APPENDIX C

ESTUARY IMPACT ASSESSMENT

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Potential Great Bay estuary water quality impacts by alternatives are summarized qualitatively in Table 1.

Table 1 – Potential Great Bay Estuary Water Quality Impacts by Alternative				
Parameter	**Alternatives**			
	1 No Action	2 Regional Gulf of Maine Discharge	3 Decentralized Treatment plus Existing WWTFs	4 Existing WWTFs with Land Application
Flows	WWTF flows are projected to increase by an average of about 8.2% from 2004 to 2025.	WWTF flows to the estuary would be entirely eliminated.	Direct WWTP discharges to the estuary would increase by about 2.7%, and indirect discharge would increase by about 5.5%[1].	Direct WWTF discharges to the estuary would be eliminated. Indirect discharges would increase by about 8.2%[1].
Salinity	Decreased salinity due to increased WWTF flows to river.	Increased salinity due to decreased WWTF flows to rivers.	Slightly decreased salinity when decentralized systems wastewater reaches the estuary[1].	Decreased salinity when land applied wastewater reaches the estuary[1].
Dissolved oxygen	Small changes, due to reductions in BOD and nutrient loadings, where regulatory requirements become more stringent[2].	Small increase in DO levels due to reduced BOD and nutrient loadings[3].	Small changes, due to reductions in BOD and nutrient loadings, where regulatory requirements are strengthened[2].	Increase in DO levels due to reduced BOD and nutrient loadings[3].
Eutrophication[4]	Some changes due to reductions nutrient loading where regulatory requirements become more stringent[2].	Reduced eutrophication due to eliminated nutrient load[5].	Some changes due to reductions nutrient loading where regulatory requirements are strengthened[2].	Reduced due to nitrogen limit of 10mg/l for land application, and travel time[6].
Pathogens	No change.	Eliminated risk of accidental discharge.	No change.	Eliminated risk of accidental discharge.
Toxics	Slight increase due to increased flow and incomplete removal during treatment.	Eliminated.	Slight increase due to minor increases in future flows.	Largely eliminated, since many toxics do not travel in groundwater.

Notes:
[1] Indirect discharges to the Great Bay are for land application discharges that will eventually reach the estuary through groundwater flow.
[2] Regulatory limits are projected to be more stringent for some plants.
[3] The increase in DO will be small inasmuch as current DO deficits are generally low and occasional deficits exceeding 25% of saturation may not be related to the WWTF discharges (NHEP, 2006).
[4] Eutrophication effects include increased turbidity and algae and reduced eelgrass.
[5] Nitrogen loadings from WWTFs will be eliminated representing about 34% of all nitrogen loadings to Great Bay and Upper Piscataqua River.
[6] Some additional nitrogen reduction would occur in groundwater as the effluent plume travels. Plumes would take several years to reach the estuary.

Methodology

The impacts of the alternatives on salinity were estimated quantitatively using a two-dimensional model developed at the University of New Hampshire by Jon P. Scott. The model utilizes the RMA-2 and RMA-4 software (Donnell, Letter and McAnally, 2003; Letter and Donnell, 2003). The model is a finite elements model with triangular and quadrilateral elements of varying sizes. The model extends from the Piscataqua River mouth in Portsmouth to the dams in each of the rivers discharging to the estuary system. The model grid is shown in Figure 1.

