Internal Phosphorus Loading: What is it and how do we manage it?

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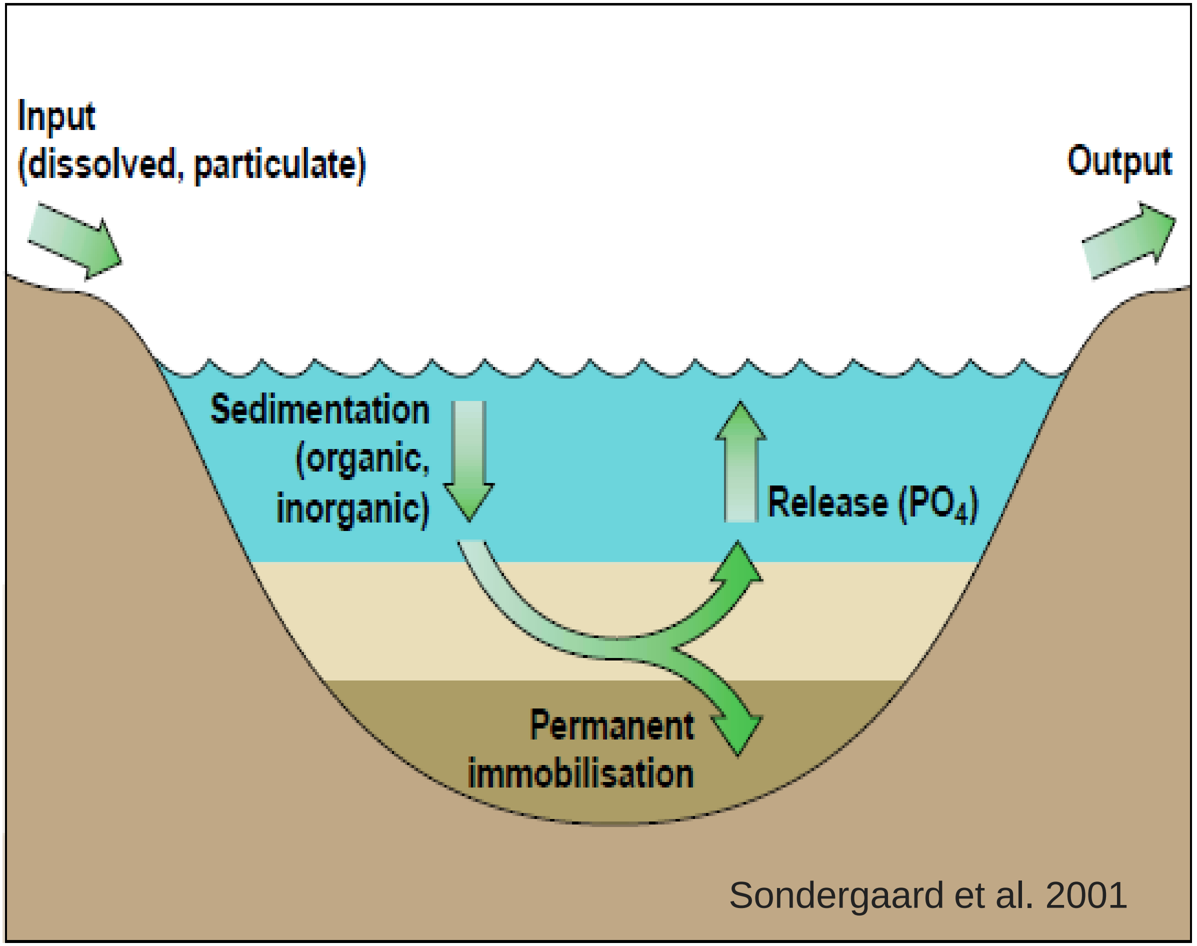
Stantec

Background on Stormwater Ponds

- Stormwater ponds are important tools for managing runoff in urban areas
  - Quality and quantity
- Traditional wet ponds provide treatment by retaining water ≤ pond volume, and allowing settling of sediments and pollutants
- Pond maintenance is key to maximizing performance and capacity
  - Many ponds have little or no follow-up maintenance
  - Leads to accumulation of total suspended solids (TSS) and total phosphorus (TP)
- Historically, urban stormwater mgmt practices and models assume that TP is retained.
  - Sediment P release and export more common than traditionally expected

Phosphorus Accumulation in Sediments



Sondergaard et al. 2001

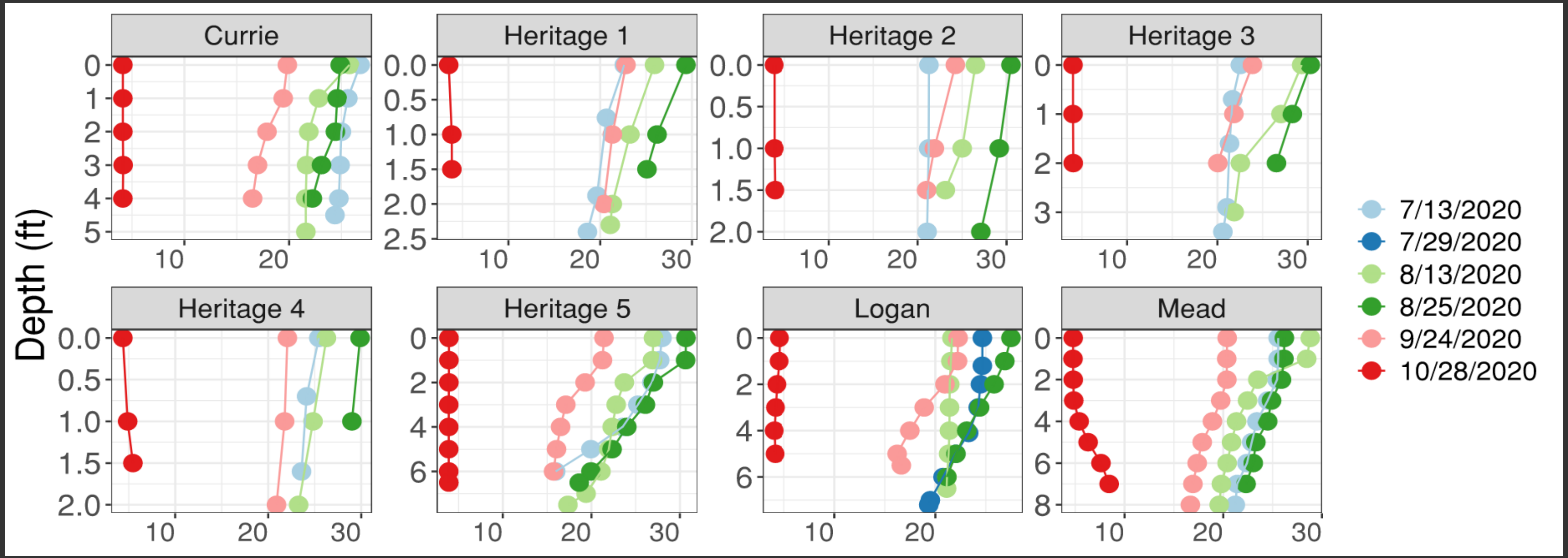
P-forms in the sediment:

