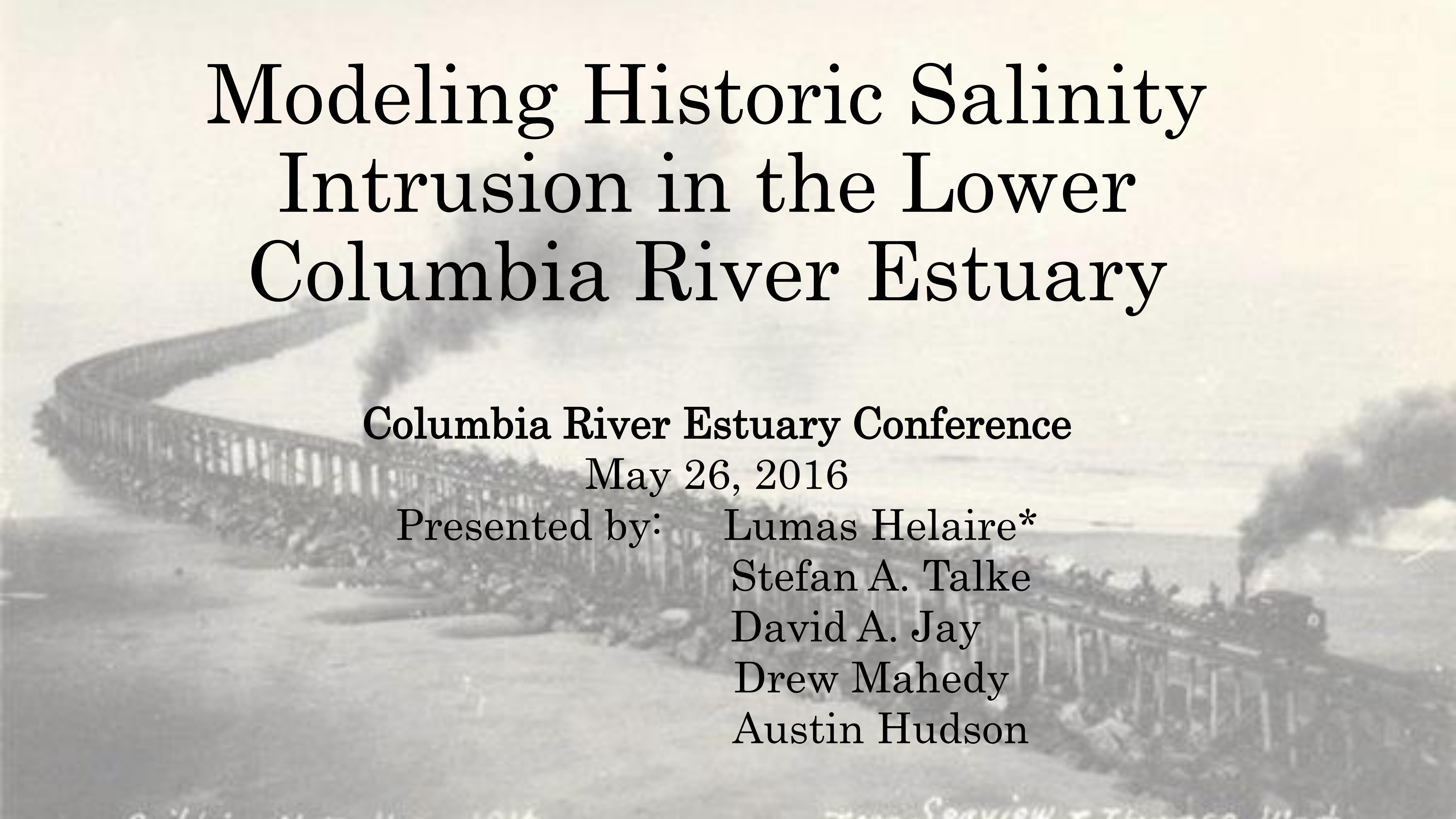

Modeling Historic Salinity Intrusion in the Lower Columbia River Estuary

Columbia River Estuary Conference

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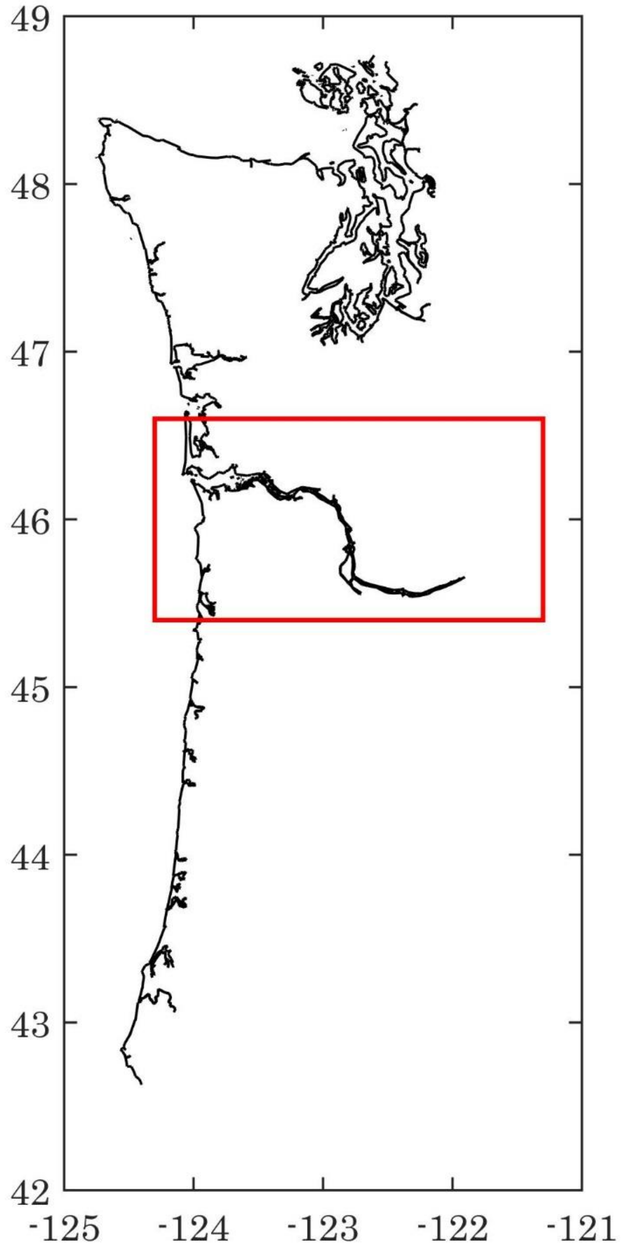
Overview

- Lower Columbia River (LCR) background
- Problem Statement
- Model Development
- Results
- Summary
- Future Directions
- References
- Questions

