UTAH LAKE C, N, AND P PROJECT UPDATE

ULWQS Science Panel Meeting

2021-04-20

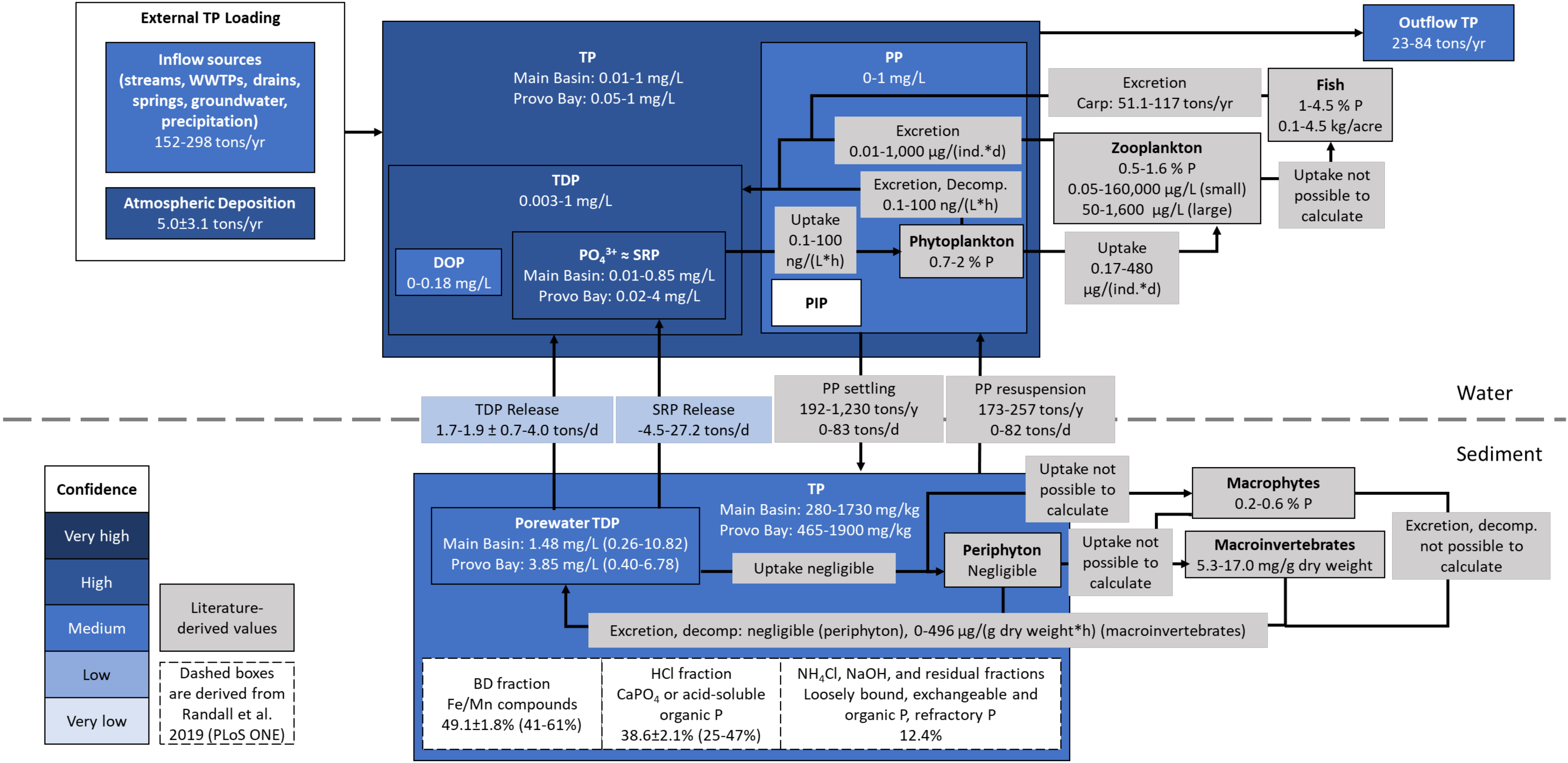
Presented by Kateri Salk, Tetra Tech

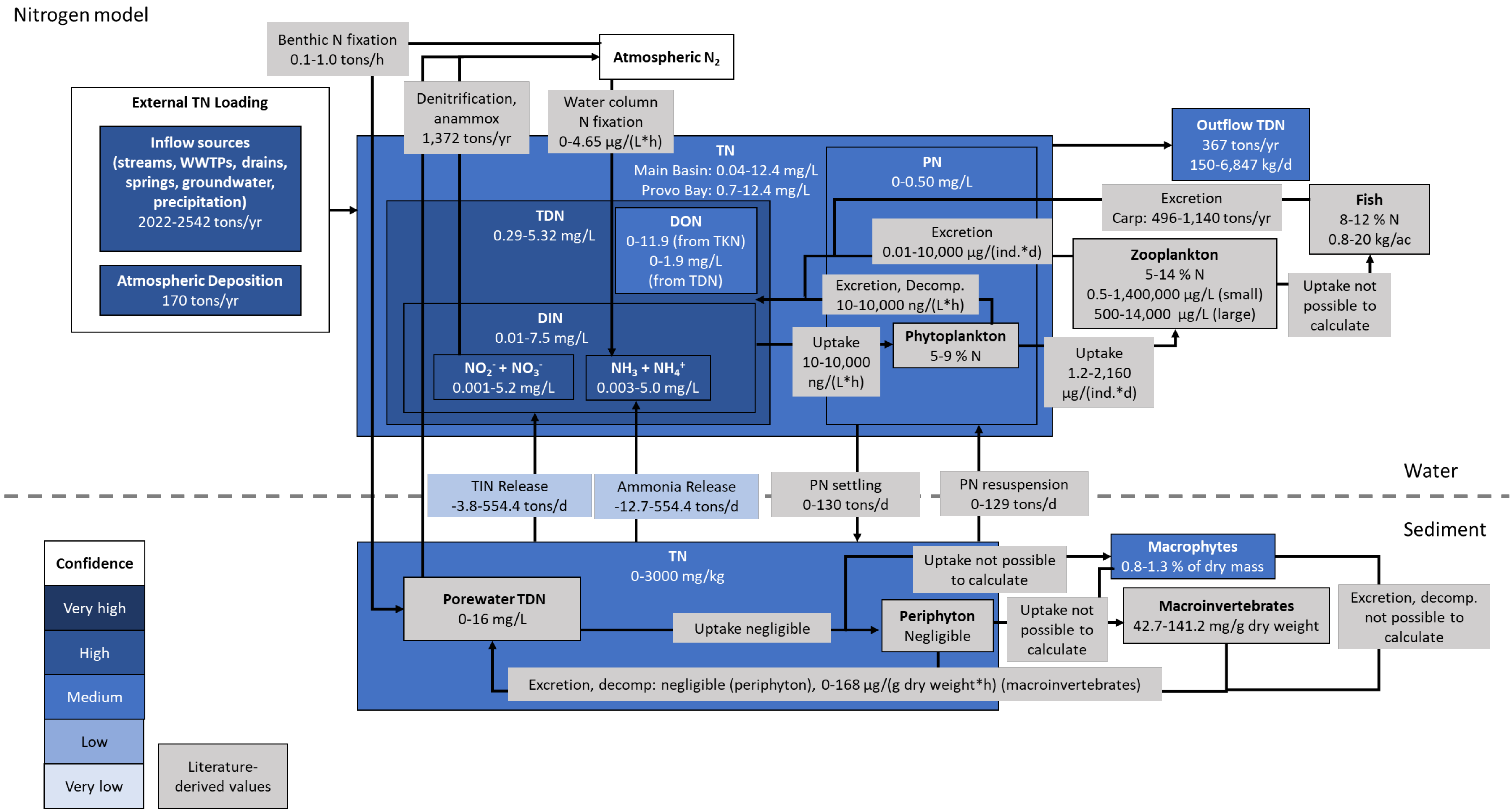
COMPONENTS

1. Quantify conceptual models of N and P cycles in Utah Lake
2. Create external mass balance of C, N, and P for Utah Lake
3. SedFlux modeling of sediment-water fluxes of nutrients and oxygen