- Dissolved (PO_4, organic P)
- Particulate

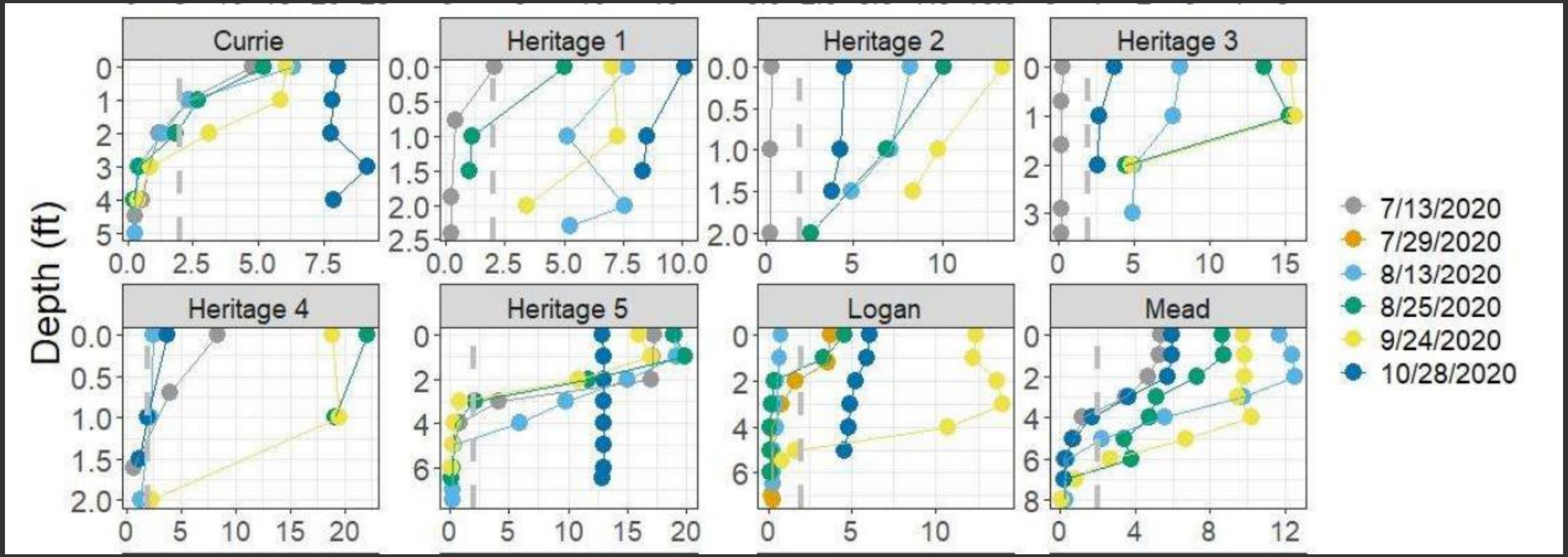
Iron:	Fe (III) hydroxides, Fe (OOH), (ads.) Strengite, Fe PO_4 Vivianite, $Fe_3 (PO_4)_2$ 8 H_2O
Alum:	Al $(OH)_3$ (ads.) Variscite, Al PO_4
Calcium:	Hydroxyapatite, $Ca_{10} (PO_4)_6 OH_2$ Monetite, Ca H PO_4 Calcite (ads.)
Clay:	(ads.)
Organic:	"Labile" "Refractory"

Misconceptions with Shallow Pond Mixing

Temperature



Dissolved Oxygen



How do we diagnose internal P loading?

- Field measurements/Data Collection
  - Sediment accumulation
  - Sediment coring for quantification of
    - P release rates
    - Mass of P fractions in sediments
  - Water quality data
    - TP
    - Dissolved P
    - Temperature/Dissolved Oxygen Profiles
- Modeling tools to determine proportion of internal vs external loads

How do we manage internal P loading?

- Dredging (hydraulic or mechanical)
- Aluminum sulfate (alum) treatments
  - Phoslock®, polyaluminum chloride

Alum Application Strategies

Water column stripping: This strategy targets the phosphorus in the water column but does not account for the mass of phosphorus in the sediments.

Sediment phosphorus inactivation: This strategy targets the mass of phosphorus in the sediments that is subject to mobilization and diffusion from the sediments to the water column.

Phosphorus interception: This strategy involves addition of alum (or an alum-based coagulant) to a tributary inflow to reduce the external phosphorus load before entering the lake.