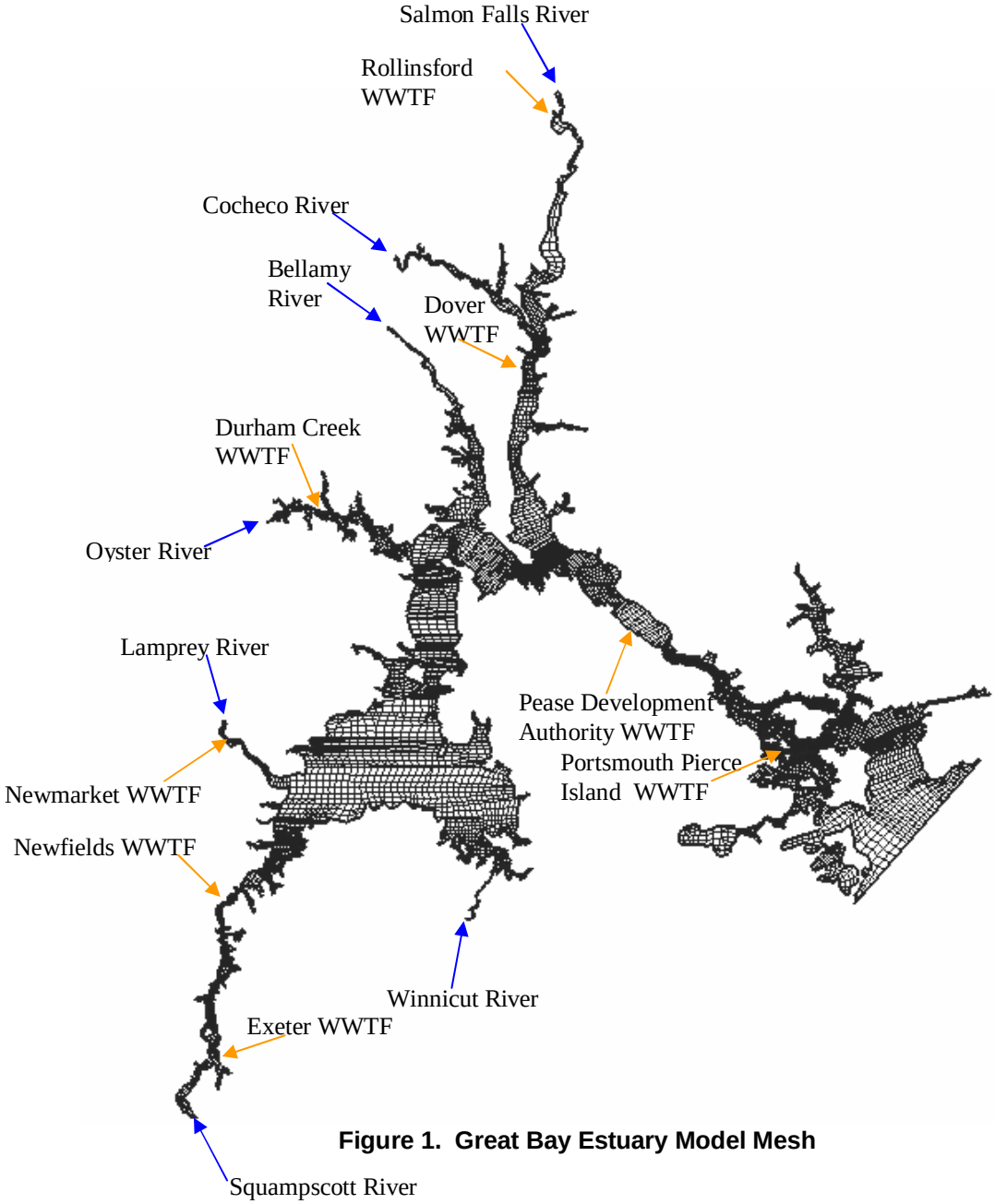


Figure 1. Great Bay Estuary Model Mesh

The hydrodynamic model, RMA2, was calibrated to tide levels at various points in the Great Bay estuary by Jon Scott. The water quality model, RMA4 was calibrated to salinity data in this study. The primary data that were used for the calibration are continuous salinity measurements at a number of monitoring locations throughout the Great Bay system, as shown in Figure 2. The data were collected as part of the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) Great Bay Real-Time Environmental Monitoring Network. The data are available on the Internet at http://www.greatbaydata.org/arc_port.php.