CONCEPTUAL MODELS

Phosphorus model




Nitrogen model
Benthic N fixation
0.1-1.0 tons/h
Atmospheric N_2
External TN Loading
Inflow sources (streams, WWTPs, drains, springs, groundwater, precipitation)
2022-2542 tons/yr
Atmospheric Deposition
170 tons/yr
Denitrification, anammox
1,372 tons/yr
Water column N fixation
0-4.65 µg/(L*h)
TN
Main Basin: 0.04-12.4 mg/L
Provo Bay: 0.7-12.4 mg/L
PN
0-0.50 mg/L
Outflow TDN
367 tons/yr
150-6,847 kg/d
Excretion
Carp: 496-1,140 tons/yr
Fish
8-12 % N
0.8-20 kg/ac
TDN
0.29-5.32 mg/L
DON
0-11.9 (from TKN)
0-1.9 mg/L
(from TDN)
Excretion
0.01-10,000 µg/(ind.*d)
Zooplankton
5-14 % N
0.5-1,400,000 µg/L (small)
500-14,000 µg/L (large)
Excretion, Decomp.
10-10,000 ng/(L*h)
Uptake not possible to calculate
DIN
0.01-7.5 mg/L
Uptake
10-10,000 ng/(L*h)
Phytoplankton
5-9 % N
$NO_2^- + NO_3^-$
0.001-5.2 mg/L
$NH_3 + NH_4^+$
0.003-5.0 mg/L
Uptake
1.2-2,160 µg/(ind.*d)
TIN Release
-3.8-554.4 tons/d
Ammonia Release
-12.7-554.4 tons/d
PN settling
0-130 tons/d
PN resuspension
0-129 tons/d
Water
Sediment
TN
0-3000 mg/kg
Uptake not possible to calculate
Macrophytes
0.8-1.3 % of dry mass
Confidence
Very high
High
Medium
Low
Very low
Porewater TDN
0-16 mg/L
Uptake negligible
Periphyton
Negligible
Uptake not possible to calculate
Macroinvertebrates
42.7-141.2 mg/g dry weight
Excretion, decomp. not possible to calculate
Excretion, decomp: negligible (periphyton), 0-168 µg/(g dry weight*h) (macroinvertebrates)
Literature-derived values

QUESTIONS/DISCUSSION

Questions or comments on the conceptual models?

EXTERNAL MASS BALANCE

EXTERNAL MASS BALANCE: POOLED MONTHLY DATA 2015-2020

Inputs

- Tributary loads: monitored watersheds
- Tributary loads: unmonitored watersheds
- Groundwater loads
- Atmospheric loads → *values from Brahney 2019* and *ULWQS SP AD Loading Recommendation - Approved – Final* (subject to updates as new data come in)
- Precipitation (for water balance) → *values from EFDC/WASP output*

Outputs

- Jordan River
- Evaporation (for water balance) → *values from EFDC/WASP output*

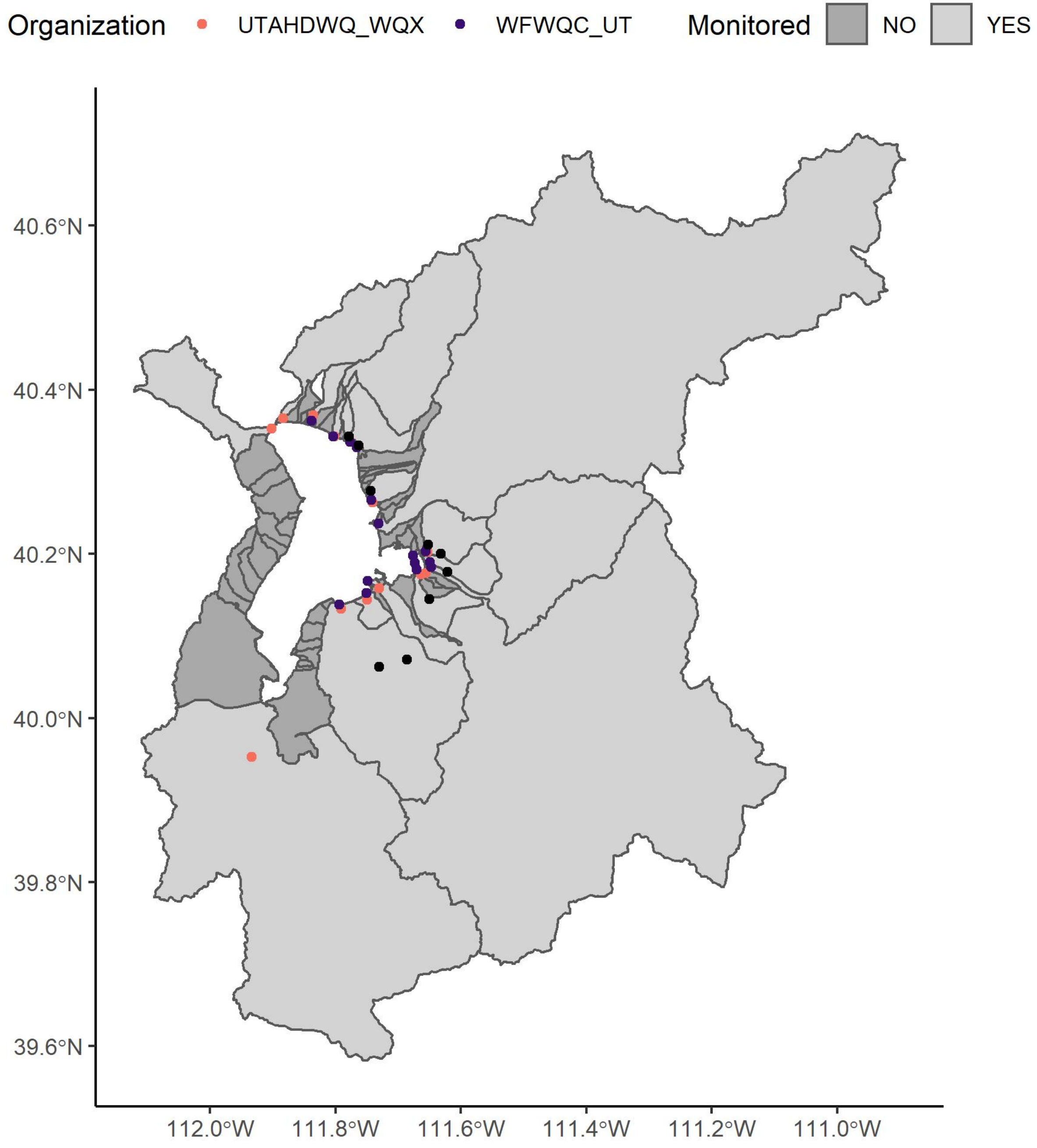
EXTERNAL MASS BALANCE: DECISION POINTS

- Focus today: tributary loads in monitored watersheds
- 2 Decision points:
  1. Comparing DWQ and WFWQC data → use one or both entities?
     - Discussed with SP members 4/16
     - Preliminary decision presented today
  2. For watersheds with WWTP, how to address DMR loads vs. tributary data?
     - Does nutrient attenuation occur moving downstream of WWTP? If so, which watershed(s)?
     - Addressing changing lake level – how to deal with sites that are inundated sometimes?
     - *To be discussed at future meeting, NOT a topic to discuss today*

WATERSHEDS

- UDWQ sites: orange
- WFWQC sites: purple
- Facility sites: black

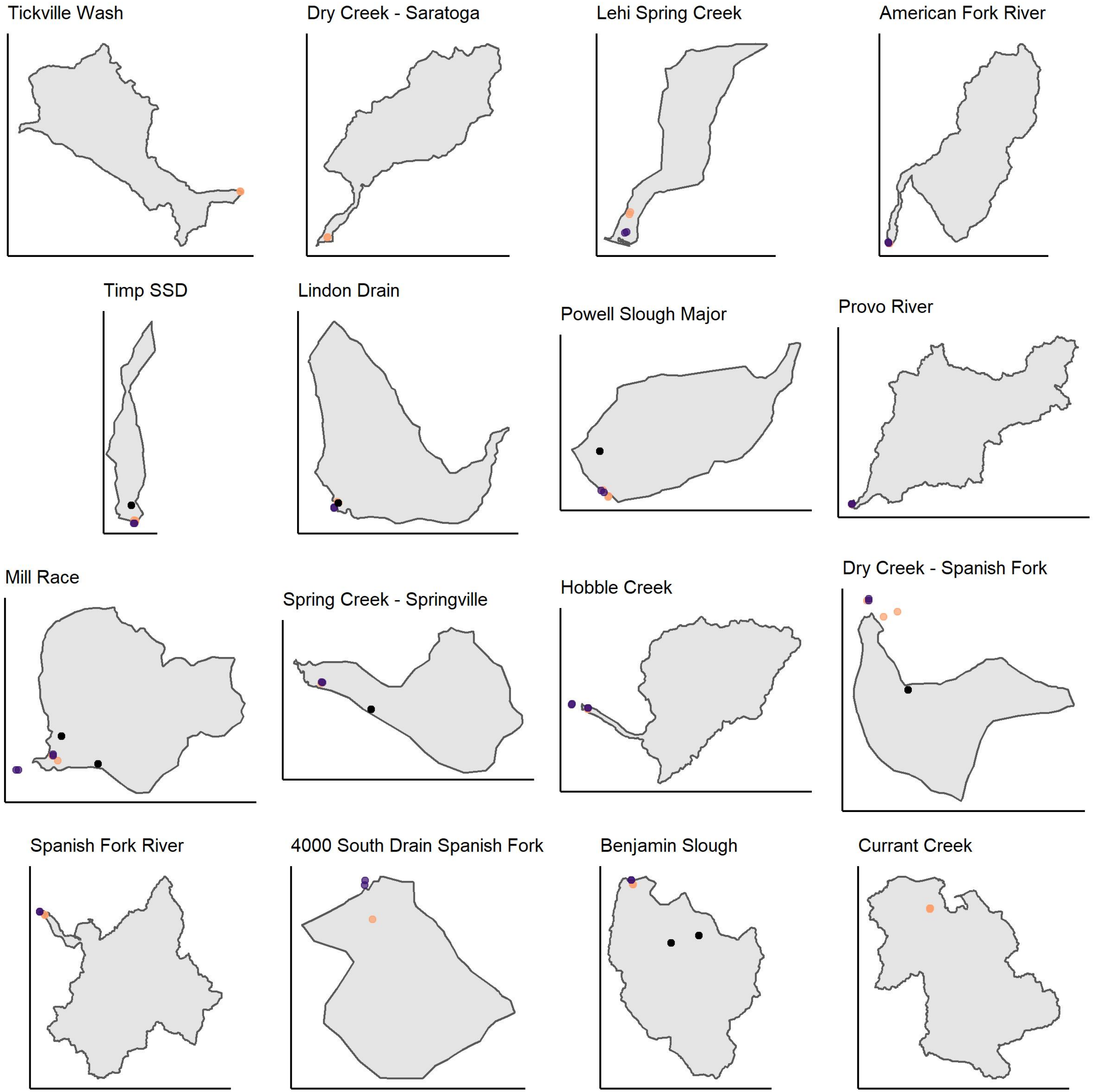
Majority of watershed is monitored → infer unmonitored watersheds from similar monitored watersheds and/or model for ephemeral flow