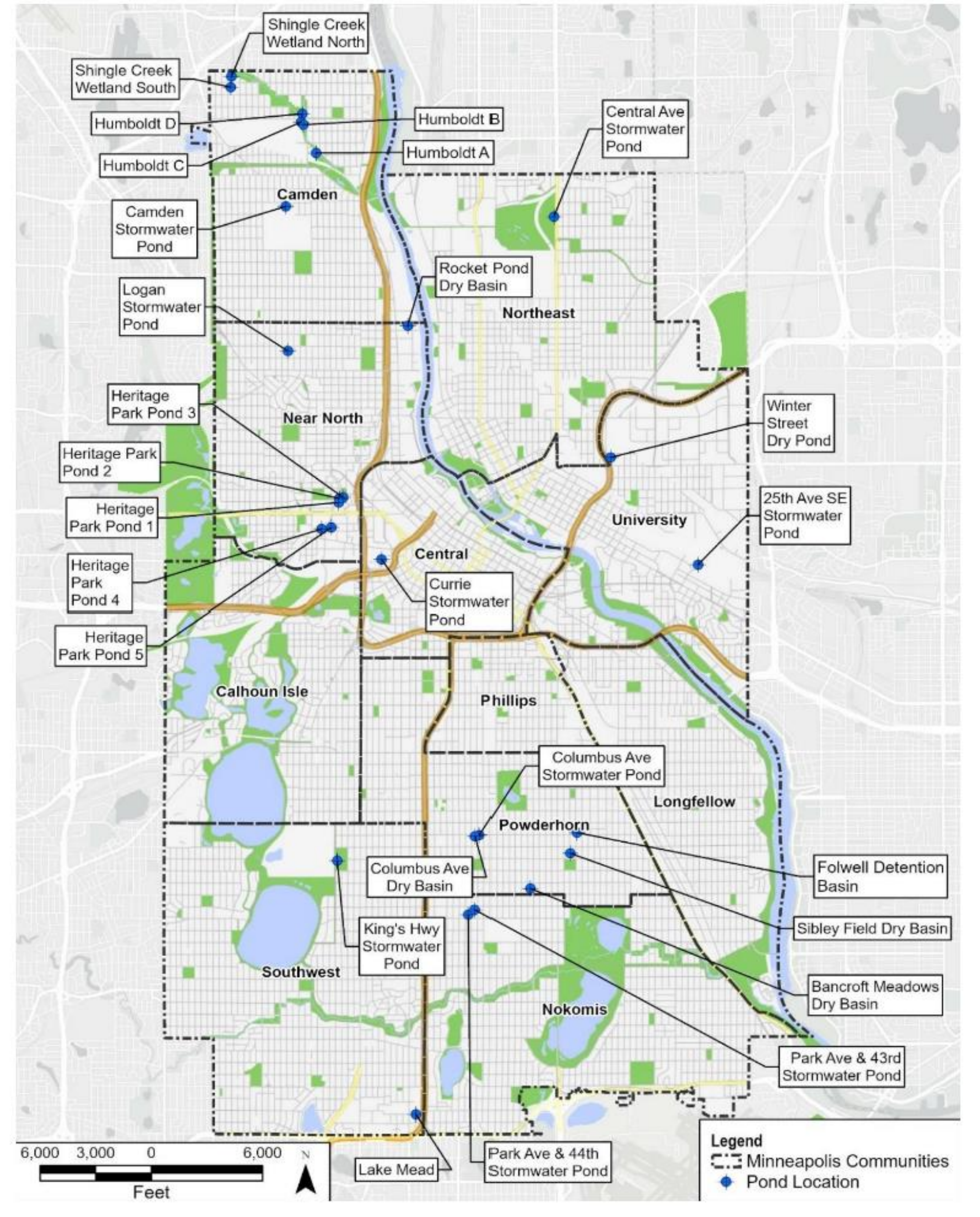
Maintenance treatments: Maintenance dosing may target the water column or the sediments depending on the goal.

