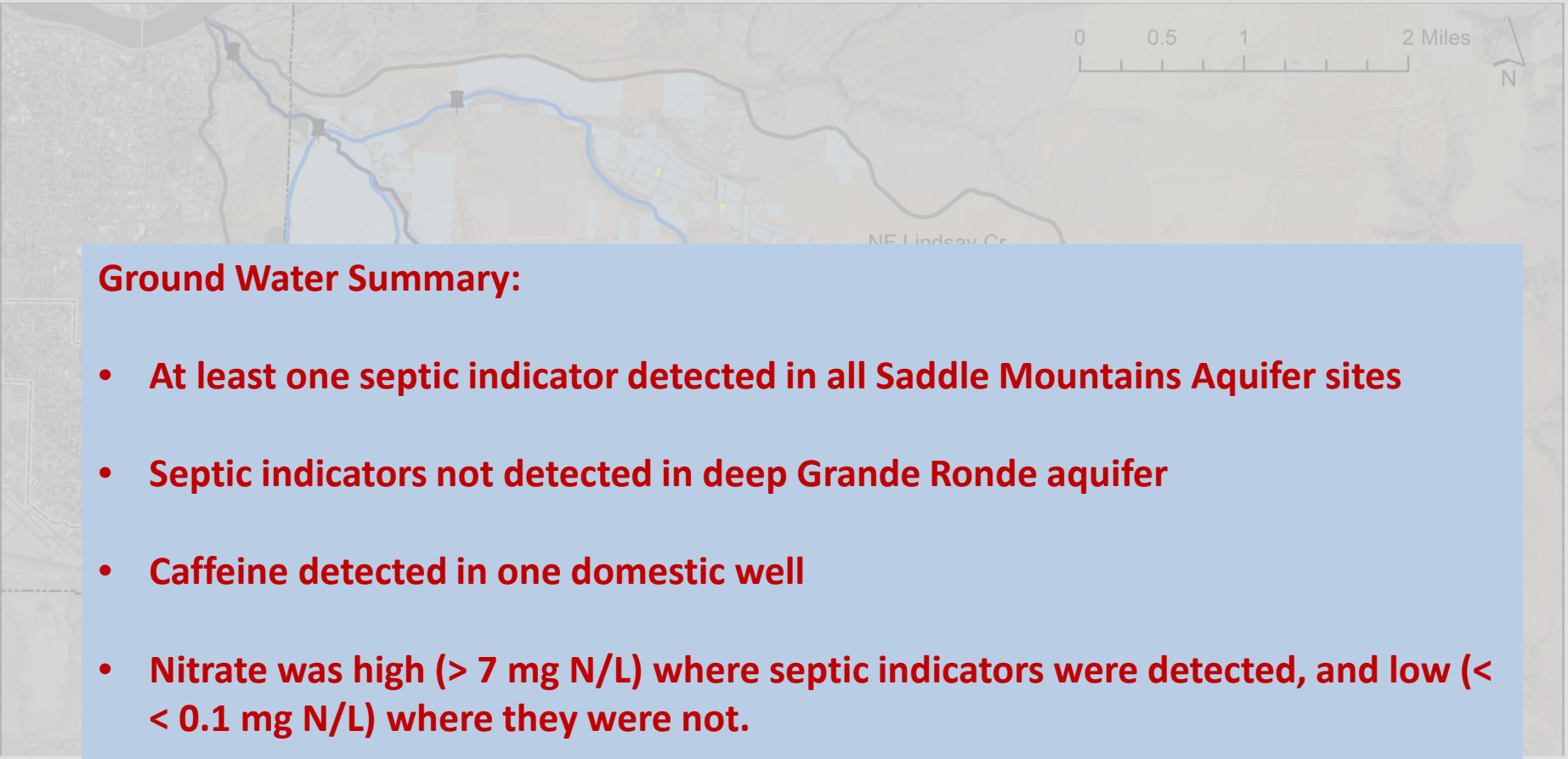

Ground Water Summary:

- **At least one septic indicator detected in all Saddle Mountains Aquifer sites**
- **Septic indicators not detected in deep Grande Ronde aquifer**
- **Caffeine detected in one domestic well**
- **Nitrate was high (> 7 mg N/L) where septic indicators were detected, and low (< < 0.1 mg N/L) where they were not.**

