Initial hydrodynamic model scenarios to inform Coorong Infrastructure Investigations project

Department for Environment and Water
June, 2021

DEW Technical Report 2021/10

Government of South Australia

Department for Environment and Water

Department for Environment and Water

Government of South Australia

June 2021

81-95 Waymouth St, ADELAIDE SA 5000

Telephone +61 (8) 8463 6946

Facsimile +61 (8) 8463 6999

ABN 36702093234

www.environment.sa.gov.au

Report prepared by

Alison Miller and Matt Gibbs
Water Science Unit
Science, Information and Technology Branch
Strategy, Science and Corporate Services Division
Department for Environment and Water

Preferred way to cite this publication

Department for Environment and Water (2021). *Initial hydrodynamic model scenarios to inform Coorong Infrastructure Investigations project*, DEW Technical report 2021/10, Government of South Australia, Department for Environment and Water, Adelaide.

Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

The Department for Environment and Water (DEW) acknowledges the Traditional Custodians of the lands and waters, current land managers, and all Aboriginal and Torres Strait Islander South Australians. The Department also acknowledges that Aboriginal Nations are the first managers and decision makers of Country and that Country has sustained their culture and economy for thousands of generations. The care, skill and knowledge of Aboriginal Nations has shaped the character of Country across the continent and is seen as an integrated and interdependent cultural landscape.

This project is part of the South Australian Government's *Healthy Coorong, Healthy Basin* Program, which is jointly funded by the Australian and South Australian governments.

The work undertaken in the Phase 1 Hydrodynamic Modelling informed the Ecological Investigations, and was part of the Coorong Infrastructure Investigations Project.

Contents

List of figures

1 Introduction

The Coorong, Lower Lakes and Murray Mouth (CLLMM) are located at the ocean terminus of the Murray Darling system, Australia's largest river system. The Lower Lakes (Lake Alexandrina and Lake Albert) are separated from the Coorong by five barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere) built in the 1930-40s. Lake Albert is a terminal lake connected to Lake Alexandrina by a narrow channel (the Narrung Narrows), and the Coorong is connected to the Southern Ocean (Encounter Bay) through the Murray Mouth. The CLLMM is listed as a Ramsar Wetland of International Importance, and as such the Australian Government has international obligations to maintain the ecological character of the site.

Drought and consumptive use of the River Murray has led to the ecological decline of the Coorong and Lower Lakes region. With reduced flows from the river, dredging is required to maintain an open Murray mouth and reduced frequency of high flow events leads to increased salinity and sedimentation in the Coorong.

The scope of the Coorong Investigations Infrastructure Project (CIIP) is to investigate the feasibility of long-term infrastructure options for improving the ecological health of the Coorong. A short list of potential management options was developed through options analysis and community consultation. Options identified for further investigation include:

- A connection between the Coorong South Lagoon and Southern Ocean
- Coorong Lagoon dredging to improve connectivity
- Lake Albert to Coorong Connector
- Further augmentation of South East Flows to the Coorong
- Additional automated barrage gates.

This report documents preliminary hydrodynamic modeling of various dredging and pumping options, as well as a connection with Lake Albert and south east catchments, to inform further investigations for the CIIP.

2 Model schematisation

The preliminary scenario modelling utilised the existing two-dimensional TUFLOW hydrodynamic model, with the configuration as outlined in BMT (2019). The model dynamically solves for water level/depth and salinity over the whole Coorong, from the barrages to south of Salt Creek, as seen in Figure 2-1. The sediment transport module was not used.

The model simulates the period 07/05/2013 to 28/01/2016, a period of below average barrage inflows leading to poor flushing and increased salinity in the Coorong South Lagoon, providing a good test case for benefits from infrastructure options. It should be noted that this is a relatively short simulation length in the context of the response time of the south lagoon to infrastructure changes, which is expected to be in order of a number of years depending on the change. Along with barrage flow, other inputs to the model such as net evaporation, wind and tides, will also influence the results, and can result in changes up to 40 g/L in south lagoon salinity (Lester et al., 2012). As such, the results presented in this report are specific to the boundary conditions considered, and different conditions will produce different results. It is expected that the relative comparisons between scenarios would be maintained irrespective of the input conditions, however the magnitude of the differences between scenarios will change. For example, with higher barrage flows the differences between options may be smaller, and with higher evaporation rates the differences larger. The scenarios undertaken in this work are intended to provide an envelope of representative responses within the system to enable future work to consider more refined options, and longer term simulations, to assess the influence of the different infrastructure options on the Coorong under a range of conditions.

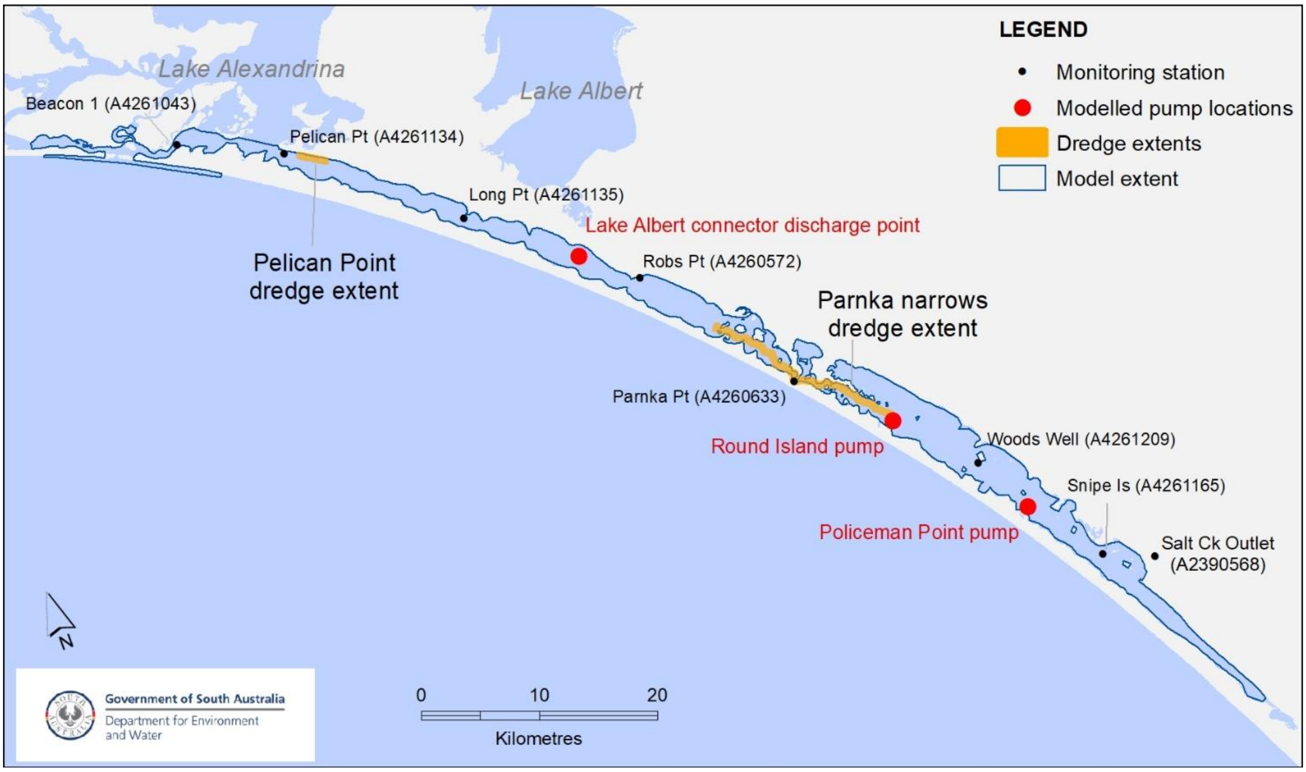

Figure 2-1. Model extent, monitoring stations and location of infrastructure options assessed

2.1 Modifications

Initial salinity concentrations were modified from those used in BMT (2019) to provide a closer representation to the observed values at the start of the simulation. Bathymetry of the Murray mouth was configured from survey data aligning with the start of the simulation. The modelling did not utilise the sediment transport module and as such the bathymetry of the mouth remains unchanged throughout the simulation, and represents a relatively constricted Tauwitchere channel throughout the simulation. This simplification resulted in significantly reduced run times, allowing numerous scenarios to be tested.

The diurnal tide ratio (DTR) is used as a measure of the openness of the Murray mouth, as the ratio of the amplitude of the tidal signal recorded at Victor Harbor compared to downstream of Goolwa and Tauwitchere barrage. The calculated DTR from observed data over the modelled period can be seen in Figure 2-2, suggesting the range of mouth openness that would occur if the model was not static. The Tauwitchere side of the mouth starts in a constricted state, and this opens up with barrage flow over October 2013-April 2014, before largely being controlled by the dredges in the latter half of 2014, and slowly opening up again over 2015. The static mouth simplification does influence the model results in the north lagoon (see below), but is not expected to affect the comparison of infrastructure options.

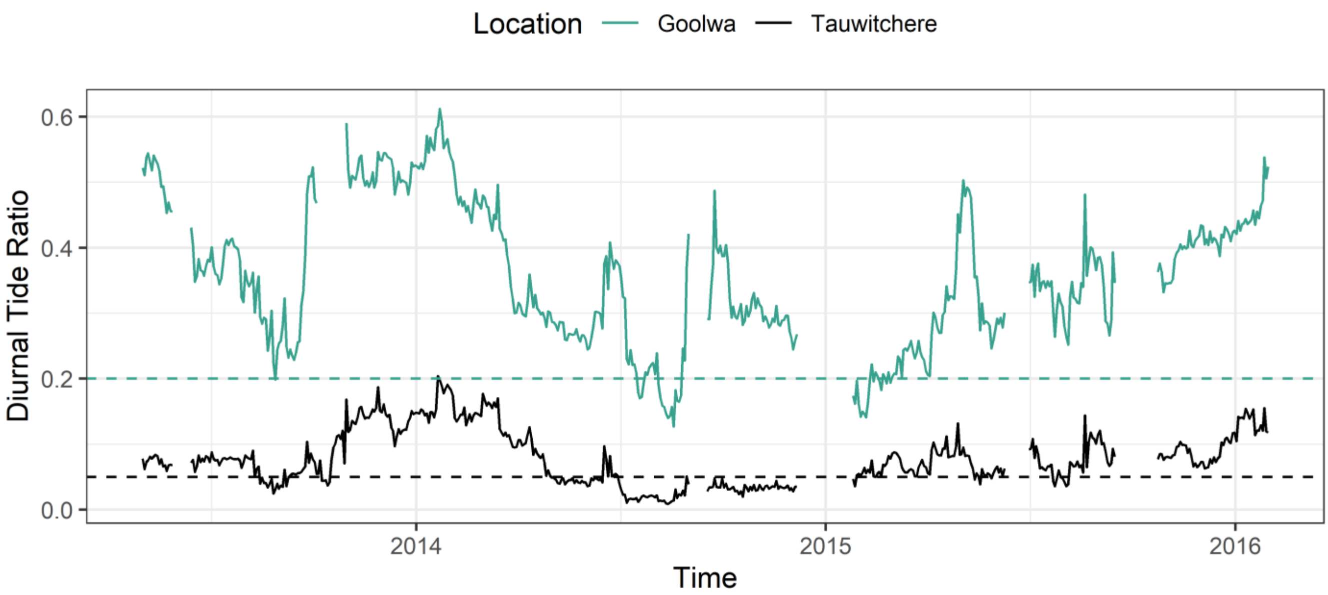

Figure 2-2 Calculated diurnal tide ratio at Goolwa and Tauwitchere barrage, with the minimum target values for each location shown as the dashed horizontal line.

2.2 Validation

Modelled outputs were compared to observed water levels (Figure 2-3) and salinities[1] (Figure 2-4) recorded at seven monitoring stations across the model domain. The effect of the static bathymetry of the mouth in the model in the latter half of the simulation can be seen with both 1) fresher flows (i.e. lower modelled salinities) from Ewe Island (A4261043) to Robs Point (A4260572) in the north lagoon, and 2) the slight underestimation of water levels as the simulation progresses. This materialises in the statistics as a mean absolute error of 11-14 g/L from the Murray mouth through the Coorong North Lagoon to Parnka Point. The impact dissipates further south, away from the mouth, with the mean absolute error reducing to approximately 4 g/L. Mean absolute error in water levels is slightly higher near the mouth and between the lagoons at Parnka Point of 0.13-0.16 m, slightly reducing in the main lagoons of ~0.08 m.

Despite this limitation in representing the mouth dynamics and subsequent effect in the estuary and north lagoon, the model is considered to replicate observed conditions for the period considered well, particularly in the Coorong South Lagoon (CSL) (R^2 > 0.93 for both salinity and water level at Snipe Island and Woods Well).

Table 2-1 Statistics of model accuracy at each station for water level and salinity over the modelling period. MAE=mean absolute error, RMSE = root mean squared error, R^2 = coefficient of determination.

Station	Site	Salinity			Water level		
		MAE	RMSE	R^2	MAE	RMSE	R^2
Beacon 1	A4261043	10.8	13.7	0.35	0.13	0.16	0.68
Pelican Point	A4261134	11.7	13.5	0.30	0.13	0.15	0.81
Long Point	A4261135	10.1	11.8	0.35	0.08	0.10	0.88
Robs Point	A4260572	13.5	16.4	0.65	0.08	0.10	0.88
Parnka Point	A4260633	12.4	17.8	0.69	0.16	0.17	0.95
Woods Well	A4261209	3.2	5.0	0.95	0.09	0.11	0.95
Snipe Island	A4261165	3.7	5.1	0.96	0.08	0.11	0.93

[1] Observed salinity in g/L has been calculated from the recorded salinity in electrical conductivity (EC) by TDS (g/L) = ($3E\text{-}06 \times EC^2 + 0.5517 \times EC$)/1000. This equation was updated by AWQC in 2019. The updated equation reduced the error between laboratory derived TDS by Evap @180 ^{0}C and calculated TDS from EC from approximately 10% to 4% error for the data considered over 2005 – 2018.

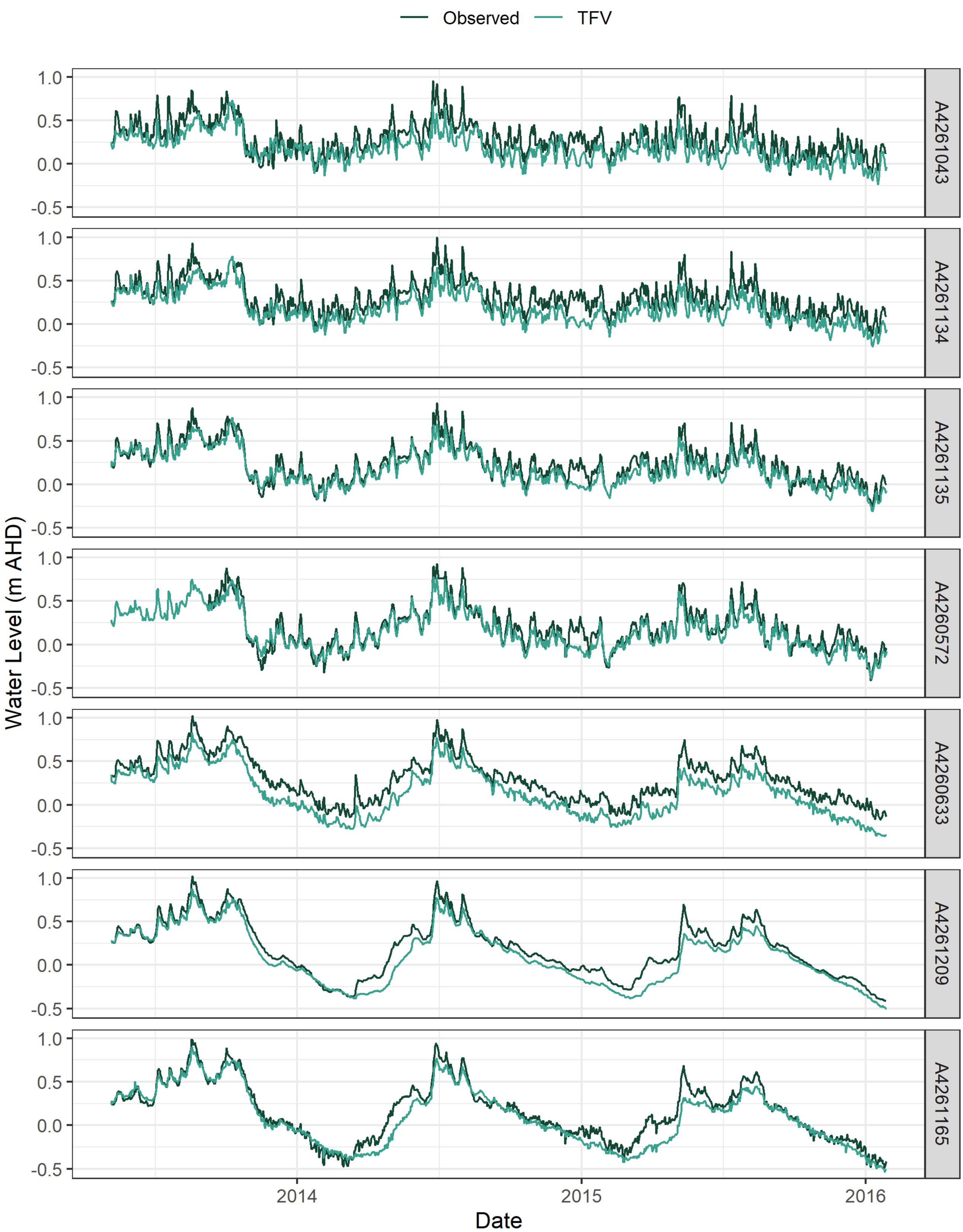

Figure 2-3. Modelled and observed water levels at monitoring stations along the Coorong from the north west at Ewe Island (A4261043), to the south east at Snipe Island (A4261165).

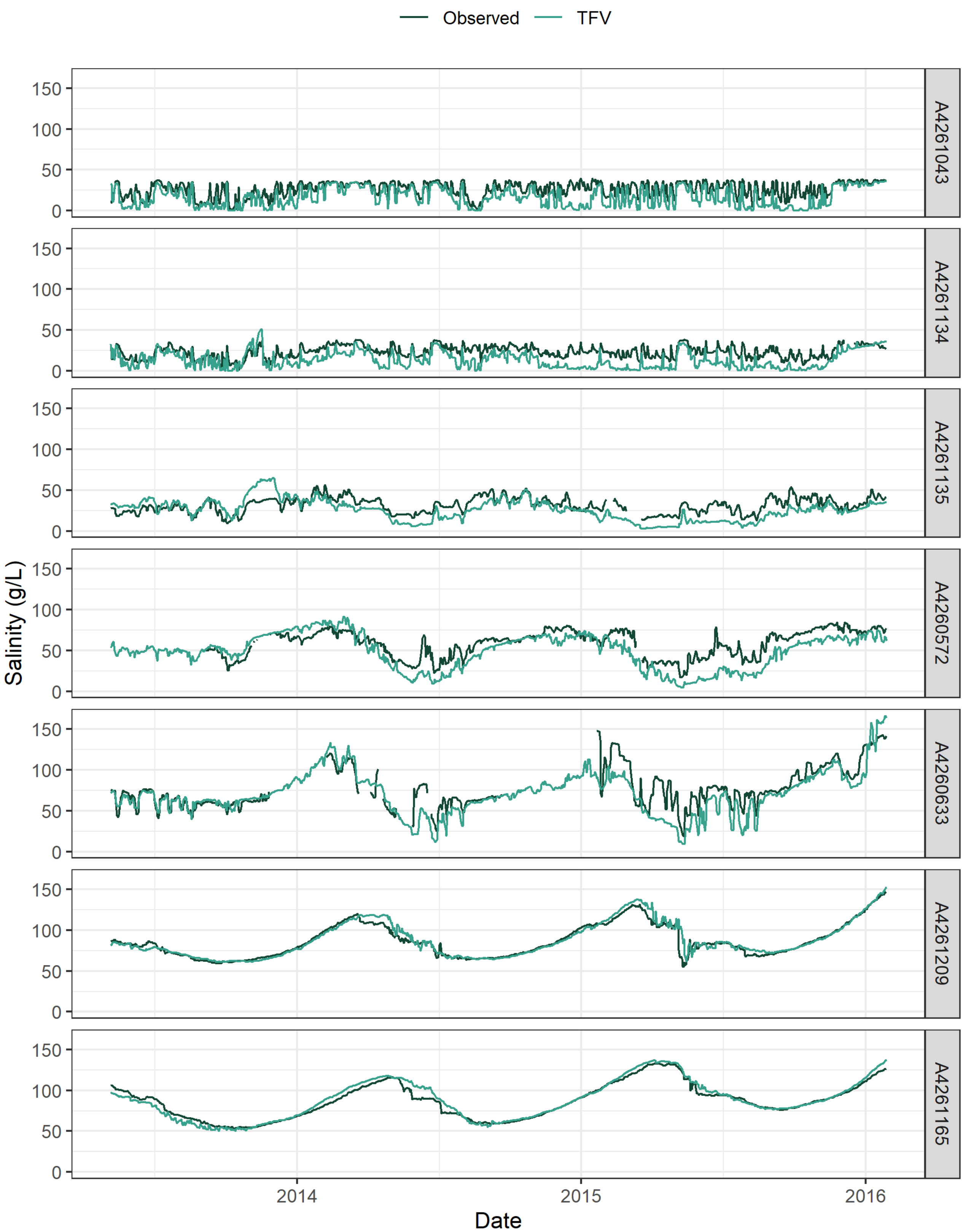

Figure 2-4. Modelled and observed salinity at monitoring stations along the Coorong from the north west at Ewe Island (A4261043), to the south east at Snipe Island (A4261165).