Case Study
Minneapolis Pond Assessment

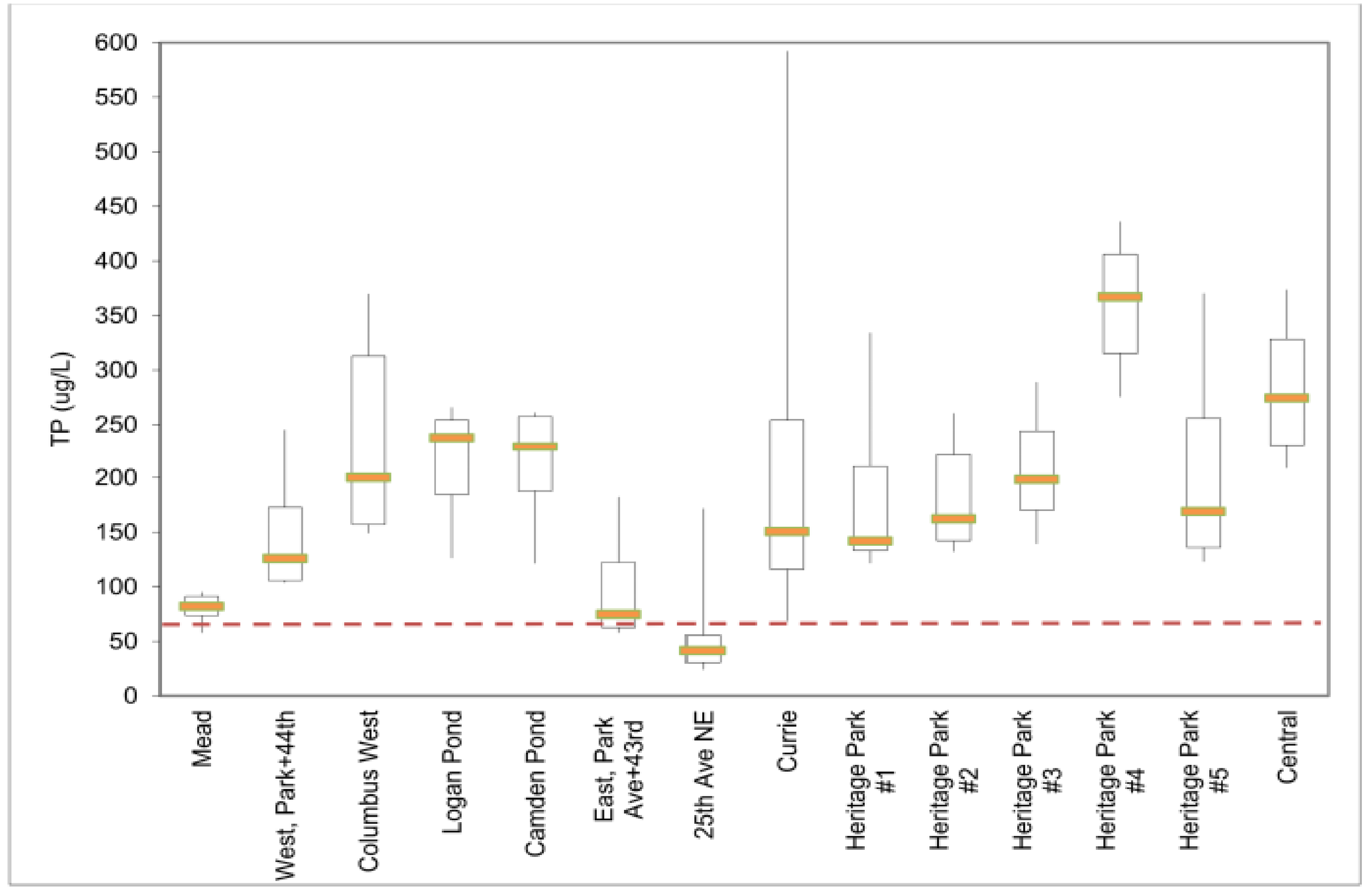
- Stantec was contracted by the City of Minneapolis to conduct a stormwater pond assessment (2022)
- Purpose:
  - Characterize current condition of ponds and function
    - Bathymetry, infrastructure (inlets/outlets), sediment accumulation, surrounding topography
    - Nutrient/water quality data, sediment P concentrations and release rates
  - Identify and prioritize maintenance actions to improve water quality and pond function
- 28 stormwater basins were assessed (20 wet ponds + 8 dry basins)
- Pond age ranged from 8 - 32 years

Pond Locations Minneapolis

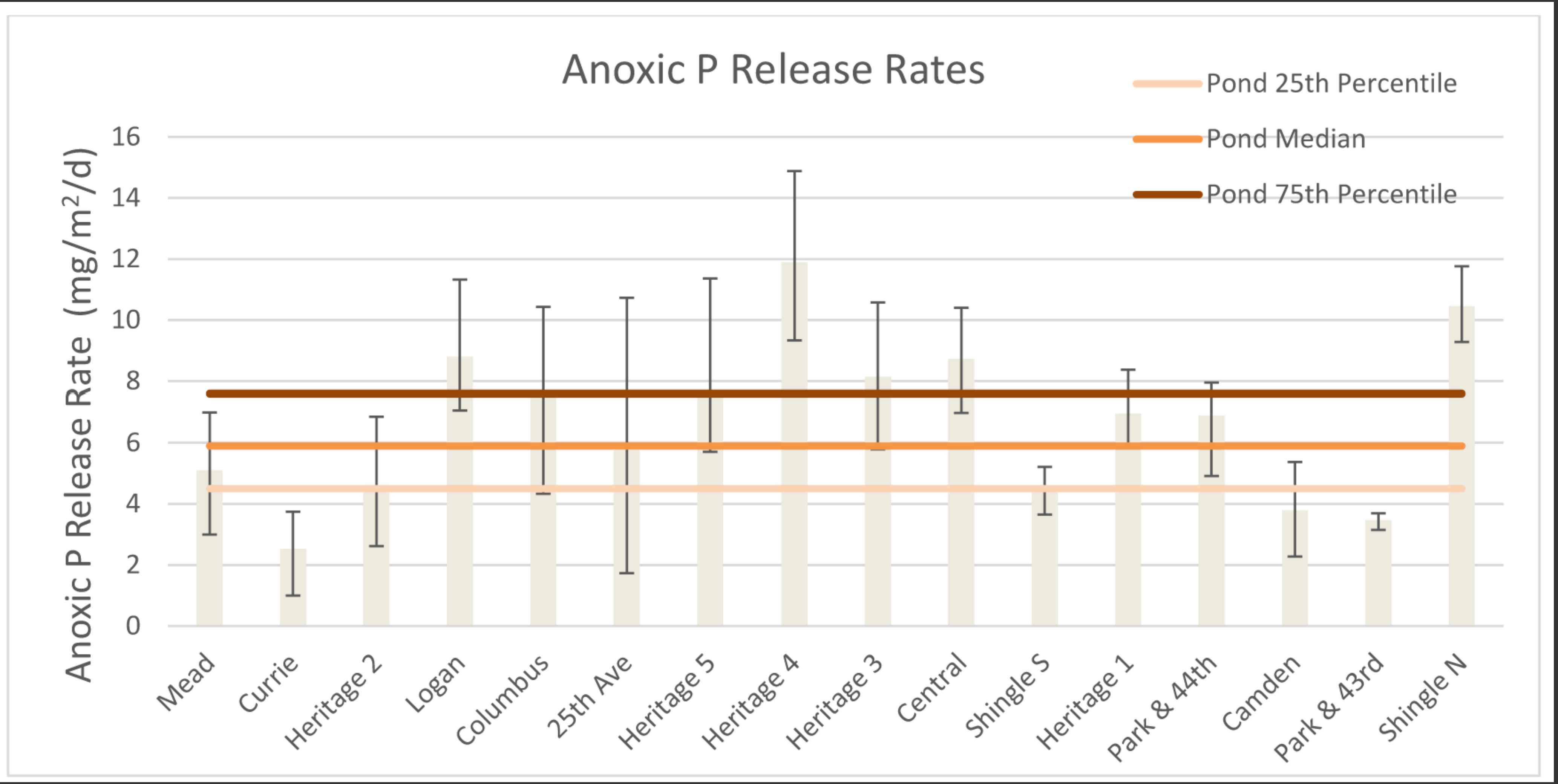
- Three major conditions evaluated:
  - Sedimentation
  - TP removal efficiency
  - Internal P Loading



