Water Budget Assessment of Water Supply Alternatives in the Ipswich River Watershed

NEWWA Water Resources & Sustainability Symposium

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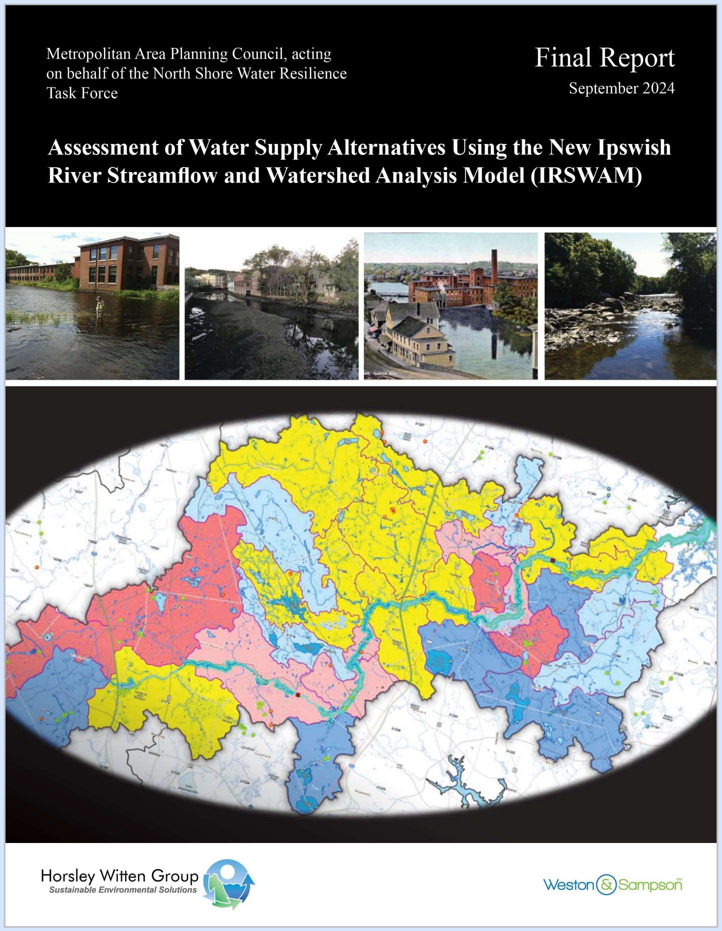

Background – Key Challenges

- **Limited sand and gravel aquifer** extents / storage
- **Groundwater wells** are close to Ipswich with little lag
- **Low slopes producing expansive wetlands**
  - High evapotranspiration (ET) losses
  - Potential for low flow restrictions
- **Significant water supply population** outside the watershed
- **Net wastewater export**
- **In-line reservoirs** exacerbate low flow conditions

WSE Photo of Hamilton, MA

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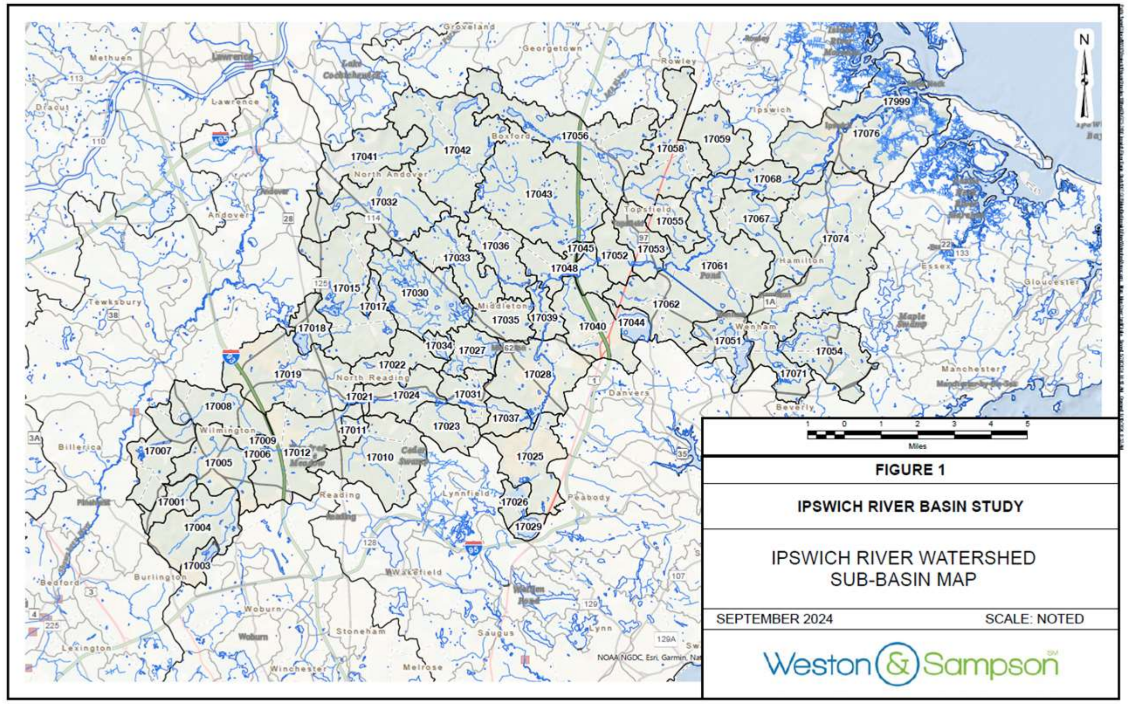
Background – Project Context

- **Task Force formed in 2022** to “identify and advance long-term solutions to improve water supply resilience and ecosystem health”

- **Commissioned an early 2023 study** to identify water supply alternatives and evaluate feasibility (ongoing)

- **This project, initiated in late 2023,** sought to evaluate those alternatives’ relative benefits by harnessing the Water Management Act (WMA) Tool