WATERSHEDS (NOT TO SCALE)

- UDWQ sites: orange
- WFWQC sites: purple
- Facility sites: black

- WFWQC sites are downstream or at the same location as UDWQ sites
- Some sites are below the compromise elevation



WATERSHEDS

Watersheds w/o WWTP, monitored by only UDWQ	Watersheds w/o WWTP, monitored by both UDWQ and WFWQC	Watersheds with WWTP
Tickville Wash	Lehi Spring Creek	Timp SSD (*Timpanogos*)
Dry Creek – Saratoga	American Fork River	Powell Slough Major (*Orem*)
Currant Creek	Lindon Drain	Mill Race (*Provo*)
	Provo River	Spring Creek – Springville (*Springville*)
	Hobble Creek	Dry Creek – Spanish Fork (*Spanish Fork*)
	Spanish Fork River	Benjamin Slough (*Payson, Salem*)
	4000 South Drain Spanish Fork	

↓	↓	↓
Use values directly	Compare entities, use values from one or both	Compare entities + address potential for attenuation of WWTP loading

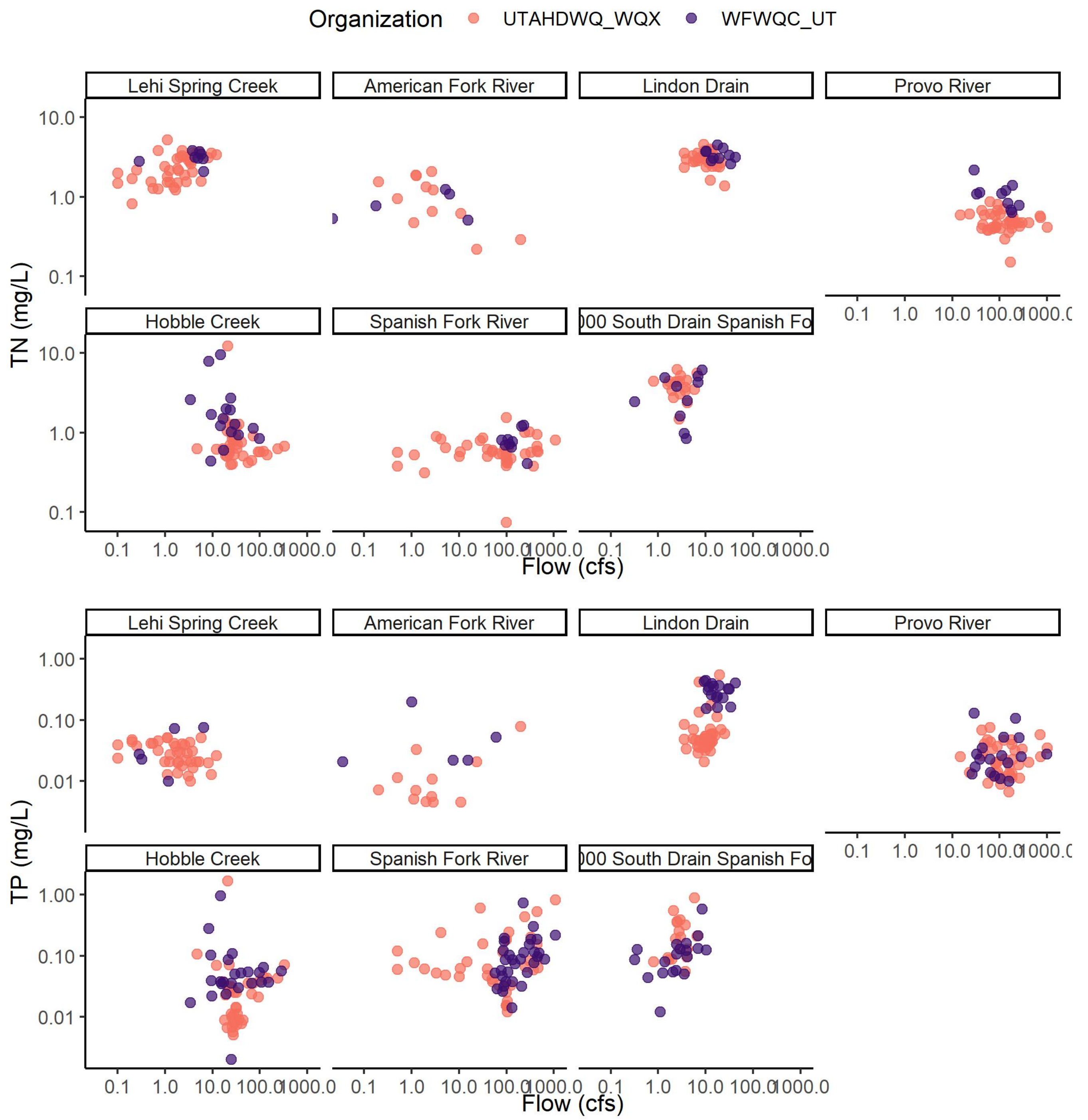
Constituent	Method and Reporting Limit UDWQ	Method and Reporting Limit WFWQC
TP	EPA-NERL: 365.1: (4823) Phosphorus (all forms) by Semi-Automated Colorimetry 0.02	Hach Co.: 8048: Orthophosphate by Colorimetry 0.021
TDP	EPA-NERL: 365.1: (4823) Phosphorus (all forms) by Semi-Automated Colorimetry 0.02	Hach Co.: 8048: Orthophosphate by Colorimetry 0.021
TN	APHA 4500-N Persulfate Method for Total Nitrogen 0.2	Hach Co.: 10242: (TNTplus 880) Simplified Spectrophotometric Measurement of TKN in Water and Wastewater 0.7
TDN	APHA 4500-N Persulfate Method for Total Nitrogen 0.2	
TOC	APHA 5310 B Total Organic Carbon by Combustion-Infrared Method 0.5	
DOC	APHA 5310 B Total Organic Carbon by Combustion-Infrared Method 0.5	

C-Q RELATIONSHIPS WATERSHEDS W/O WWTP

- Watersheds w/ similar distributions
  - Hobble Creek
  - 4000 South Drain Spanish Fork
  - Provo River (Q, TP)

- Watersheds w/ truncated distribution for WFWQC
  - Lindon Drain
  - Spanish Fork River

- Watersheds w/ few WFWQC samples
  - Lehi Spring Creek
  - American Fork River
  - Provo River (TN)
  - Spanish Fork River (TN)