3 Scenarios

Various configurations of dredging, pumping and connections with Lake Albert and the South East drainage network were modelled, as outlined in Table 3-2 below.

3.1 Base case

Four 'do nothing' scenarios have been modelled to form the benchmark for comparing the performance of infrastructure options. These were:

1. 'normal', the observed inflows from the barrages and Salt Creek. This is a relatively low flow period in the context of barrage flow, with an annual average of 1524 GL/yr and maximum of 2201 GL/yr for the calendar years of 2013-2015, compared to a long term (1963-2020) average of 4312 GL/yr.
2. 'extreme dry' with no barrage or Salt Creek inflow, representing extreme conditions (i.e. Millennium drought) when the infrastructure options are likely to be of most value,
3. climate change, representing changes to evaporation from the Coorong (increase by 5%) and sea level rise (increase of 0.24 m) projected to occur by 2050, under the representative concentration pathway (RCP) 8.5 scenario (Green and Pannell, 2020). This scenario does not attempt to reflect climate change impacts on available flows from the River Murray, and adopts 'normal' scenario inflows from the barrages and Salt Creek. For time horizons of up to 2050, high emissions scenarios (i.e. RCP 8.5) are recommended to consider by Green and Pannell (2020), and
4. Climate change with increased bed levels at the Murray mouth, representing the conditions described in the point above, but acknowledging the plentiful supply of sand offshore may result in a consistent depth of water at the Murray mouth, and as such the bathymetry in the active zone (directly inside the mouth between the Goolwa and Tauwitchere channels) of the model increased by the same amount as the sea level rise.

3.2 Pumping

The intent of pumping water from the Coorong is to export salt and nutrients from the system, drawing lower salinity marine water in through the Murray mouth, thus further reducing salinity in the north and south lagoons and reducing retention time in the system. Pumping water in at certain locations may also aid in circulation of waters in the Coorong. Pumping seawater into the Coorong is intended to provide dilution of hypersaline and nutrient rich CSL water and in some scenarios also provide export of this water out of the Coorong through the Murray mouth.

Pumping scenarios incorporate pumping in or out at either Policeman Point or Round Island, the locations of which are shown in Figure 2-1. The Policeman Point location was that selected during the Salinity Reduction Scheme investigations in 2009/10. The Round Island location was selected further north in the south lagoon, to test the impact of different pumping locations.

Various pumping rates were trialed in the hydrodynamic modelling scenarios. Unless indicated otherwise, the pumping rate was constant. Some scenarios have included water level triggers for pumping rather than continuously pumping at the constant rate. Water level triggers that were incorporated include pumping *out* only when water levels in the Coorong are above 0.2 and 0.3 mAHD (i.e. approximately the level at which the north and south lagoons are well connected); and pumping *in* only when water levels in the Coorong drop below 0.15 or 0.1 mAHD (to test sensitivity of the low water level assumption).

3.3 Passive ocean connection

A passive connection (i.e. pipes) between the Coorong and ocean is an alternative option to pumping in and out of the Coorong. A passive connection would allow water from the south lagoon to flow to the ocean when water levels in the lagoon are higher than the ocean (typically winter), and sea water into the lagoon when the lagoon levels are lower (typically summer).

The inlet/outlet of the pipe was modelled to be the same location as the Policeman Point pump location.

Various iterations of pipe configurations were trialed, to determine the size and number of pipes required to achieve sufficient flow exchange, accounting for head loss over a 2,500 m long pipe, the small head difference and shallow lagoon depths. A range of configurations have been modelled: 10 x 2000 mm diameter pipes, 10 x 1500 mm pipes, 10 x 1000 mm pipes, 5 x 1000 mm pipes and 5 x 750 mm pipes.

3.4 Dredging and mouth openness

Dredging will remove sediment in the Coorong at targeted locations to improve hydraulic conveyance between the north and south lagoon, allowing lower salinity marine water to more readily circulate through the Coorong. The targeted locations were identified by inspection of the modelled water level profile, where sharp increases identify bathymetric constrictions that are restricting flow in the model.

Four options for dredging, and combinations of these, have been used in the scenario modelling:

1. Dredging along an 18.5 km length of the Parnka narrows, as indicated in Figure 2-1. The dredge extent is 200 m wide along the entire length, with a bed elevation of -1.2 mAHD.
2. Dredging along a 2.5 km length of narrow channel near Pelican Point, as indicated in Figure 2-1. Similarly, this dredge extent is 200 m wide along the entire length, but with a lower bed elevation of -1.5 mAHD.
3. An extreme case of dredging along the entire length of the centerline of the Coorong (102 km), to a width of 300 m, and depth of -2.0 mAHD.
4. A 'natural' mouth configuration, which is representative of the mouth under more natural (higher) inflows. The mouth is wider and deeper in these conditions as the natural high flows would have prevented sand ingress and scoured the channels more frequently. The width of the mouth was increased to extend to where there is vegetation on the dunes on each peninsula, and increased to a depth of -5 mAHD. The region inside the mouth has also been deepened, including the removal of Bird Island. The bathymetry for this option is the same as that investigated by Gibbs (2020).

3.5 Lake Albert Connector

To test the performance of connecting the Coorong with Lake Albert, three flow scenarios were modelled, introducing water into the Coorong, near where a pipe or channel from the Lake would discharge, as indicated in Figure 2-1. The flow scenarios were:

1. **Maximum Lake Albert Connector inflows (LAC)**. The 1 GL/d capacity was selected based on the design from the 2014 Lake Albert scoping study, noting this was focused on benefits to Lake Albert, as opposed to the Coorong. Inflow from the barrages was reduced by the same amount (i.e. 1 GL/d of flow through the barrages is instead transferred through Lake Albert). When available this volume was removed from the Tauwitchere barrage flow, on the assumption that releases from this barrage are intended to provide flow to the Coorong. If flow from Tauwitchere barrage was less than 1 GL/d, flow from other barrages was also reduced. The barrage flow on any given day was not increased above the observed flows used for the base case.

2. **Additional Lake Albert Connector inflows**. This scenario is as above, however the 1 GL/d flow through the Lake Albert Connector is in addition to the flow through the barrages, rather than a diversion of that portion of flow. This hypothetical scenario is designed to test the potential benefits of a LAC with additional environmental water available from the River Murray.
3. **A more realistic operational scenario**, where the Lake Albert Connector channel is only used after a total of 2 GL/d flow has passed through the barrages. This is the notional flow expected to prevent additional sand ingress at the Murray Mouth, and provides for other objectives such as fish passage and maintaining estuarine conditions inside the Murray Mouth. If this condition is met, inflow from the barrages was reduced, to allow up to 1 GL/d flow through Lake Albert, as per the description in the simplified inflow scenario.

For all three scenarios, salinity of flow through the connector has been assumed to be the same as Lake Albert at 1500 EC, or 0.9 g/L.

3.6 South east flows

The South East Flows Restoration project (SEFRP) was completed in 2018, which included construction of the infrastructure and channel to enable the Blackford Drain in the South East drainage network to divert flow toward the Coorong. Further augmentation of the network has been considered previously (e.g. Taylor et al., 2014, Inside Infrastructure, 2017). This scheme (referred to as South East Flows Augmentation, SEFA) would divert additional volumes from the Drain L and K catchments into the Coorong.

Previous modelling undertaken by Inside Infrastructure (2017) determined additional flows to the CSL available through the SEFRP and SEFA projects. The time series of both these modelled datasets were analysed here to determine which three-year rolling periods over the 1896 – 2016 period (i.e. 120 years) had a large contribution from SEFA relative to without augmentation, i.e. the SEFRP inflows. For this analysis the historical climate results were used. The intent being to select periods where the SEFA project produced a relatively large volume contribution compared to the drainage network without the additional diversions. The periods starting May 1943 and May 1975 were found to have volumes of interest, summarised in Table 3-1 and Figure 3-1.

Table 3-1 Average annual volumes over 3 year periods to Salt Creek from SEFRP project

	Volume available to Coorong, GL/yr	
3 year period starting	**SEFRP**	**SERFP & SEFA**
May 1943	35	35 + 17
May 1975	16	16 + 11

The flow series for each of these periods (i.e. 1943 and 1975 for both current and augmented SE flows) were introduced to the hydrodynamic model at the location adjacent Salt Creek outlet identified in Figure 2-1. The salinity of this water source is as modelled by Inside Infrastructure, and ranges between 0.003 and 0.015 g/L (approximately 10,000 EC). Note that no other changes to the model have been made, i.e. the bathymetry of the Coorong and time series of barrage flows and climate data remains unchanged representing the May 2013 to January 2016 period.

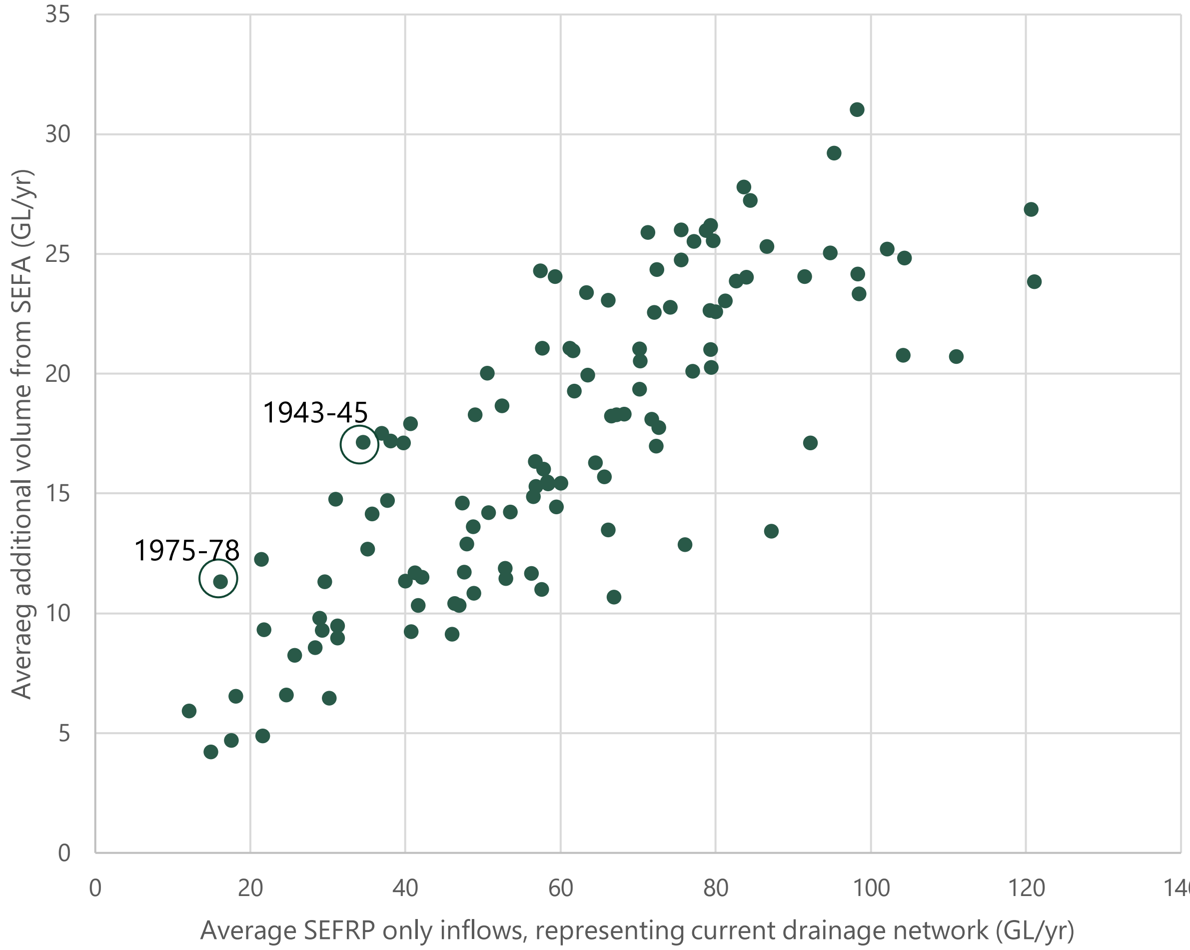

Figure 3-1 Average annual volumes over 3 year periods to Salt Creek from SEFRP project, against additional volume available from the SEFA project. Based on modelling and diversion assumptions used in Inside Infrastructure (2017).

3.7 Automated barrages

Currently there are 20 automatic gates at the Tauwitchere barrages, which can be remotely opened and closed in response to tidal conditions. An infrastructure option as part of CIIP is to modify the gates to automate an additional20 gates at Tauwitchere and 3 additional automated gates at the Goolwa barrages.

During some desirable periods, current operation of the existing automatic gates involves releasing water on tide and wind combinations that are favourable to pushing water into the Coorong, rather than it flowing out to sea. There has been limited historical analysis to demonstrate how effective this practice is, however, with the additional 23 gates operated in this manner, the result may be more marked. Flow through an individual gate is approximately 400 ML/d.

Analysis of modelled flow through the mouth into the Coorong, and from the north to south lagoon, suggests that favourable conditions are typically experienced during autumn (i.e. March to May inclusive). Three operational scenarios were used to alter the flow from the 40 (future) automatic gates at Tauwitchere. Two take the approach of accumulating flow behind the barrages (but maintaining fishway flows) over a defined period and releasing this in a pulse, so as to maximise flow rates through the barrages with the intent of maximising the potential for flushing. The third approach was to use known future flows from the north to south lagoon (while not realistic in practice, modelling of these conditions allows for testing the intent of the approach, without needing the need to develop a predictive mechanism), to identify target release timings. In detail, the three operational scenarios are:

1. Pulsing accumulated flow through the 40 automated gates at the maximum flow rate each week during the autumn months (on average, cumulative flow delivered in 8 hours)
2. As above, but with cumulative flow pulsed through on a fortnightly basis (on average, cumulative flow delivered in 24 hours)
3. Using the modelled flows in the Coorong base case scenario to identify periods of inflow to the Coorong and target high barrage flow releases. The approach adopted a trigger of flow going into the Tauwitchere channel at the Murray Mouth greater than 10 GL/d over a future 3 hour period. Under these conditions, the operation was to open all 40 automated gates at Tauwitchere for the initial hour, releasing 667 ML over the hour, (a rate of 400 ML/d for each gate). While it may not be possible to develop a predictive mechanism for such conditions in practice, this approach was used to attempt to generate the maximum benefit, where inflow to the Coorong could be expected to drive the high barrage flows into the Coorong. When these desirable conditions were no longer met, the water balance was maintained by preventing release of flow over Tauwitchere barrage until the volume released in the preceding pulse had been accumulated (in line with the base case). This approach resulted in a maximum difference in barrage release volume of 67 GL, which is approximately 8 cm of lake level, and as such assumed that could feasibly be delivered with the Lower Lakes water level operating envelope. Only Tauwitchere barrage flow was modified, other barrages remained unchanged.

While these scenarios do not represent the day to day operational decisions informed by weather forecasting and conditions on the ground, they are intended to represent ‘best case’ scenarios (i.e. maximum change) and hence useful in assessing the impact on water levels and salinity in the Coorong.

Table 3-2. Modelled scenarios

ID	Inflow	Bathymetry			Pumping		Lake Albert Connector
		Parnka narrows	*Pelican point*	*Mouth*	*Policeman Pt*	*Round Island*	
BaseCase	Observed	Existing		Existing	None		None
Dry	None	Existing		Existing	None		None
Climatechange	Observed	Existing		Existing	None		None
Climatechange_bedlift	Observed	Existing		Bed level + 0.24m	None		None
LAC	Observed less 1GL/d	Existing		Existing	None		1 GL/d
LAC_1GL/d	Observed	Existing		Existing	None		1 GL/d additional
LAC_Realistic	Observed less 1 GL/d conditional	Existing		Existing	None		1 GL/d conditional
LAC_Dredge	Observed less 1GL/d	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		1 GL/d
Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		None
DredgeLarge	Observed	Dredge 300m wide to -2m		Existing	None		None
DredgePelican	Observed	Existing	Dredge 200m wide to -1.5m	Existing	None		None
DredgeParnka	Observed	Dredge 200m wide to -1.2m	Existing	Existing	None		None
WideMouth	Observed	Existing		Widened	None		None
WideMouth_LargeDredge	Observed	Dredge 300m wide to -2m		Widened	None		None
Widemouth_ParnkaDredge	Observed	Dredge 200m wide to -1.2m	Existing	Widened	None		None
In125	Observed	Existing		Existing	In 125 ML/d	None	None
In250	Observed	Existing		Existing	In 250 ML/d	None	None
In500	Observed	Existing		Existing	In 500 ML/d	None	None
Out125	Observed	Existing		Existing	Out 125 ML/d	None	None
Out250	Observed	Existing		Existing	Out 250 ML/d	None	None
Out250_0.3m_In0.15m	Observed	Existing		Existing	250 ML/d *out* when water level >0.3m and *in* when water level <0.15m	None	None
Out500_0.2m	Observed	Existing		Existing	500 ML/d *out* when water level >0.2m	None	None

ID	Inflow	Bathymetry			Pumping		Lake Albert Connector
		Parnka narrows	*Pelican point*	*Mouth*	*Policeman Pt*	*Round Island*	
Out500_0.2m_In0.1m	Observed	Existing		Existing	500 ML/d *out* when water level >0.2m and *in* when water level <0.1m	None	None
Out500_0.2m_In0.1m_ Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	500 ML/d *out* when water level >0.2m and *in* when water level <0.1m	None	None
Out500_0.3m_In0.15m	Observed	Existing		Existing	500 ML/d *out* when water level >0.3m and *in* when water level <0.15m	None	None
Out500_0.3m	Observed	Existing		Existing	500 ML/d *out* when water level >0.3 mAHD	None	None
In125_Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	In 125 ML/d	None	None
In250_Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	In 250 ML/d	None	None
In500_Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	In 500 ML/d	None	None
Out125_Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	Out 125 ML/d	None	None
Out250_Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	Out 250 ML/d	None	None
Out500_Dredge	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	Out 500 ML/d	None	None
In500_Dredge_Dry	None	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	In 500 ML/d	None	None
Out250_Dredge_Dry	None	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	Out 125 ML/d	None	None
Out250Round	Observed	Existing		Existing	None	Out 250 ML/d	None
In250RoundOut250	Observed	Existing		Existing	Out 250 ML/d	In 250 ML/d	None
Out250_DredgeLarge	Observed	Dredge 300m wide to -2m		Existing	Out 250 ML/d	None	None
Out250_Dredge_Pelican	Observed	Existing	Dredge 200m wide to -1.5m	Existing	Out 250 ML/d	None	None
Out250_Dry	None	Existing		Existing	Out 250 ML/d	None	None
Out125_Dry	None	Existing		Existing	Out 152 ML/d	None	None
Pipe750x5	Observed	Existing		Existing	Passive connection (5 x 750 mm pipes)		None
Pipe1000x5	Observed	Existing		Existing	Passive connection (5 x 1000 mm pipes)		None

ID	Inflow	Bathymetry			Pumping		Lake Albert Connector
		Parnka narrows	*Pelican point*	*Mouth*	*Policeman Pt*	*Round Island*	
Pipe1000x10	Observed	Existing		Existing	Passive connection (10 x 1000 mm pipes)		None
Pipe1500x10	Observed	Existing		Existing	Passive connection (10 x 1500 mm pipes)		None
Pipe2000x10	Observed	Existing		Existing	Passive connection (10 x 2000 mm pipes)		None
Auto_Tau1week	Observed (as weekly pulse)	Existing		Existing	None		None
Auto_Tau2weeks	Observes (as fortnightly pulse)	Existing		Existing	None		None
Auto_Tau3hr	Observed (as 40 gates/hr based on 3 hour window)	Existing		Existing	None		None
SE_1943_Actual	Observed + Actual SE flows (1943)	Existing		Existing	None		None
SE_1943_Augment	Observed + Augmented SE flows (1943)	Existing		Existing	None		None
SE_1975_Actual	Observed + Actual SE flows (1975)	Existing		Existing	None		None
SE_1975_Augment	Observed + Augmented SE flows (1975)	Existing		Existing	None		None
SE_1943_Actual_Dredge	Observed + Actual SE flows (1943)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		None
SE_1943_Augment_Dredge	Observed + Augmented SE flows (1943)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		None
SE_1975_Actual_Dredge	Observed + Actual SE flows (1975)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		None
SE_1975_Augment_Dredge	Observed + Augmented SE flows (1975)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		None
SE_1943_Actual_Dredge_ LAC	Observed - 1 GL/d conditional + Actual SE flows (1943)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		1 GL/d conditional
SE_1943_Augment_Dredge_ LAC	Observed - 1 GL/d conditional + Augmented SE flows (1943)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		1 GL/d conditional
SE_1975_Actual_Dredge_ LAC	Observed - 1 GL/d conditional + Actual SE flows (1975)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		1 GL/d conditional
SE_1975_Augment_Dredge_ LAC	Observed - 1 GL/d conditional + Augmented SE flows (1975)	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	None		1 GL/d conditional

4 Results

4.1 Modelled outputs

For comparison of scenario performance, model results have been assessed as:

- Time series of water level and salinity at 7 point locations corresponding to existing gauging stations (as indicated in Figure 4-1).
- Long sections, representing the water level and salinity at a distance from the mouth, along a centerline (as indicated in Figure 4-1). In order to represent the changes in time, we present average water levels and salinities experienced across seasons.
- Time series of the proportion of mass remaining in the Coorong South Lagoon. This represents how much of the total volume of water initially present remains in the CSL at a point in time, and is analogous to 'turn-over'. The smaller the amount of mass remaining in a given time period, the larger the flushing of the system that has occurred.