Figure 2. Model Calibration Points

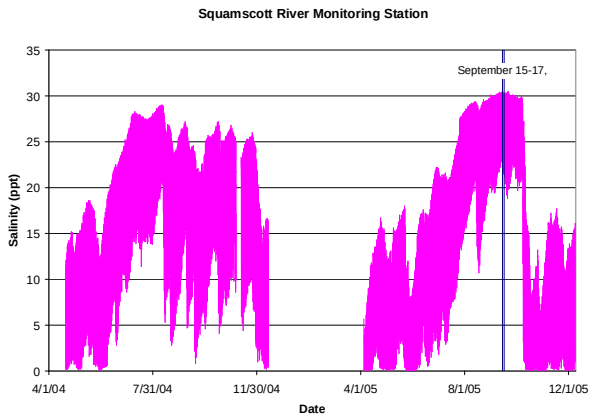
The CICEET monitoring has salinity data at 15-minute intervals from April 2004 to December 2005, with some interruptions. These data are plotted in Figure 3. Because of the compressed time scale, details are not visible, but general features are apparent. Considerable variations of salinity occur during the tide cycle as well as seasonally. The larger tidal variations are observed at the stations in the tributaries. A possible reason for this observation is that at least during some parts of the year, the rivers are vertically stratified with less saline river water near the surface and denser saline waters near the bottom. Since the monitoring instruments are typically located near the bottom, the variations they record are a combination of temporal and depth variations of salinity. At the Great Bay Monitoring Buoy, salinity variations during the tide cycle are more muted, likely because the instruments are attached to the buoy and therefore at a fixed depth below the surface.

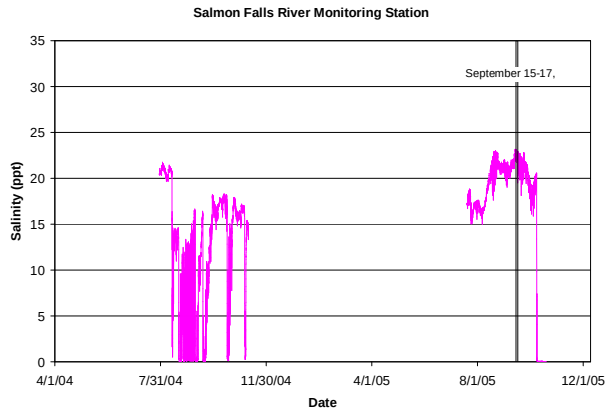
On a seasonal basis, salinity is highest in the fall when the river lows are low and lowest in the spring and other times when the river flows are high.

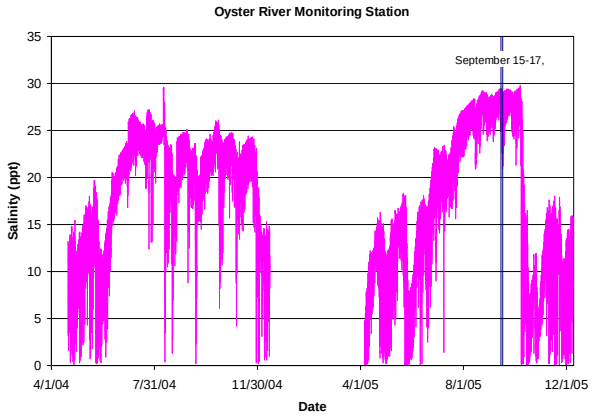
The impact of removing the wastewater treatment plant discharges on salinity would be greatest during periods of low river flows, when the WWTF discharge flows represent a higher fraction of the river fresh water discharge to Great Bay. Therefore, the model was calibrated for a period of low flows – September 15-17, 2005. For this period, the flow at the Oyster River USGS gauge was on the order of 2.4 cfs, which is low, but somewhat above the 7Q10 flow of 0.45 cfs for this gauge. Comparable relationships with 7Q10 can be assumed for the other rivers. The 7Q10 river flows are compared to the plant flows in Table 2.

