Tidal Culvert Analysis in Georgetown, ME

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Background & Objectives

Flying Point Road culvert (left) and Williams Road culvert (right)

Georgetown is a coastal Maine town with over 200 culverts, most of which were surveyed and analyzed by past student groups. This year's project focused on two culverts that carry tidal channels beneath marsh-top roads. Tidal culverts must support two-way flow and are more difficult to analyze.

The Flying Point Road culvert is a 5' circular corrugated metal pipe. The single-lane gravel road above it connects one household to the Georgetown mainland and serves as a walking route to conservation land managed by the Kennebec Estuary Land Trust (KELT). The crossing frequently floods and the water levels do not appear even upstream and downstream of the culvert at times.

The Williams Road culvert is a 15ft-wide pipe-arch corrugated metal pipe. The State of Maine installed it in 1997 to replace a rotting wooden bridge, but the town owns the paved road above it that connects six households to the Georgetown mainland. The crossing approaches on the marsh occasionally flood at high tide.

Each crossing was studied to determine if the culvert restricted tidal flow and if surrounding marsh vegetation showed evidence of tidal restriction. Recommendations were made to improve flow at Flying Point Road and prevent future flooding at Williams Road.

The Community Scientist Culvert Monitoring Program, started by past student groups to evaluate predicted culvert performance, was continued for 2020-21. A training was held to refresh the volunteers in Georgetown on how to monitor rainfall intensity and photograph assigned culverts around town during ≥ two-year rain events.

Field Work & Data Processing

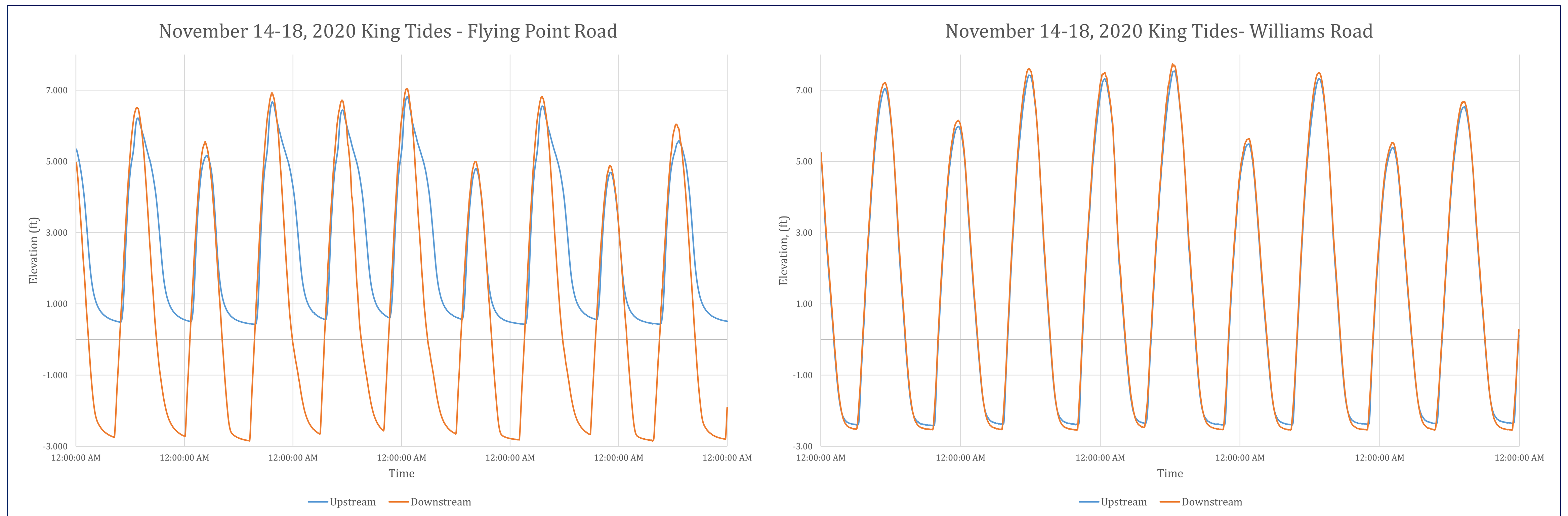
Surveys of the Flying Point Road and Williams Road culverts were completed in September and November 2020 primarily using a laser level, manual level, rod, and tape measure. At each site, students documented the crossing properties, took channel elevation profiles and representative cross-sections upstream and downstream, installed water level loggers upstream and downstream, and measured vegetation elevations in visually distinct clusters around the crossing. The segment of Williams Road spanning the marsh was also surveyed. Ruth Indrick of KELT and Bill Bennett of US Fish & Wildlife guided the September survey.