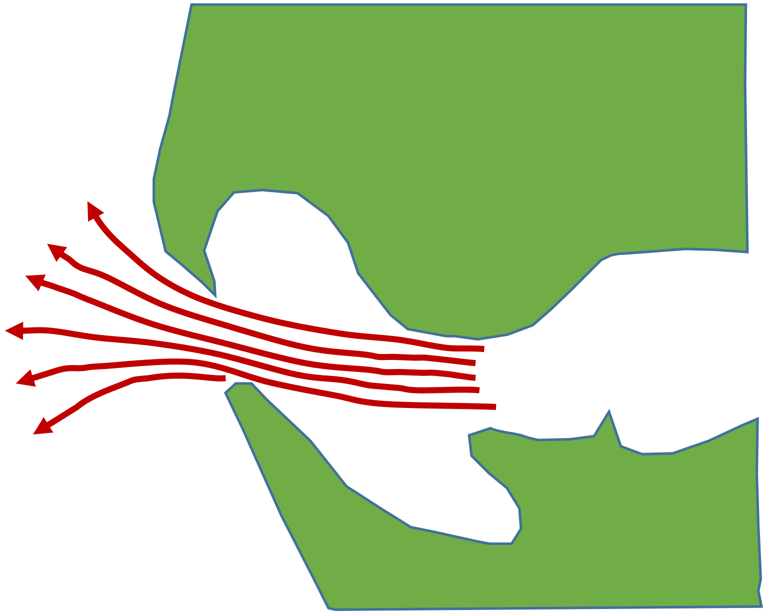


LCR Changes last 150 years

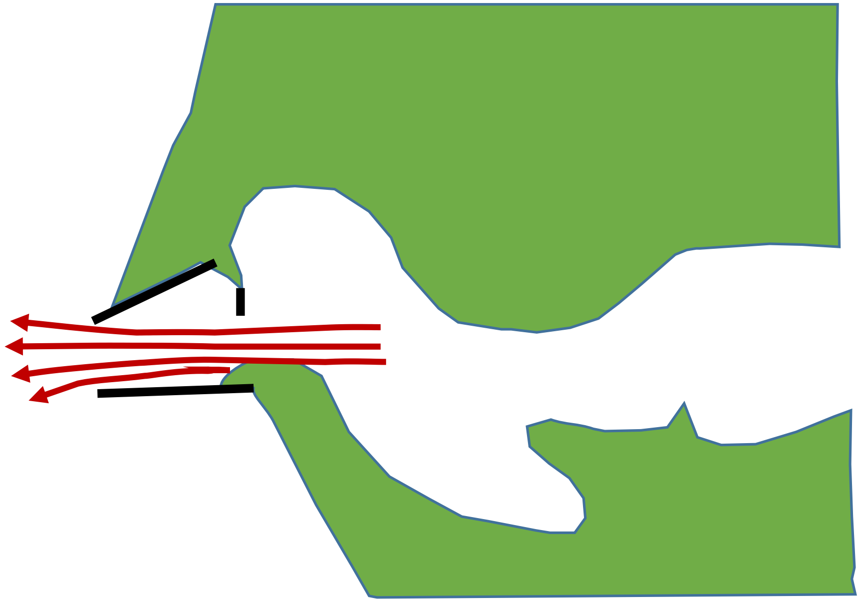
- Increase channel depth from 6m (1878) to 13m (2010)
- Extension of the Columbia River channel approximately 5km further into Pacific due to installation of jetties.
- Columbia River - 17% reduction in mean discharge, 40 – 45% reduction in peak discharge
- Tidal Peak moved approximated 25 km further upstream

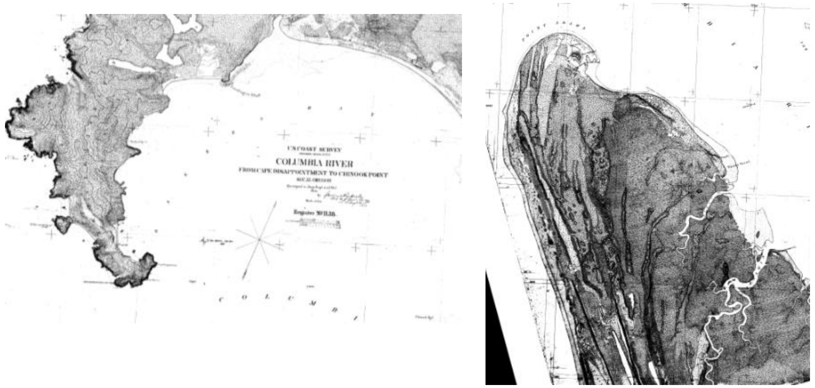
Jetties at the mouth of the LCR

Columbia Rvr Plume late 19th century



Columbia Rvr Plume present day





19th century Columbia River topography sheet, [*Burke*, 2005]

Columbia River mouth
[*Google Earth*, 2015]

Problem Statement

Hypotheses

Bathymetry shifts and seasonal changes in river output have shifted salinity intrusion, LCRE has shifted from a seasonally freshwater estuary to an estuary with nearly permanent salinity intrusion.

Scaling of Tidal Propagation

$$-\frac{1}{\rho_0} p_x = -g\eta_x - g\beta \bar{s}_x z$$

Lateral pressure gradient related to tidally average surface elevation (η) [*MacCready*, 2004]

Scaling of Salinity Intrusion Length

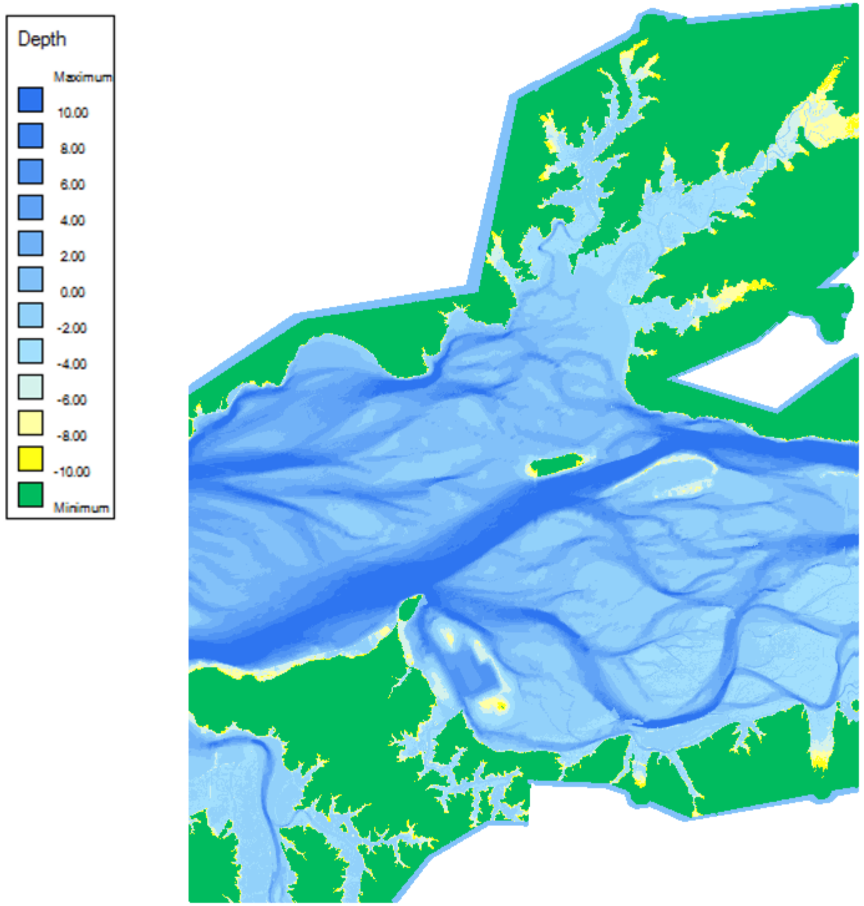
$$X_s \sim \frac{(W\alpha)^{1/3}(\beta g S_0)^{2/3} H^3}{Q^{1/3} \upsilon_t}$$

Increase in channel depth (H) and reduction in river flow (Q) increases the salinity intrusion length (X_s) [*Monismith et al.*, 2002]

Historic & Modern Bathymetry

T-sheet t1234lam83 So. Side of Col. River from John Day's River to Warren's Ldg (1870) – Wildlife Ecosystem Team, Univ. of WA [Burke, 2005]