Site	density mi^2)	(ft)	(mg N/L)	(µg/L)	(µg/L)	ame (µg/L)
Surface Water						
LC1 (mouth)	800, 3.6	--	8.24	ND	ND	0.141
LC2 (Gun Club Creek)	5, 4.3	--	8.92	ND	ND	0.0535
LC3 (NF Lindsay Creek)	271, 69	--	9.8	0.0167	1.32	0.265
LC4 (SF Lindsay Creek)	360, 70	--	10	0.0132	7.56	0.0644
LC5 (Burrell Ave culvert)	--	--	--	--	--	--
LC6 (headwaters)	0	--	1.14	ND	ND	ND
LOID distribution system	0	--	0.185	ND	ND	ND

Summary

Objectives

1. Test for presence/absence of septic effluent using artificial sweeteners
2. Test for presence/absence of effluent from poorly-functioning septic systems using caffeine
3. Assess reliability of artificial sweeteners and as septic indicators
4. Document spatial distribution of septic effluent and its relationship to nitrate in GW and SW

Septic Effluent is Present

- in Saddle Mountains Aquifer
- In Lindsay Creek

- sweeteners were detected in GW and SW

Objectives

1. Test for presence/absence of septic effluent using artificial sweeteners
2. Test for presence/absence of effluent from poorly-functioning septic systems using caffeine
3. Assess reliability of artificial sweeteners and as septic indicators
4. Document spatial distribution of septic effluent and its relationship to nitrate in GW and SW

Effluent From Poorly-Functioning Septic Systems is Present

- in Saddle Mountains Aquifer
- In Lindsay Creek

- caffeine detected in septic liquid, 2 stream sites, one shallow well

Objectives

1. Test for presence/absence of septic effluent using artificial sweeteners
2. Test for presence/absence of effluent from poorly-functioning septic systems using caffeine
3. Assess reliability of artificial sweeteners and caffeine as septic indicators
4. Document spatial distribution of septic effluent and its relationship to nitrate in GW and SW

Sweeteners Are Reliable Markers for Septic Effluent

- Sweeteners were detected downstream of septic systems, and not at locations with no suspected septic inputs

Caffeine Is A Reliable Marker for Effluent from Poorly-Functioning Septic Systems

- Caffeine detected downstream of areas with recent history of septic failures
- Caffeine patterns consistent with local public health district records

Objectives

1. Test for presence/absence of septic effluent using artificial sweeteners
2. Test for presence/absence of effluent from poorly-functioning septic systems using caffeine
3. Assess reliability of artificial sweeteners and as septic indicators
4. Document spatial distribution of septic effluent and its relationship to nitrate in GW and SW

Nitrate is High Where Septic Effluent is Present, and Low Where it is Not

- 7.1-10.3 mg N/L where septic indicators detected
- ND-1.14 mg N/L where septic indicators were not detected

Big Picture

- Septic effluent is present in GW and SW downstream of septic systems (not surprising)
- Spatial distribution of septic effluent now documented
- Overlap of septic indicators & nitrate suggests septic effluent is one nitrate source
- Relative (percent) contribution of septic systems to nitrate contamination beyond scope of this study & merits further investigation