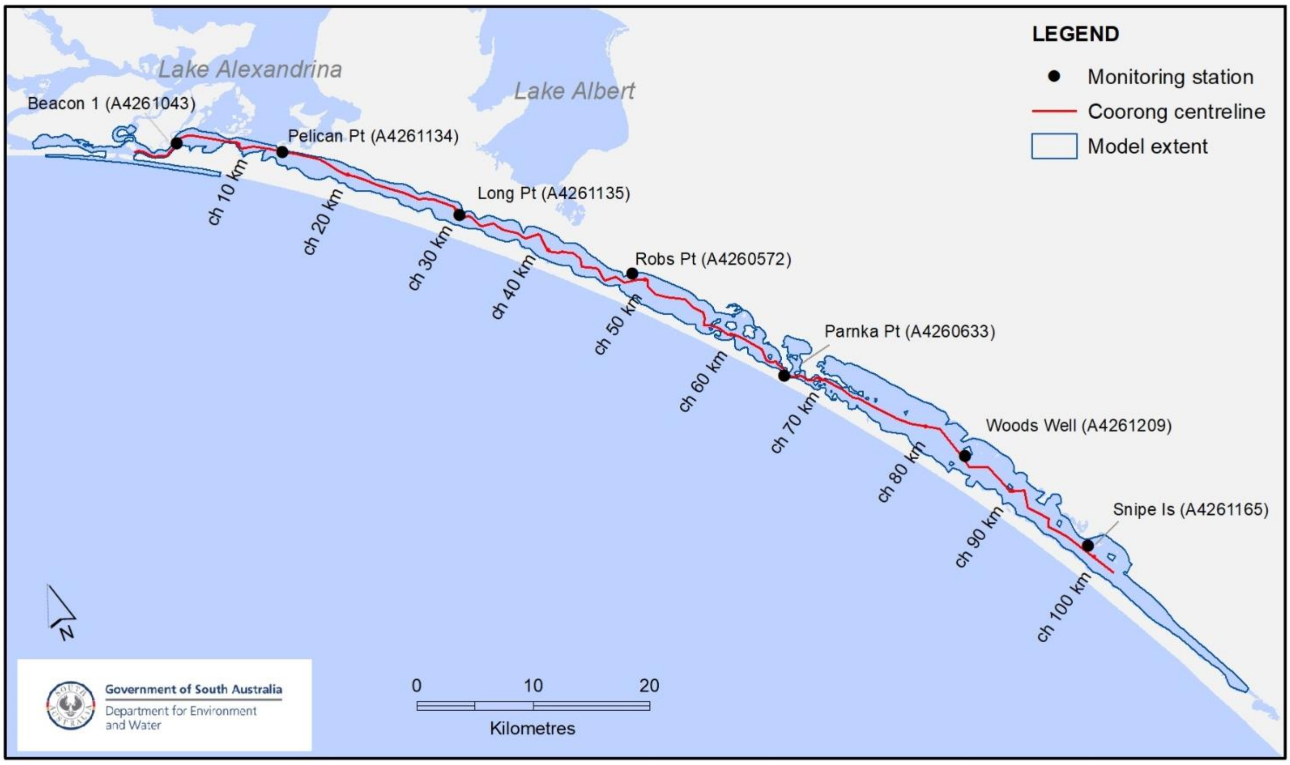

Figure 4-1 **Location of reporting points for model outputs**

4.2 Interpretation of outputs

In this preliminary modelling, the following assumptions were used to assess the performance of the different measures:

- Lower salinity is generally considered better as all biota have upper salinity thresholds. Below marine salinities (35 g/L) is considered suboptimal for Ruppia (Collier et al., 2018), and as such salinity below this threshold in the South Lagoon is undesirable.

- A greater reduction in the initial mass of Coorong South Lagoon water is better, i.e. an increase in flushing. Both lower salinity and reduction in initial mass are indicators of shorter retention time. Increasing retention time is a key driver of eutrophication (Mosley et al., 2020).
- Maintaining higher water levels, in the order of 0.25 m AHD, until late December each year is beneficial for Ruppia to complete its life cycle (Asanopoulos and Waycott, 2020, Paton et al., 2018).
- Water levels across the Coorong (i.e. the whole system) between 0.15 and 0.2 mAHD will maximise to the area of suitable mudflat habitat for shorebirds (Hobbs et al. 2019).

4.3 Altered climate scenarios

Results for altered climate scenarios (i.e. dry and climate change conditions) are shown in Figure 4-2 to Figure 4-5. Dry conditions, with no inflow from the barrages, result in dramatic increases in the salinity throughout the south lagoon over time, with concentrations almost double that of the base case conditions.

Conversely, climate change scenarios show a small reduction in salinity in the CSL despite the increased evaporation rates, resulting from the increased flux of tidal water into the lagoon (as a result of sea level rise) and improved connectivity between the lagoons. The north and south lagoons have longer periods of connection each year. Water levels in summer generally greater than 0.1 mAHD, and in winter greater than 0.4 mAHD. Water levels are moderately higher for the bedlift scenario. The improved connectivity and higher water levels means that evaporation (despite being increased by climate change) doesn't dominate the CSL and result in the extent of drawdown experienced over autumn each year compared to basecase (Figure 4-4). This results in lower salinities over the same period (Figure 4-3).

There is negligible difference in salinity between the two climate change scenarios (i.e. the existing or raised mouth bathymetry). Export of water from the South Lagoon (Figure 4-6), is similar to basecase for the existing mouth climate change scenario, but reduced with a raised mouth bathymetry.

These results indicate that two of the main changes expected with increased greenhouse gas emissions, sea level rise and increased evaporation rates, largely counteract each based on 2050 RCP 8.5 (high emission) projections. However, it should be noted that the barrage flow in the two climate change scenarios is the same as base case, and projected reductions in end of system flow would also be expected to increase salinities in the Coorong, as indicated by the no flow "Dry" scenario.

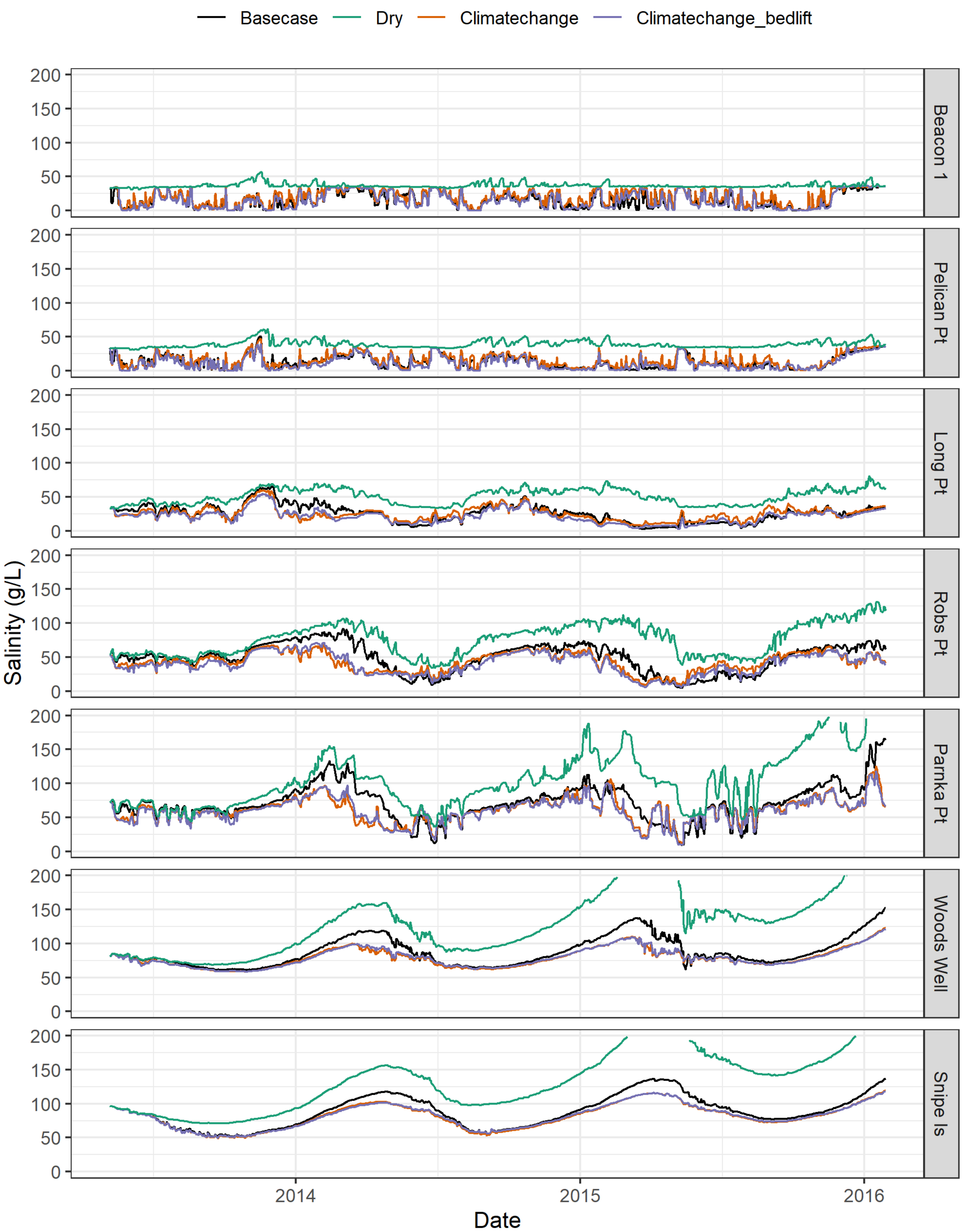

Figure 4-2. Modelled salinity under base case, dry and climate change scenarios

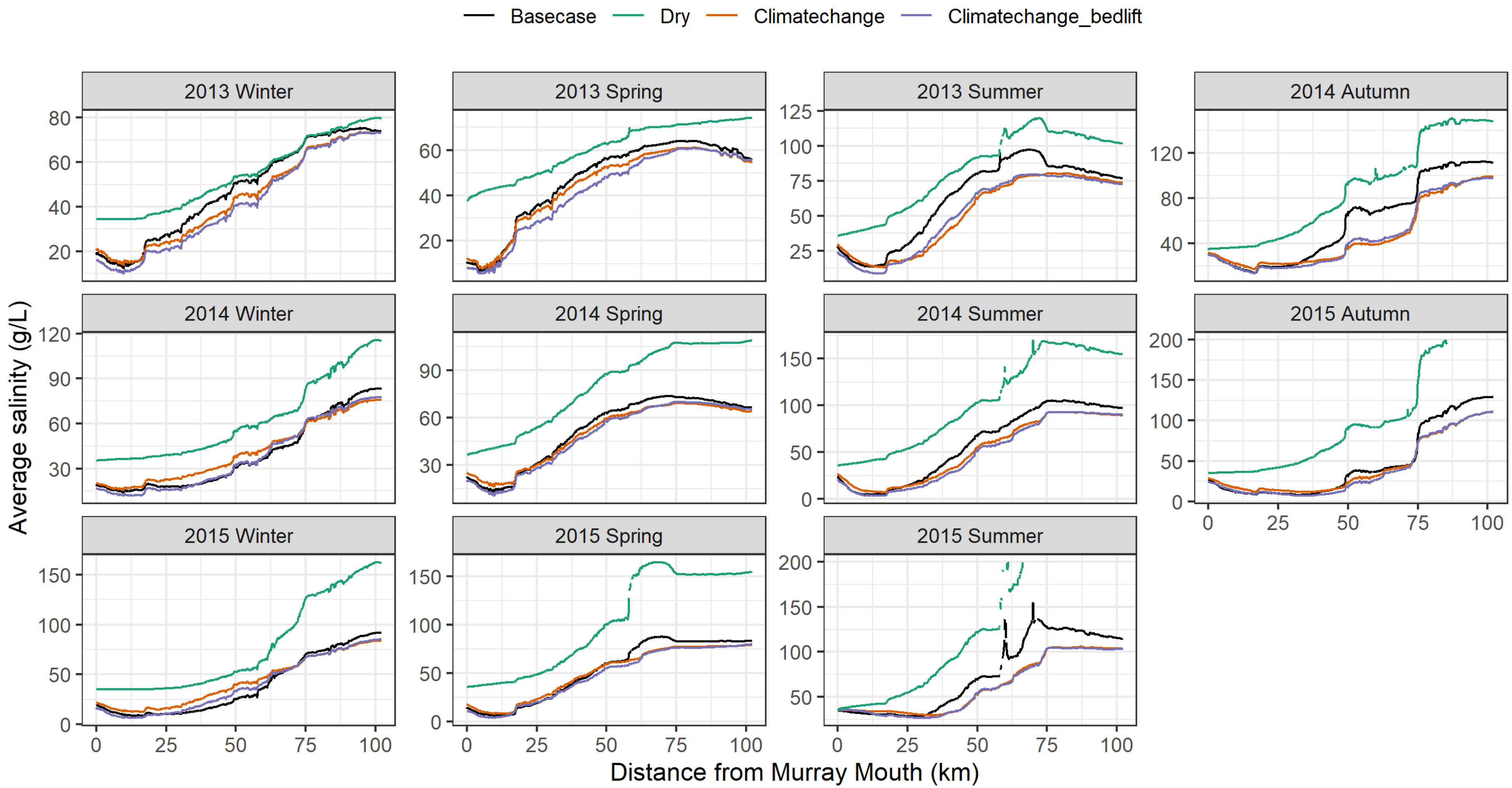

Figure 4-3. Modelled salinities along the length of the Coorong (north to south) for base case, dry and climate change scenarios

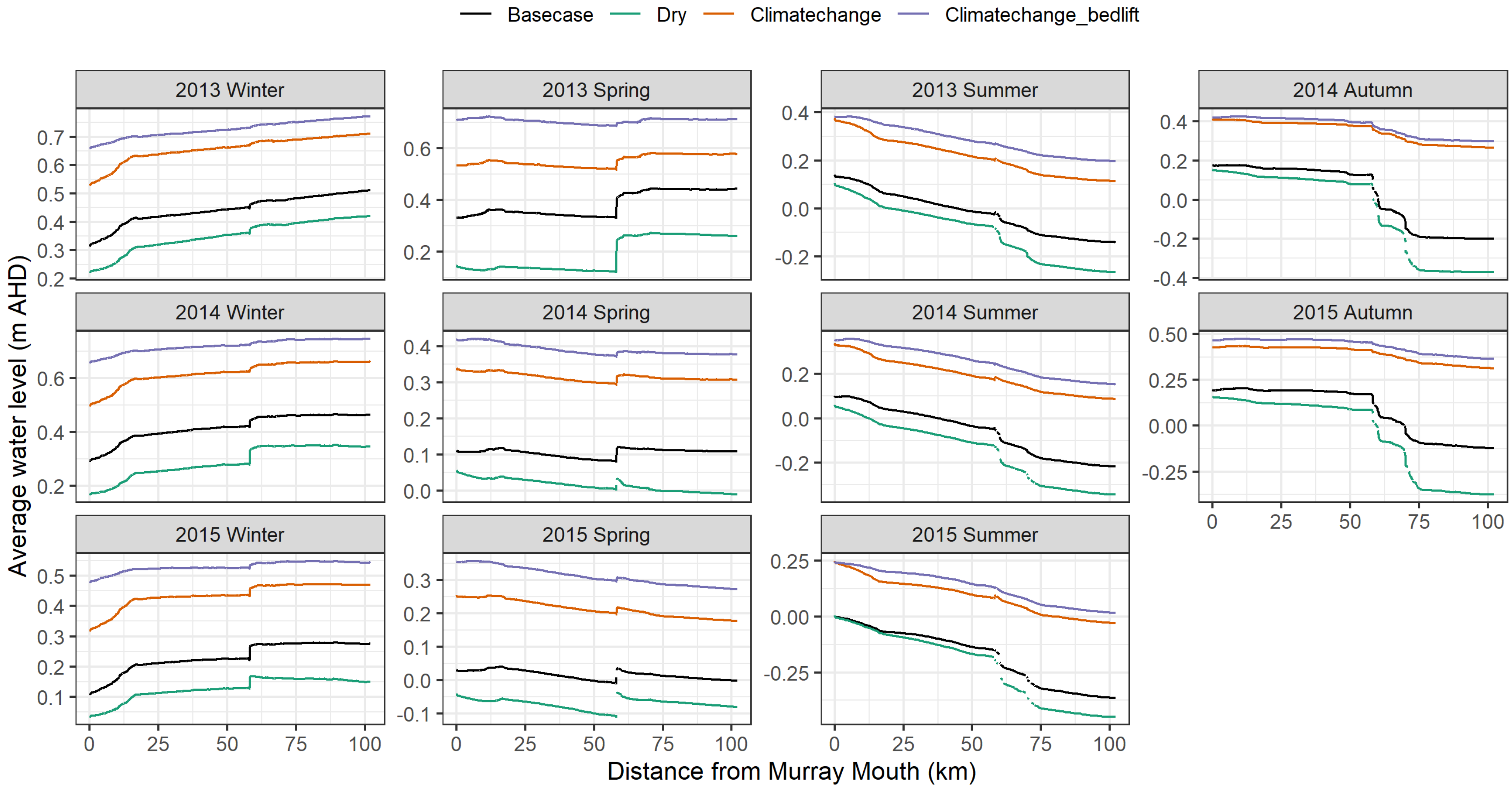

Figure 4-4. Modelled water levels along the length of the Coorong (north to south) for base case, dry and climate change scenarios

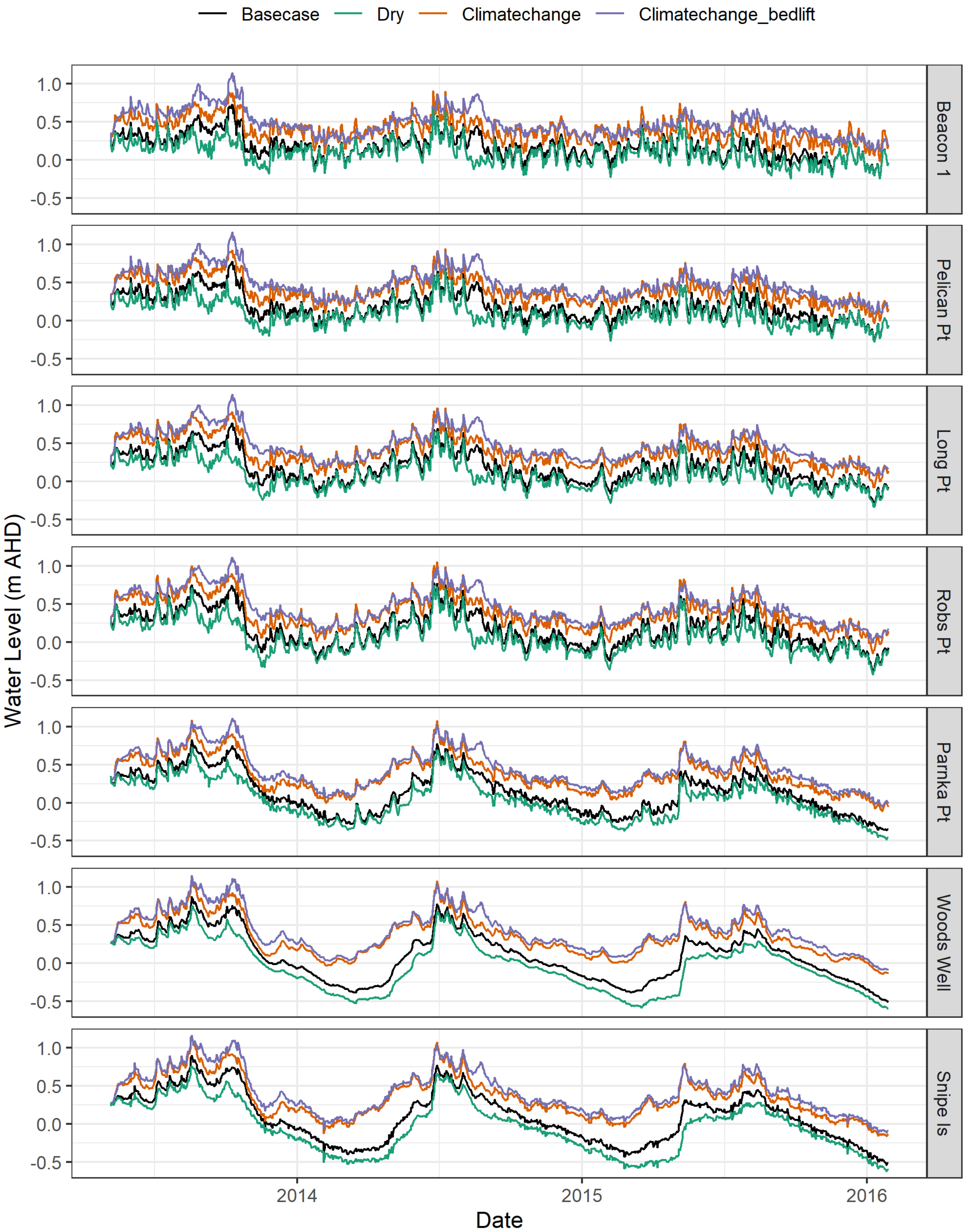

Figure 4-5. Modelled water levels at gauging stations across the Coorong for base case, dry and climate change scenarios