T-sheets are georeferenced and have qualitative info about land cover



LiDAR and surveys used for the modern model

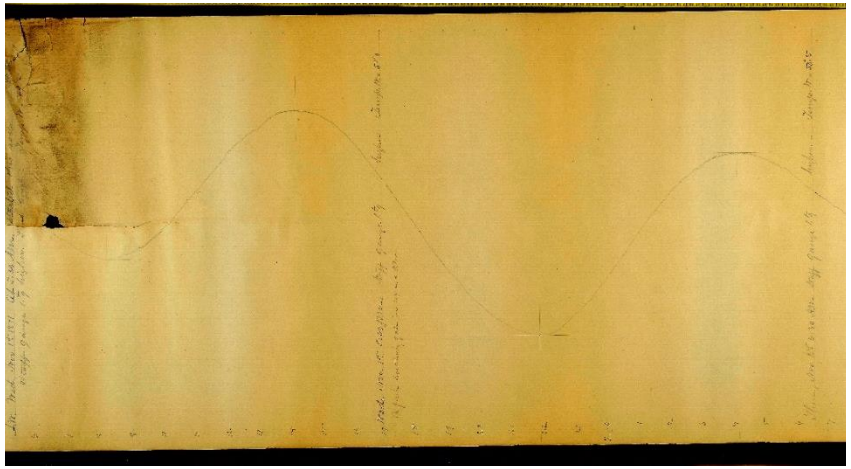
Historic Model – Tide Logs

Tide Logs used to calibrate historic model

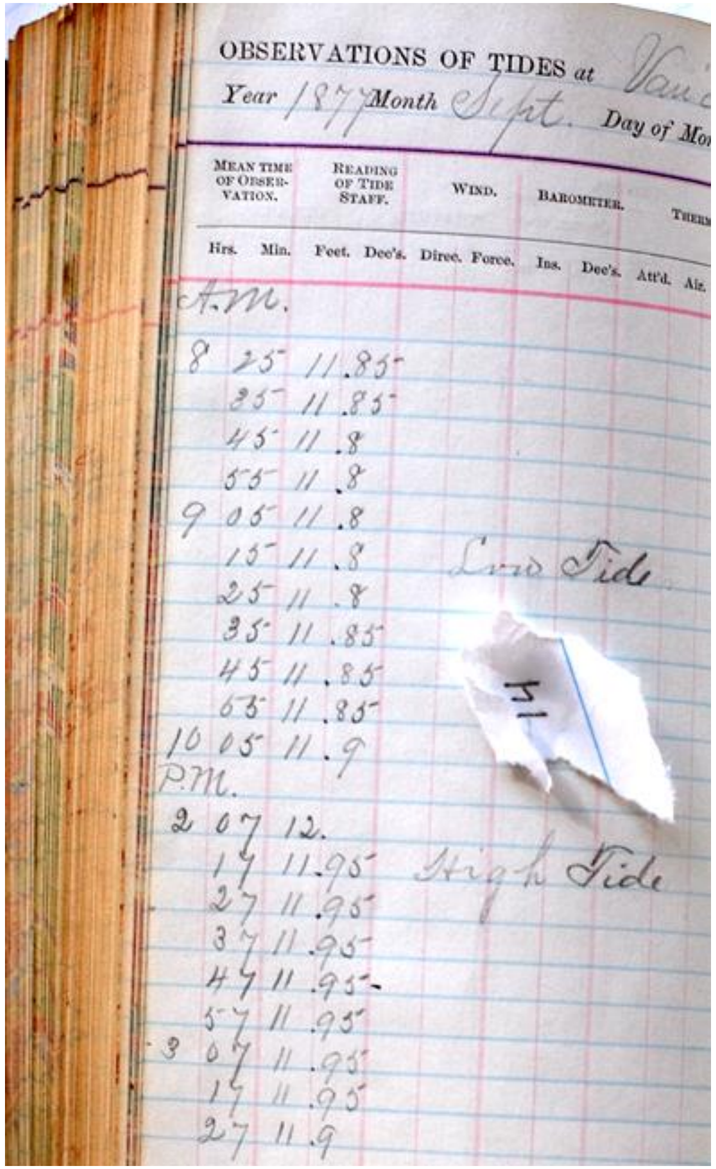
Station	**Location (RKM)**	**Type**	**Dates**
Fort Canby, OR	2.6	high/low	Jul 13 - Aug 13, 1877
Astoria, OR	24	hourly	1853-1876
Cathlamet, WA	60	high/low	Sep 12 - Oct 15, 1877
Oak Point, WA	87	high/low	Sep 12 - Oct 15, 1877
Rainier, OR	108	high/low	Sep 12 - Oct 15, 1877
Vancouver, WA	165	high/low	Sep 12 - Oct 15, 1877
Warrendale, OR	228	high/low	Sep 13 - Oct 10, 1877

Sep 1877 Columbia River tide log from Vancouver, WA [*Talke & Jay*, 2013]

19th century spatial data available throughout the LCRE



Marigram – Columbia River, Astoria, Nov. 1871



OBSERVATIONS OF TIDES at Van
Year 1877 Month Sept. Day of Mo

MEAN TIME OF OBSERVATION. Hrs. Min. | READING OF TIDE STAFF. Feet. Dec's. | WIND. Direc. Force. | BAROMETER. Ins. Dec's. | THERM Att'd. Air.

A.M.

8 25 11.85
35 11.85
45 11.8
55 11.8
9 05 11.8
15 11.8 Low Tide
25 11.8
35 11.85
45 11.85
55 11.85
10 05 11.9

P.M.

2 07 12.
17 11.95 High Tide
27 11.95
37 11.95
47 11.95
57 11.95
3 07 11.95
17 11.95
27 11.9

MCR Baroclinic Study

June 1 – July 1, 2011

Discharge

Columbia
- 3000 CMS (low)
- 7000 CMS (med)
- 15000 CMS (high)

Willamette @ Oregon City
- 250 CMS for all runs

Roughness

MCR A – Sea
MCR B - Estuary
MCR C – Mid River
Constant Chézy of 65

MCR D – Upriver
MCR E – Upriver
CZ49 Roughness parameterization

Vertical Layers

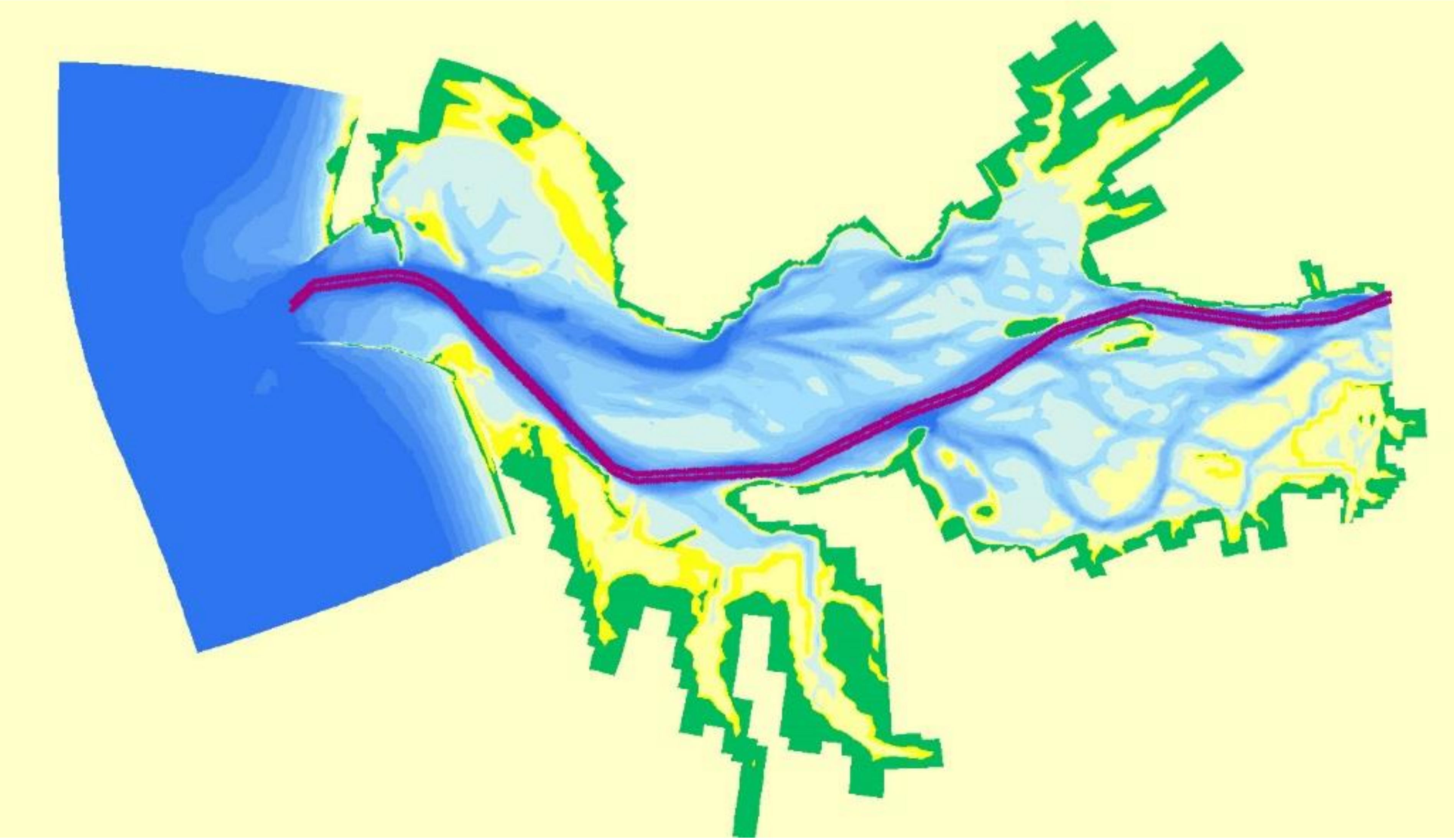
Ocean – 15 layers
Estuary – 15 layers
Upriver – 1 layer