Water level data from September 26 to November 27 were converted from units of pressure (psi) to length of water (ft) and adjusted to NAVD 88. A local tidal datum of mean high-high water, mean high water, mean low water, and mean low low water was calculated for each site. The upstream and downstream water levels at each site were compared to evaluate tidal restriction.

Vegetation elevations were adjusted to NAVD 88, the intraspecies mean and standard deviation upstream and downstream of the crossing were calculated, and the means were compared with t-test of a 95% confidence level for each species at each site. Ruth Indrick and Bill Bennett were consulted to interpret the results.

Williams Road survey elevations were adjusted to NAVD 88 and compared to the minimum road elevation of 13.27ft above mean low low water needed to prevent flooding under 100-year storm surge conditions and the intermediate sea level rise forecast for 2100. Research was conducted on the road's construction history and marsh soil compaction to account for the additional load of raising the road.

Tidal Restrictions

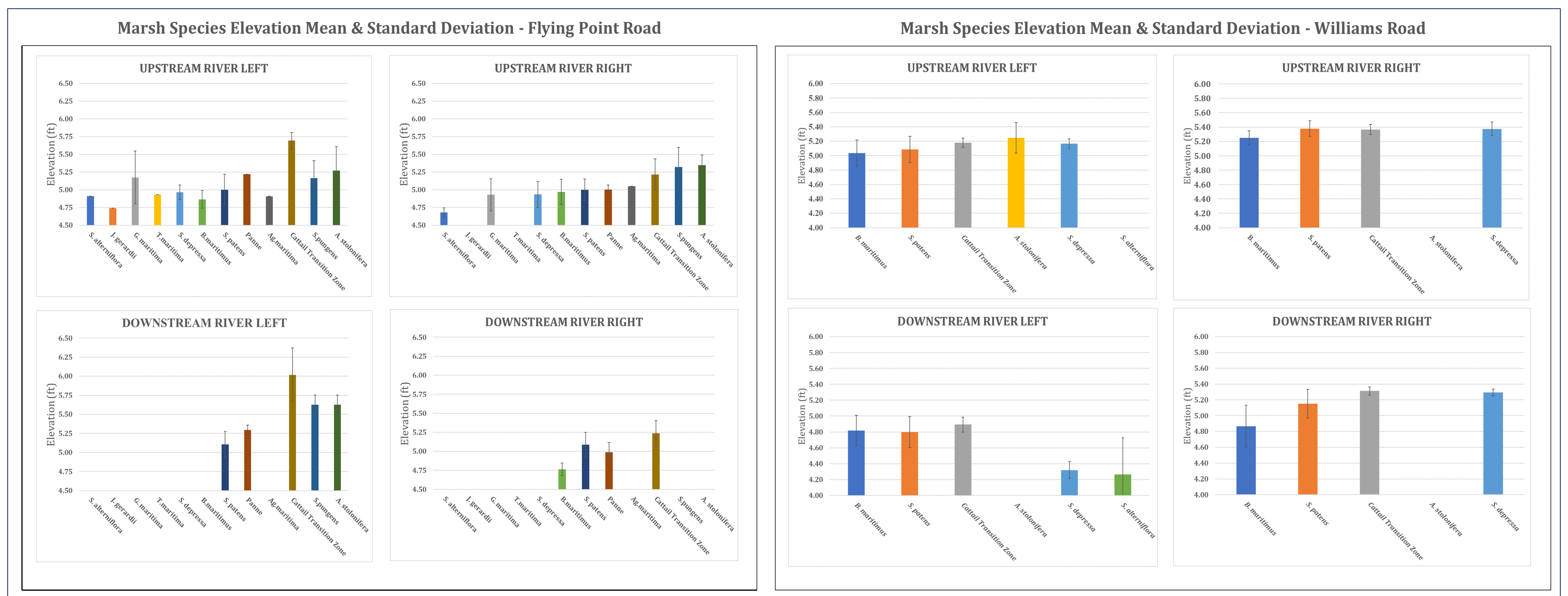


Water levels are displayed for each crossing during the annual king tides from November 14-18, 2020.