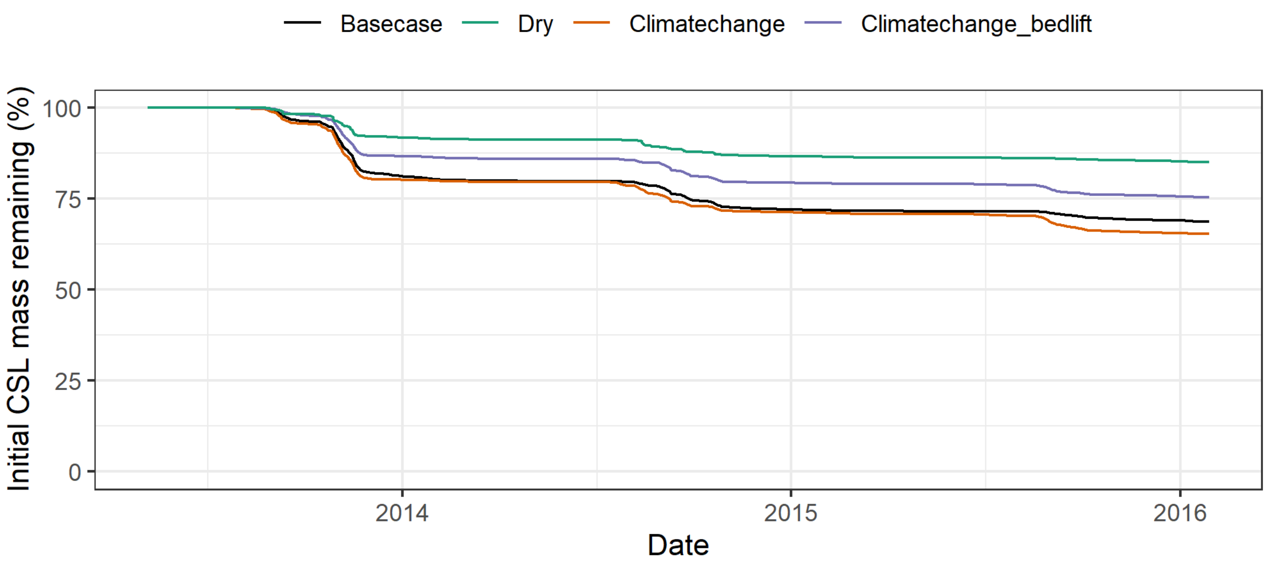

Figure 4-6 Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case dry and climate change scenarios

4.4 Pumping scenarios

4.4.1 Pumping direction

Results for scenarios with pumping in/out of the Coorong South Lagoon (i.e. at Policeman Point) as the only treatment measure, compared to the base case (normal) scenario are presented in Figure 4-7 to Figure 4-11.

The results indicate that pumping either into or out of the south lagoon reduces salinity in the south lagoon. The impact of pumping 250 ML/d *out* of the south lagoon is similar to pumping *in* 500 ML/d. Pumping out of the lagoon into the southern ocean is therefore more efficient than pumping into the lagoon to drive water out through the mouth.

Pumping into the south lagoon pushes higher salinity water into the north lagoon, causing salinity in the north lagoon to exceed the base case. This is particularly evident at the gauge locations for Long Point and Robs Point. This effect persists into the third year of simulation time, even after some freshening is experienced in the south lagoon. The results suggest salinities in the north lagoon exceed the management trigger threshold of 40 g/L for two months when pumping into the south lagoon.

4.4.2 Pumping rate and duration

Results comparing the various pumping out options are shown in Figure 4-12 and Figure 4-13. Pumping out at a constant rate of 125 ML/d reduces the peak salinity over time with observed inflows. Salinity reduces at a relatively faster rate for pumping out at 250 ML/d and 500 ML/d. Pumping at a constant rate of 500 ML/d out of the south lagoon reduced water levels at critical times of the year and is therefore not considered a feasible option. Pumping at 500 ML/d only when water levels in the south lagoon are above 0.2 mAHD is slightly less effective in reducing salinity than pumping out at a constant rate of 125 ML/d, and further less effective for pumping only above 0.3m AHD. This is likely because water levels are only high enough to trigger pumping for approximately 6 months, during the period in which salinities are lowest. However, the variable pumping has negligible impact on water levels.

This reduction in water levels is the main disadvantage of a constant flow rate pumping out option. Once levels drop below approximately 0.3 mAHD the evaporation rate from the south lagoon can exceed the conveyance capacity of the connection between the lagoons and the south lagoon water level drops below the north lagoon over summer. This seasonal trend is further exacerbated by increasing the volume removed from the south lagoon through pumping. The pumping out options result in a relatively small reduction in water levels over the period relevant for Ruppia to complete its annual life cycle (approximately end of December), however this increases to approximately 0.25 m lower water levels over February – March for the 250 ML/d scenario compared to base case.

4.4.3 Pumping location

Results for scenarios with pumping out 250 ML/d at Policeman Point and Round Island, along with circulation of 250 ML/d from Round Island to Policeman Point, compared to the base case (normal) scenario are presented in Figure 4-14 to Figure 4-16.

The results indicate that pumping from the southern end (Policeman Point) is more effective than pumping at the northern end (Round Island) for reducing salinity in the south lagoon – but the difference is minimal.

Circulating water from Round Island to Policeman Point (i.e. pumping sea water *in* at Round Island and Coorong water *out* from Policeman Point) has almost the same benefit in reducing salinity to pumping out from Round Island alone, but has minimal effect on water levels in the south lagoon (because of the maintained water balance). This is further discussed in the next section.

4.4.4 Circulation pumping

Results for the scenarios that incorporate both pumping in and out (i.e. simultaneously circulating ocean water in at Round Island and Coorong water out at Policeman Point, and pumping in and out at Policeman Point based water level triggers), alongside base case and comparable uni-direction pumping scenarios are shown in Figure 4-17 to Figure 4-21.

As noted above, circulating water from Round Island to Policeman Point at a rate of 250 ML/d has almost the same salinity reduction benefit, but without detrimentally lowering water levels, compared to pumping out alone.

The scenario of pumping in *and* out based on water level triggers does not flush water from the south lagoon as much, but is able to maintain salinity levels in the southern lagoon over summer and autumn through dilution, when other scenarios see an increase in salinity over these periods due to evapoconcentration. Pumping water in to the Coorong at low water levels has the result of increasing water levels, closer to those where greater areas of suitable wading habitat is created (maximised at approximately 0.1 mAHD). There is little difference in the resulting water level and salinity for the different water level triggers, i.e. above 0.2 m compared to 0.3 m for the trigger to pump water *out,* and below 0.1 m or 0.15 m for the trigger to pump water *in*. The difference is most noticeable during spring (Figure 4-19), where water levels are higher in the south lagoon for the water level trigger of pumping in at 0.15 m and out at 0.3 m. In autumn, the pumping in scenarios can result in high salinity south lagoon water being pushed into the north lagoon, which could be mitigated through a suitable water level trigger to cease pumping in.

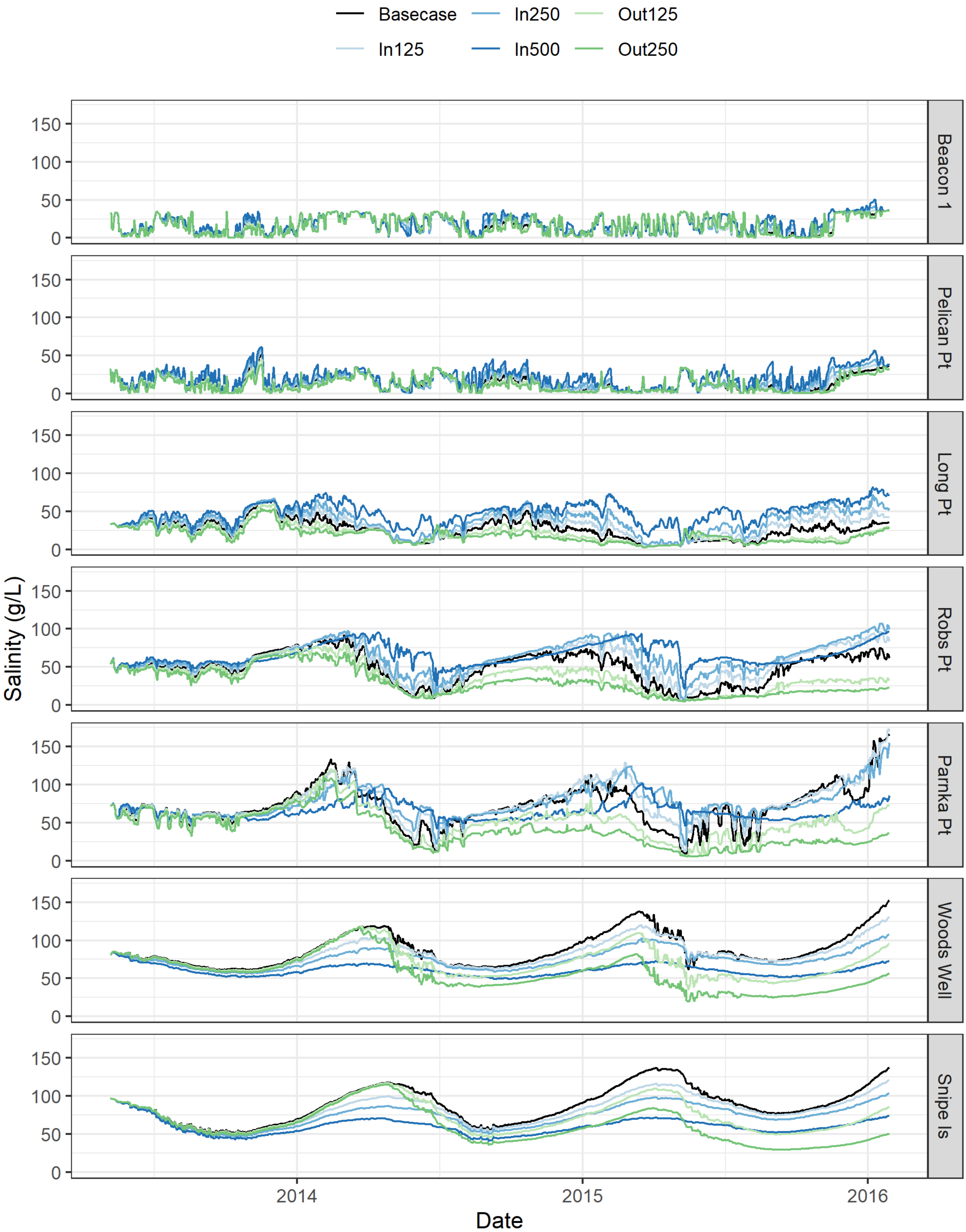

Figure 4-7. Modelled salinity under base case and south lagoon pumping only scenarios

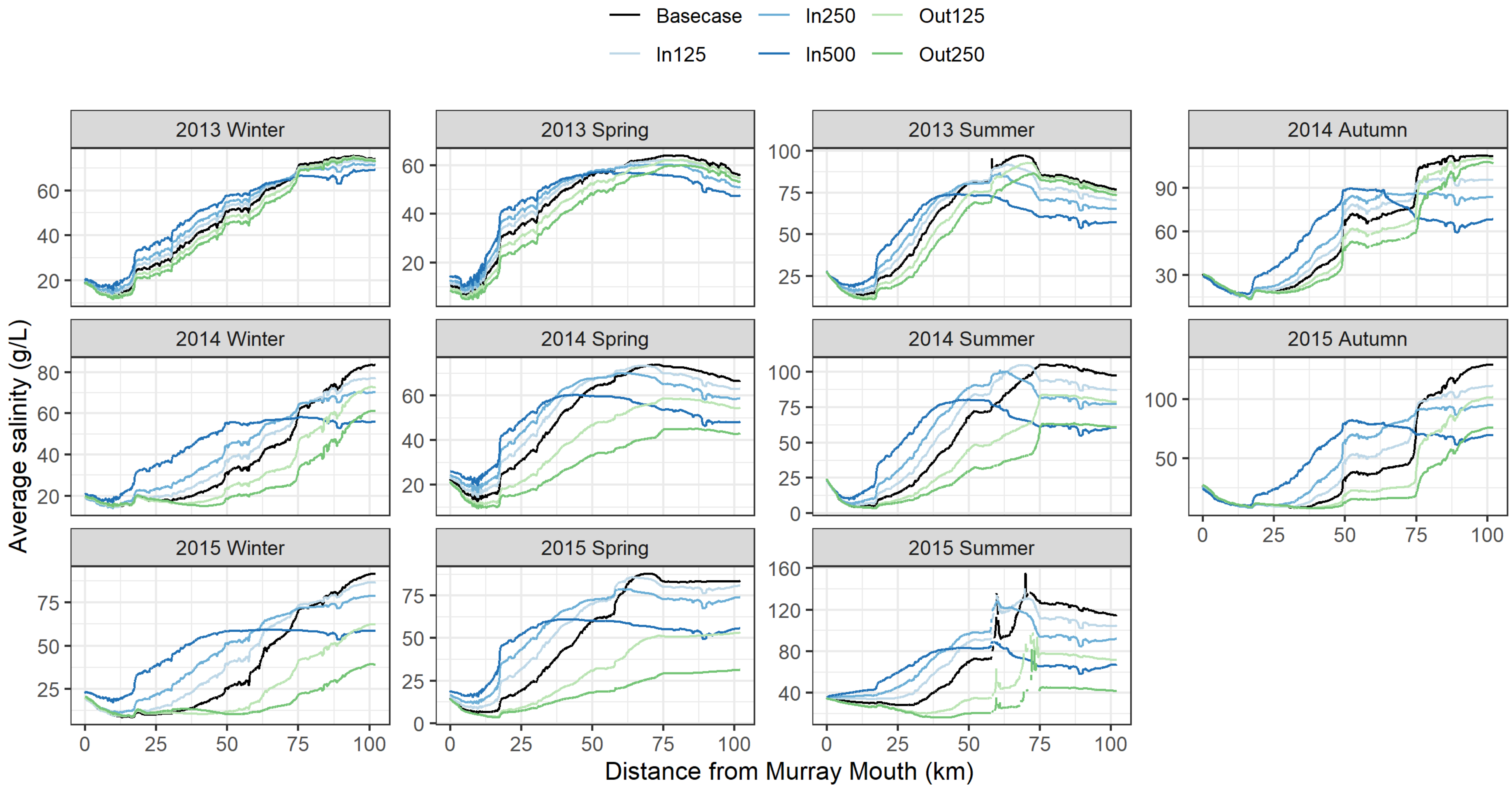

Figure 4-8. Modelled salinities along the length of the Coorong (north to south) for base case and pumping scenarios

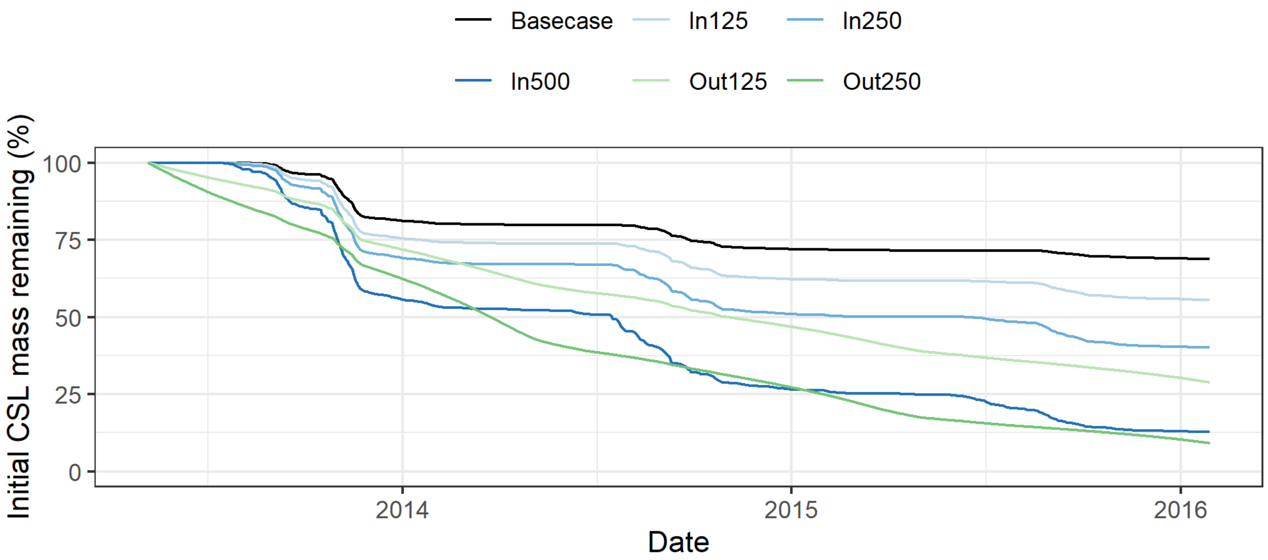

Figure 4-9. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and south lagoon pumping only scenarios

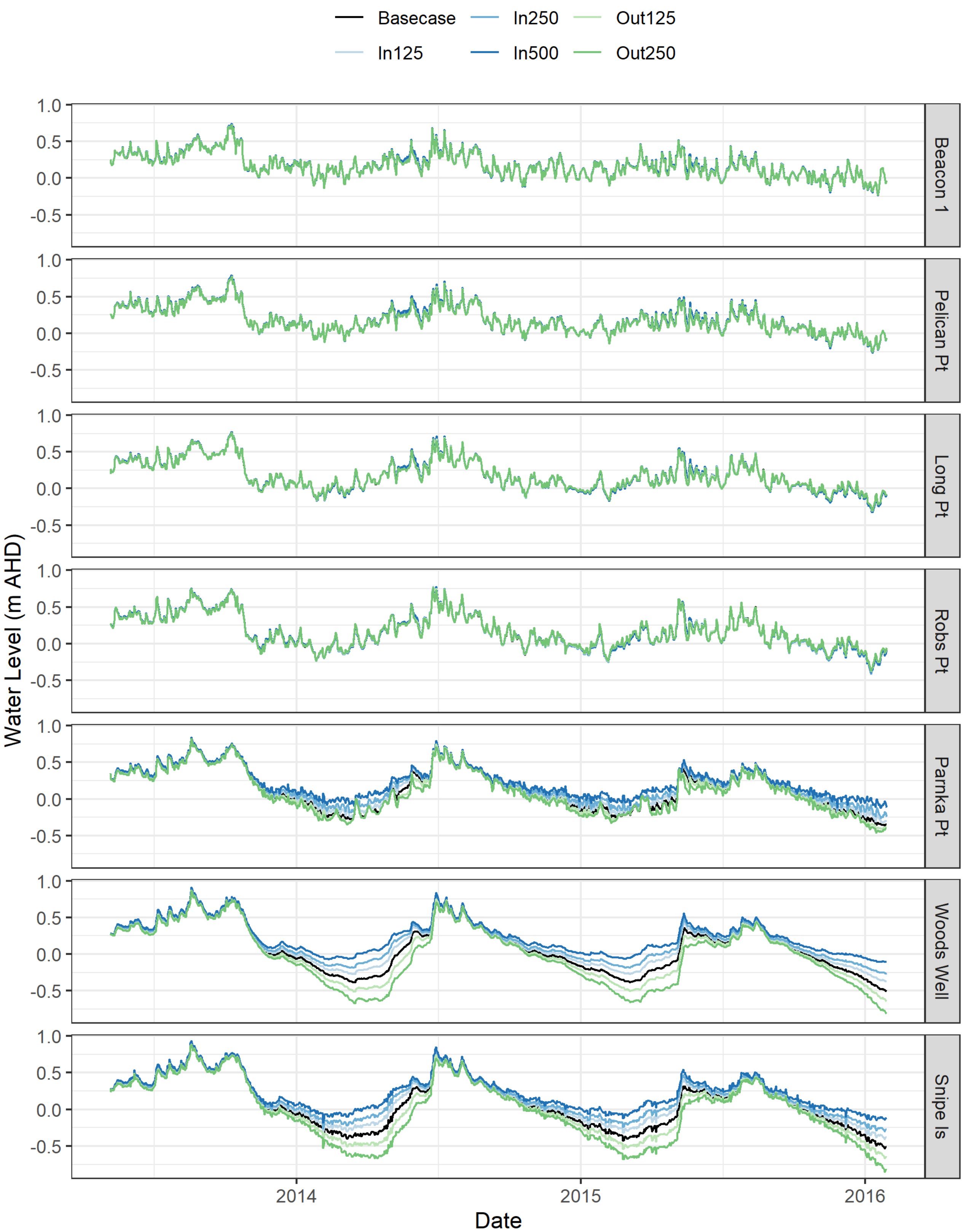

Figure 4-10. Modelled water levels at gauging stations across the Coorong for base case and south lagoon pumping only scenarios