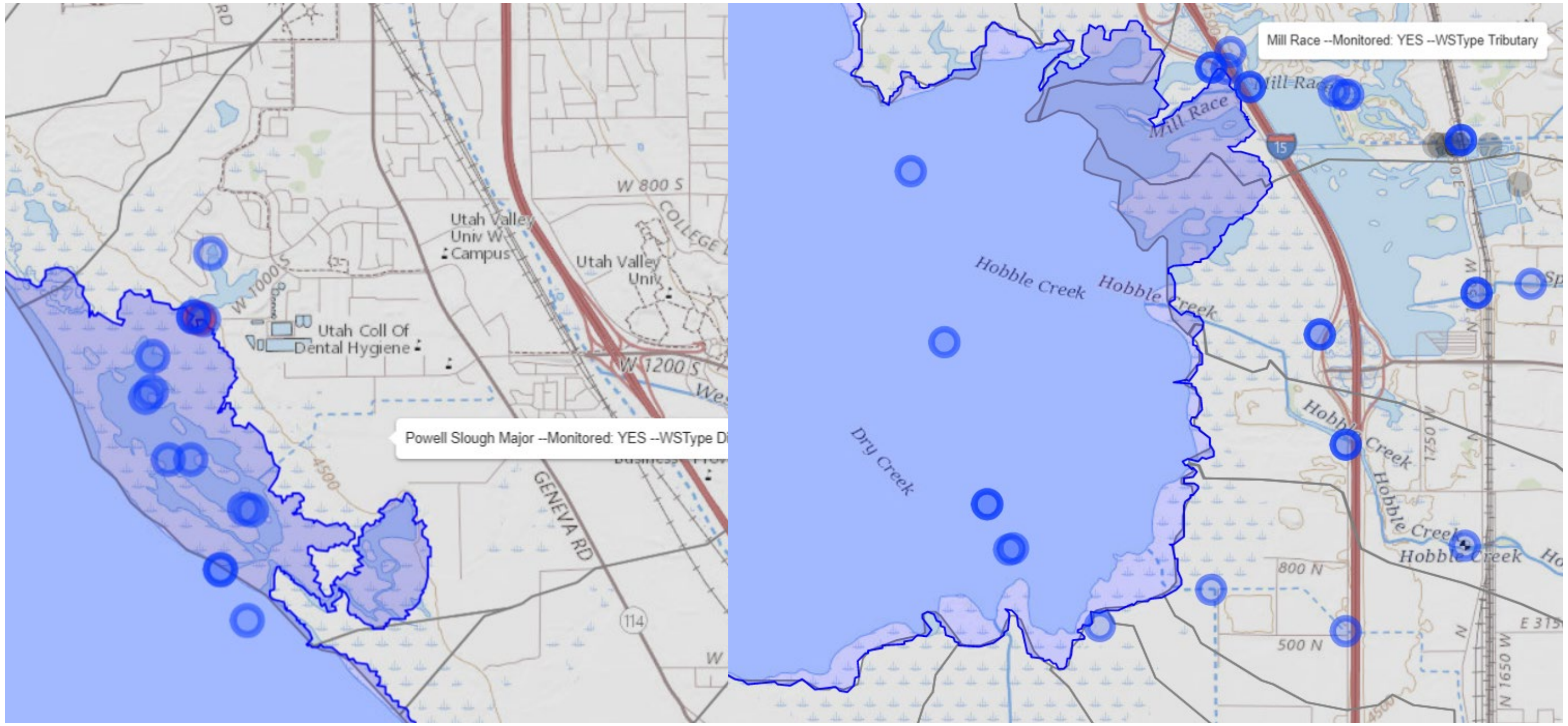


WATERSHEDS W/ WWTP

Higher concentrations of nutrients → detection limit likely not an issue

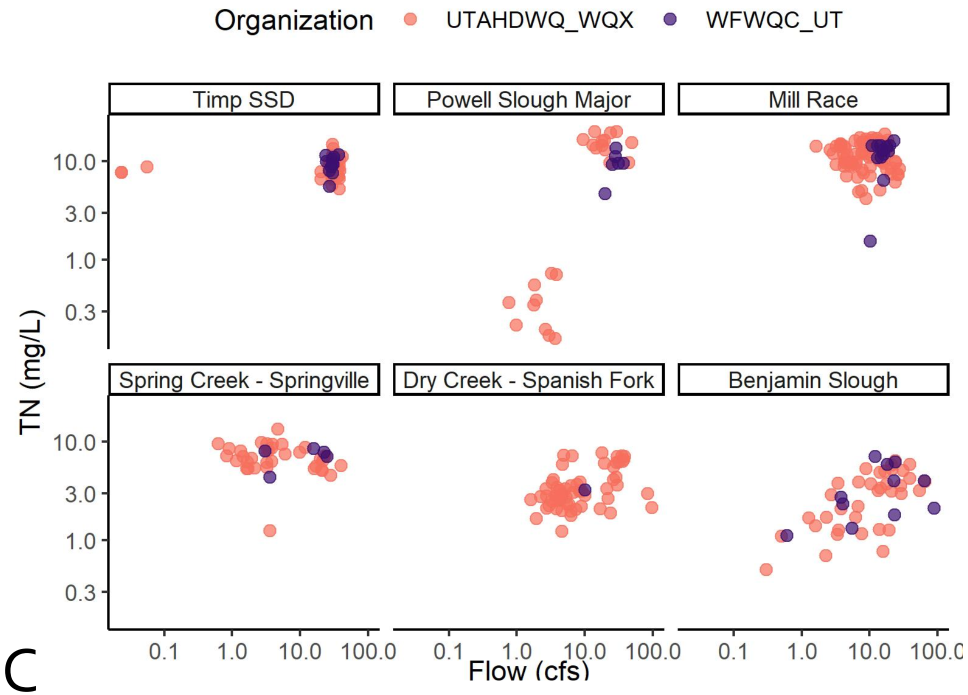
Downstream monitoring sites are below compromise elevation → limited data

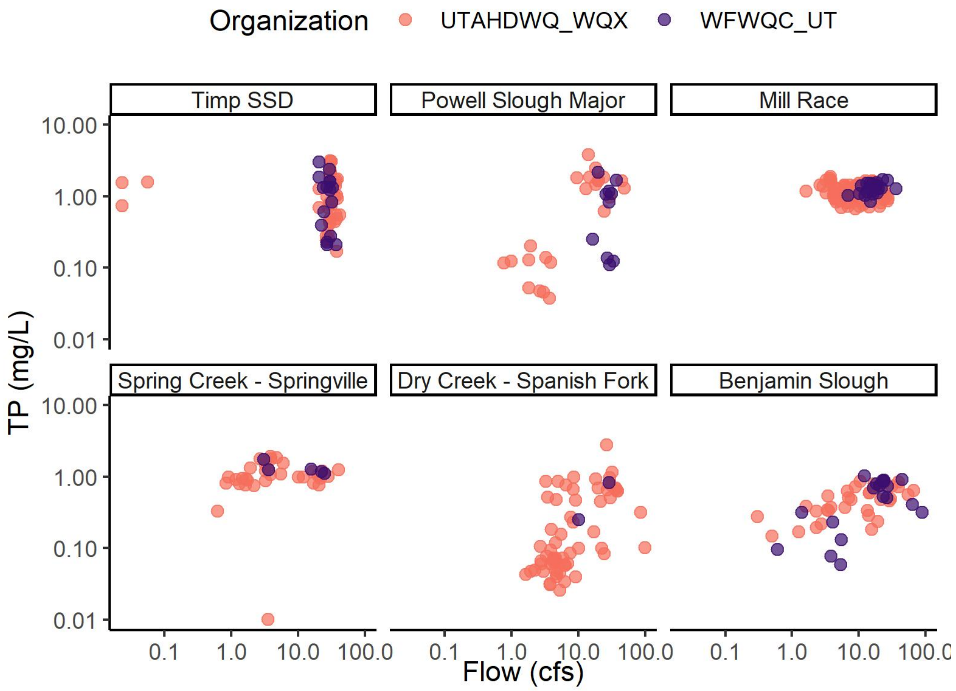
- Powell Slough
- Mill Race
- Dry Creek- Spanish Fork



C-Q RELATIONSHIPS WATERSHEDS W/ WWTP

- Watersheds w/ similar distributions
  - Timp SSD
  - Benjamin Slough
- Watersheds w/ truncated distribution for WFWQC
  - Powell Slough Major
- Watersheds w/ few WFWQC samples
  - Powell Slough Major
  - Mill Race
  - Spring Creek – Springville
  - Dry Creek – Spanish Fork