Total Phosphorus – Minneapolis Ponds



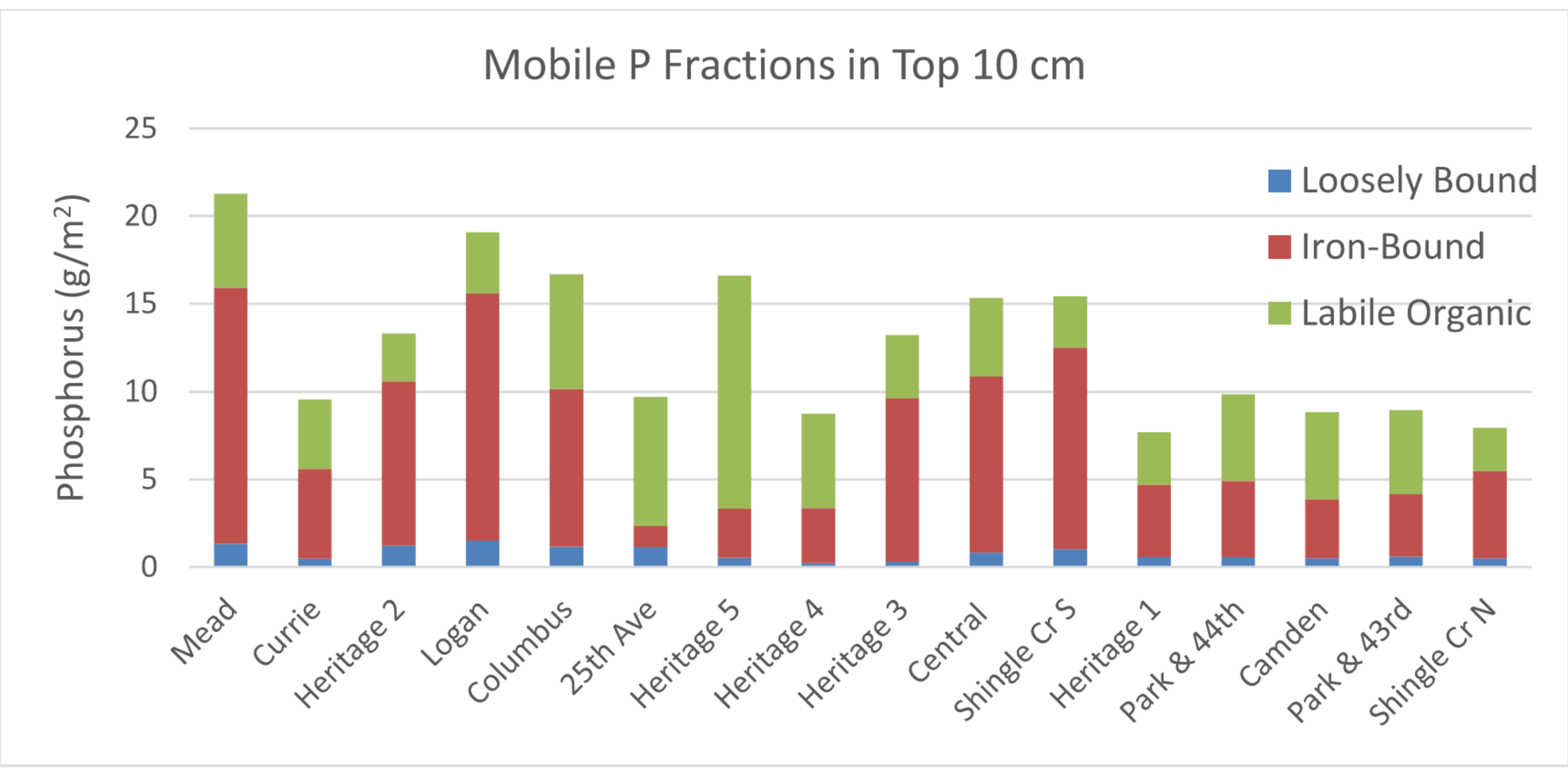
Sediment P Release – Minneapolis Ponds



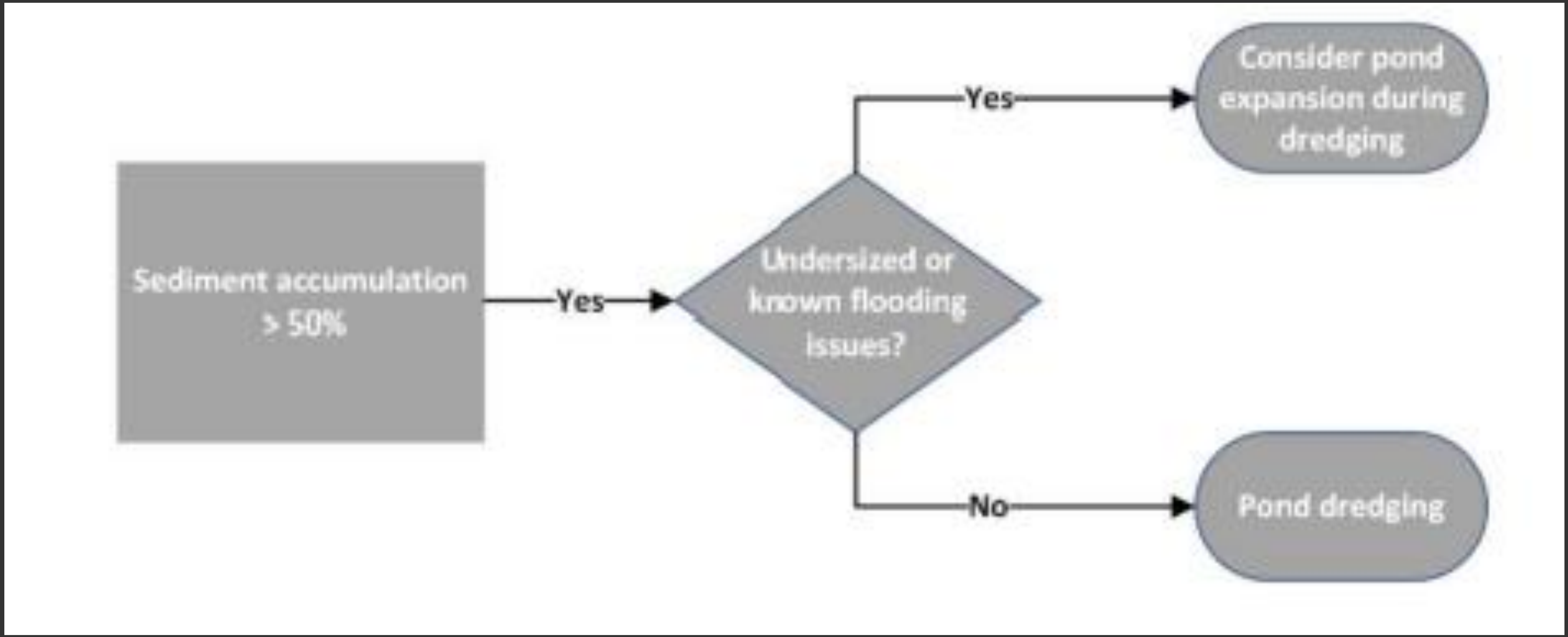
Recycling potential of phosphorus fractions

Operational Grouping	P Fraction	Recycling Potential
Mobile P pool	Iron-bound P	Biologically-labile and subject to mobilization