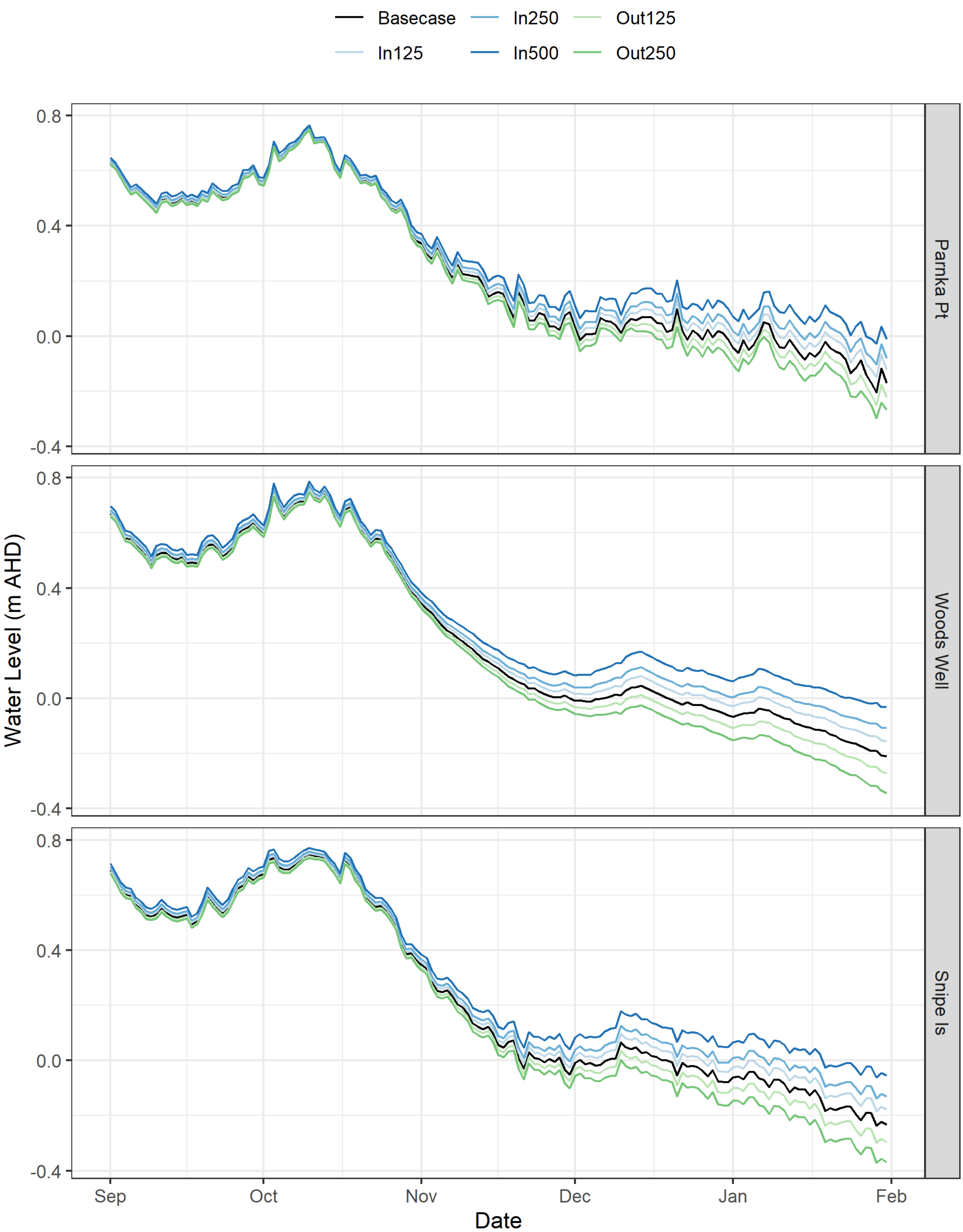

Figure 4-11. Modelled water levels at gauging stations in the Coorong south lagoon for base case and south lagoon pumping only scenarios in 2013/14

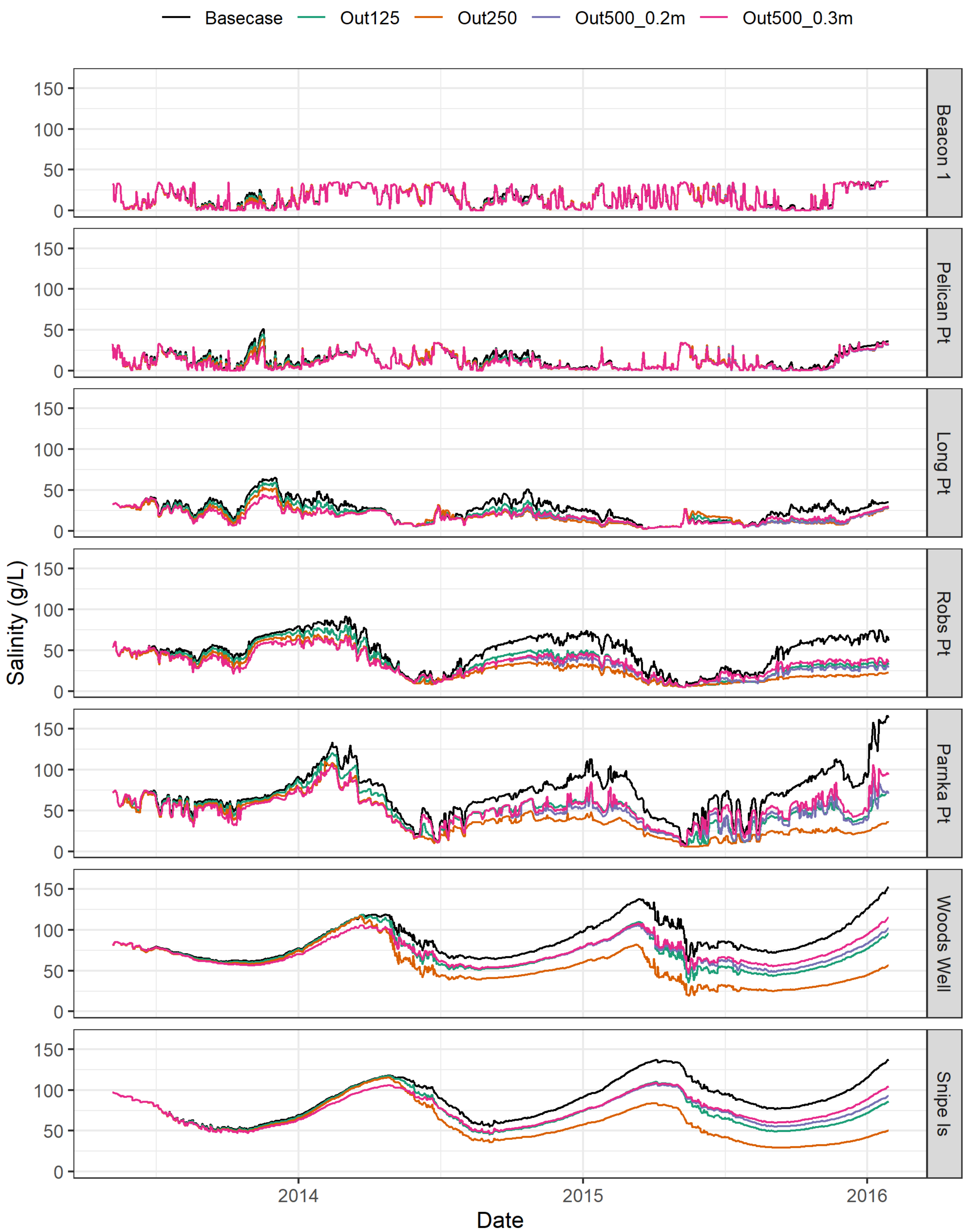

Figure 4-12. Modelled salinity at gauging stations across the Coorong for base case and various pumping out rates

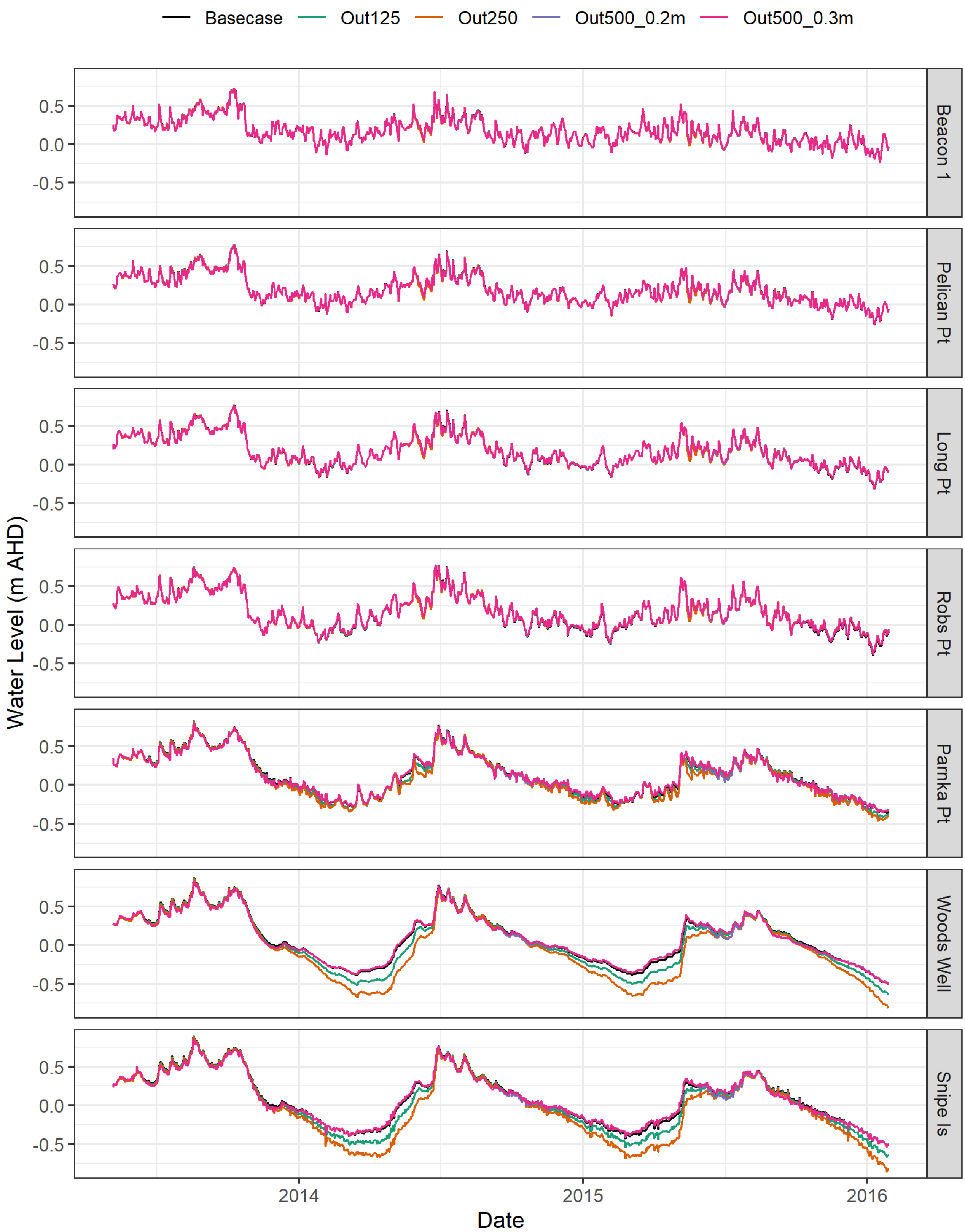

Figure 4-13. Modelled water levels at gauging stations across the Coorong for base case and various pumping out rates

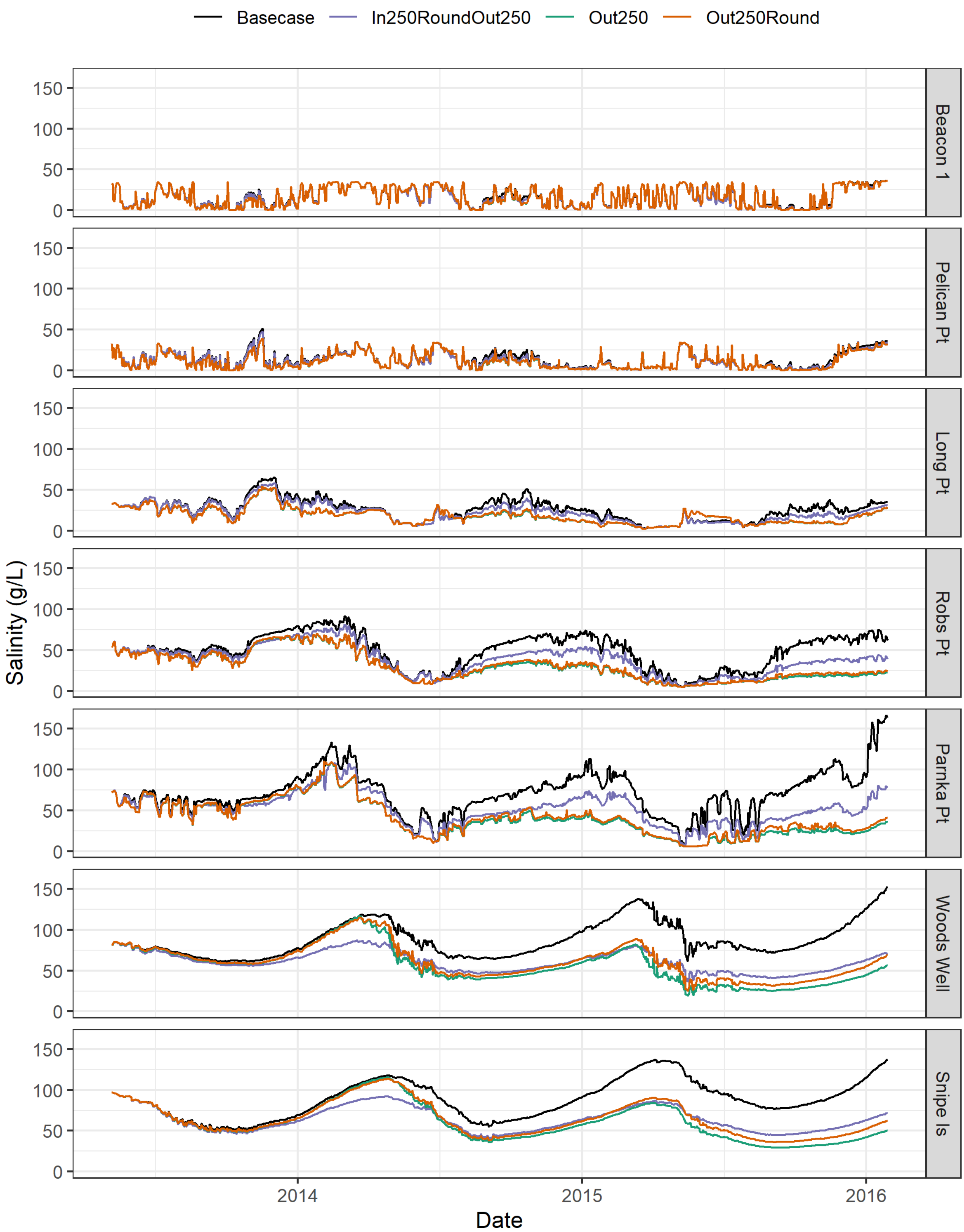

Figure 4-14. Modelled salinity under base case and different pumping location scenarios

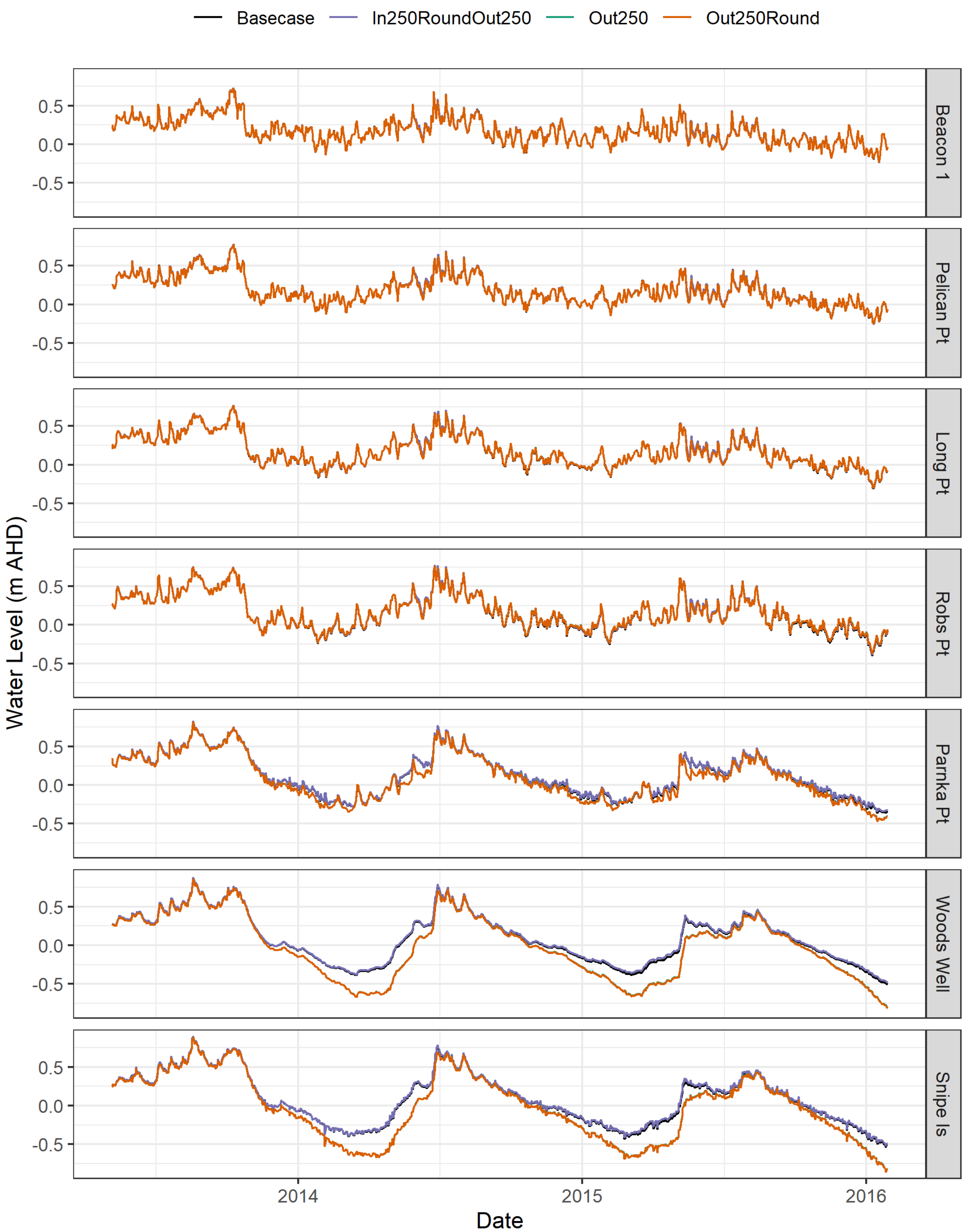

Figure 4-15. Modelled water levels at gauging stations across the Coorong for base case and different pumping location scenarios