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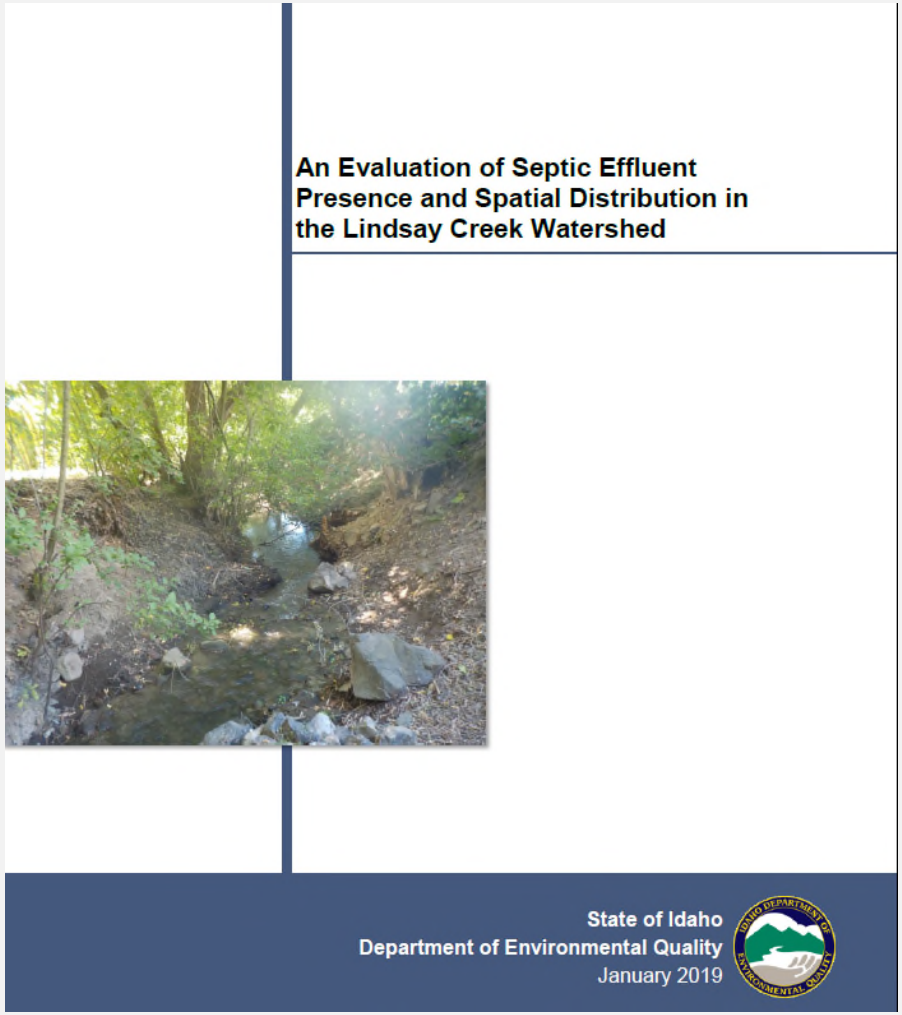
- Bill Reynolds, Nez Perce County Assessors Office
- Daniel Sturgis, IDWR