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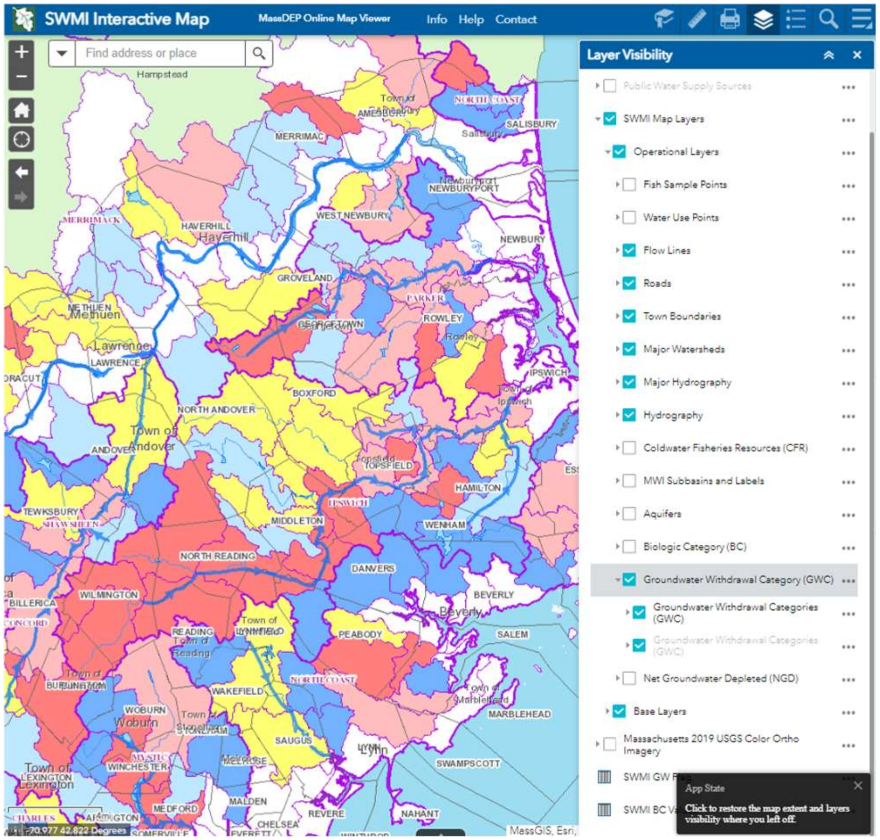
Background – SWMI / WMA Metrics

- **Flow Alteration =** GW Pumping (public and private / Unaffected August Median Flow
- **GWC based on Flow Alteration:**
  - 1 (0-3%)
  - 2 (3-10%)
  - 3 (10-25%)
  - 4 (25-55%)
  - 5 (55+%)
- **Net Groundwater Depletion =** (GW Pumping – GW Discharges) / Unaffected August Median Flow
- **BC based in part on Net Groundwater Depletion:**
  - 1 (0-5%)
  - 2 (5-15%)
  - 3 (15-35%)
  - 4 (35-65%)
  - 5 (65+%)



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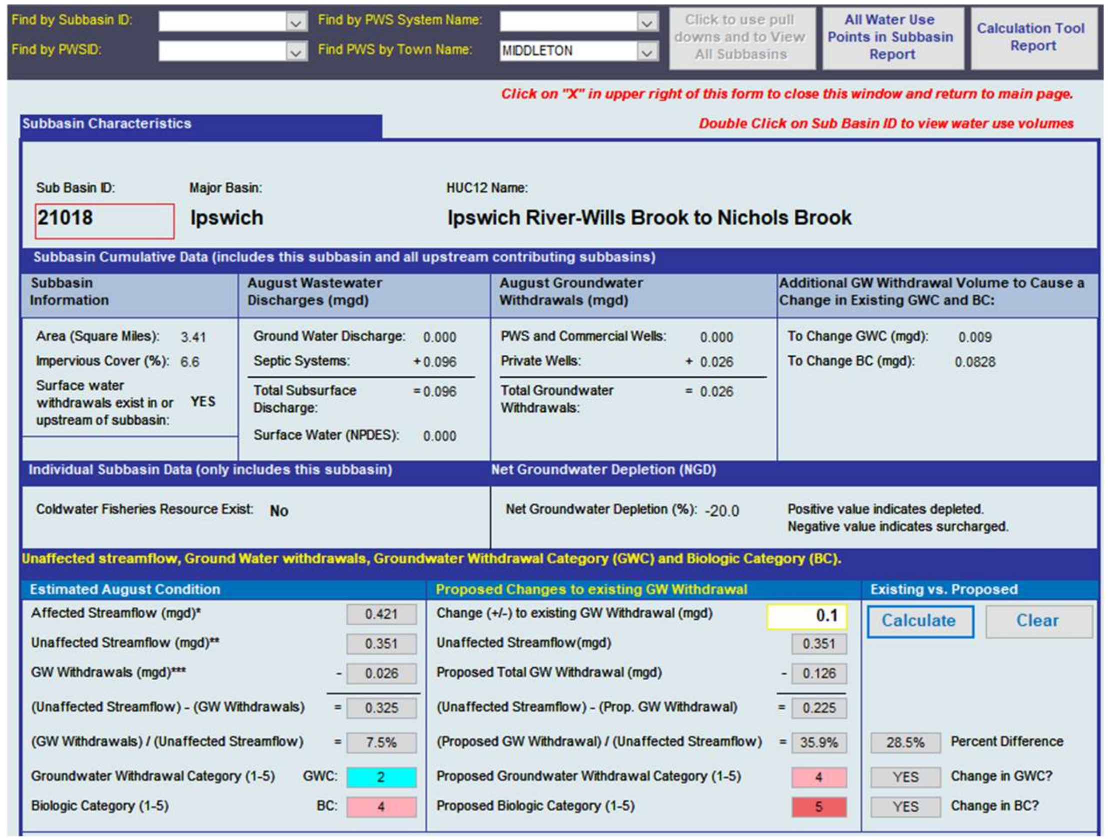
Background – WMA Tool

- **Mass balance model** representing a snapshot in time (median August)
- **Microsoft Access**
- **SYE-based unaffected streamflow**
- **Inflows/outflows**
  - PWS and Commercial Wells
  - Private Wells
  - Groundwater Discharge
  - Septic Systems
- **Sub-basin basis** but cumulative