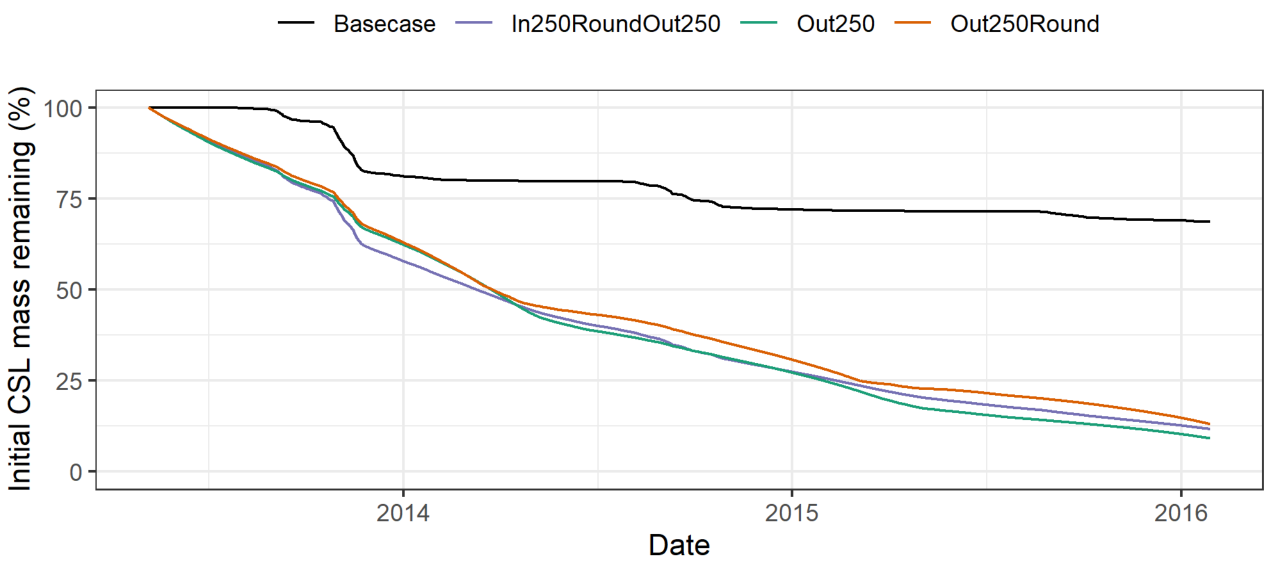

Figure 4-16. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and different pumping location scenarios

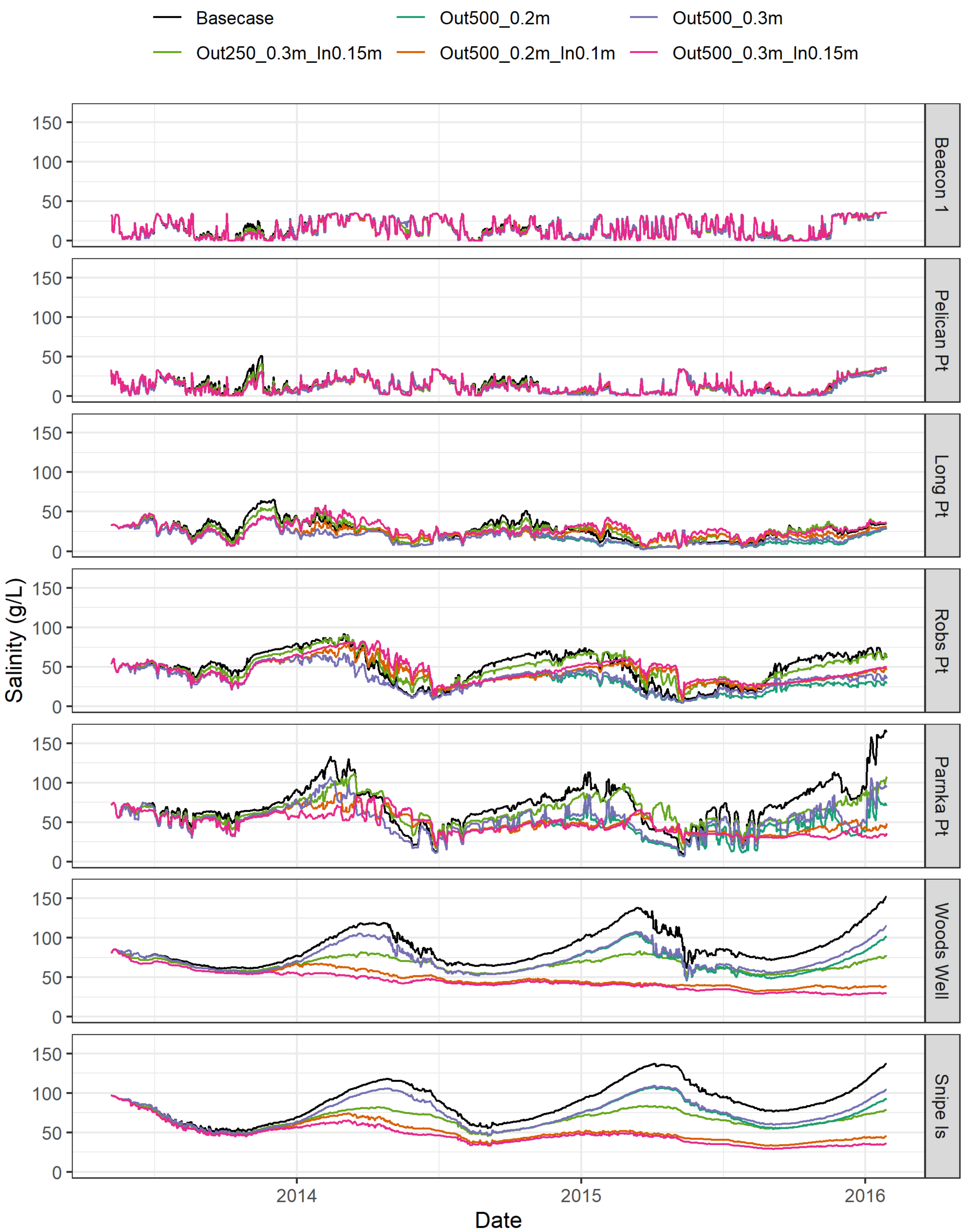

Figure 4-17. Modelled salinity under base case, bi-directional pumping, and comparable uni-directional pumping at water level trigger scenarios

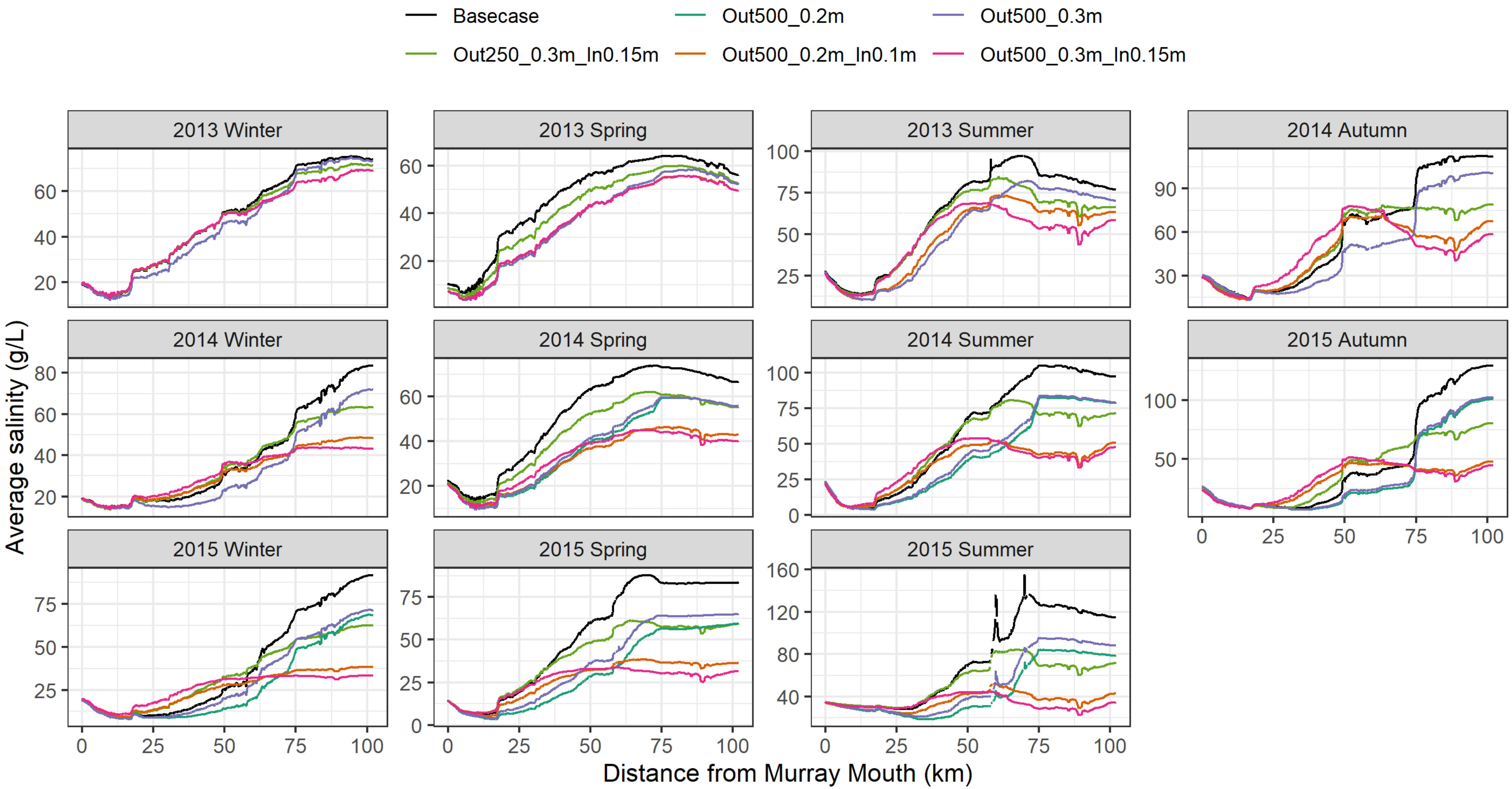

Figure 4-18. Modelled salinities along the length of the Coorong (north to south) under base case, bi-directional pumping, and comparable uni-directional pumping at water level trigger scenarios

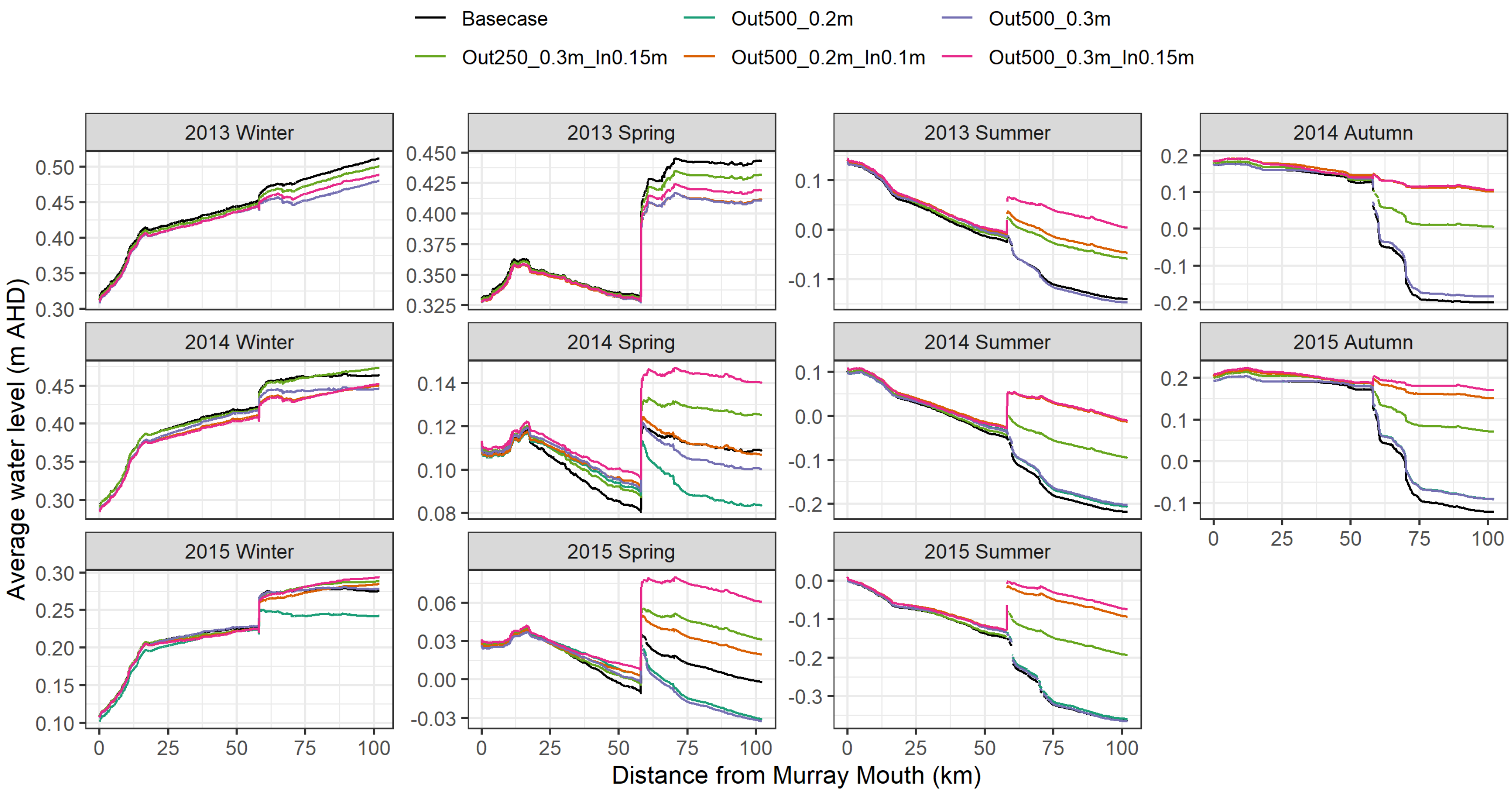

Figure 4-19. Modelled water levels along the length of the Coorong (north to south) under base case, bi-directional pumping, and comparable uni-directional pumping at water level trigger scenarios

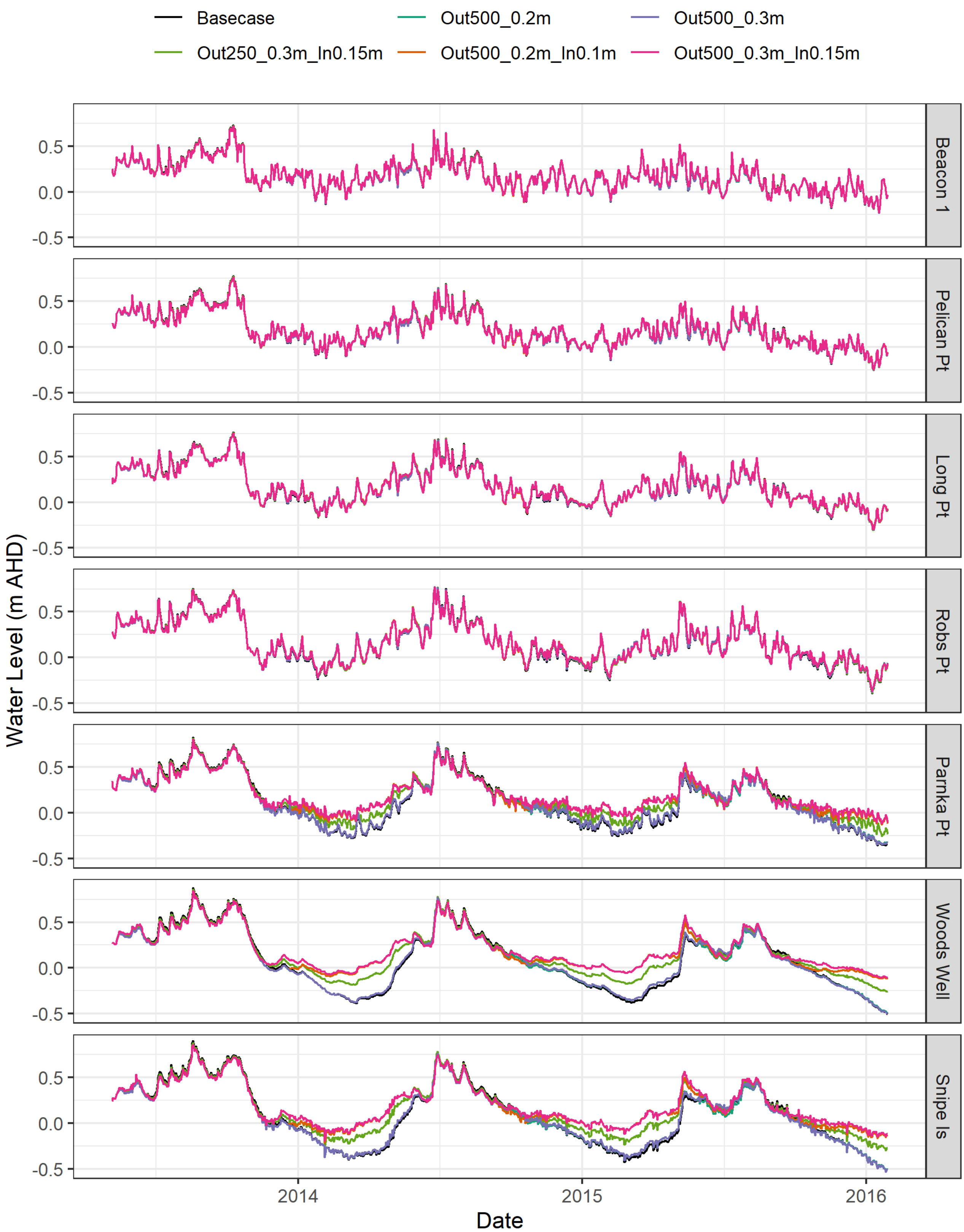

Figure 4-20. Modelled water levels at gauging stations across the Coorong for under base case, bi-directional pumping, and comparable uni-directional pumping at water level trigger scenarios

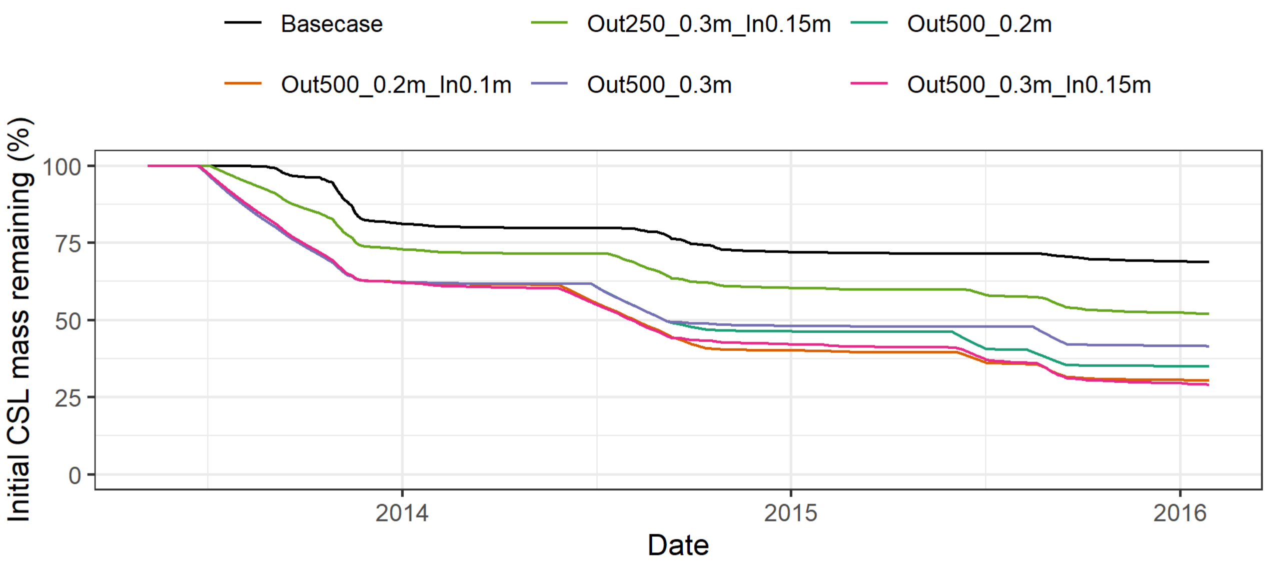

Figure 4-21. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon under base case, bi-directional pumping, and comparable uni-directional pumping at water level trigger scenarios

4.4.5 Temporary vs permanent pumping options

Both temporary and permanent options for a connection between the Coorong South Lagoon and Southern Ocean have been proposed. The concept for the temporary option is that a one-off intervention could reset the system and then not require further pumping. Modelling has not considered long-term scenarios to investigate this as yet. The observed salinity data in the south lagoon is presented in Figure 4-22. The increasing salinity over the Millennium drought from 2002 can be seen at the Sand Spit point site before it was closed, and then the high flows break the drought in 2010 and continue until 2014 can be seen to somewhat 'reset' the system. Following this, salinities start to increase again, until the high flows at the end of 2016. Since this time, salinities have continued to increase with low flow conditions. In each of the periods between high flow events, south lagoon salinities have increased each year in the order of 11-16 g/L.