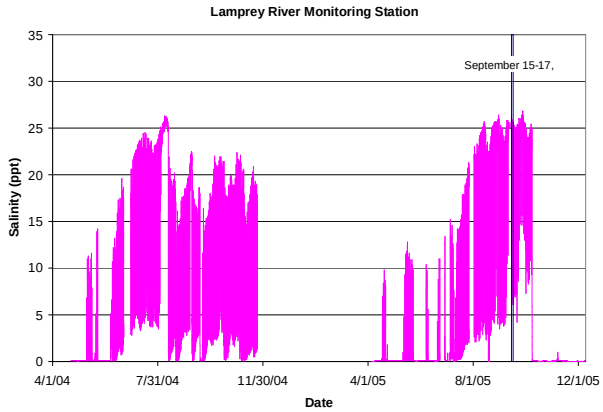
The transport model, RMA-4, was run for several tide cycles repeated for about 60 days, to allow calculated salinities to stabilize. A salinity of 31.5 ppt was specified at the estuary mouth. During the model calibration process, the diffusion coefficient, E, and Manning's coefficient, n, were varied, but they were found to have little effect on the calculated salinities. The final values that were used were E = 1 m^2/s and n = 0.02.

The measured and calculated salinities at the CICEET stations for the calibration period are shown in Figure 4. Also shown on these plots are salinity measurements made in September 1975 (Silver and Brown, 1979). The calculated salinities are lower than the 2005 measurements for the river stations, but very close to the measurements for the Great Bay station. The difference for the river stations is attributed to the fact that the model calculates depth averaged salinities, while the measurements are at depth, in the lower, more saline layer. At the Great Bay Station, stratification can be expected to be less, and the model closely matches the measurements. The 1975 data are generally closer to the model predictions.









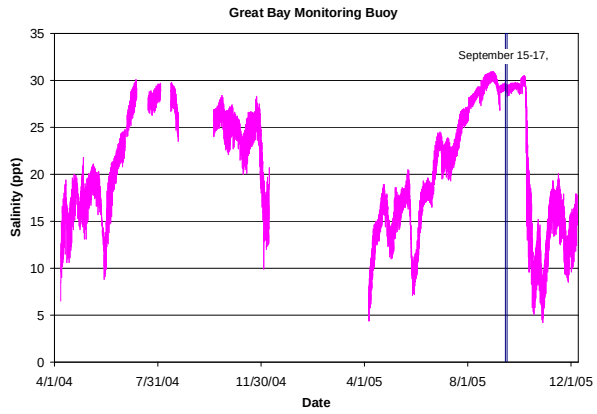


Figure 3. CICEET Salinity Data

Table 2. River and Plant Flows

River			River Flow				Plant Flow		
			Reported 7Q10 (cfs)	Drainage Basin Area (mi^2)	7Q10/mi^2 (cfs/mi^2)	Calculated 7Q10 (cfs)	Permit (cfs)	Annual Average (cfs)	September Average (cfs)
Salmon Falls River	USGS Gauge	No. 01072100 - SF River @ Milton		108					
	Dam	Rollinsford Dam		238		9.52 (2)			
	Downstream Plant	Rollinsford WWTF	28.7 (1)				0.23	0.15	0.14
	Upstream Plants	South Berwick Maine WWTF							
		Somersworth WWTF	28.7 (1)				3.72	1.72	1.47
		Milton WWTF	25.4 (1)				0.15	0.09	0.09
Cocheco River	USGS Gauge	No. 01072800 Cocheco River		85.7					
	Dam	Central Avenue Dam		107.5		6.07			
	Downstream Plants	None							
	Upstream Plants	Rochester WWTF	4.74 (1)	85.7	0.055		6.08	4.66	3.99
		Farmington WWTF	2.52 (1)	43.8	0.058		0.54	0.33	0.27
Bellamy River	USGS Gauge	None							
	Dam	Sawyer Mill Dam		81.3		3.252 (2)			
	Downstream Plants	None							
	Upstream Plants	None							
Oyster River	USGS Gauge	No. 01073000 Oyster River	0.45	12.1	0.037				
	Dam	Mill Pond Dam		33		1.22			
	Downstream Plant	Durham Creek WWTF					3.87	1.58	1.62
	Upstream Plants	None							
Lamprey River	USGS Gauge	No. 01073500 Lamprey River		183					
	Dam	Macallen Dam		190.6		5.06			
	Downstream Plant	Newmarket WWTF	4.9 (1)	183.0	0.027		1.32	0.98	0.84
	Upstream Plant	Epping WWTF	3.0 (1)	114.0	0.026		0.77	0.29	0.26
Squamscott River	USGS Gauge	None							
	Dam	Exeter River Dam		105		4.20 (2)			
	Downstream Plant	Exeter WWTF					4.64	3.49	3.00
		Newfields WWTF					0.18	0.27	0.25
	Upstream Plants	None							
Winnicut River	USGS Gauge	None							
	Dam	Winnicut River Dam		19.9		0.80 (2)			
	Downstream Plants	None							
	Upstream Plants	None							
Plants discharging directly to Great Bay		Dover WWTF					7.27	4.25	3.46
		Pease & Newington WWTFs (3)					2.31	0.95	0.80
		Portsmouth Pierce Island WWTF					6.96	7.31	5.60
		Portsmouth Schiller WWTF							
Total						30.12	38.05	26.06	21.80