Salinity = 31 ppt (ocean) , 0 ppt (river)
Temp = 15°C

MCR Monitoring

mapping of grid pts (60 min) [water level salinity]

Observation pts at 5km (10 min) [water level salinity]



Historic Baroclinic Study

June 1 – July 1, 2011

Discharge

Columbia Rvr (applied at Longview)
- 3000 CMS (low)

Willamette @ Oregon City
- 250 CMS for all runs

Roughness

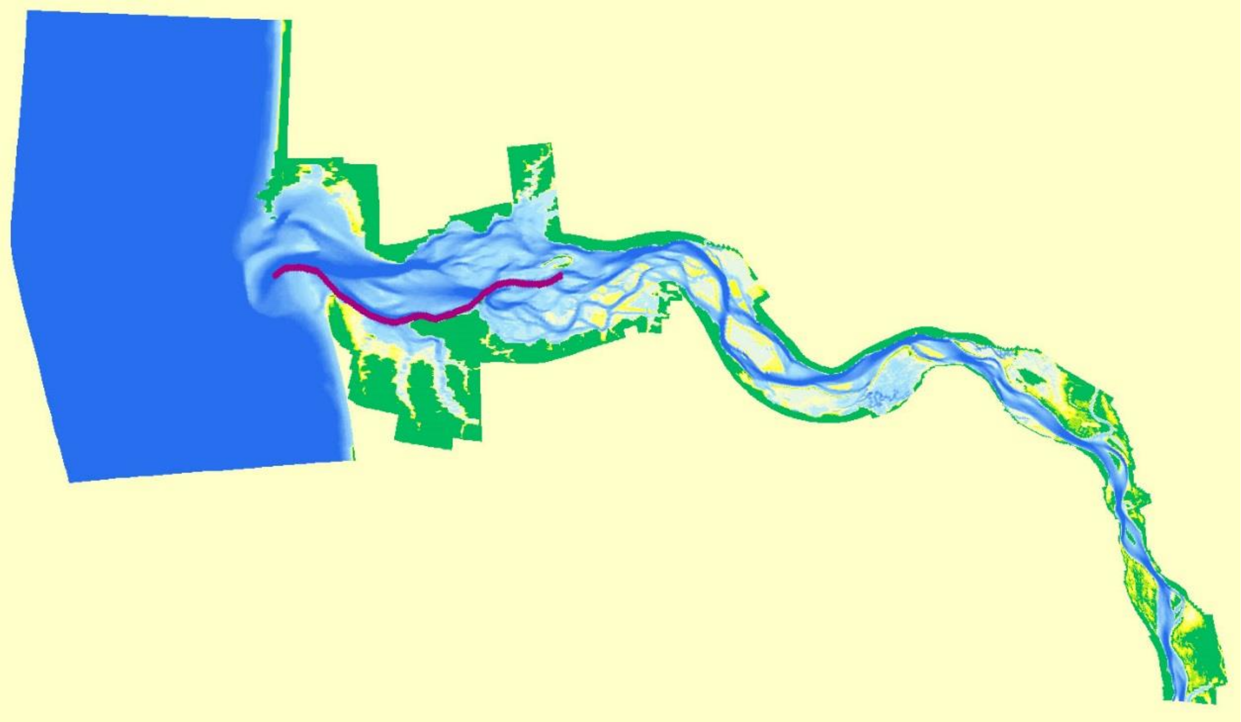
Constant Chézy of 45

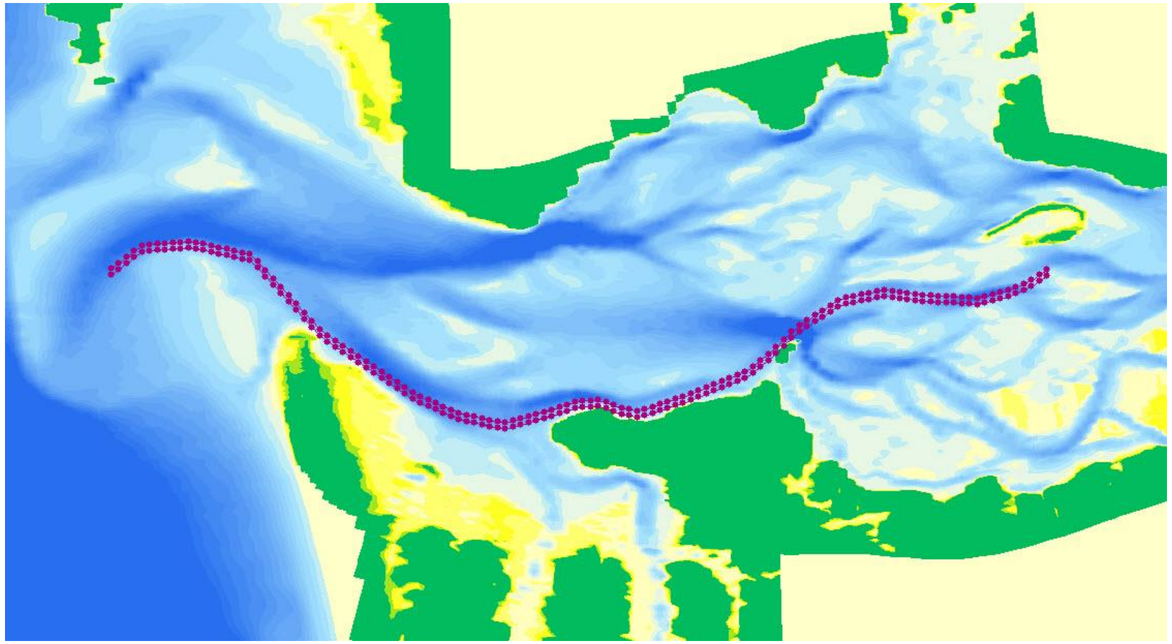
Vertical Layers

10 layers – entire model

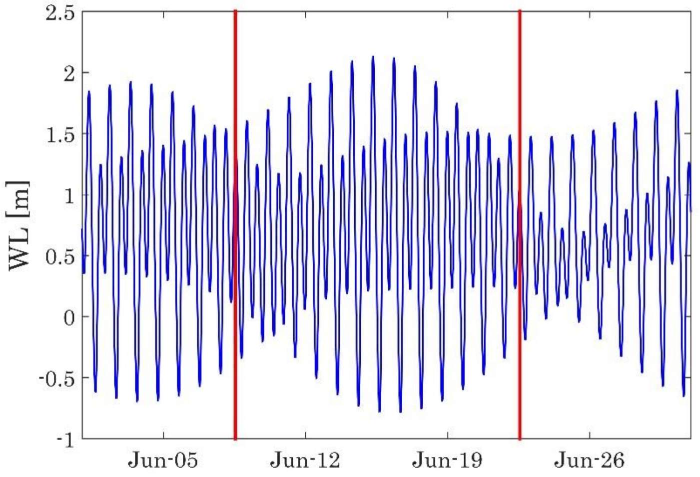
HCR Grid

Observation pts at 5km (10 min) [water level salinity]