Based on this observed data, a one off temporary reset option is not expected to provide enduring benefits to the Coorong south lagoon without significant increases in barrage flow.

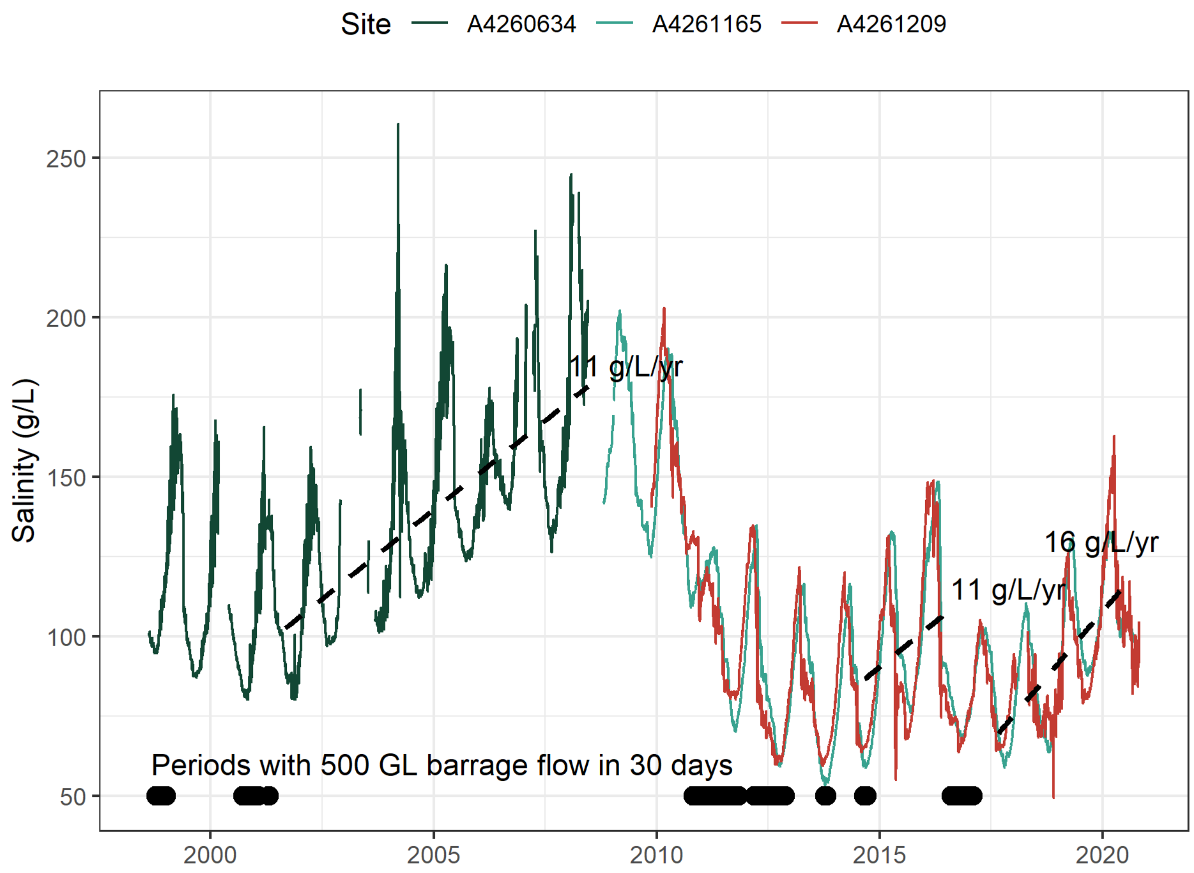

Figure 4-22. Observed south lagoon salinities at Sand Pit point (A4260634, closed in 2008), Snipe Island (A4261165) and Woods Well (A4261209). Periods of high barrage flow (greater than 500 GL in 30 days) are shown as black dots, and trends in salinity between these periods as dashed lines.

4.5 CoorongPassive ocean connection scenarios

The passive connection behaves as expected, with flow from the Coorong to ocean predominately in the winter months, and flow from the ocean to Coorong over summer (Figure 4-24). The rate of transfer out of the Coorong in winter only exceeds 250 ML/d in scenarios where the pipe number and size equals or exceeds 1000 x 10. It is therefore not surprising that the smaller passive ocean connections trialled are not as effective as pumping out of the south lagoon 250 ML/d.

As expected, the greater the number (or size) of pipes, the greater the impact on reducing salinity in the CSL. The impact, however, is not substantial. Salinities remain above 50 g/L at the very south end, with roughly 40% of the initial CSL mass remaining after three years, except in the two largest pipe scenarios, which perform similarly to the pumping out at 250 ML/d scenario. The passive system has minimal impact on water levels, except in the autumn months where the inflow from the ocean directly to the south lagoon increases water levels. The two largest pipe scenarios do not see as much reduction in water levels in the south lagoon during the summer months, as evaporation is offset by inflow from the ocean. Water levels are somewhat reduced in spring and winter for these two larger scenarios.

For a passive ocean connection to have sufficient impact on reducing salinities in the south lagoon, a considerably large number of pipes, or pipe diameter, would be required.

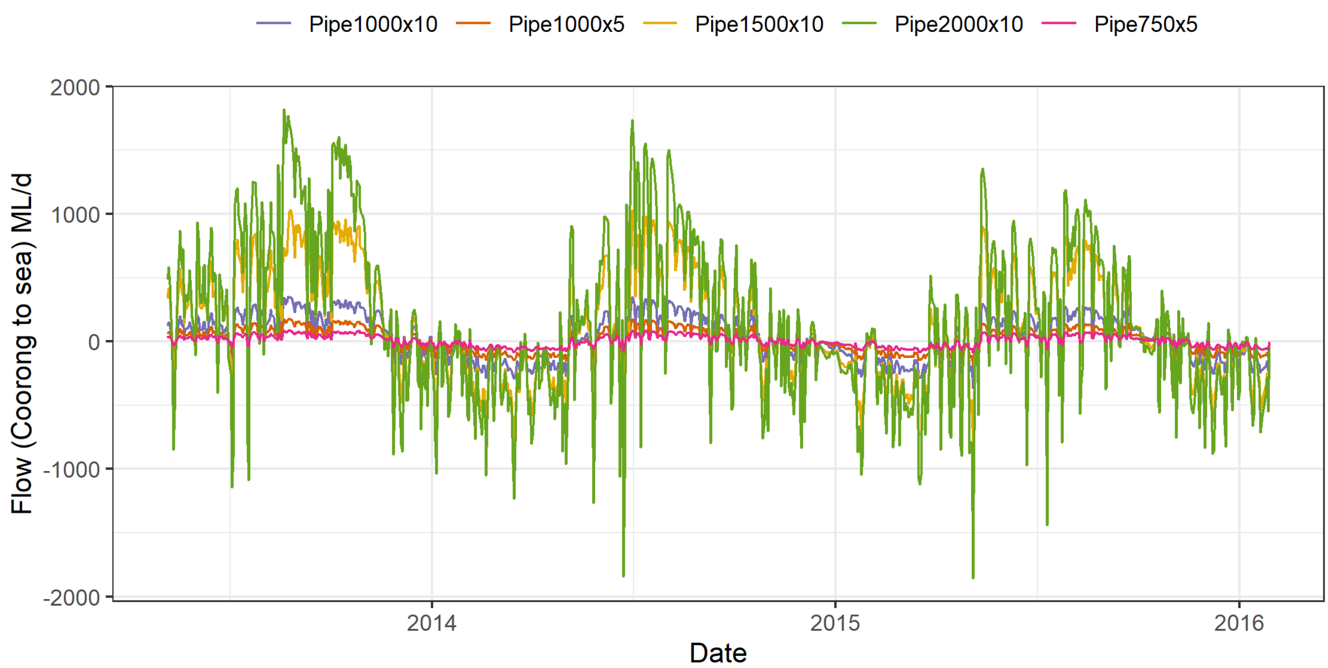

Figure 4-23. Total daily cumulative flow through from Coorong to Sea

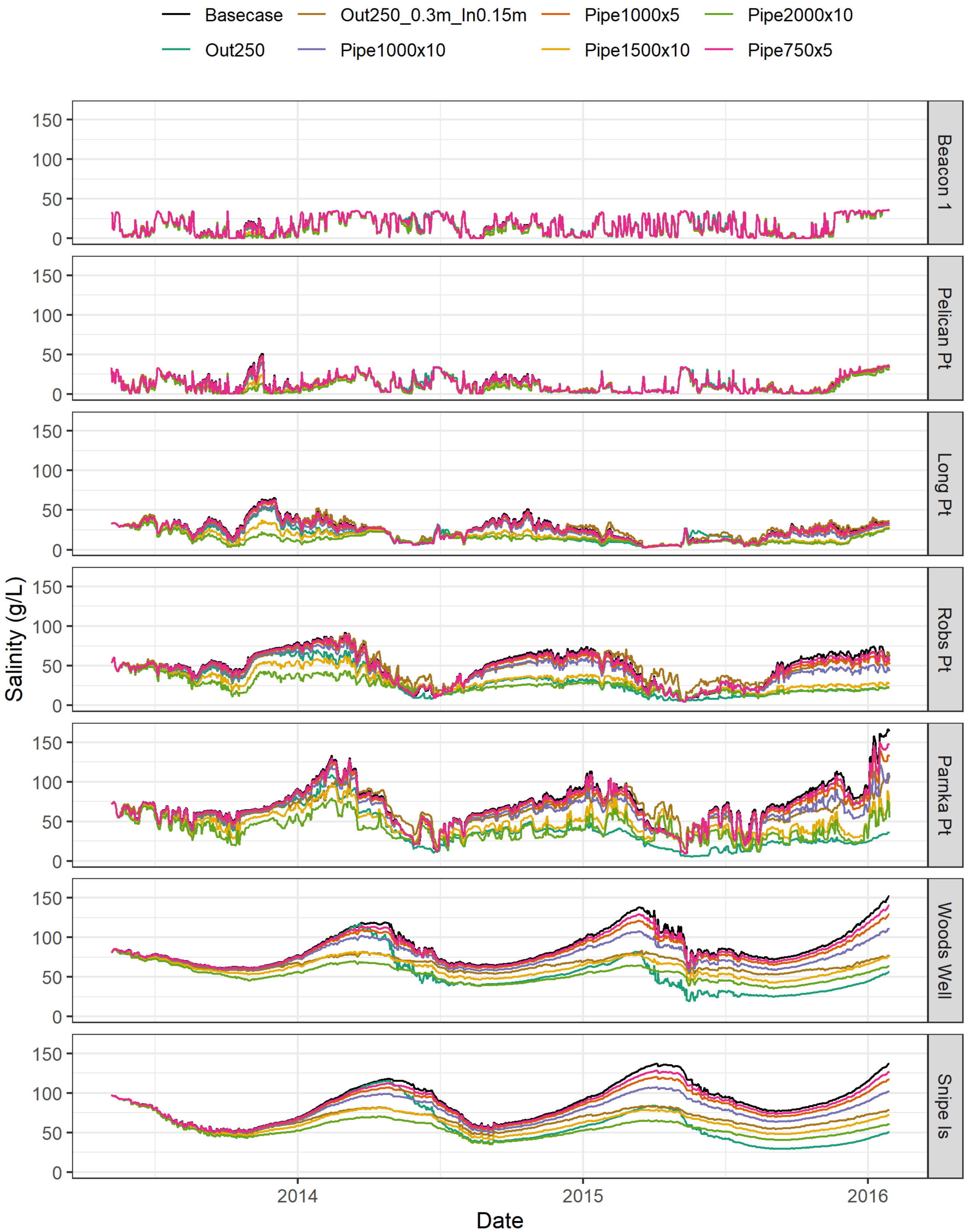

Figure 4-24. Modelled salinity under base case, passive connection and pumping out 250 ML/d scenarios

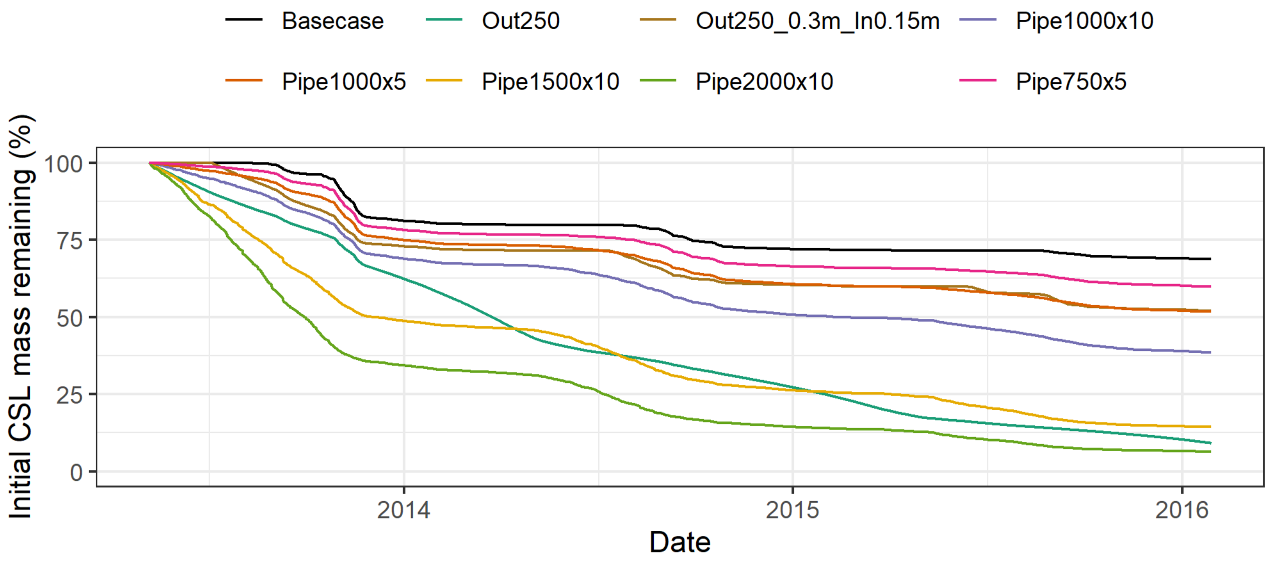

Figure 4-25. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case, passive connection and pumping out 250 ML/d scenarios

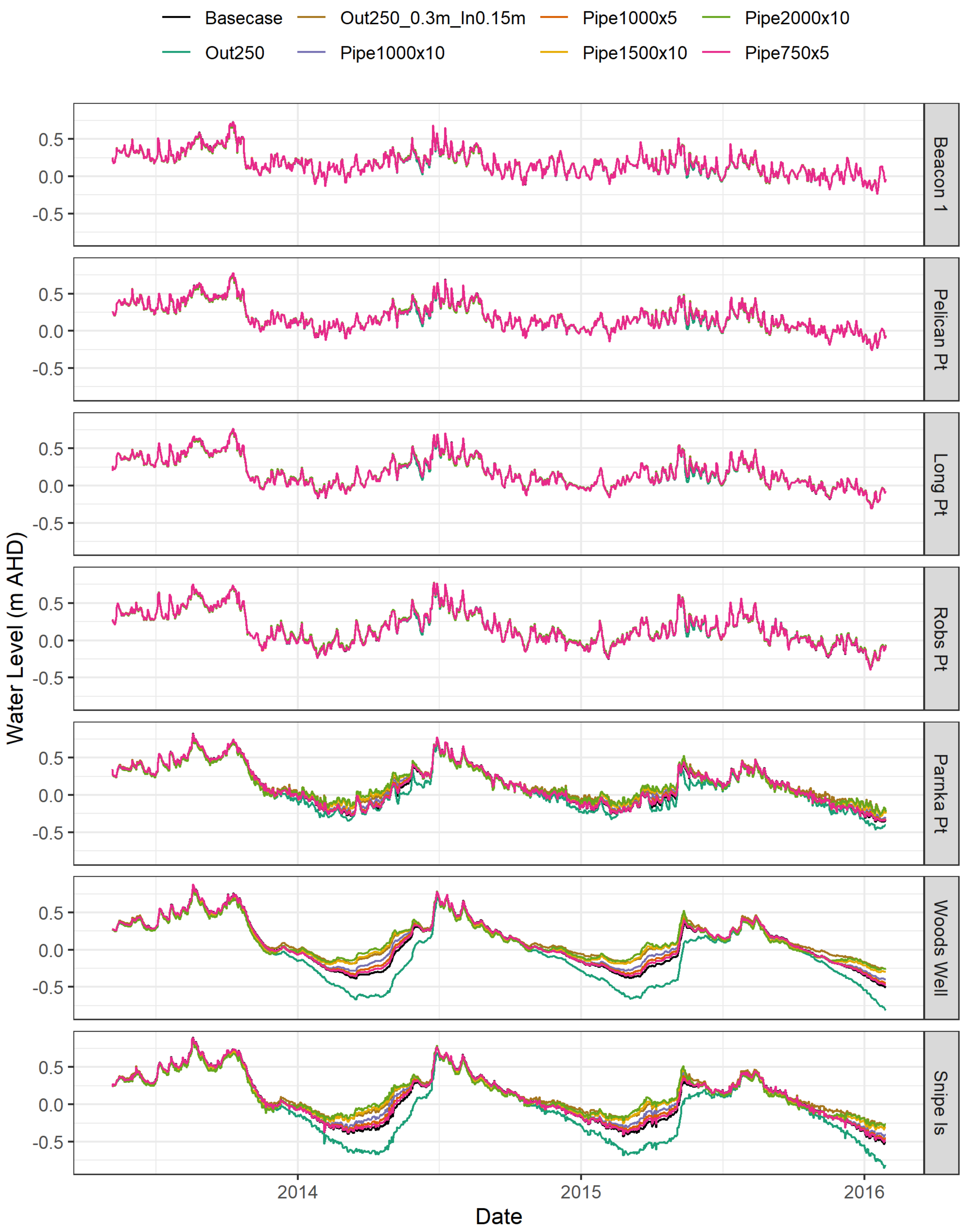

Figure 4-26. Modelled water levels at gauging stations across the Coorong for base case, passive connection and pumping out 250 ML/d scenario

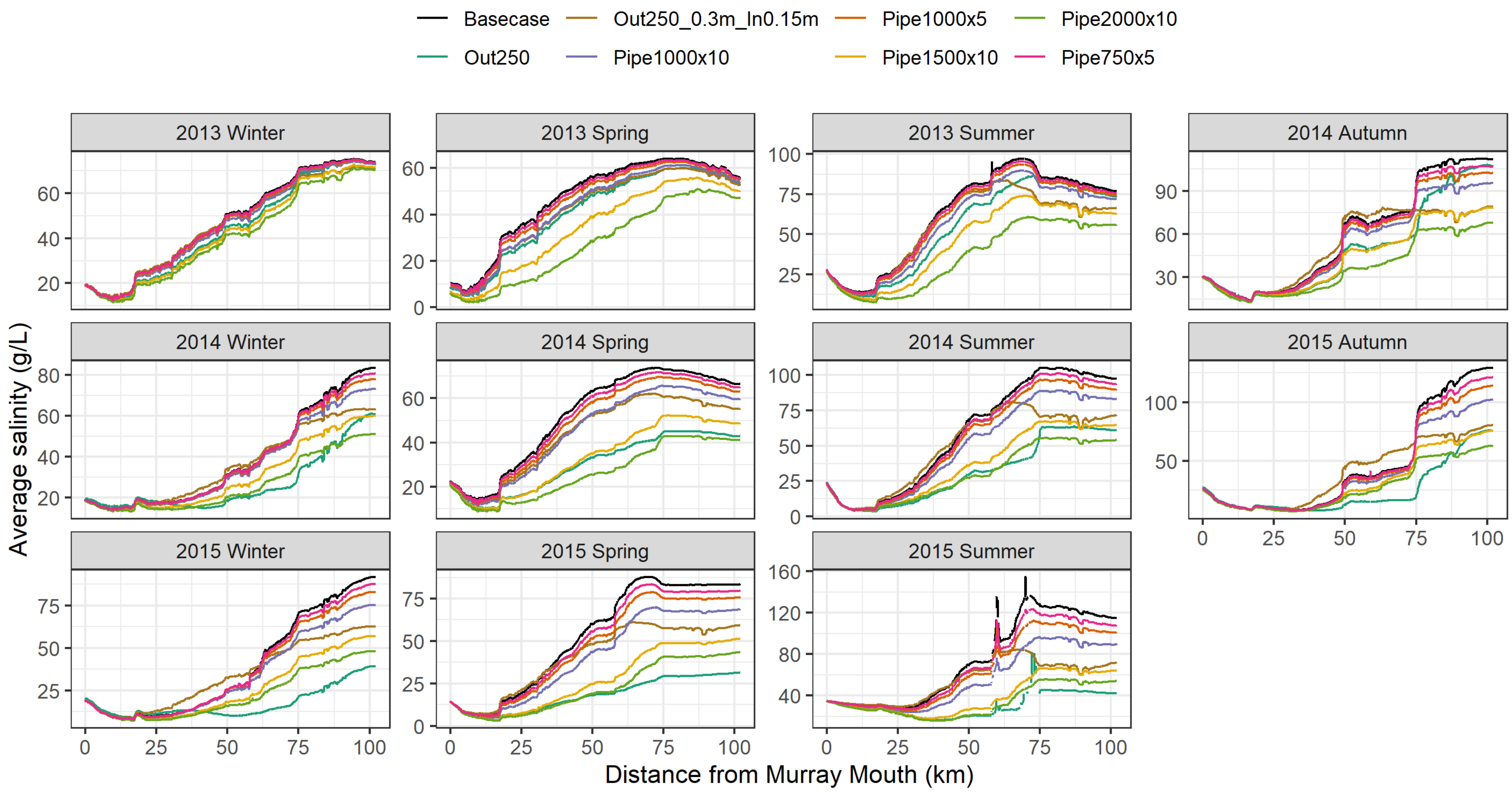

Figure 4-27. Modelled salinities along the length of the Coorong (north to south) for base case, passive connection and pumping out 250 ML/d scenarios

4.6 Dredging scenarios

Results for scenarios with channel dredging compared to the base case (normal) scenario are presented in Figure 4-28 to Figure 4-32.