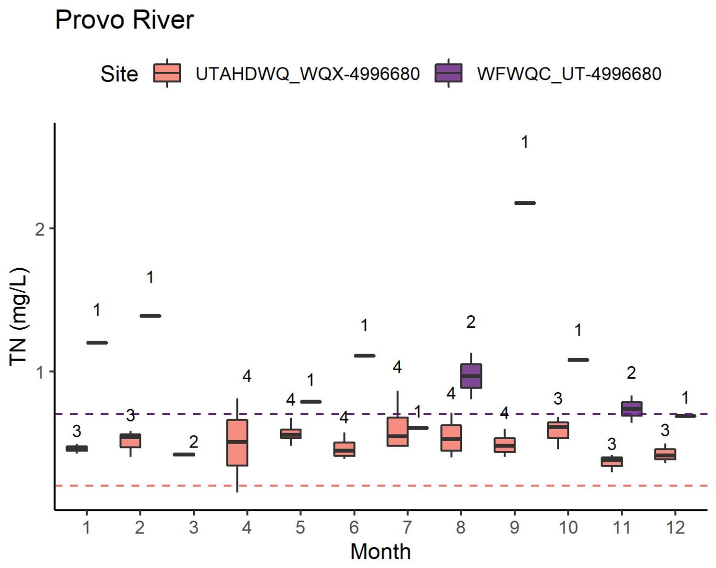


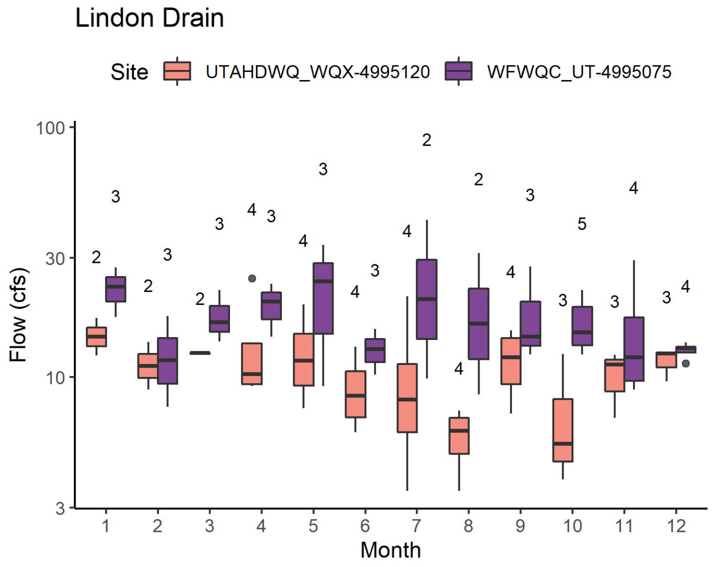
TAKEAWAYS: COMPARISON OF DWQ AND WFWQC MONITORING

- Reporting limit is an issue for WFWQC samples in watersheds w/o WWTP
- UDWQ sampling is more comprehensive than WFWQC for some watersheds
- Concentrations and flows are often, but not always equivalent → discrepancies could be a function of bias or limited sampling

PRELIMINARY DECISIONS

- Most watersheds have comparable concentrations and flows
  → use both DWQ and WFWQC data
- Watersheds with low TN concentrations (below detection limit for WFWQC method)
  → use DWQ data only
  - Provo River
  - Hobble Creek
  - Spanish Fork River
- Watersheds with discrepancy between DWQ and WFWQC → follow up
  - Lindon Drain
  - Spanish Fork River





ADDITIONAL NOTES

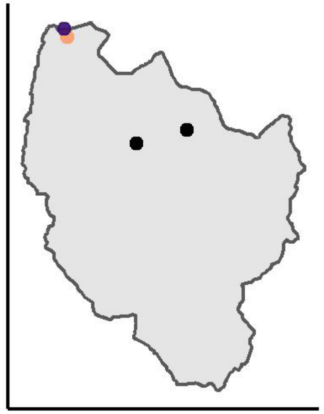
- When a watershed has missing data for a given month (≠ no flow) → interpolate to generate load estimate (nearest neighbor or linear)
- Follow-up on TN values from WFWQC (method listed as TKN)
  - Theron Miller to follow up with any info he knows
  - May need to add NO_3^- and NO_2^- to generate TN
- Theron Miller to update us w/ additional information known on:
  - Flow methodology (should be USGS w/ 10 cross-sections)
  - If lat/long for any site is inaccurate

LOOKING AHEAD: ATTENUATION OF NUTRIENTS

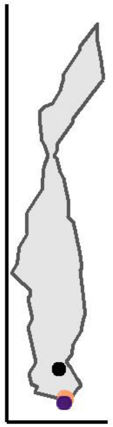
Comparing WWTP DMR data to tributary monitoring data:

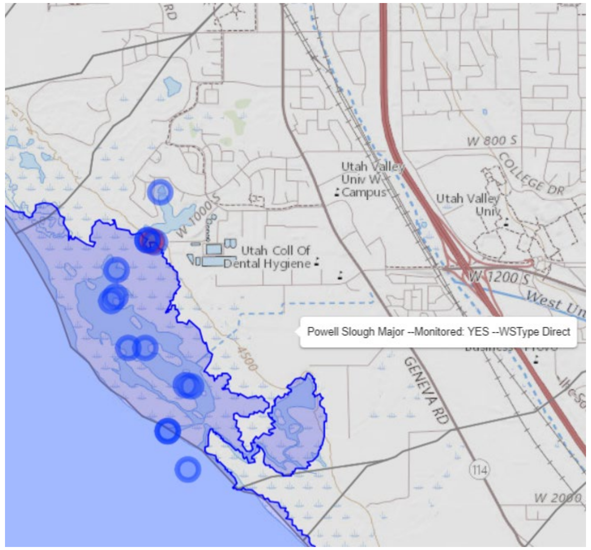
1. WWTP is far away from lake
   - Tributary data likely a better representation of the lake load
   - e.g., Benjamin Slough
2. WWTP is close to the lake + tributary site is above compromise elevation
   - Compare DMR and tributary data
   - e.g., Timpanogos SSD
3. WWTP is close to the lake + tributary site is below compromise elevation
   - Need to determine what constitutes loading "to the lake"
   - Analyze transect from WWTP to downstream site → attenuation or not?
   - e.g., Powell Slough, Mill Race

Benjamin Slough



Timp SSD





QUESTIONS/DISCUSSION

Questions or comments on the proposed approach?

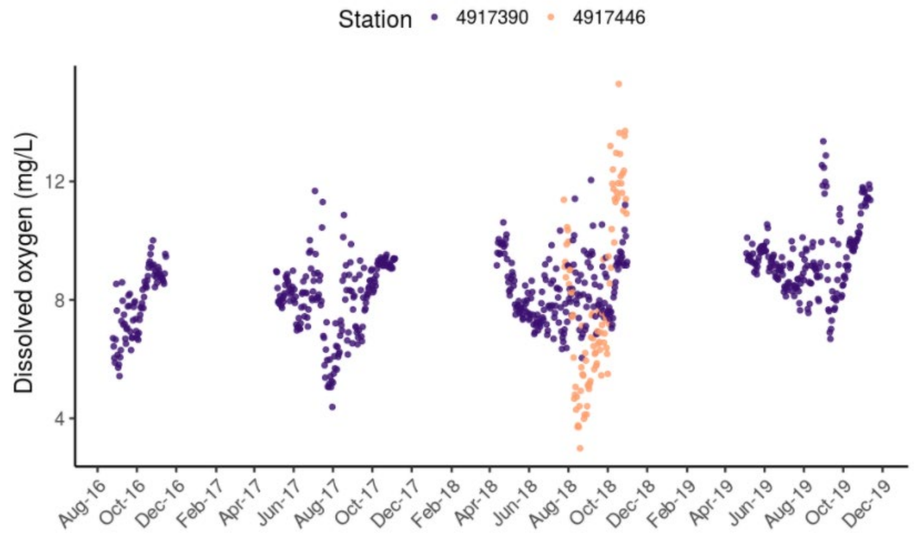
SEDFLUX MODELING

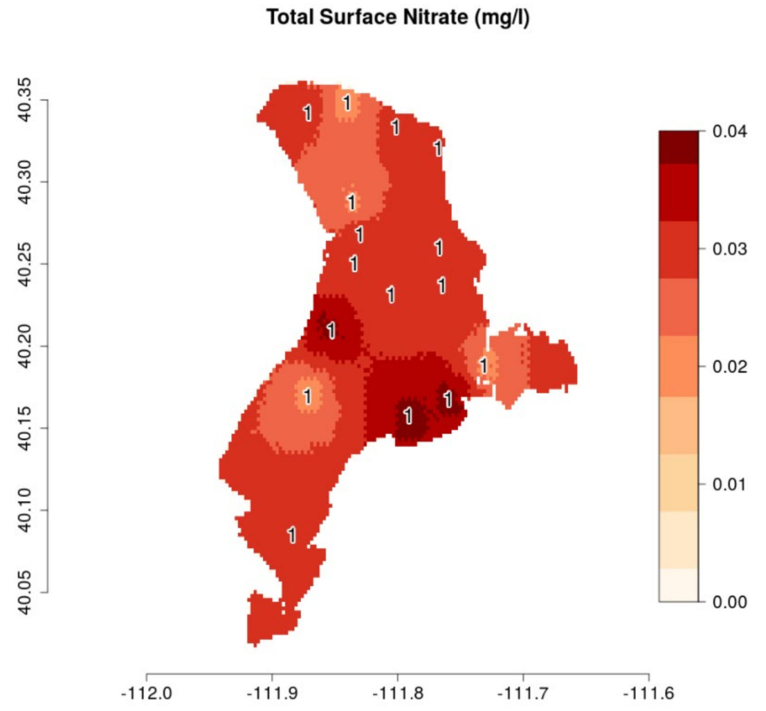
SEDFLUX MODEL BACKGROUND

- Mechanistic model
- Calculates rates of processes and fluxes across the sediment-water interface (C, N, P, other elements)
- Includes sediment diagenesis
- User-supplied data:
  - Water column conditions across time series (*input*)
  - Initial sediment conditions at the start of the model run (*initial*)
  - Rate-specific parameters for reaction network (*parameters*)