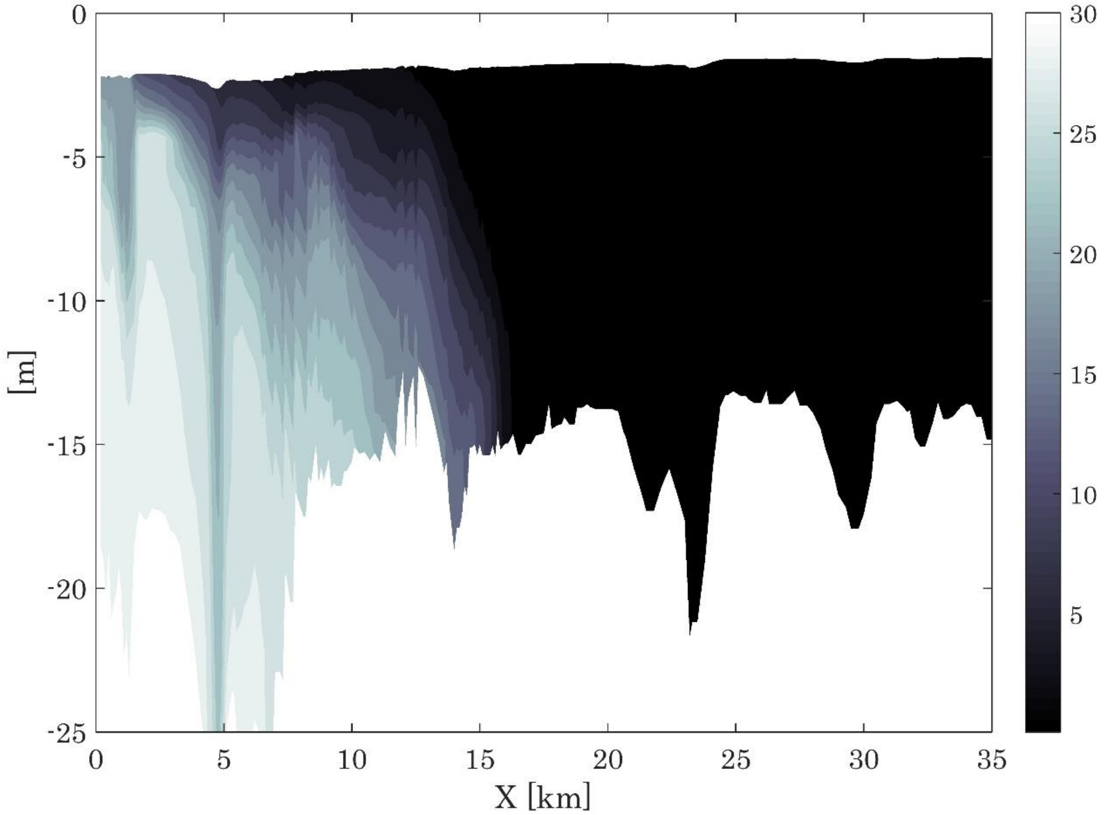


Modern Channel Salinity – High Discharge [15 kCMS]

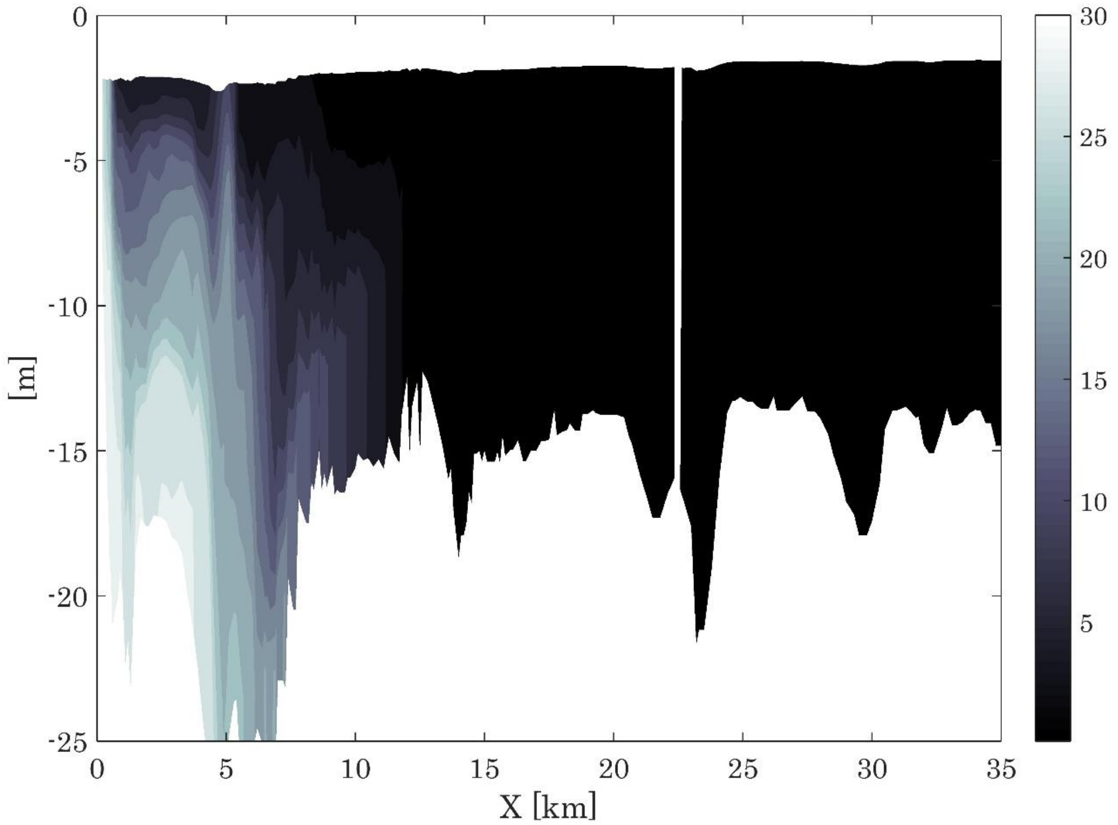


At High discharge there is salinity intrusion on spring tide but very little intrusion on neap tide