through biogeochemical and geochemical reactions.
	Loosely-bound P	
	Labile organic P	
Non-mobile P pool	Aluminum-bound P	Biologically-refractory and subject to burial; not readily available for biological uptake.
	Calcium-bound P	
	Refractory P	

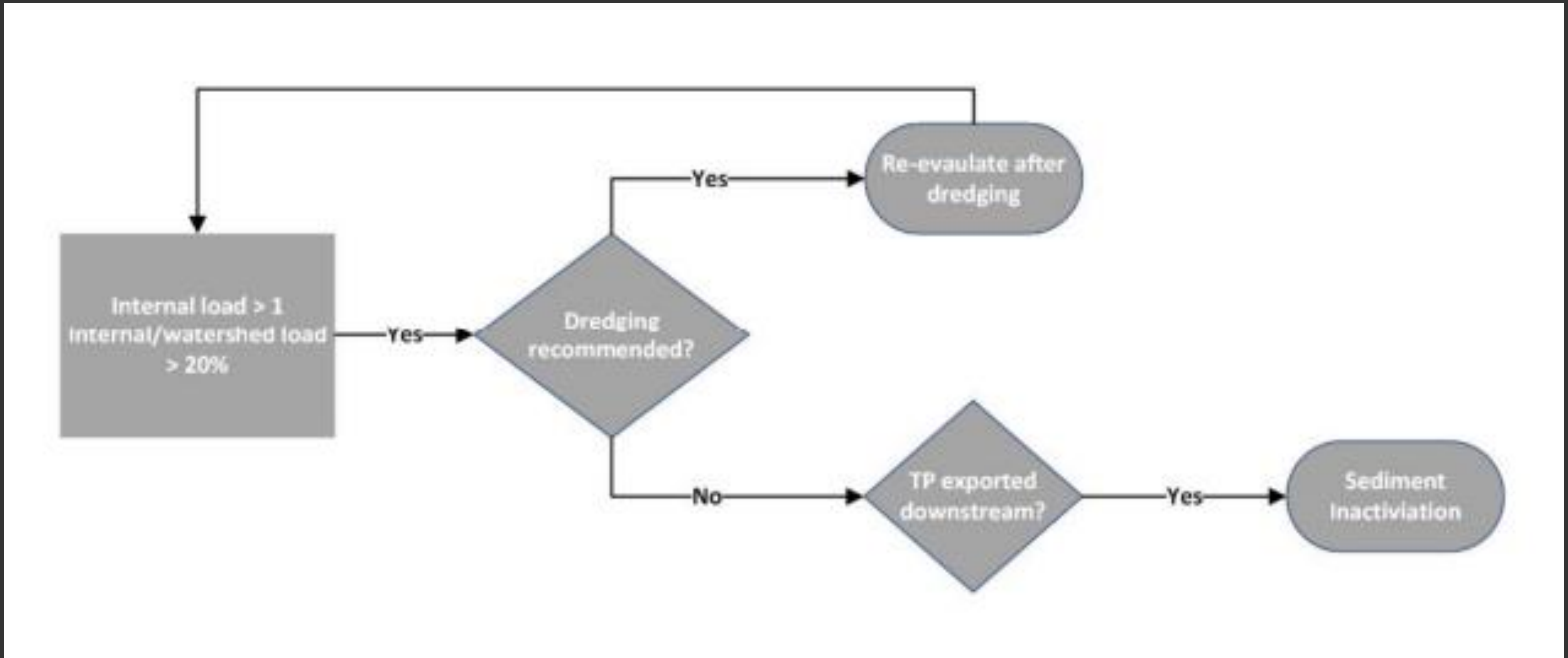
Sediment P Fractions – Minneapolis Ponds