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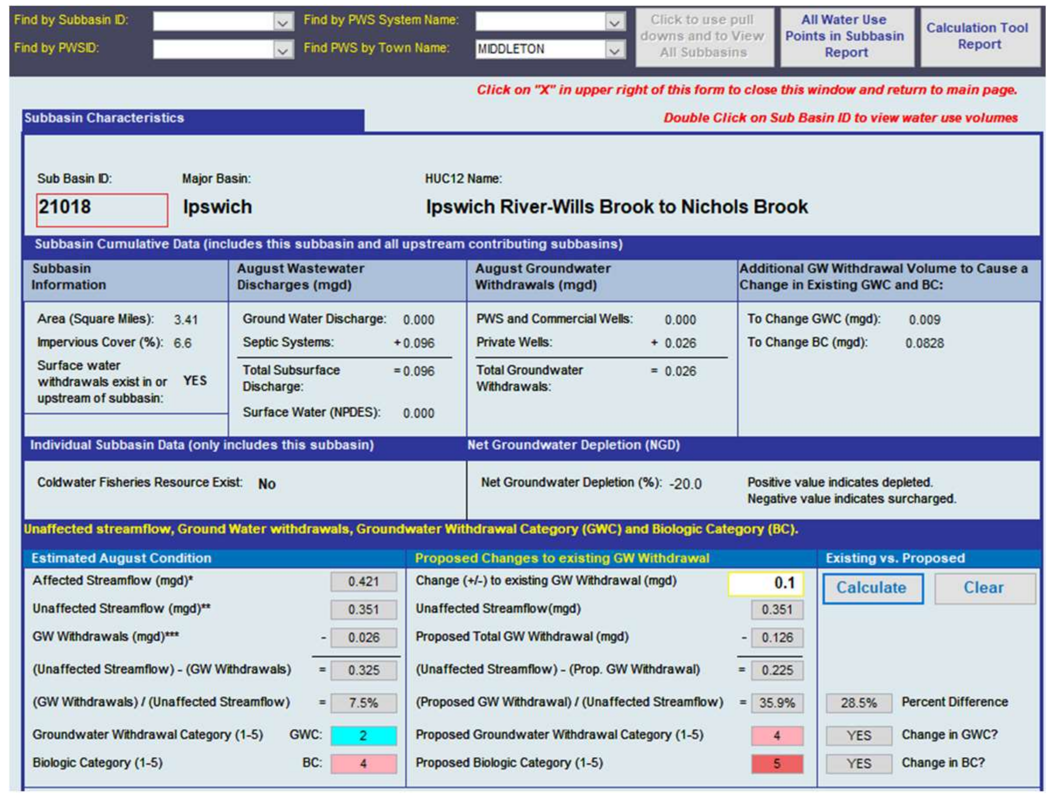
Background – WMA Tool

- **Add/subtract withdrawals**
- **Outputs GWC and BC**
- **Limitations (in our project context)**
  - Changes are constant rate, no time lag
  - Change one sub-basin at a time
  - View impacts one sub-basin at a time
  - Can't compare multiple alternatives
  - No surface water withdrawals or discharges



IRSWAM – Goals

- Evaluate **changes to multiple sources simultaneously**
- Understand how **seasonality/lag impacts effectiveness**
- Understand how **impacts propagate downstream** (watershed scale benefits)
- Build off of **peer-reviewed science and existing regulatory tools** (WMA Tool)

WSE Photo of the Winona WTP in Peabody at a low water level

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IRSWAM – Development

Called Ipswich River Streamflow and Watershed Analysis Model (IRSWAM)

- Convert to Microsoft Excel
- Disassemble model inputs to represent individual sub-basins
- Evaluate model outputs for all sub-basins, not just where changes are made
- Manipulate individual water supplies rather than sub-basin totals
- Incorporate seasonality/lag methodology
- Maintain WMA outputs (e.g. GWC, BC); estimate Affected August Median Flow too

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IRSWAM – Updated Baseline

- **PWS and Commercial Wells**
  - Significant reductions in PWS withdrawals between 2003 and 2006 (Reading & Wilmington)
  - Updated PWS and commercial withdrawals 2000-2004 (8.972 MGD) → 2018-2022 (4.217 MGD)
- **Private Well** withdrawals increased but sub-basin scale data is unavailable and basin-scale estimates vary
- **Groundwater Discharge and Septic System Discharge** have likely increased, but data is not available
- Switch from **groundwater to in-line surface water reservoirs** (Danvers-Middleton) per Task Force

In-Line Reservoir Modifications to Updated Baseline Scenario			
Waterbody	**Drainage Area (mi^2)**	**MASYE2.0 August Median Unaffected Flow (MGD)**	**Sub-Basin**
Wenham Lake	2.16	0.304	21032
Middleton Pond	2.79	0.243	21018
Emerson Brook Reservoirs	3.46	0.278	21020

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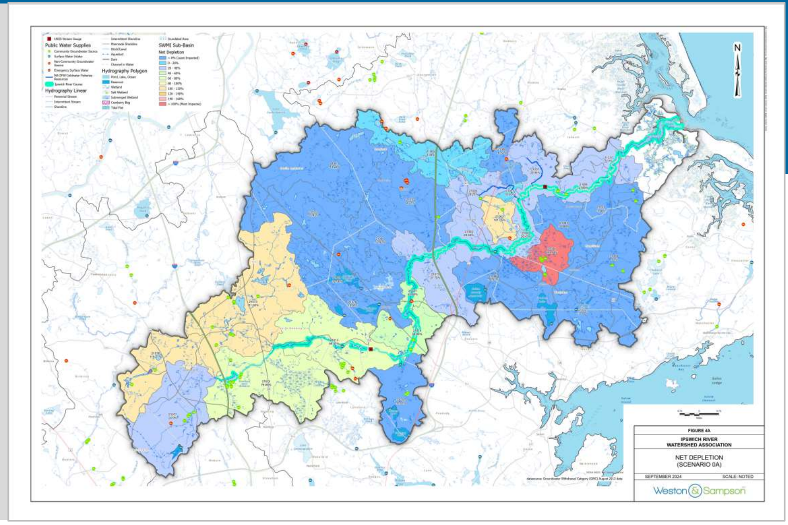
IRSWAM – Updated Baseline