MODEL INPUTS

- 6-hour increments, May-October, 2017-2019
- DO and Temperature: high-frequency buoy data
  - 4917390 for Main Basin
  - 4917446 for Provo Bay
- NH_4^+, NO_3^-, PO_4^{3-}, DOC: routine monitoring
  - average across sites
  - linear interpolation between sampled dates
- Salinity: 0.8 PSU
- Depth: 3.26 for Main Basin, 2.0 for Provo Bay





INITIAL SEDIMENT CONDITIONS & REACTION PARAMETERS

- Initial conditions: default SedFlux values except dissolved PO_4^{3-} in porewater
  - 1.48 mg/L in Main Basin
  - 3.85 mg/L in Provo Bay
- Parameters: set to default except where noted in Su and von Stackleberg (2020)

Nutrient WASP Input Parameter	Units	Value	Data Source
Temperature-Correction for Nitrification	None	1.07	Stantec Consulting Ltd (2010) for the Jordan River WASP
Half-Saturation for Nitrification	mg-O_2/L	2	Maximum value recommended by WASP
Temperature-Correction for Denitrification	None	1.07	Stantec Consulting Ltd (2010) for the Jordan River WASP
Half-Saturation for Denitrification	mg-O_2/L	2	Maximum value recommended by WASP
Temperature-Correction for DON Mineralization	None	1.07	Stantec Consulting Ltd (2010) for the Jordan River WASP
Orthophosphate Partition Coefficient to Water Column Solids (Silt)	L/kg	2	"Best" Calibrated Value
Orthophosphate Partition Coefficient to Water Column Solids (Clay)	L/kg	2	"Best" Calibrated Value
Temperature-Correction for DOP Mineralization	None	1.07	Stantec Consulting Ltd (2010) for the Jordan River WASP

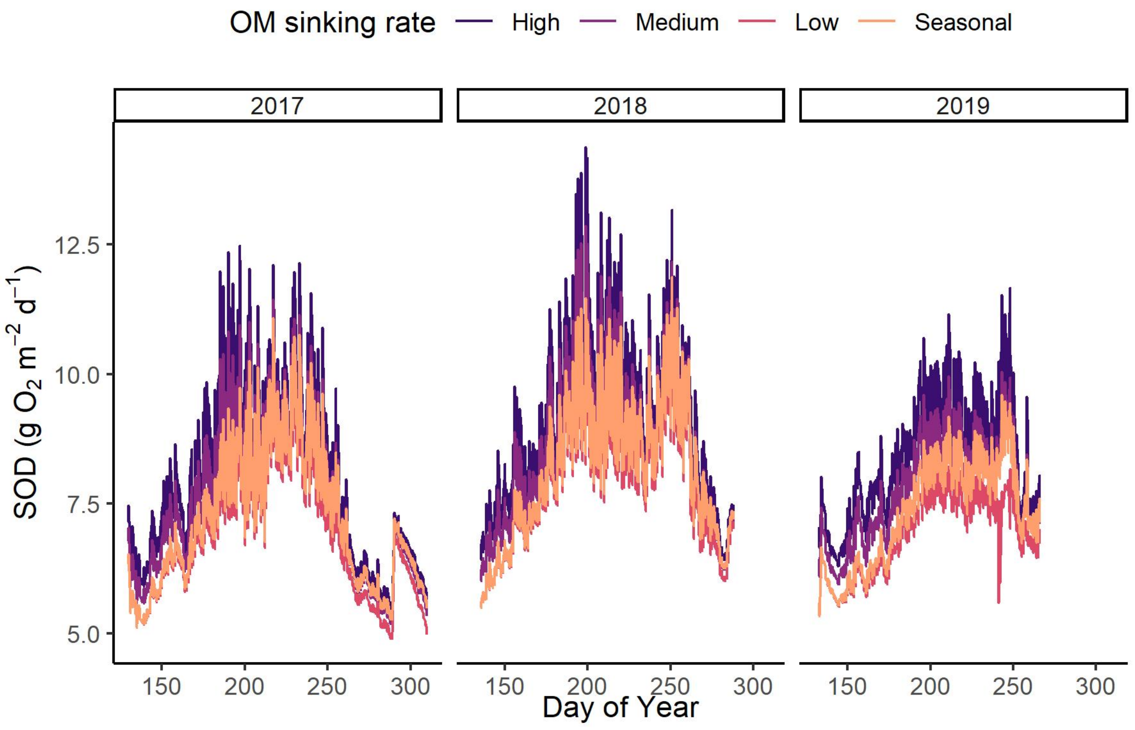
MODEL INPUTS: ORGANIC MATTER (OM)

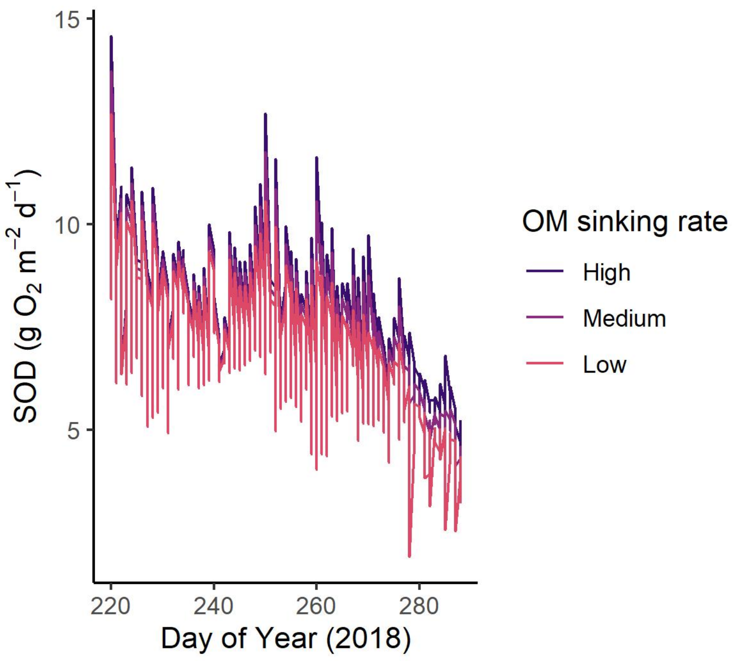
Missing data: OM load to the sediment (aka sinking rate)

- OM stoichiometry estimated in conceptual model → just need total rate
- Range of rates observed in Molongoski and Klug 1980: Wintergreen Lake (KBS, MI)
- 4 scenarios run:
  - Low sedimentation: minimum rate, steady across time series
  - Medium sedimentation: mean rate, steady across time series
  - High sedimentation: maximum rate, steady across time series
  - Seasonal sedimentation: minimum rate at the start of the time series, linear increase to maximum rate on August 1. Maintain high rate for the rest of the time series. Consistent with phytoplankton biomass seasonal trends from Analysis Report

SEDIMENT OXYGEN DEMAND (L: MAIN BASIN, R: PROVO BAY)

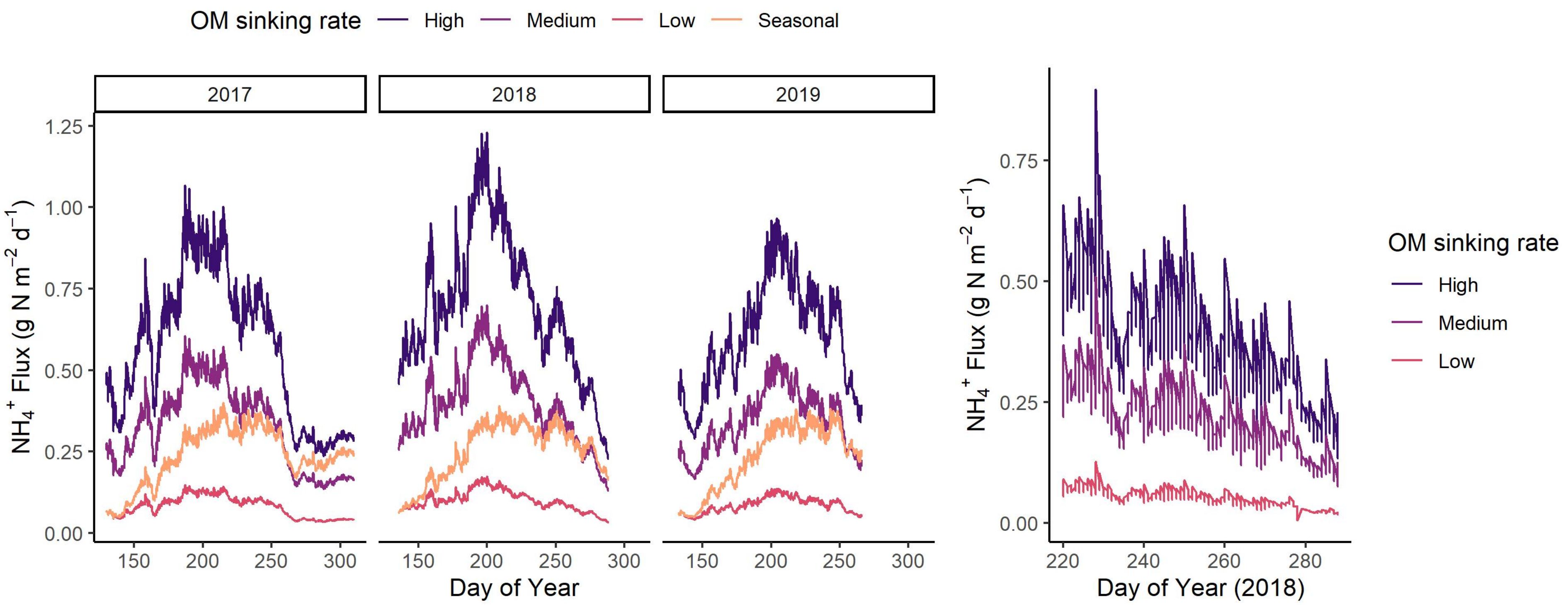
- Somewhat variable based on sedimentation
- Peaks from mid-July through August





