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

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Assessment of Water Supply Alternatives Using the New Ipswish River Streamflow and Watershed Analysis Model (IRSWAM)





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







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





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

Find by Subbasin ID: Find by PWSID:	Find	by PWS Syste PWS by Town	em Name: n Name:	MIDDLETON	Click to use p downs and to All Subbasi	oull View ns	All Water Points in Sul Repor	lse basin	Calculation Tool Report
Subbasin Characteristics				Click on "X" in upper rig	ht of this form t Double Clie	o close t ck on Su	his window a b Basin ID to	nd retui view wa	rn to main page. ater use volumes
Sub Basin ID: Major Basin: 21018 Ipswich			HUC12 Name: Ipswich River-Wills Brook to Nichols Brook						
Subbasin Cumulative Data (inc	August Waster	asin and all u water	upstream	contributing subbasins)		Additio	nal GW Witho	irawal V	folume to Cause a
Information	Discharges (m	gd)		Withdrawals (mgd)		Change	in Existing (WC and	BC:
Area (Square Miles): 3.41 Impervious Cover (%): 6.6 Surface water withdrawals exist in or YES upstream of subbasin:	Ground Water D Septic Systems Total Subsurfac Discharge: Surface Water	Discharge: () :: + () :e = () (NPDES): ()	0.000 0.096 0.096 0.096	PWS and Commercial Wells: Private Wells: Total Groundwater Withdrawals:	0.000 + 0.026 = 0.026	To Cha To Cha	unge GWC (mg unge BC (mgd)	d): 0 : 0.	009
Individual Subbasin Data (only i	ncludes this sub	obasin)		Net Groundwater Depletion	n (NGD)				
Coldwater Fisheries Resource Ex	Coldwater Fisheries Resource Exist: No			Net Groundwater Depletion (%): -20.0 Positive value indicates depleted. Negative value indicates surcharged.					
Unaffected streamflow, Ground	Water withdraw	als, Ground	water Wit	hdrawal Category (GWC) ar	nd Biologic Cate	gory (BC	c).		
Estimated August Condition			Propose	ed Changes to existing GW	Withdrawal		Existin	ıg vs. Pr	roposed
Affected Streamflow (mgd)* Unaffected Streamflow (mgd)** GW Withdrawals (mgd)***		0.421	Change (Unaffection	+/-) to existing GW Withdrawa ed Streamflow(mgd) 1 Total GW Withdrawal (mod)	il (mgd)	0.35	1 Calo	ulate	Clear
(Unaffected Streamflow) - (GW W	thdrawals) =	0.325	(Unaffec	ted Streamflow) - (Prop. GW V	Vithdrawal) ed Streamflow)	= 0.22	5	% De	ercent Difference
Groundwater Withdrawal Category Biologic Category (1-5)	(1-5) GWC: BC:	2	Proposed	d Groundwater Withdrawal Ca d Biologic Category (1-5)	tegory (1-5)	4	YE	S Ch	nange in GWC?





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

Find by Subbasin ID: Find by PWSID:	Find by PWS S	ystem Name: MIDD	LETON V	Click to use pul downs and to Vie All Subbasins	All Water Use Points in Subbasin Report	n Calculation Tool Report
Subbasin Characteristics		Click	: on "X" in upper rig	ht of this form to c Double Click	lose this window and re on Sub Basin ID to view	turn to main page. water use volumes
Sub Basin ID: Ma 21018 Ip	njor Basin: DSWICh	HUC12 Name: Ipswich F	River-Wills Broo	ok to Nichols	Brook	
Subbasin Cumulative Data	a (includes this subbasin and a August Wastewater	all upstream contri Augu	buting subbasins) st Groundwater	A	dditional GW Withdrawa	I Volume to Cause a
Area (Square Miles): 3.41 Impervious Cover (%): 6.6 Surface water withdrawals exist in or Yf upstream of subbasin:	Ground Water Discharge: Septic Systems: Total Subsurface Discharge: Surface Water (NPDES):	0.000 +0.096 = 0.096 0.000	and Commercial Wells: e Wells: Groundwater rawals:	0.000 + 0.026	To Change GWC (mgd): To Change BC (mgd):	0.009 0.0828
Individual Subbasin Data (Coldwater Fisheries Resour	only includes this subbasin) ce Exist: No	Net Gr	oundwater Depletion Groundwater Depletion	n (NGD) (%): -20.0	Positive value indicates de Negative value indicates su	pleted. Ircharged.
Unaffected streamflow, Gro	ound Water withdrawals, Grou	ndwater Withdraw	al Category (GWC) ar	nd Biologic Catego	ry (BC).	
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Groundwater Withdrawal Ca Biologic Category (1-5)	tegory (1-5) GWC: 2 BC: 4	Proposed Groun Proposed Biolog	dwater Withdrawal Ca ic Category (1-5)	tegory (1-5)	4 YES 5 YES	Change in GWC? Change in BC?





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





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



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			





IRSWAM – Updated Baseline

- Flow Alteration: $54\% \rightarrow 28\%$
- **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 mi²)
- *Associated impacts to streamflow are more complex than model outputs might suggest







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%		





Results: Map Legend

USGS Stream Gauge Public Water Supplies Community Groundwater Source ٠ Surface Water Intake 8 Non-Community Groundwater 0 Source **Emergency Surface Water** • MA DFW Coldwater Fisheries Resources Ipswich River Course Hydrography Linear Perennial Stream Intermittent Stream

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

Hydrography Polygon

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

SWM Sub-Basin Change in Net Depletion

- No Change
- 0 10%
- 10 20%
- 20 30%
- > 30%



Public Water Supplies Turned Off for Scenario





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



Wenham, Hamilton & Ipswich Scenario 5: 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.





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)	∆ Flow Alteration / Net GW Depletion (%)	∆ August Median Affected Flow (%)		
OB					
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.





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
 <u>efficient</u>
- Scenarios 1 and 5 were both effective and efficient



Thank You

Any Questions?



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