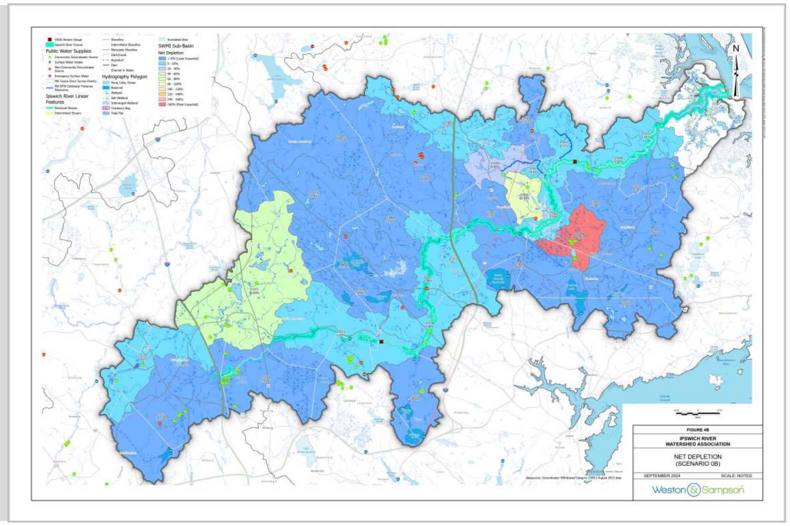
- **Flow Alteration:** 54% → 28%
- **GWC:** 3.40 → 2.82
- **Net GW Depletion:** 29% → 3%
- **BC:** 2.54 → 1.54
- **August Median Flow:** 0.168 → 0.184 cfsm (10%) = 21 → 23 cfs at the USGS gage in Ipswich (125 mi^2)

***Associated impacts to streamflow are more complex** than model outputs might suggest

Scenario 0A: Original WMA Withdrawals (2000-2004)



Scenario 0B: Updated PWS Withdrawals (2018-2022)



Water Supply Alternatives

- **Six scenarios***
- Cease town(s)-wide withdrawals May-Sept.
- Significant variation in ceased volumes (0.461 to 1.837 MGD, not including combo)
- Scenario 3 (and 6) include surface water withdrawal changes
- **Lag effect minor**

Watershed-Wide Reduction in Groundwater Withdrawals by Scenario, With and Without Accounting for a Lag in Streamflow Response

Scenario	Supplier(s)	Reduction (MGD)	Reduction with Lag (MGD)	Deviation (MGD)	Deviation (%)
1	Wilmington	1.837	1.664	0.173	9%
2	Lynnfield	0.461	0.413	0.048	10%
3*	Danvers-Middleton	0.597	0.591	0.006	1%
4	Topsfield & Ipswich	0.724	0.682	0.042	6%
5	Wenham, Hamilton & Ipswich	1.265	1.143	0.122	10%
6	Combined 1, 2, 3, 4, and 5	4.637	4.574	0.367	7%

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Results: Map Legend

USGS Stream Gauge

Public Water Supplies

- Community Groundwater Source
- Surface Water Intake
- Non-Community Groundwater Source
- Emergency Surface Water
- MA DFW Coldwater Fisheries Resources
- Ipswich River Course

Hydrography Linear

- Perennial Stream
- Intermittent Stream
- Shoreline
- Intermittent Shoreline
- Manmade Shoreline
- Ditch/Canal
- Aqueduct
- Dam
- Channel in Water

Hydrography Polygon

- Pond, Lake, Ocean
- Reservoir
- Wetland
- Salt Wetland
- Submerged Wetland
- Cranberry Bog
- Tidal Flat
- Inundated Area

SWM Sub-Basin

Change in Net Depletion

- No Change
- 0 - 10%
- 10 - 20%
- 20 - 30%
- > 30%
- Hatching indicates sub-basins that are not depleted under this alternative
- Public Water Supplies Turned Off for Scenario