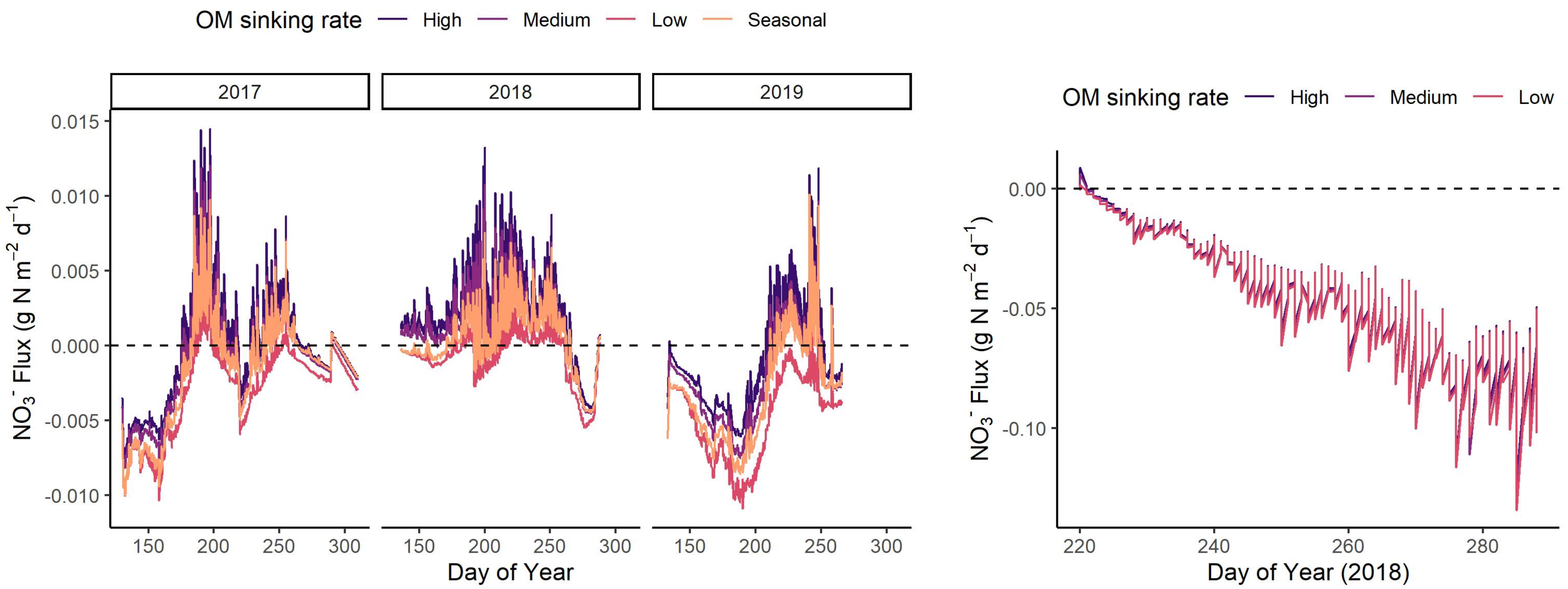
NH_4^+ FLUX (L: MAIN BASIN, R: PROVO BAY)

- Considerable variability based on sedimentation
- Net positive flux = from sediment to water column
- Peaks from mid-July through August, comparable across sites



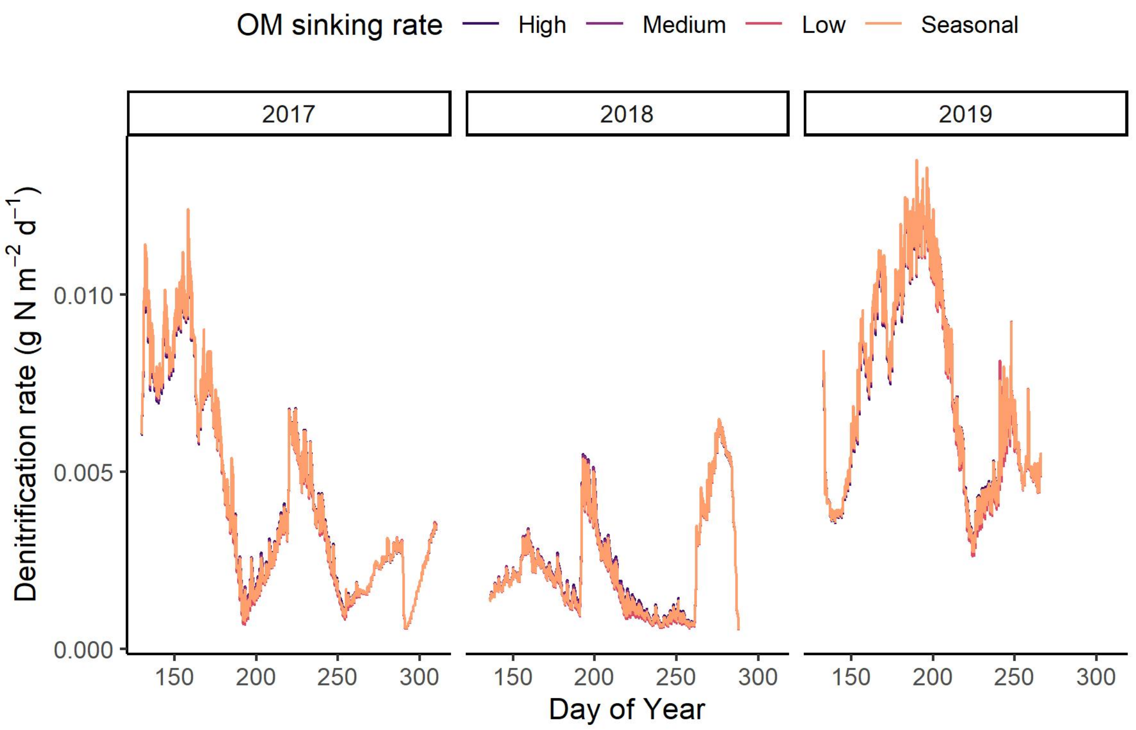
NO_3^- FLUX (L: MAIN BASIN, R: PROVO BAY)

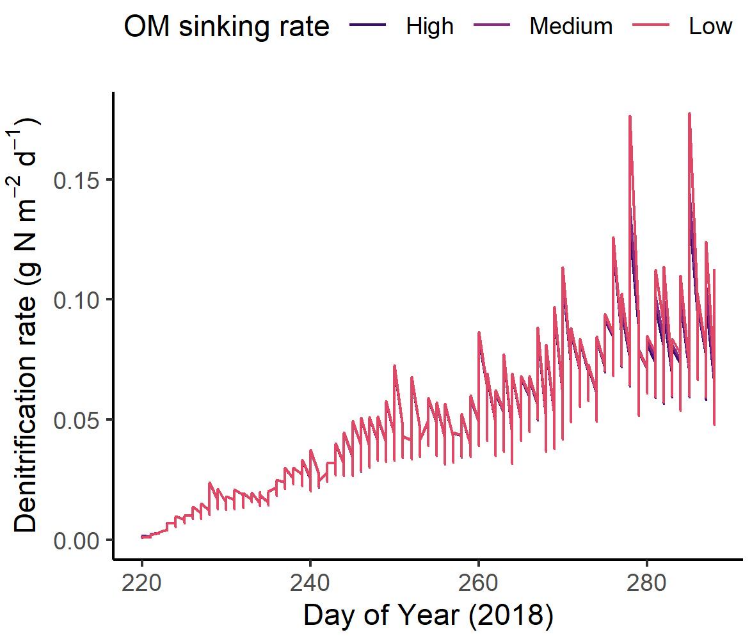
- Main basin: flux to the sediment early and late in the season, flux to the water column in mid-summer
- Provo Bay: flux to the sediment for the entire season
- Somewhat variable based on sedimentation