Notes
(1) From NPDES Permit
(2) 7Q10 flow calculated as drainage basin area multiplied by average ratio of 0.040 cfs/mi^2
(3) Pease Development Authority WWTF and the Newington WWTF are entered into the model as a single flow

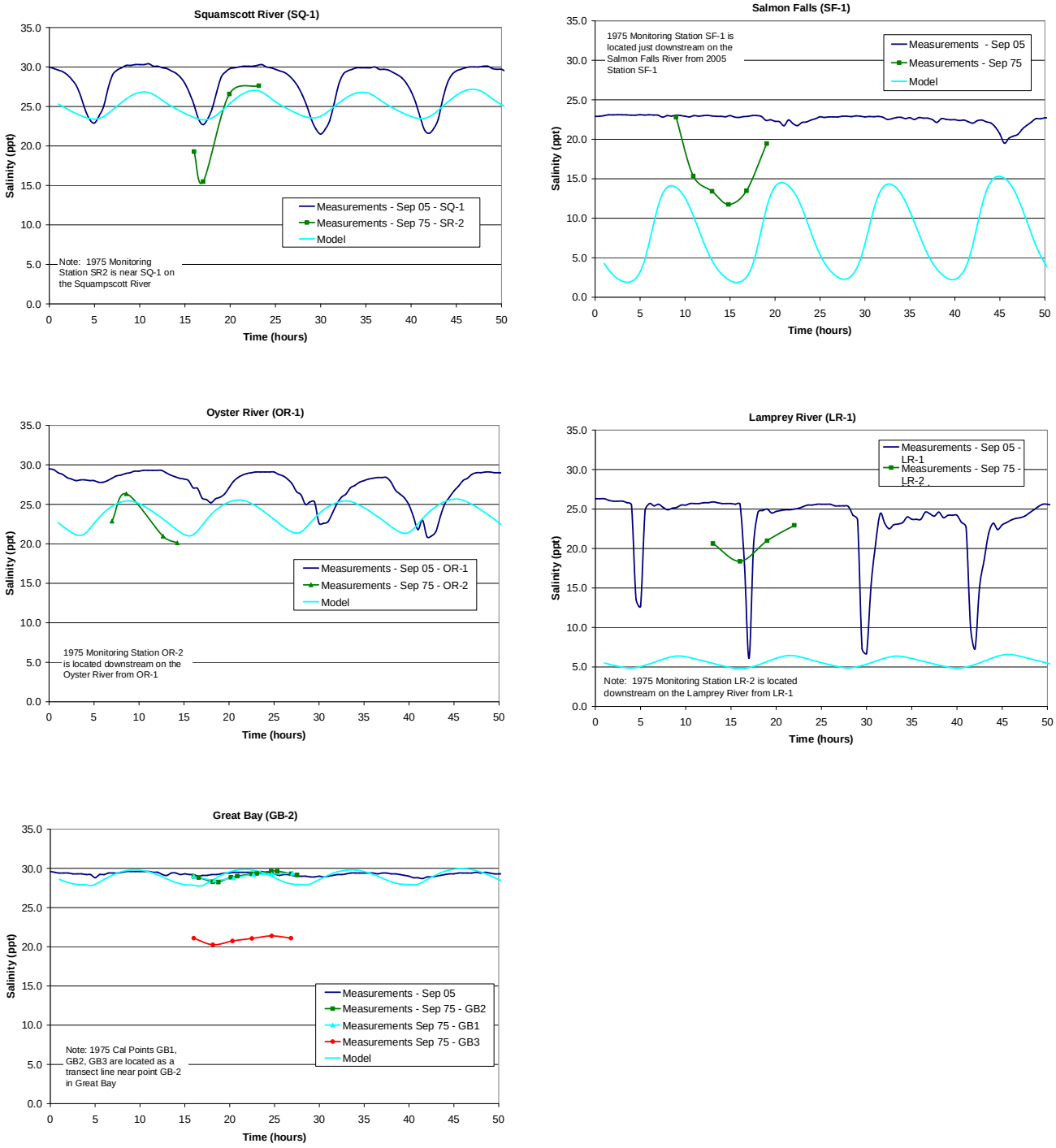


Figure 4. Salinity Model Calibration and Application

Impact Evaluation

Model simulations were conducted for current WWTF discharge conditions, as well as Alternatives 1 (No Action) and 2 (Gulf of Maine Discharge). In Alternative 1, the WWTF flows increase by an average of 8.2% compared to current conditions. In Alternative 2, the WWTFs no longer discharge to the estuary system. As shown in Table 2, during 7Q10 conditions, the total flow discharged by the rivers is 30.1 cfs, while the average WWTF discharge in September (when low river flows typically occur) is 21.8 cfs, or 72% of the river flows.

Compared to the tidal flows, the volume of water discharged by the rivers during one tide cycle is on the order of 1% of the tidal prism (volume of water flowing in and out of the estuary during one tide cycle) (Ertürk et al, 2002). During low flow periods, the river flow is an even smaller fraction of the tidal flow.

Calculated salinities for the three simulations (existing conditions, Alternative 1 and Alternative 2) are shown in Figure 5 for different locations in the estuary system under 7Q10 flow conditions. In general, the impact of increasing the plant flows (in Alternative 1) or removing them (in Alternative 2) on salinity is quite small, on the order of 1 ppt or less. This impact is much less than the natural variability of salinity concentrations. During high flow periods, the effect of WWTF flow changes would be even less.