Spring Tide

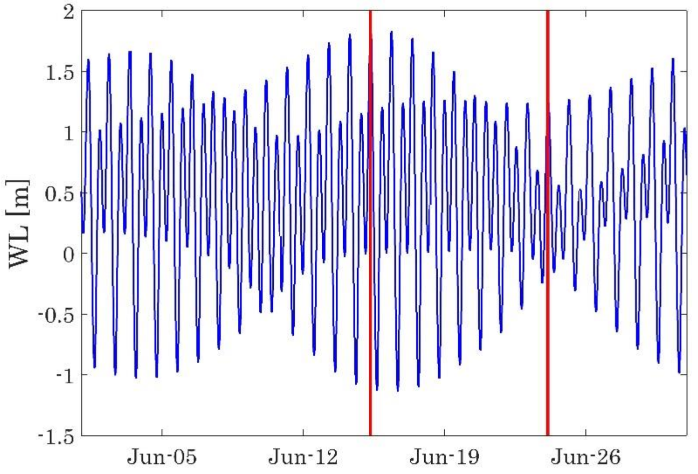


Neap Tide

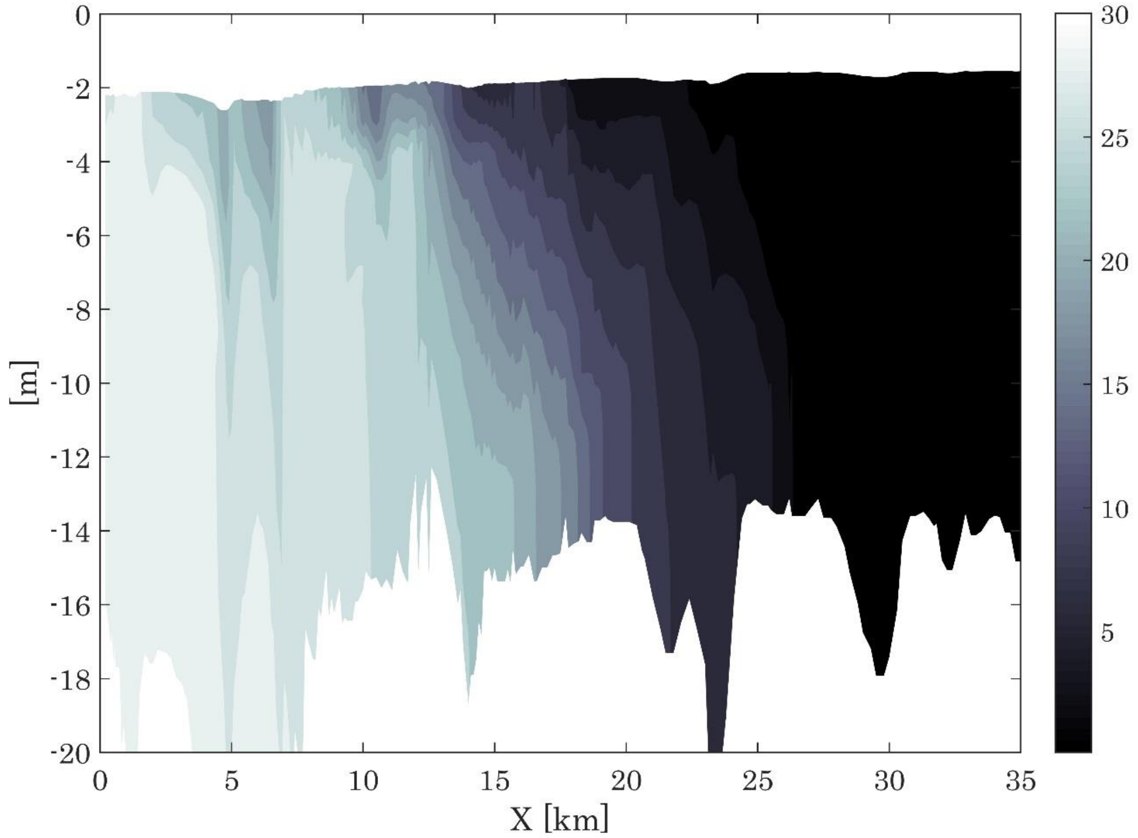


Modern Channel Salinity – Medium Discharge [7 kCMS]

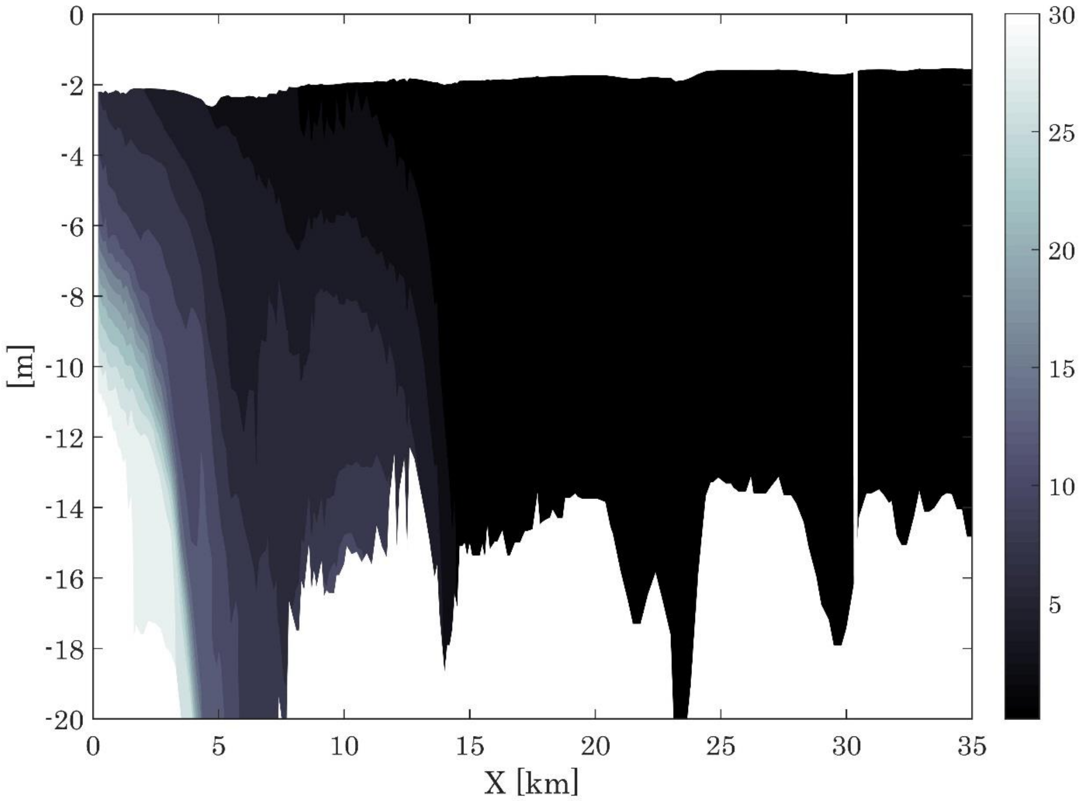
Salinity intrusion to 25km on spring tide, 15km on neap tide