DENITRIFICATION RATE (L: MAIN BASIN, R: PROVO BAY)

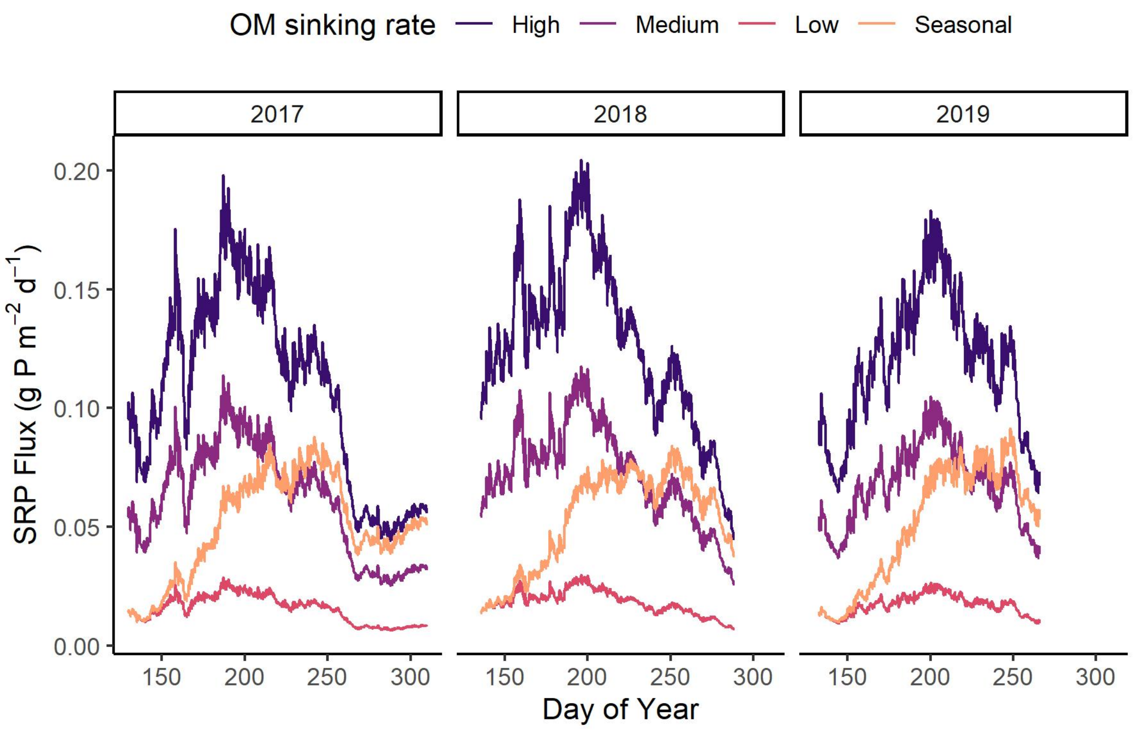
- Rate not variable based on sedimentation rate
- Considerable variability across season and years
- Provo Bay > Main Basin

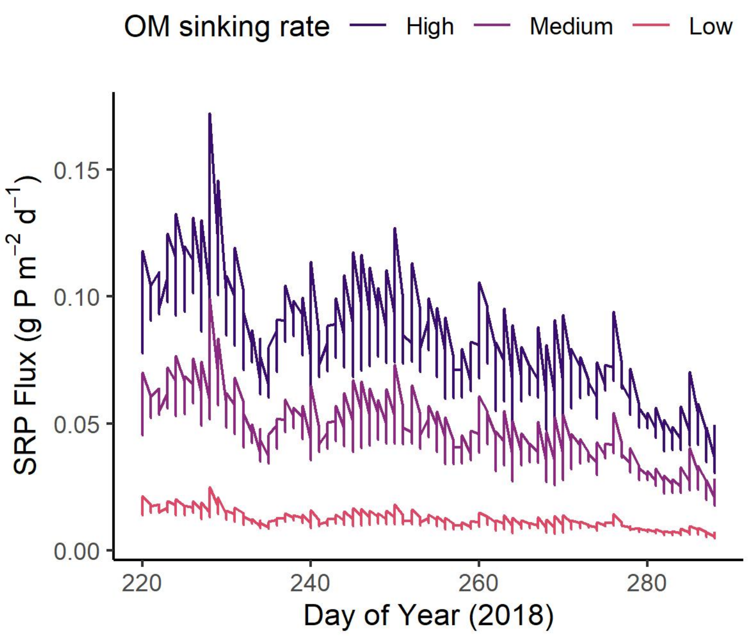




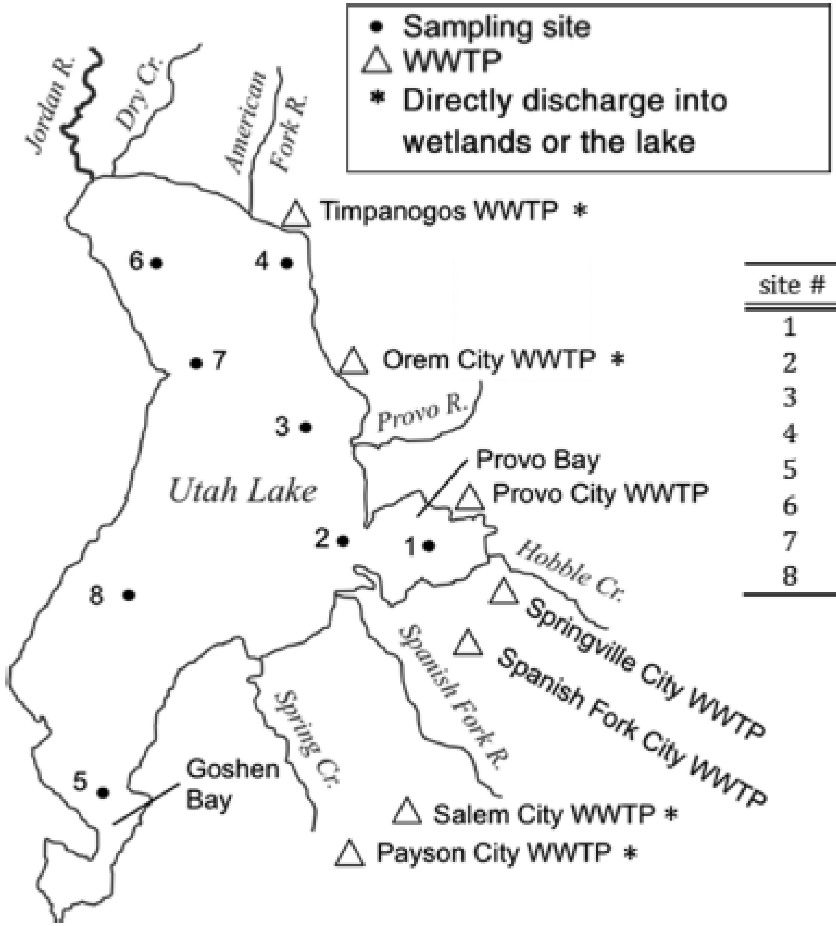
SRP FLUX

- Considerable variability based on sedimentation
- Seasonality of sedimentation is important
- Flux from sediment to water column, comparable between sites





COMPARISON TO HOGSETT ET AL. 2019



SOD: SedFlux > Hogsett

NH_4^+: SedFlux ≈ Hogsett

NO_3^-: SedFlux ≈ Hogsett

SRP: SedFlux > Hogsett

site #	description
1	Provo Bay
2	Entrance to Provo Bay
3	1 mile W of Provo Harbor
4	0.5 mile W of Geneva Steel
5	Goshen Bay
6	2 miles E of Saratoga Springs
7	1 mile E of Pelican Point
8	3 miles WNW of Lincoln Beach

Site	*SOD, $g/(m^2 \cdot day)$*	*Sediment nutrient fluxes, $g/(m^2 \cdot day)$*			
		NH_4-N	*NO_3-N*	*TIN*	*PO_4-P*
1	−4.61	1.442	0	1.442	0.010
2	−1.42	0.023	0.005	0.03	0.071
3	−1.49	−0.033	0.021	−0.01	0
4	−2.04	0.141	0	0.141	0.031
5	−1.67	0.027	0.012	0.04	0
6	−1.03	−0.001	0.004	0.00	0.010
7	−1.06	0.093	−0.008	0.09	−0.004
8	−0.9	0.027	0.08	0.11	0.001

Note: need to also compare to Goel et al. sediment report

NEXT STEPS

1. Explore sensitive parameters and initial conditions:
   - Water column depth
   - SOD-relevant parameters & inputs
   - SRP-relevant parameters & inputs
2. Compare rates with Utah Lake and other system measurements

QUESTIONS/DISCUSSION

Any questions or comments on:

- Approach
- Exploratory results