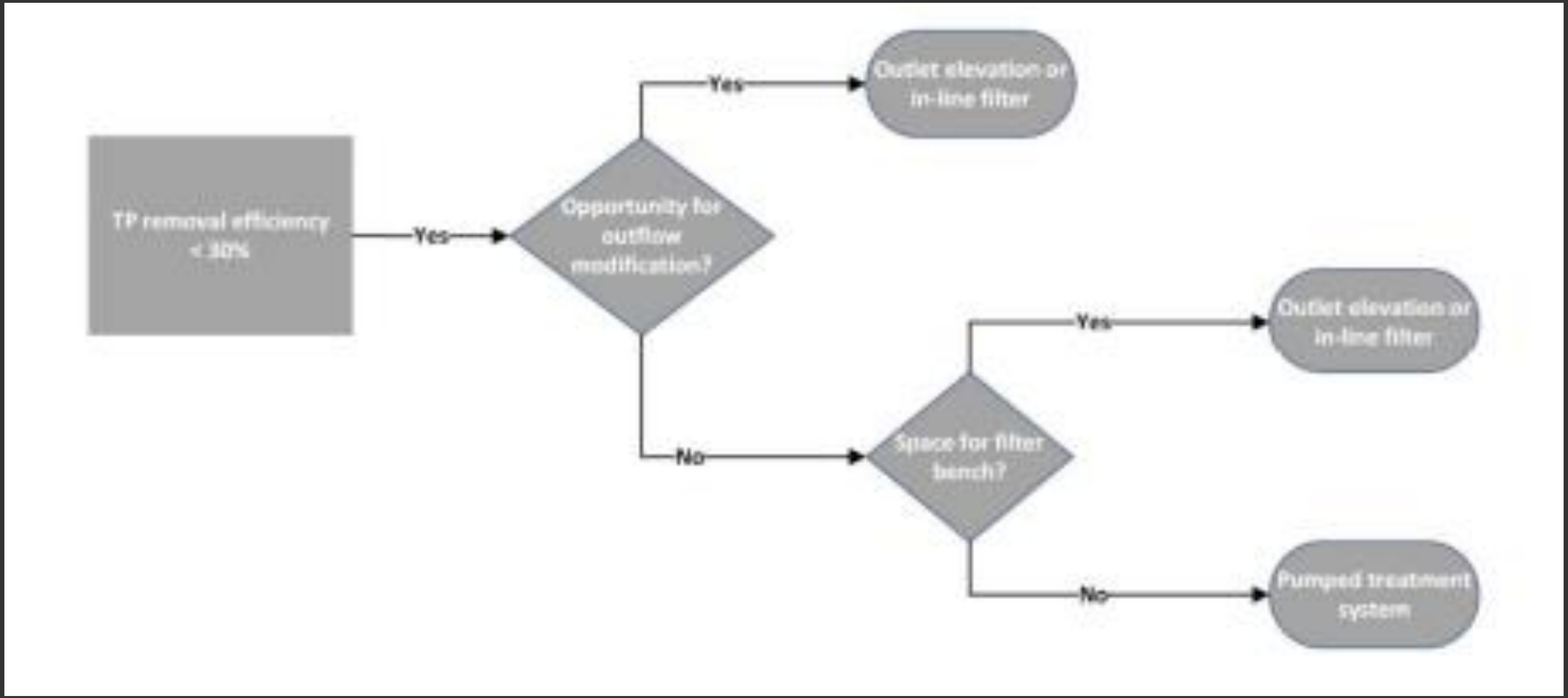
Management Decision Tree



Management Decision Tree



Management Decision Tree



10-Year Maintenance Plan

Table 4-6. 10-Year Maintenance Plan

Basin Name	Basin Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
25th Avenue SE	Wet	Monitoring/Sediment Inactivation			Sedimentation Survey					Sedimentation Survey	
Bancroft	Dry	Retrofit Opportunity									
Camden	Wet	Monitoring/Sediment Inactivation, Diagnostic									
Central	Wet	Monitor Sediment Delta, Monitoring/Sediment Inactivation			Sedimentation Survey					Sedimentation Survey	
Columbus Dry	Dry	Retrofit Opportunity									
Columbus Wet	Wet				Sedimentation Survey					Sedimentation Survey	*Dredging
Currie	Wet				Sedimentation Survey					Sedimentation Survey	
Folwell Infiltration Basin	Infiltration	Annual Inspection									
Heritage Park 1	Wet				Sedimentation Survey					Sedimentation Survey	
Heritage Park 2	Wet				Sedimentation Survey	*Dredging					Sedimentation Survey
Heritage Park 3	Wet	Monitor Sediment Delta, Clean Trench Forebays			Sedimentation Survey					Sedimentation Survey	*Dredging
Heritage Park 4	Wet	Dredging					Sedimentation Survey				
Heritage Park 5	Wet	Monitoring/Sediment Inactivation, Diagnostic									
Humboldt Greenway A	Wet	Diagnostic									
Humboldt Greenway B	Wet	Diagnostic									
Humboldt Greenway C	Wet	Dredging/Sediment Delta removal					Sedimentation Survey				
Humboldt Greenway D	Wet	Diagnostic									

Minneapolis Pond Summaries

25th AVE SE

A wet sedimentation basin constructed in 2011, draining to the Mississippi River.