http://www.deq.idaho.gov/regional-offices-issues/lewiston/



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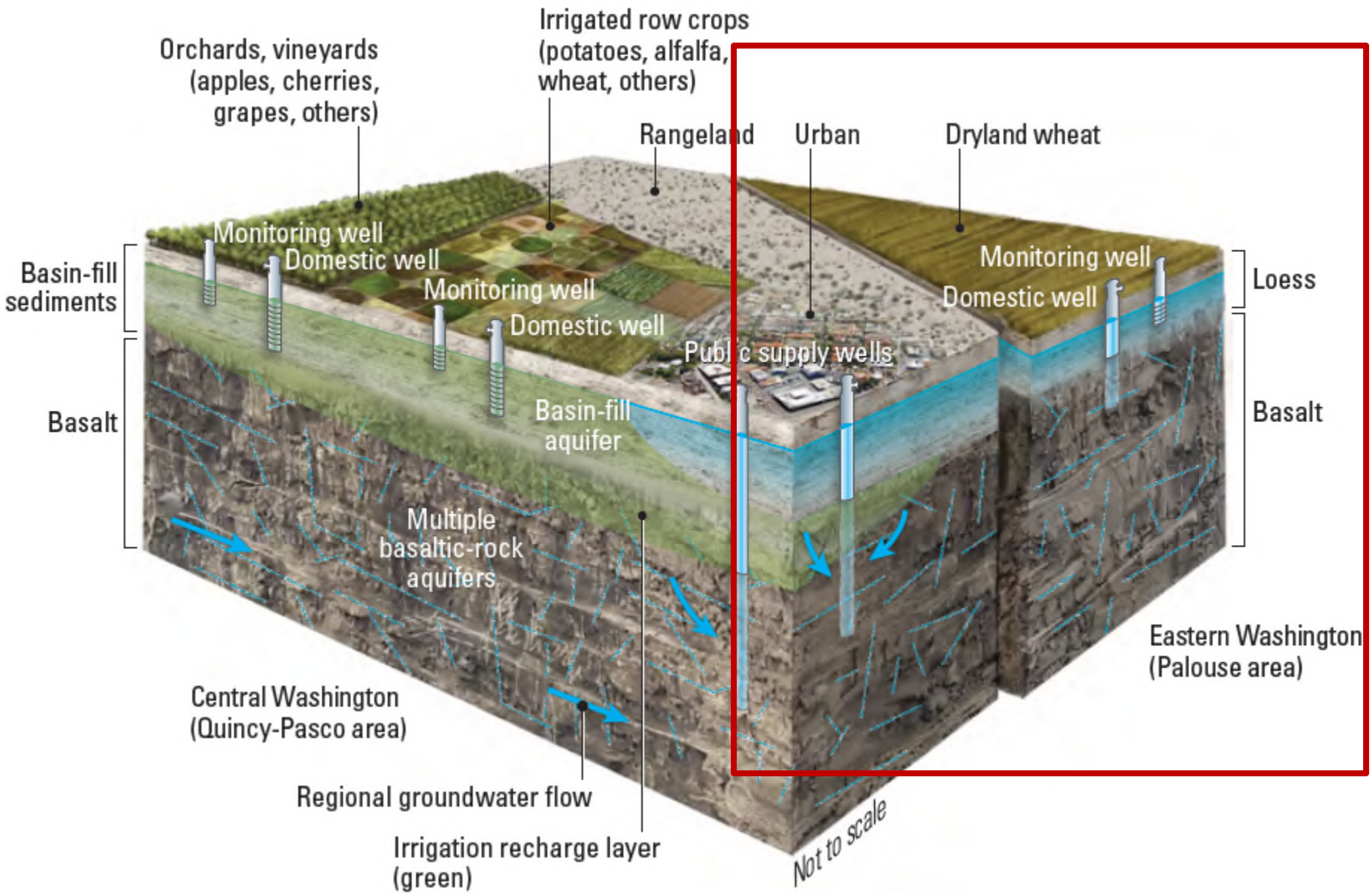
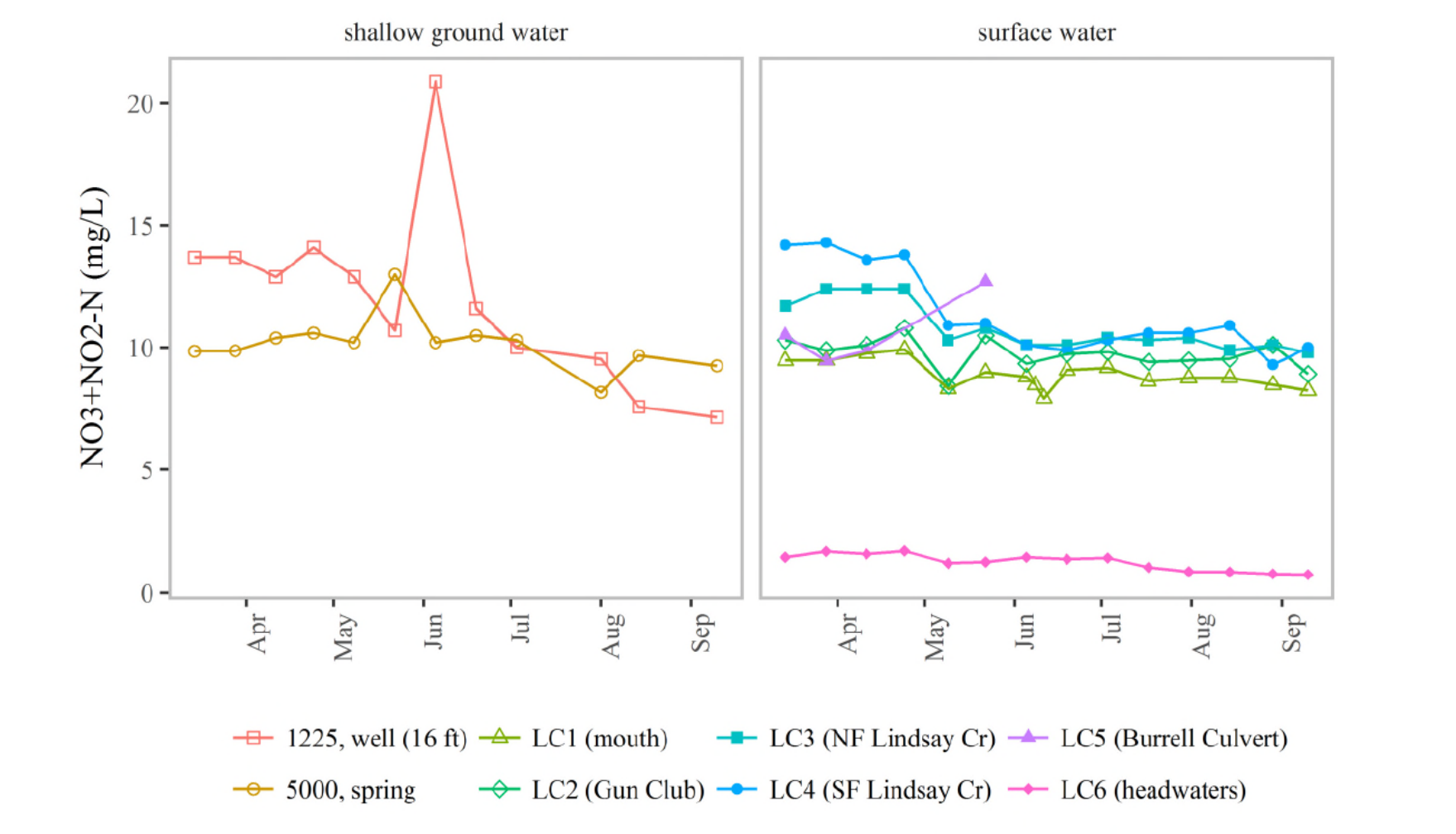