Spring Tide

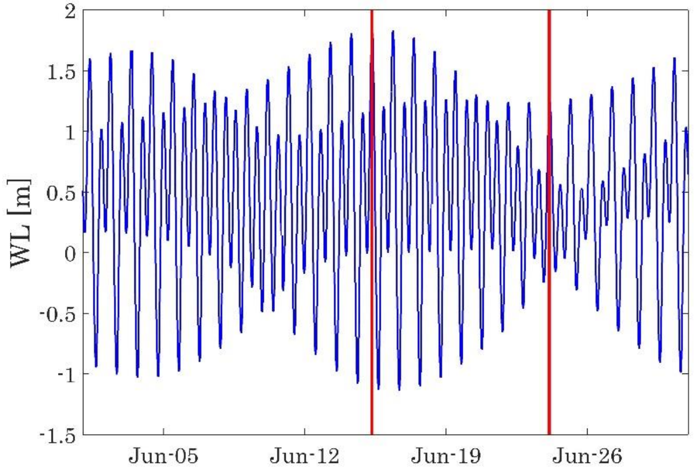


Neap Tide

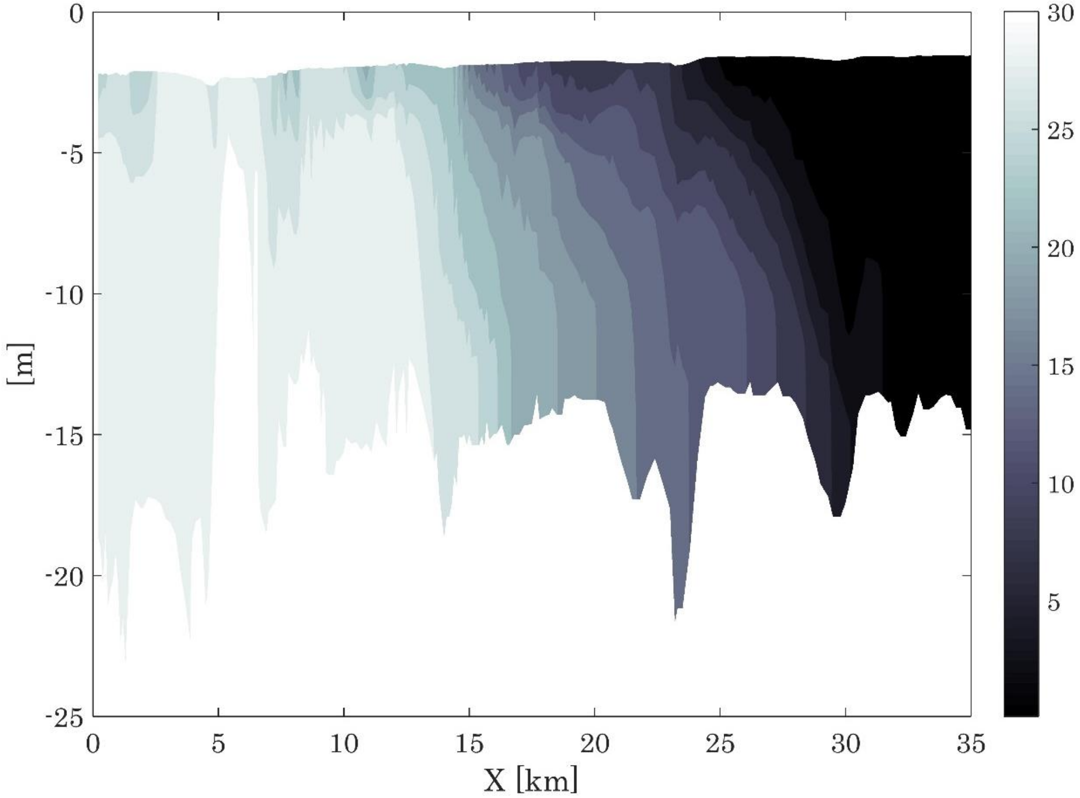


Modern Channel Salinity – Low Discharge [3 kCMS]

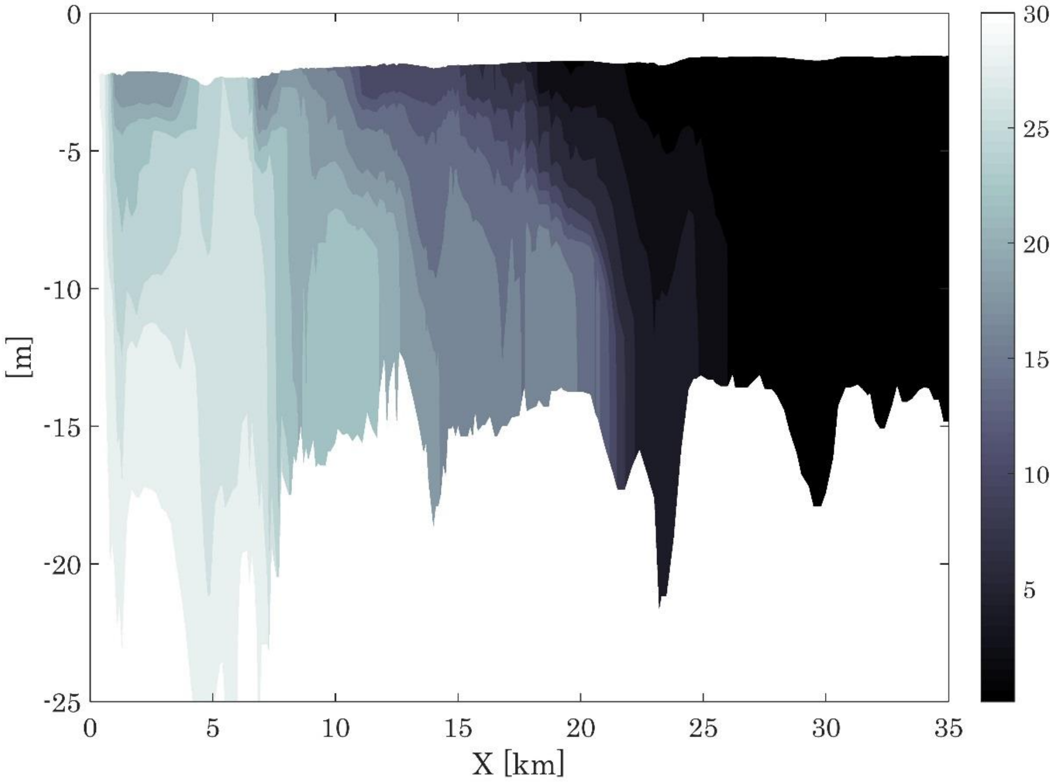
- salinity reaches 30km (5km downstream of Astoria) on spring tide
- Some trapping of salinity on spring and neap [*Hudson,* 2014]