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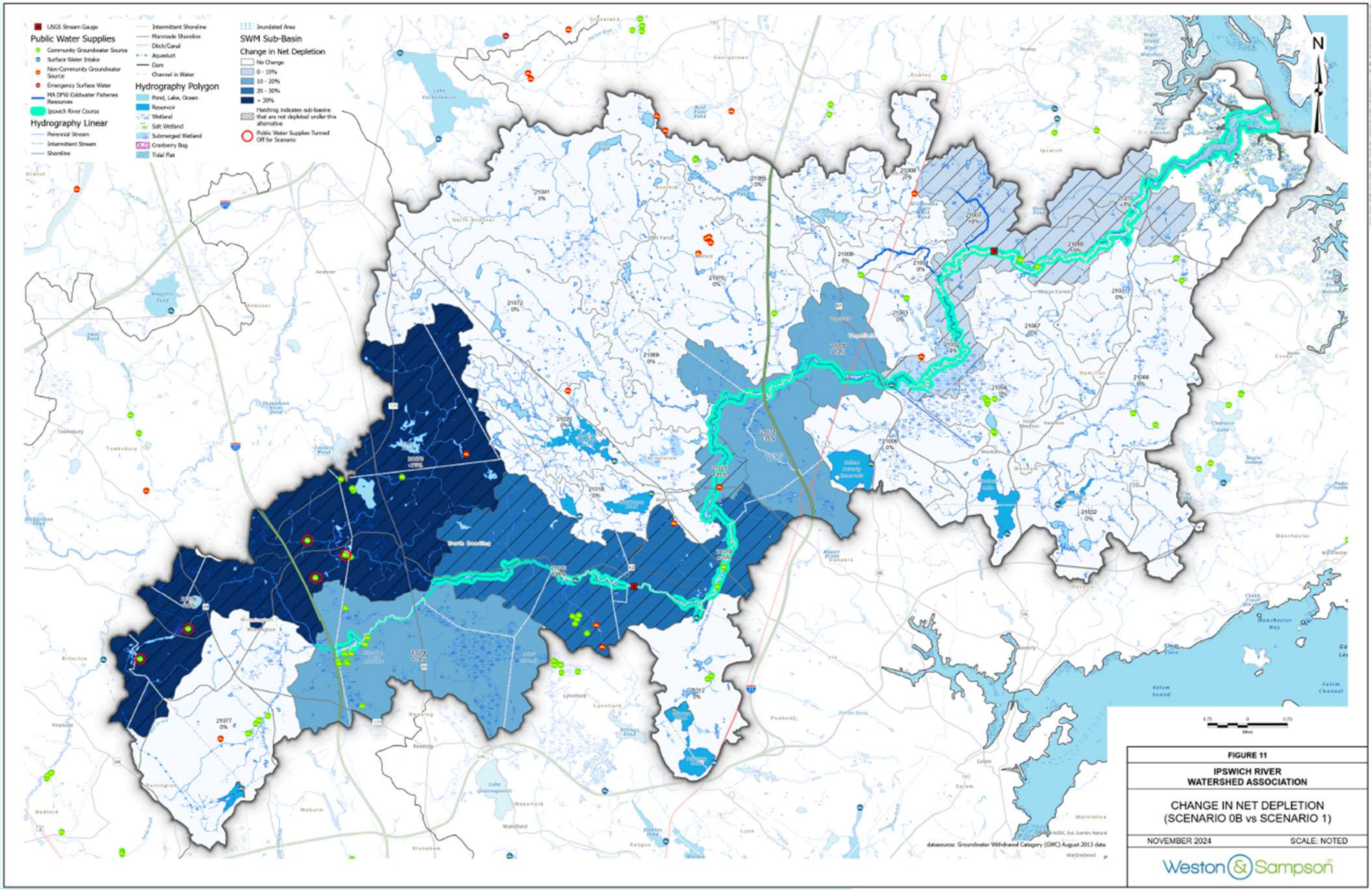
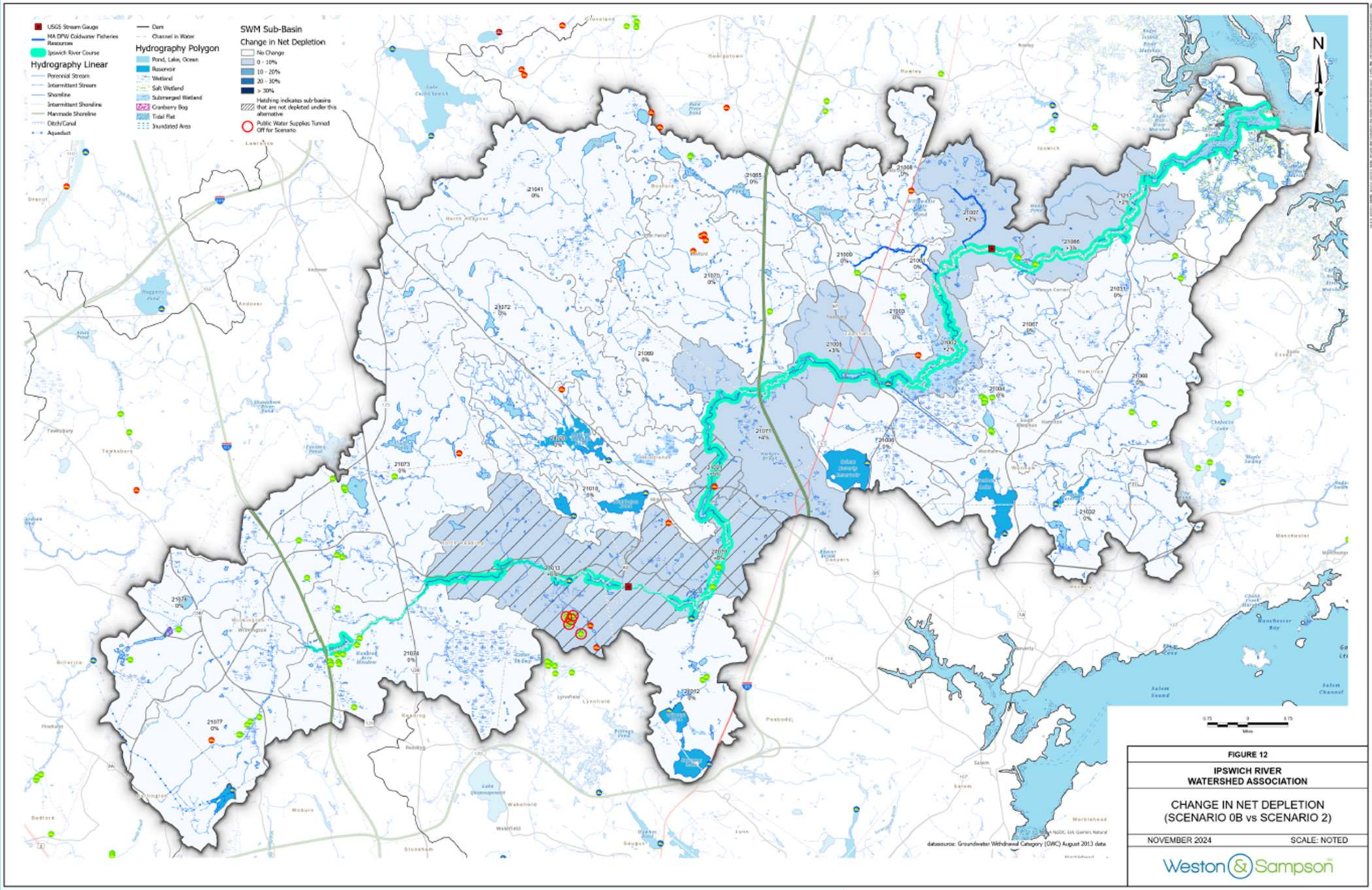
Scenario 1: Wilmington
1.837 MGD