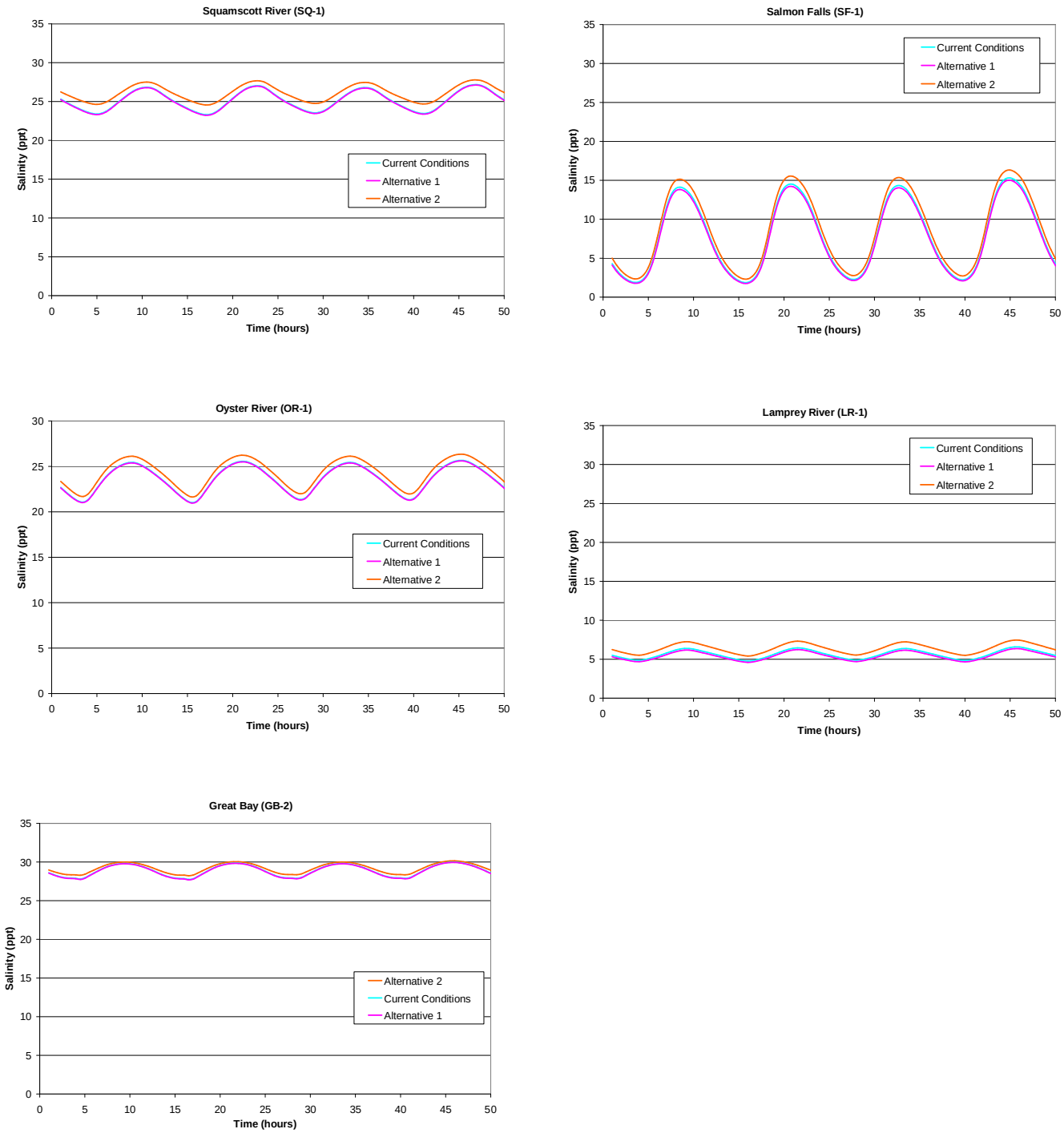


Figure 5. Model Salinity Predictions for Current Conditions and Alternatives 1 and 2 for 7Q10 River Flows

References

Bolster, C.H., Jones, S.H. and Bromley, J.M. 2003. Evaluation of Effects of Wastewater Treatment Discharges on Estuarine Water Quality. University of New Hampshire, New Hampshire Estuaries Project.

Donnell, B.P., Letter J.V. McAnally, W.H. 2003. Users Guide for RMA2 Version 4.5. US Army, Engineer Research and Development Center.

Ertürk, S.N., Bilgili, A., Swift, M.R., Brown, W.S., Çelikkol, B., Ip, J.T.C. and Lynch, D.R. 2002. Simulation of the Great Bay Estuarine System: Tides with Tidal Flats Wetting and Drying. Journal of Geophysical Research, Vol. 107, No. C5.

Letter, J. V. and Donnell, B. P. 2003. Users Guide for RMA4 Version 4.5. US Army, Engineer Research and Development Center.

New Hampshire Estuary Project. 2006. State of the Estuaries.

Silver, A.L. and Brown, W.S. 1979. Great Bay Estuarine Field Program. 1975 Data Report, Part 2: Temperature, Salinity and Density. Report No. UNH-SG-163, University of New Hampshire Sea Grant.