Spring Tide



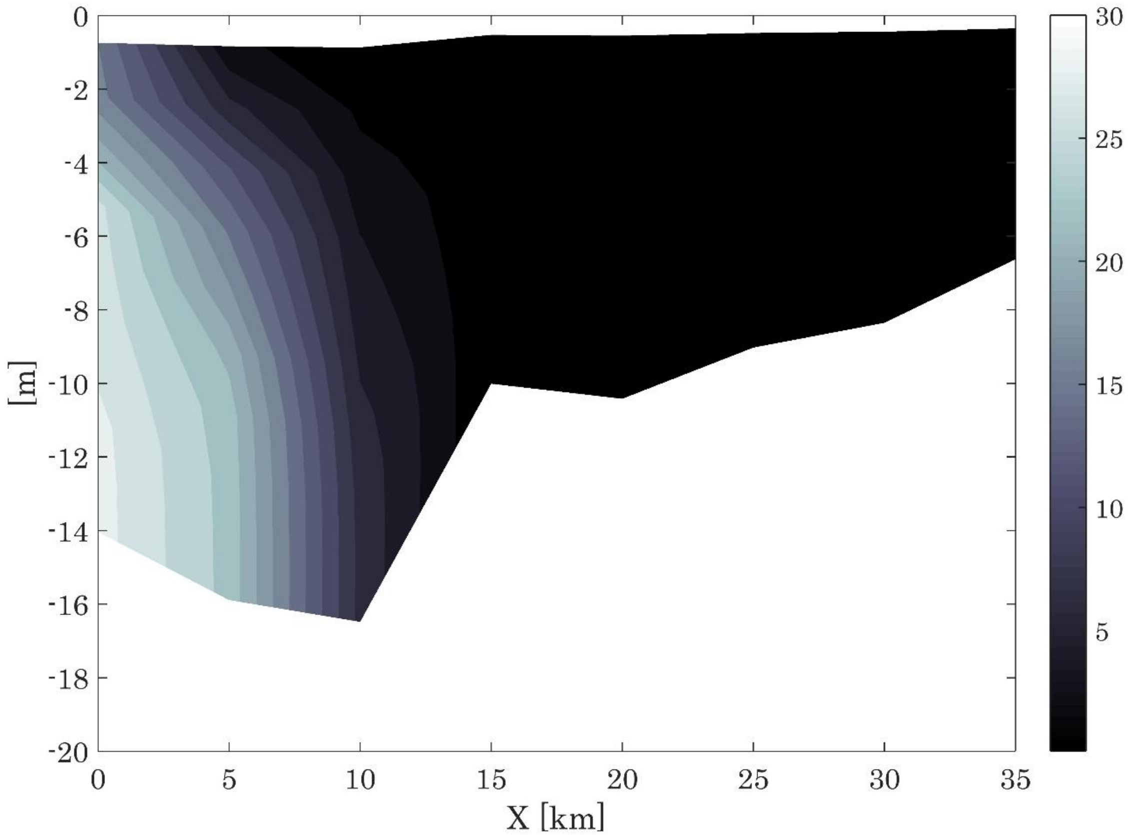
Neap Tide



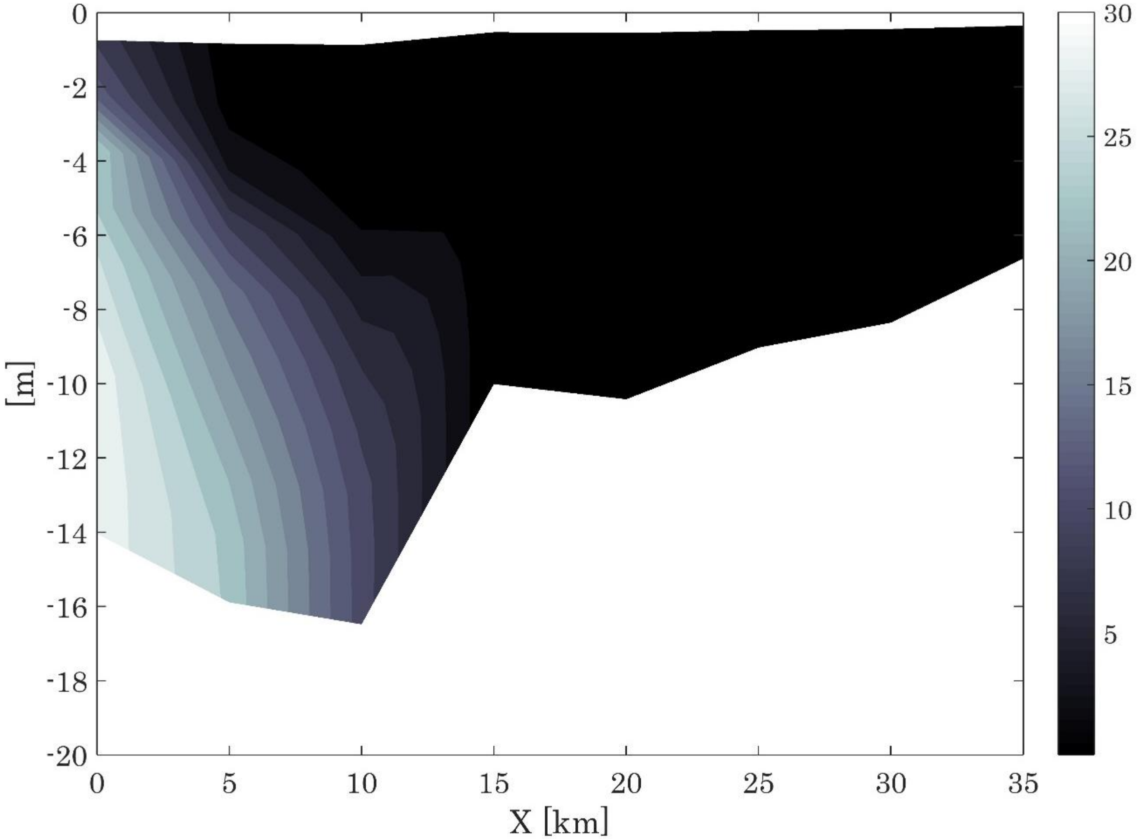
Historic Channel Salinity – Low Discharge [3 kCMS]

salinity intrusion extends only to 15km on spring tide much lower surface salinity on neap tide

Spring Tide

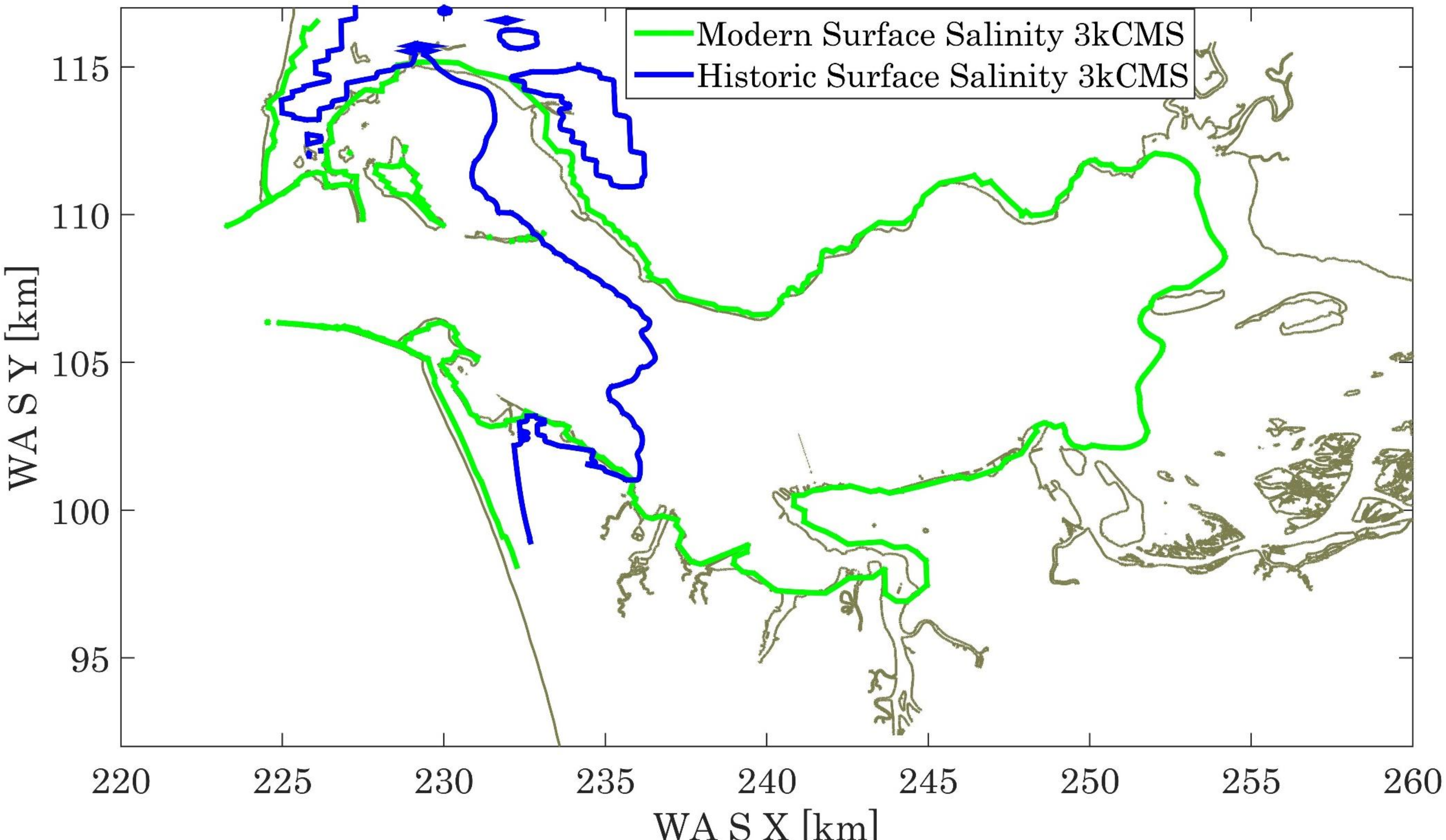


Neap Tide



Surface Salinity Contour (0.1 psu)

Modern model has much larger area of surface salinity intrusion



Summary

Modern Baroclinic Model

- very little salinity intrusion on high discharge (15 kCMS),
- Extensive salinity intrusion (30km) on low discharge (3 kCMS)
- Some trapping of salinity in topographic lows. Similar to trapping found in analytical model [*Hudson*, 2014]

Historic Baroclinic Model

- Surface and bed salinity on low discharge much less than modern model

Modern and Historic do show expected differences in salinity, more layers are needed to accurately model salinity structure (stratification and salt wedge) [*Jay & Smith*, 1990]

Future Directions

- Extend Historic and Modern Models to 40 layers in the estuary

- Incorporate more realistic boundaries
    - ocean (salinity & temperature)
    - river boundary (temperature)

- Model salinity intrusion at low, medium and high discharge to quantify discharge and bathymetry related changes in salinity structure

- Compare Historic and Modern model results to semi-analytical circulation model of the LCRE [*Hudson,* 2014]

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Questions