Minneapolis City of Lakes

POND DATA

Watershed

Drainage Area: 4.1 acres
Impervious Area: 1.8 acres
Land use:

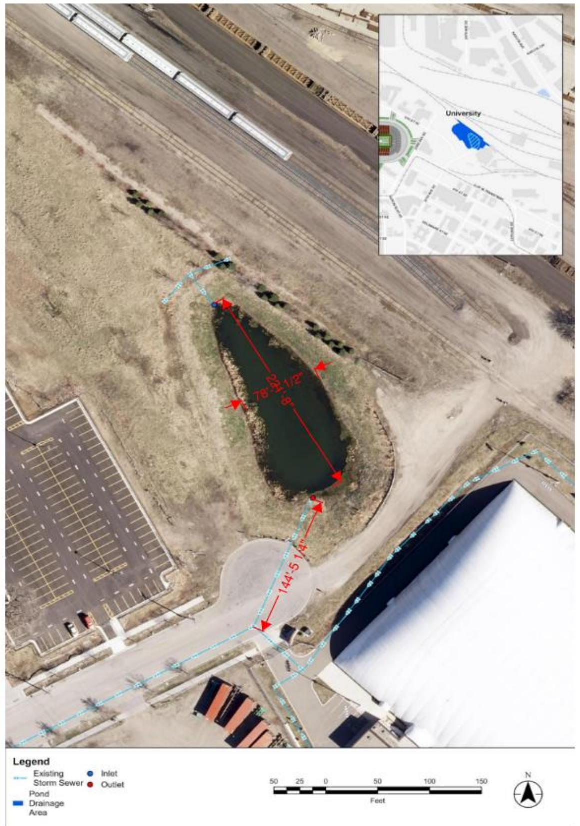
- 73% Park
- 11% Institutional
- 10% Industrial
- 6% Railway

Pond Stats

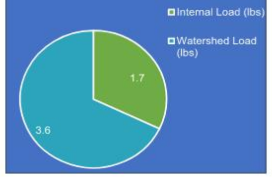
Constructed: 2011
Dredged: Never
Surface Area: 0.37 ac
Max Depth: 5.8 ft
Volume: 44,262 ft^3

Pond Performance

NURP Ratio: 2.34
Sedimentation: 3.3%
TP Removal Efficiency: 43%
TP Removed: 1.5 lbs/yr
TSS Removal Efficiency: 81%
TSS Removed: 726 lbs/yr
Internal/Watershed Load: 47%



Phosphorus Budget



Recommendations: Candidate for sediment in-activation.

Timeline: Check sedimentation levels again in 2025.

Monitoring Recommendations: Determine if the TP released from internal loading is retained within the basin or exported downstream.

Updated May 2022

Logan

A stormwater wet pond constructed in 2002, draining to Bassett Creek.

Minneapolis City of Lakes

POND DATA

Watershed

Drainage Area: 103 acres
Impervious Area: 53 acres
Land use:

- 63% Residential
- 29% ROW
- 4% Commercial
- 3% Park
- 1% Other

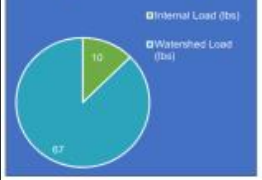
Pond Stats

Constructed: 2002
Dredged: 2017
Surface Area: 1.43 ac
Max Depth: 9.9 ft
Volume: 240,729 ft^3

Pond Performance

NURP Ratio: 0.46
Sedimentation: 13.5%
TP Removal Efficiency: 57%
TP Removed: 38.4 lbs/yr
TSS Removal Efficiency: 84%
TSS Removed: 16,188 lbs/yr
Internal/Watershed Load: 14%

Phosphorus Budget



Recommendations: Candidate for sediment in-activation.

Timeline: Check sedimentation levels again in 2025.

Monitoring Recommendations: Determine if the TP released from internal loading is retained within the basin or exported downstream.

Updated May 2022

Heritage Park – 4

A wet sedimentation basin constructed in 2007, draining to the Mississippi River.

Minneapolis City of Lakes

POND DATA

Watershed

Drainage Area: 105 acres
Impervious Area: 46 acres
Land use:

- 52% Residential
- 32% ROW
- 10% Institutional
- 5% Park
- 1% Other

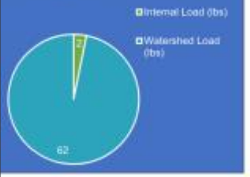
Pond Stats

Constructed: 2007
Dredged: 2014
Surface Area: 0.15 ac
Max Depth: 4.4 ft
Volume: 9,676 ft^3

Pond Performance

NURP Ratio: 0.02
Sedimentation: 57.9%
TP Removal Efficiency: 4%
TP Removed: 2.5 lbs/yr
TSS Removal Efficiency: 7%
TSS Removed: 1,278 lbs/yr
Internal/Watershed Load: 3%

Phosphorus Budget



Recommendations: Full pond dredging.

Timeline: High priority

Monitoring Recommendations: No monitoring recommendations.

Updated May 2022

Next Steps

Stantec awarded a grant from MN Stormwater Research Council to quantify phosphorus and harmful algal bloom (HAB) loads from select ponds.

Research Questions:

1. What are the P and HAB loads exported downstream?
2. Are there correlations with stormwater pond type and P and HAB export?
3. Are there design and maintenance improvements that may reduce P and HAB export?
4. Can cyanobacteria and cyanotoxins survive/persist throughout the storm sewer system?

Summary

- Multiple actions/efforts needed
  - Watershed load reduction efforts important
  - Internal P load reduction necessary in some cases
- Stormwater pond assessment and diagnostics important to ID issues and remedies
- Pond morphometry and morphology varies widely – difficult to generalize
- Stormwater pond maintenance critically important for maintaining optimal function
  - Especially when pond has an outflow
- Assumptions in watershed planning for BMP performance should be verified

Questions?

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