Idaho Department of Environmental Quality

Source: USGS Report 2012-5123

Similar patterns in shallow GW and SW in 2018

GW = A Source of Nitrate to SW



High Nitrate in Lindsay Creek

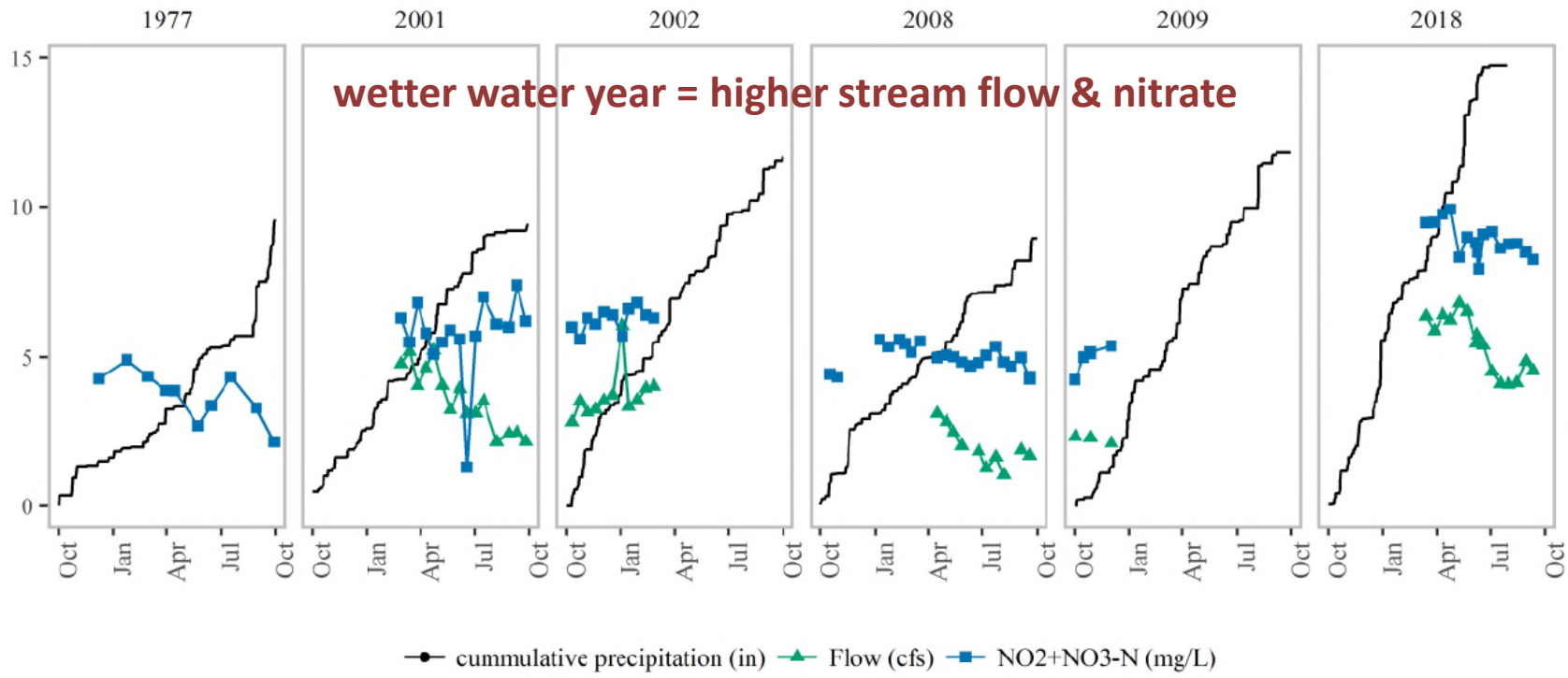


Figure 2. Water year stream flow and nitrate plus nitrite nitrogen concentrations at the Lindsay Creek mouth, and cumulative precipitation measured at the Lewiston Airport.