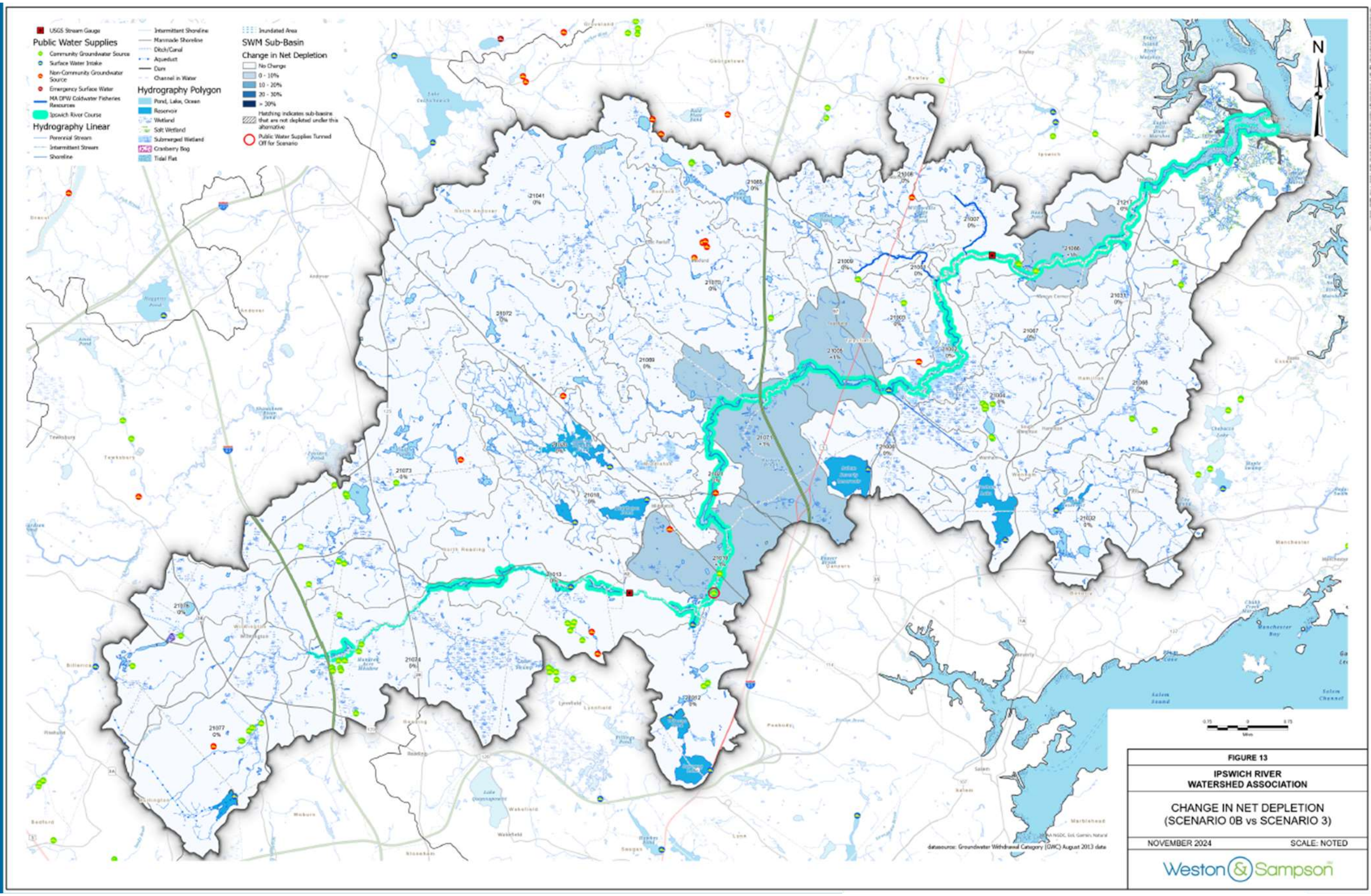


Scenario 2: Lynnfield 0.461 MGD

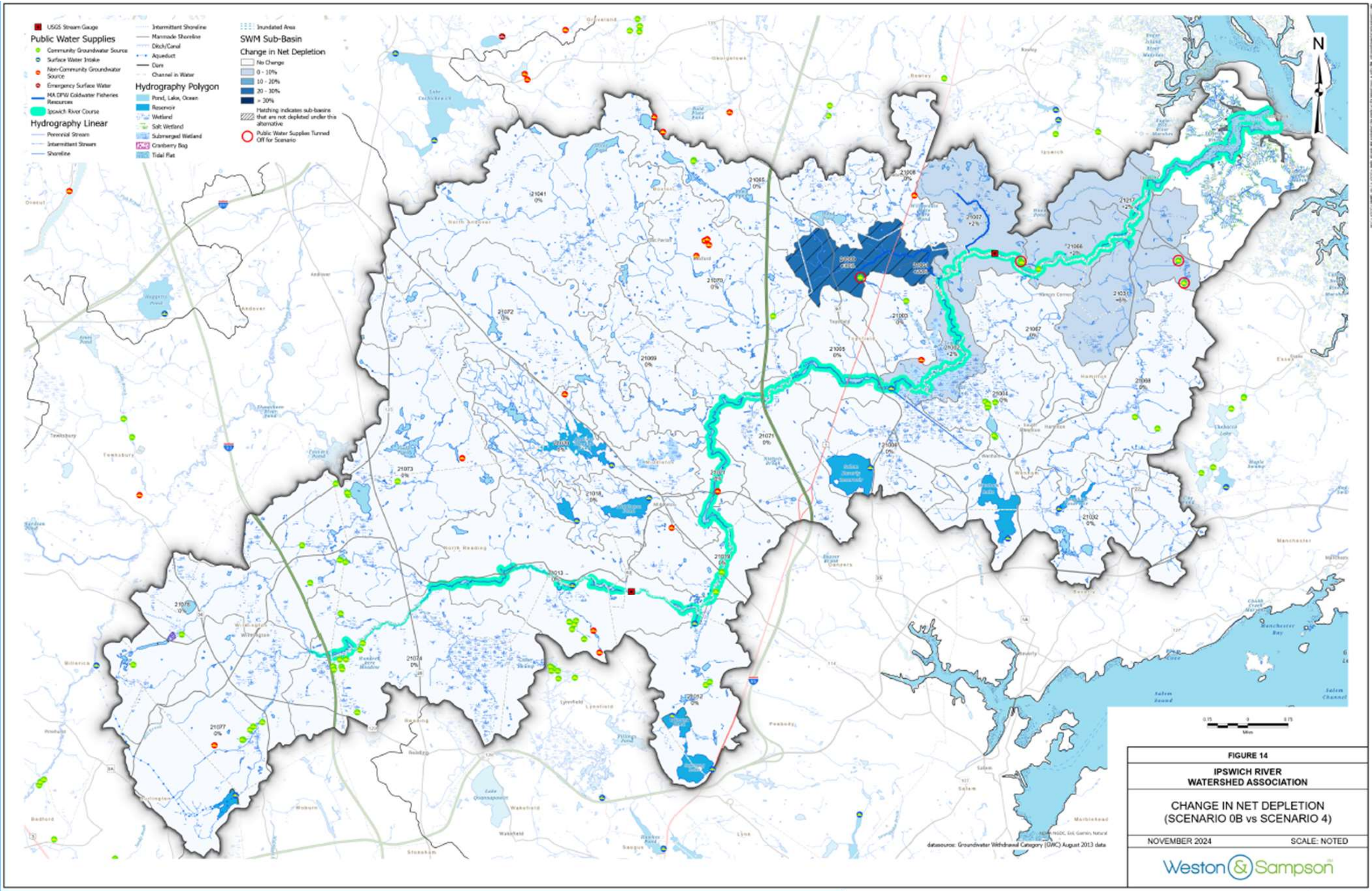


Scenario 3: Danvers-Middleton

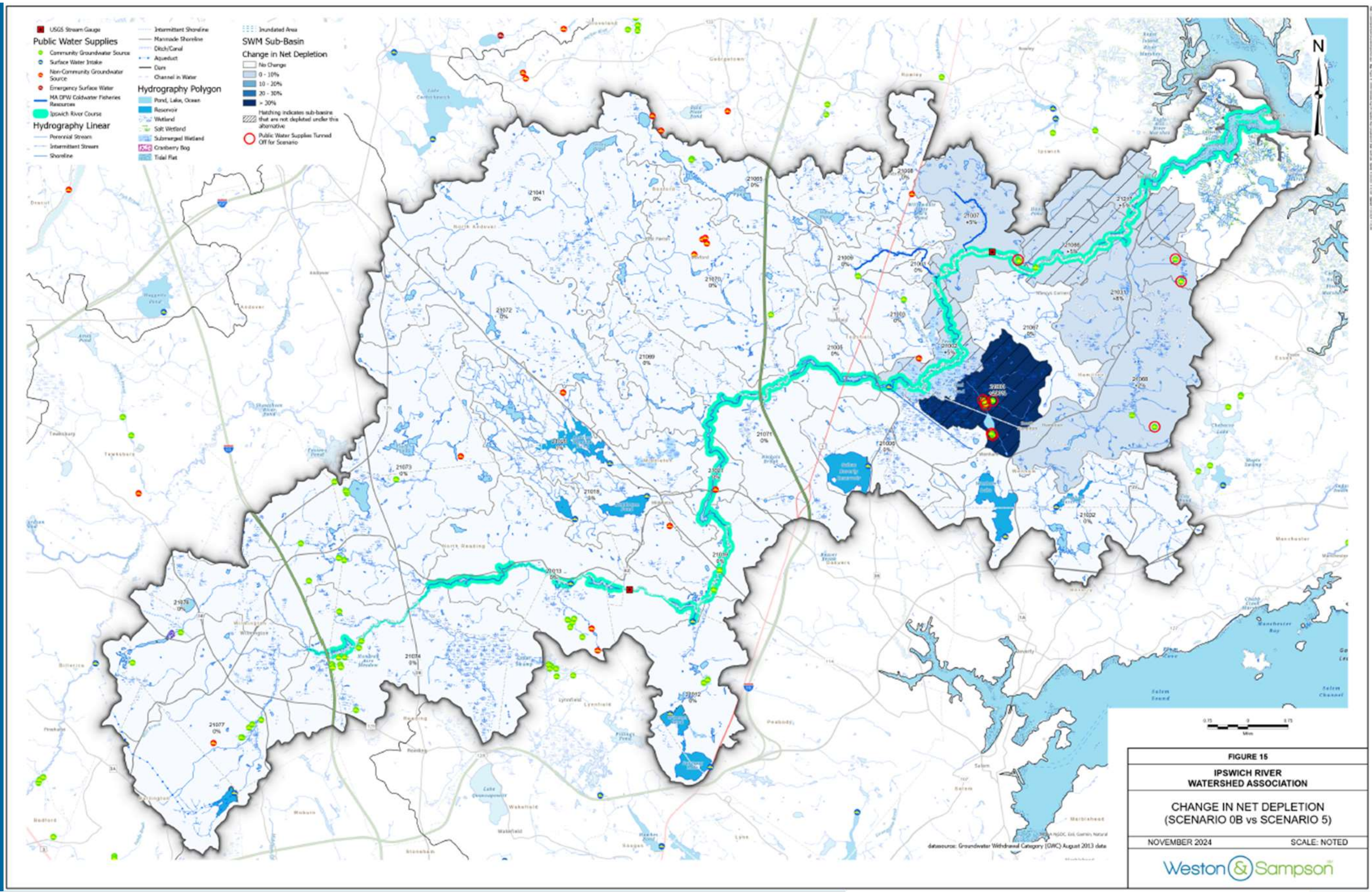
*0.901 MGD



Scenario 4: Topsfield & Ipswich 0.724 MGD

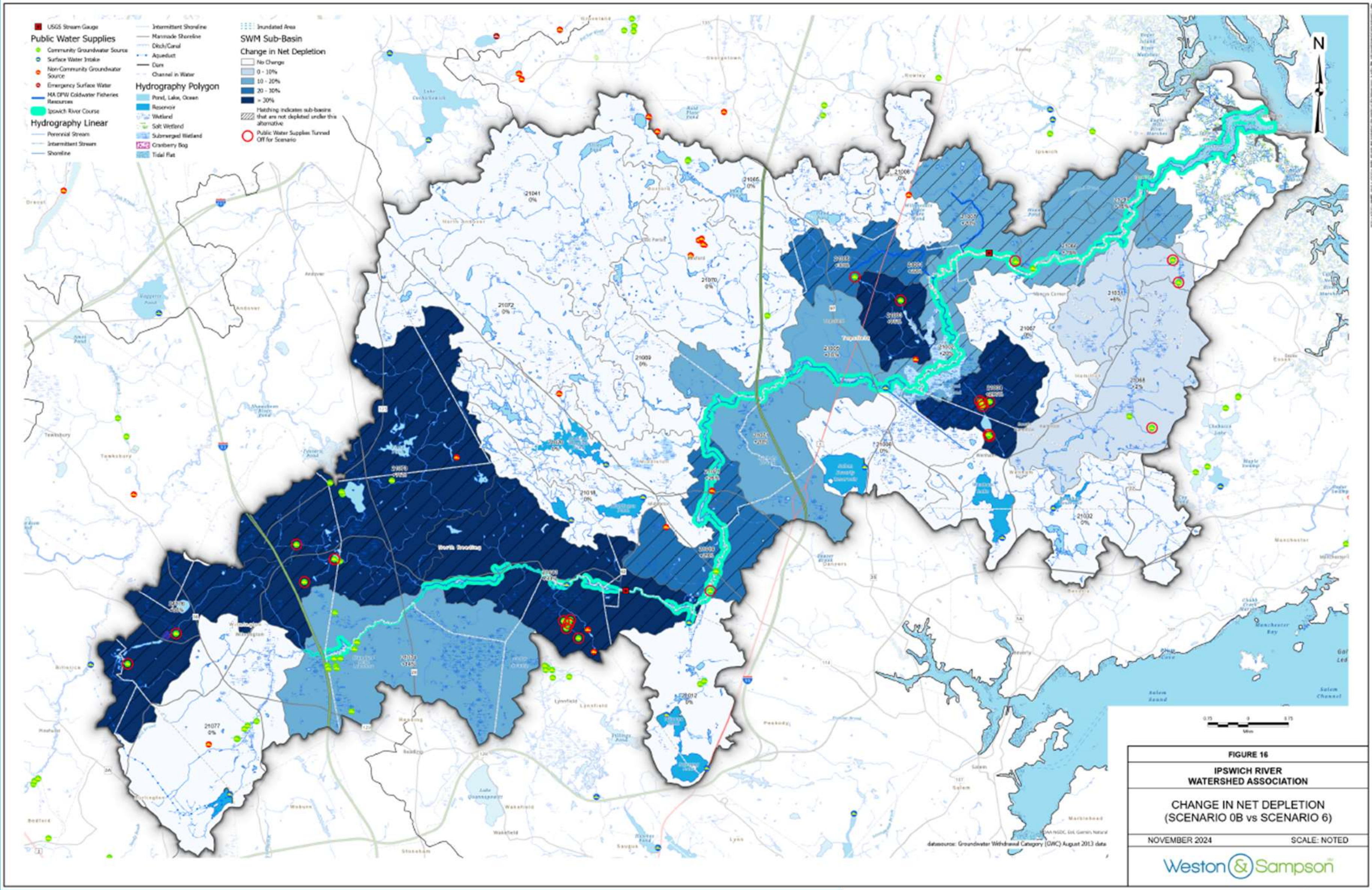


Scenario 5:
Wenham, Hamilton & Ipswich
1.265 MGD



Scenario 6: Combined 1, 2, 3, 4, and 5

4.941 MGD



Water Supply Alternatives – Watershed Scale

- **Scenario 1 is most effective** (of 1-5) across all metrics
- **Scenario 5 is 2nd most effective**
- Scenario 1 accounts for most of the Scenario 6 benefits

Watershed-Wide Weighted Averages of IRSWAM Outputs

Scenario	Flow Alteration (%)	Avg. GWC (# of Improved Sub-Basins)	Net GW Depletion (%)	Avg. BC (Flow-Only) (# of Improved Sub-Basins)	August Median Affected Flow (cfsm)
0B	27.5%	2.82 (N/A)	3.1%	1.54 (N/A)	0.184
1	14.5%	2.12 (9)	-10.0%	1.14 (5)	0.212
2	26.7%	2.80 (1)	2.2%	1.45 (3)	0.186