The Williams Road upstream and downstream water levels (right) are roughly equal throughout the cycles.

The Flying Point Road data (left) show that the upstream water level never reaches the low tide level during ebb tide and approaches its minimum water level exponentially. The rate of decrease of the upstream water level during the highest tides changes distinctly in two additional locations, decelerating soon after ebb tide begins and accelerating again a short time after. The downstream water level exhibits a tidal pattern similar to the Williams Road data.

Vegetation Evaluation



Flying Point Road Species	Downstream		Upstream		t-calc	t-crit	df	p-value	Decision
	Mean (ft)	σ (ft)	Mean (ft)	σ (ft)					
B. maritimus	4.765	0.083	4.899	0.146	1.720	2.145	14	0.108	Do Not Reject
S. patens	5.095	0.156	4.999	0.187	1.440	2.030	34	0.159	Do Not Reject
Cattail Transition Zone	5.758	0.488	5.415	0.350	1.645	2.131	15	0.1208	Do Not Reject
Panne	5.092	0.187	5.048	0.110	0.463	2.262	9	0.656	Do Not Reject
A. stolonifera	5.626	0.128	5.324	0.185	3.126	2.228	10	0.011	Reject
S. pungens	5.626	0.128	5.260	0.244	2.968	2.306	8	0.018	Reject

Williams Road Species	Downstream		Upstream		t-calc	t-crit	df	p-value	Decision
	Mean (ft)	σ (ft)	Mean (ft)	σ (ft)					
B. maritimus	4.831	0.203	5.107	0.186	4.118	2.042	32	0.0003	Reject
S. patens	4.926	0.255	5.208	0.213	3.419	2.042	33	0.002	Reject
Cattail Transition Zone	5.126	0.231	5.272	0.117	1.899	2.093	19	0.0728	Do not reject
S. depressa	4.929	0.508	5.333	0.122	3.407	2.056	26	0.002	Reject

The mean and standard deviation elevation of vegetation species observed around each crossing are displayed by quadrant in the bar charts above.

At Flying Point Road, six of twelve surveyed species were observed both upstream and downstream of the crossing. The intraspecies mean elevations of *A. stolonifera* and *S. pungens* were significantly different.

At Williams Road, four of six surveyed species were observed both upstream and downstream of the crossing. The intraspecies mean elevations of *B. maritimus, S. patens, and S. depressa* were significantly different.

Results

The Flying Point Road culvert restricts tidal flow. The upstream water level was always greater than the upstream invert elevation during the period of study and confirmed that the upstream marsh does not fully drain. The Williams Road culvert does not restrict tidal flow.

Intraspecies vegetation elevation differences upstream and downstream of the Flying Point Road culvert were largely not significant, including the most inundation-sensitive species observed: *S. patens*. This indicates the tidal restriction at Flying Point Road is likely not the cause of any observed elevation differences. Several intraspecies differences at Williams Road were significant but are likely caused by other factors because the culvert does not restrict flow into or out of the marsh.

Replacement of the Flying Point Road culvert would reduce road flood time at the 2020 highest annual tide by a maximum of 32% (78 minutes). The replacement culvert(s) should have an area of at least 49.92ft^2 to reach the upstream channel cross-sectional area, or approximately 250% of the current culvert area. The invert of the culvert(s) should be lowered to the average upstream channel depth of -2.42ft to allow for maximum drainage.

Williams Road should be raised to a minimum elevation of 10.64ft above NAVD 88 to prevent flooding with intermediate sea level rise predictions and storm surge. This would add 40,134 ft^3 of gravel and asphalt to the road and increase the load on the marsh to 2,309.8 tons. This only accounts for the current road footprint and does not include expanded shoulders or elevated approaches on either side of the marsh.

Conclusions

Flying Point Road inundation is primarily controlled by flood tide and could only be eliminated by raising the road, which would be a more extensive and costly project than culvert replacement. Lowering the upstream invert of the culvert and increasing the total crossing area would improve outflow but weir flow would still likely slow drainage after peak high tides. The current tidal restriction does not appear to significantly affect surrounding marsh vegetation.

Raising Williams Road would prevent long-term flooding and provide safe travel across the marsh for all residents. The project would require additional surveys of the approaching road segments to determine additional material needed, coordination with the owners of the culvert (the state of Maine), and soil coring to determine long-term subsidence of the road from marsh soil compaction.

Acknowledgements

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