3*	27.5%	2.82 (0)	3.0%	1.53 (1)	0.191
4	25.9%	2.75 (4)	2.3%	1.43 (5)	0.188
5	21.6%	2.67 (4)	-2.9%	1.43 (3)	0.196
6*	6.0%	1.79 (18)	-18.4%	1.00 (9)	0.235

*Scenario 3 and 6 reductions in surface water withdrawals have no impact on WMA metrics due to how they are defined, but we have estimated a change in August Median Affected Streamflow.

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Water Supply Alternatives – Watershed Scale

- **Scenario 1 is most efficient,** even compared to the Scenario 6 combo
- **Scenario 5 is 2nd most efficient**
- Scenario 3 doesn't affect WMA/SWMI metrics but may significantly affect August median flow

Normalized Watershed and Streamflow Changes			
Scenario	Reduction in Pumping (MGD)	Δ Flow Alteration / Net GW Depletion (%)	Δ August Median Affected Flow (%)
0B	---	---	---
1	1.837	7.1%	8.3%
2	0.461	1.9%	2.5%
3*	0.597	0.1%	5.9%
4	0.724	2.3%	2.5%
5	1.265	4.7%	4.9%
6*	4.637	4.6%	6.0%

*Scenario 3 and 6 reductions in surface water withdrawals have no impact on WMA metrics due to how they are defined, but we have estimated a change in August Median Affected Streamflow.

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Things to Consider

- **PWS and commercial withdrawals were updated** from 2000-2004 WMA defaults to 2018-2022 data, but discharges and private wells were not updated
- **Built from regulatory guidance tools,** not numerical models of instream flow
- **Mass balance model** of August median conditions
- **Supports relative comparisons,** not identification of absolute values

Key Takeaways

- 90+% of withdrawal **reductions are experienced instream within 3 months**
- **Upstream reductions can have a trickle-down effect** that makes them more efficient
- Scenarios 1 and 5 were **both effective and efficient**

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Thank You

Any Questions?

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