The results indicate that dredging along Parnka narrows and Pelican Point generates a small reduction in salinity levels in the south lagoon, but it is less effective than any of the pumping options discussed in Section 4.3.

As demonstrated in Figure 4-32, dredging of Parnka narrows and Pelican Point results in more equalised water levels between the north and south lagoon. In low flow years (e.g. 2013), this would result in faster recessions of water levels in the lagoons over spring. It does, however, prevent the low water levels experienced only in the south lagoon over January to April, compared to the base case. This may provide more foraging habitat for shorebirds during the period they utilise the site in the largest numbers (January – February).

Dredging at Pelican point alone generates minimal impact on water levels or salinities in the Coorong, with results near identical to the base case.

The extreme dredging scenario does not produce substantially different results to combined dredging at Parnka narrows and Pelican Point. This confirms that these two locations are the main constrictions to flow in the Coorong as represented in the model.

Results for scenarios with wide mouth bathymetry are presented alongside the base case scenario in Figure 4-33 to Figure 4-36.

The wide mouth (alone) scenario shows almost no discernible difference to base case conditions in terms of salinity or water levels in either lagoon. Slight differences begin to emerge with the connection of the wider mouth to Parnka narrows through dredging, however insignificant.

A substantial difference is only seen when the wide mouth is combined with the large (i.e. extreme) dredge option, though salinity in the south lagoon does not consistently stay below 100 g/L. Water levels in the south lagoon are higher over the autumn months (January to April).

There is only a small difference between the large dredge only and large dredge with wide mouth scenarios, indicating that the existing bathymetry of the mouth is not the limiting constriction.

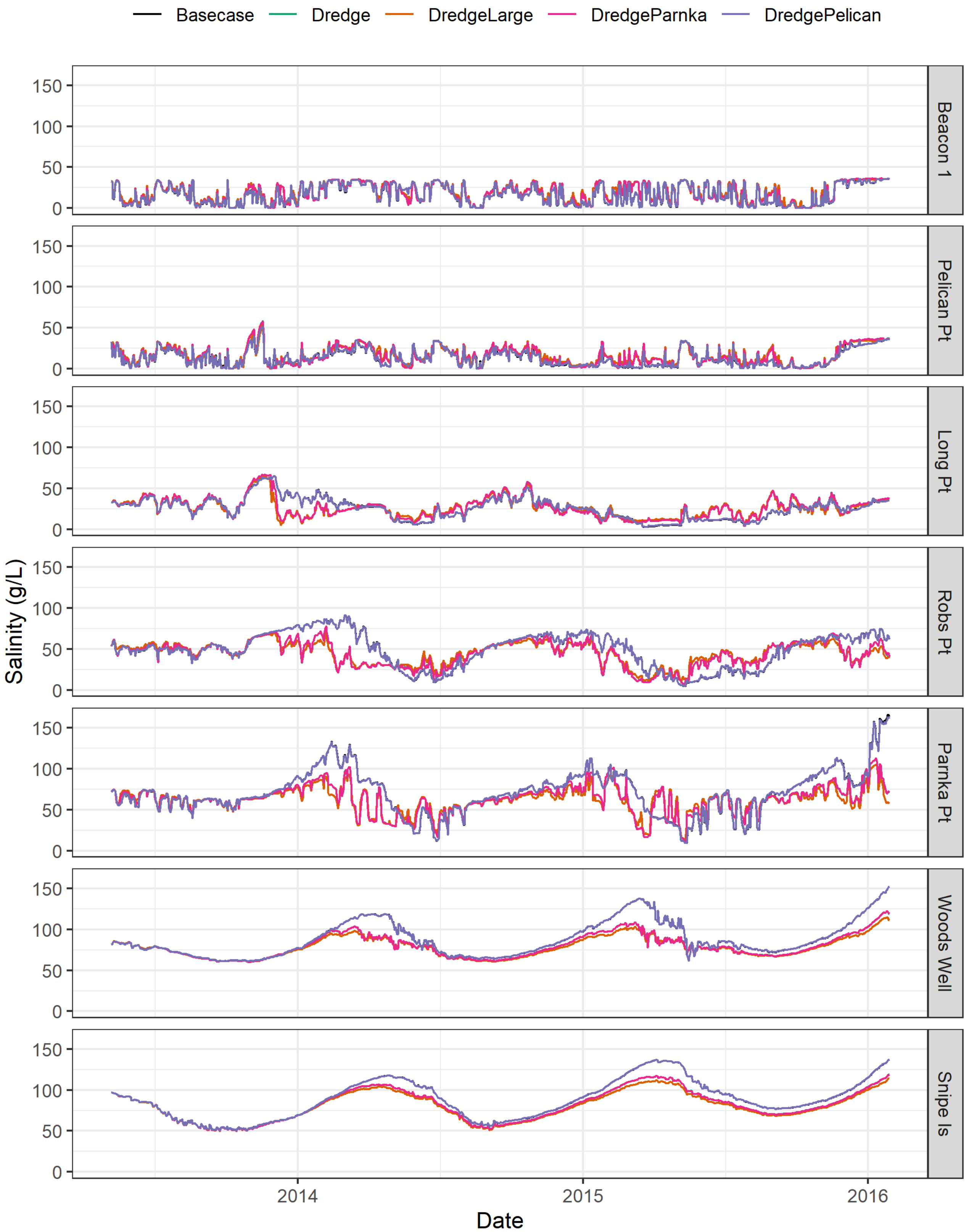

Figure 4-28. Modelled salinity under base case and dredging scenarios

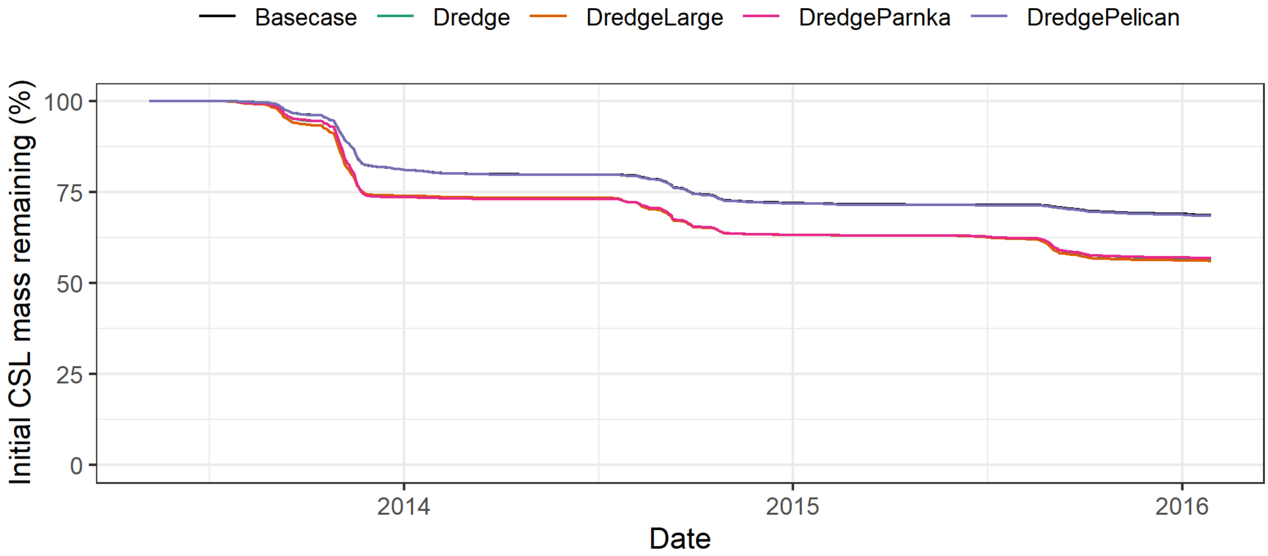

Figure 4-29. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and dredging scenarios

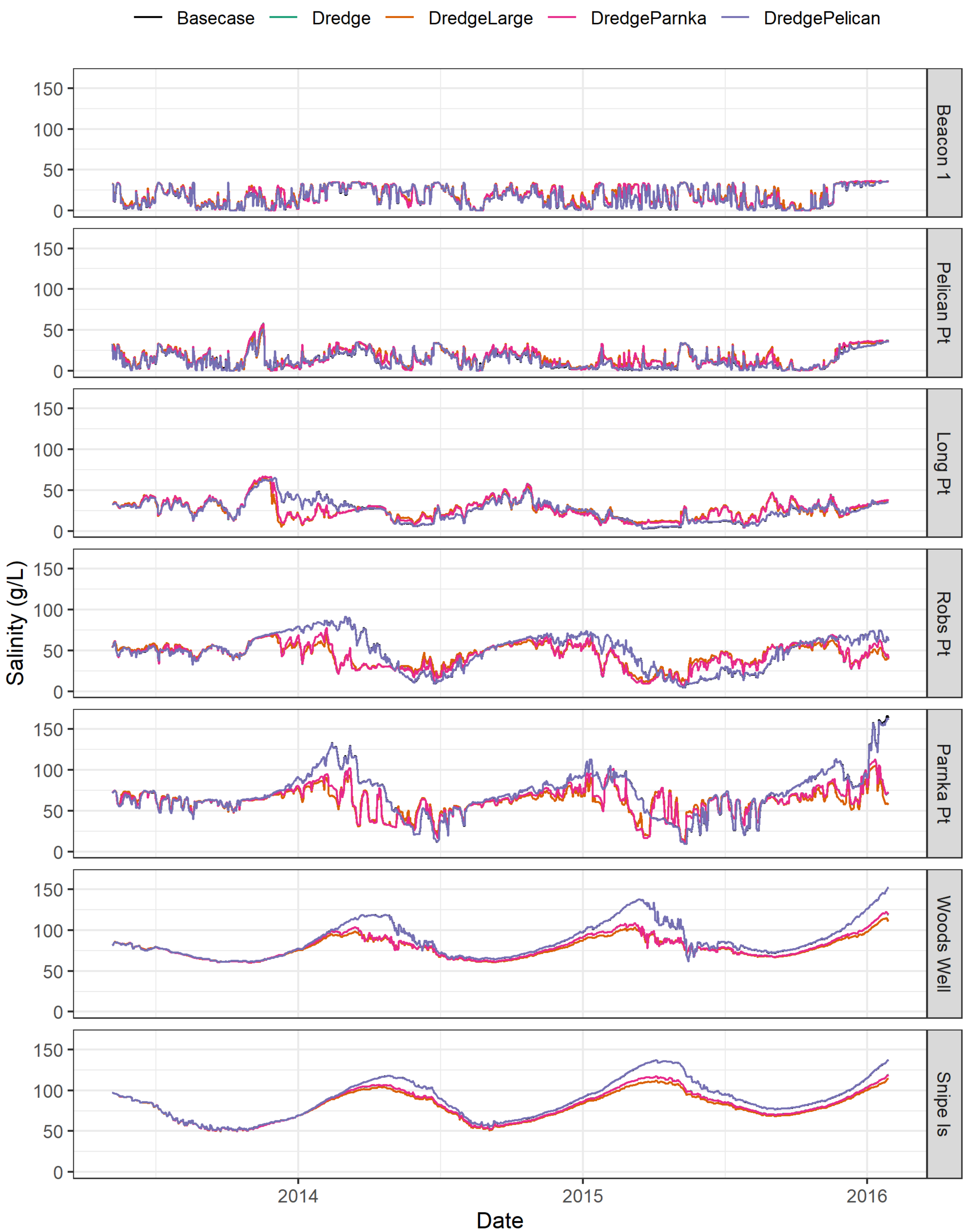

Figure 4-30. Modelled water levels at gauging stations across the Coorong for base case and dredging scenarios

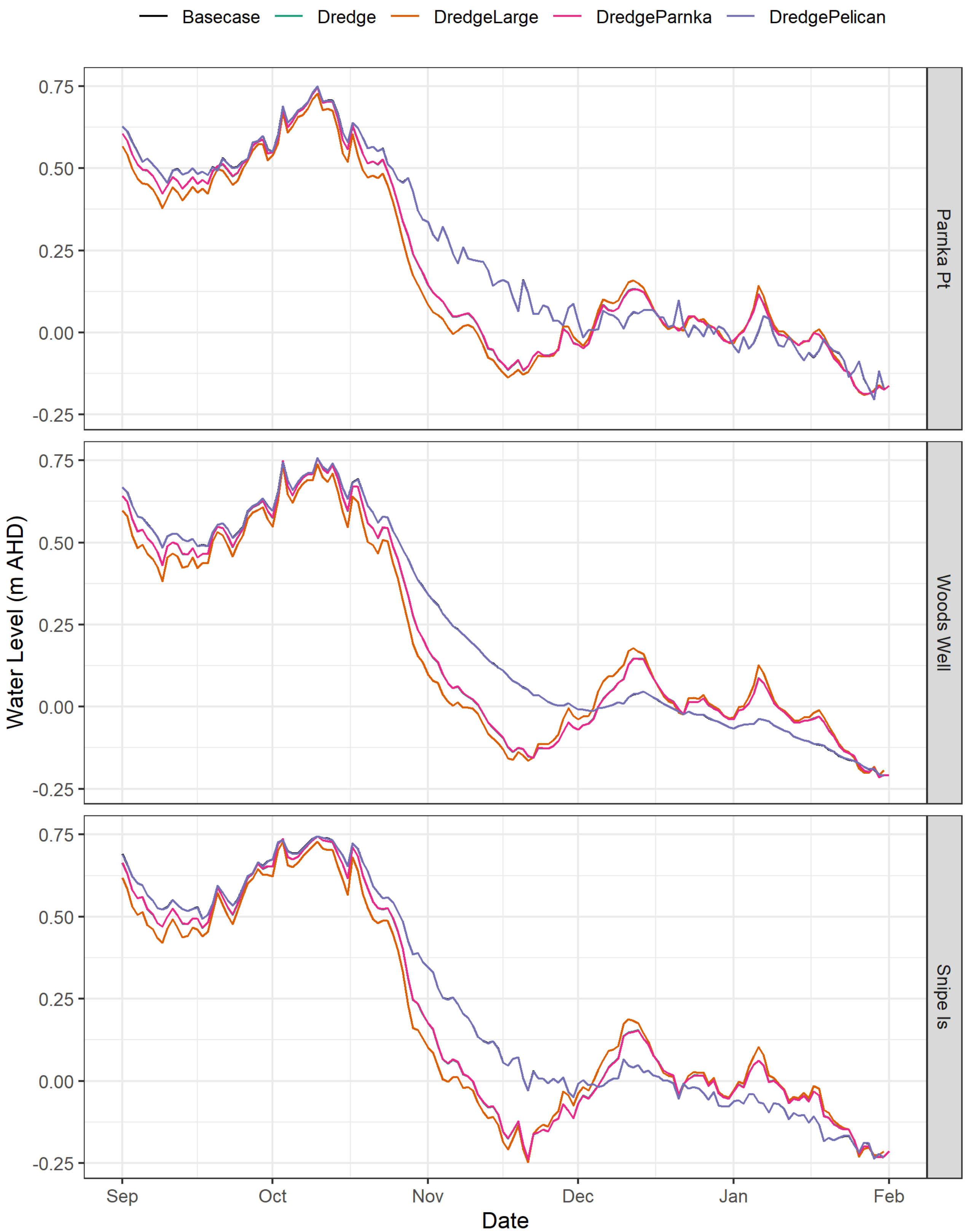

Figure 4-31. Modelled water levels at gauging stations in the Coorong south lagoon for base case and dredging scenarios for 2012/14

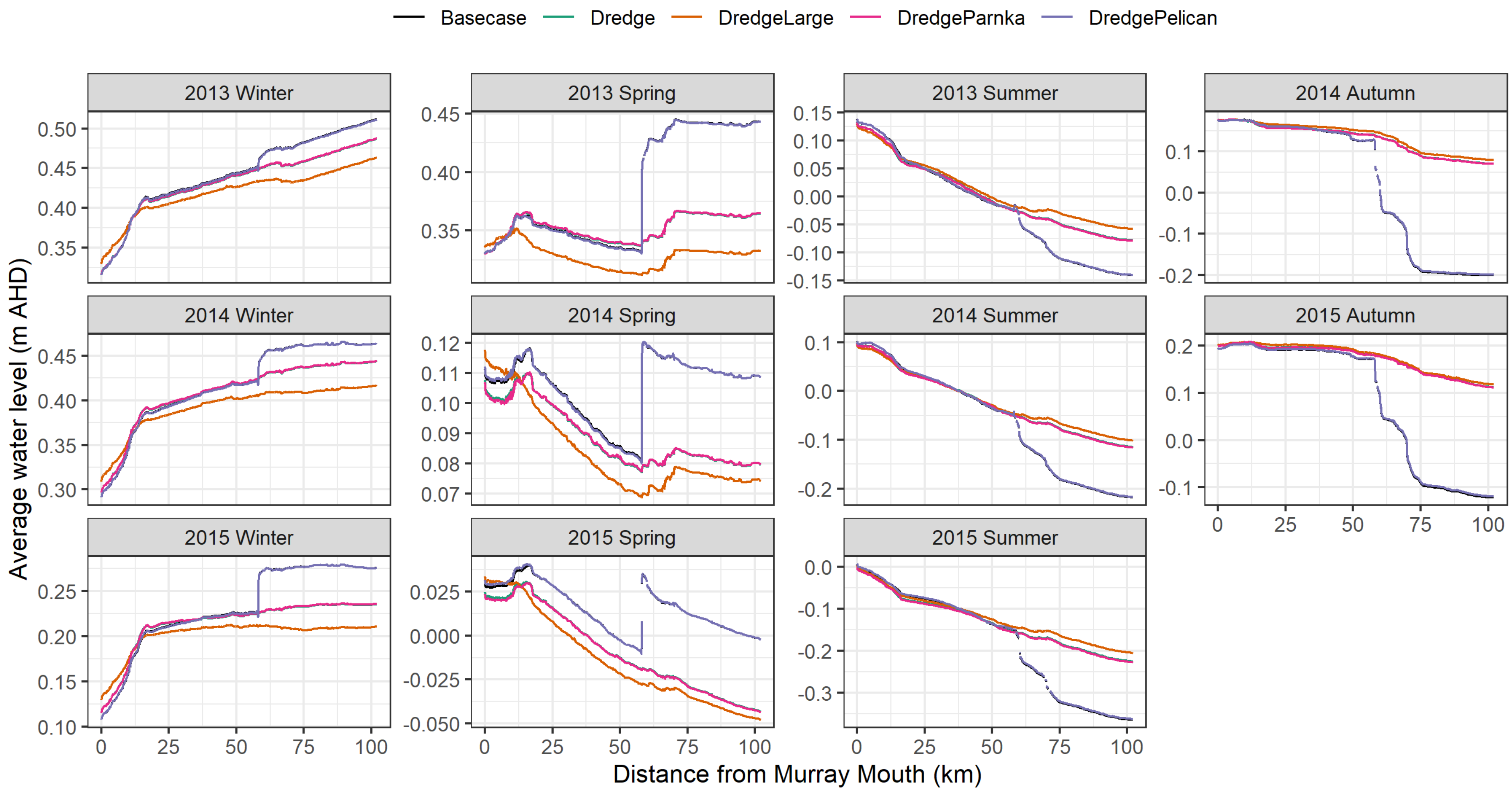

Figure 4-32. Modelled water levels along the length of the Coorong (north to south) for base case and dredging scenarios

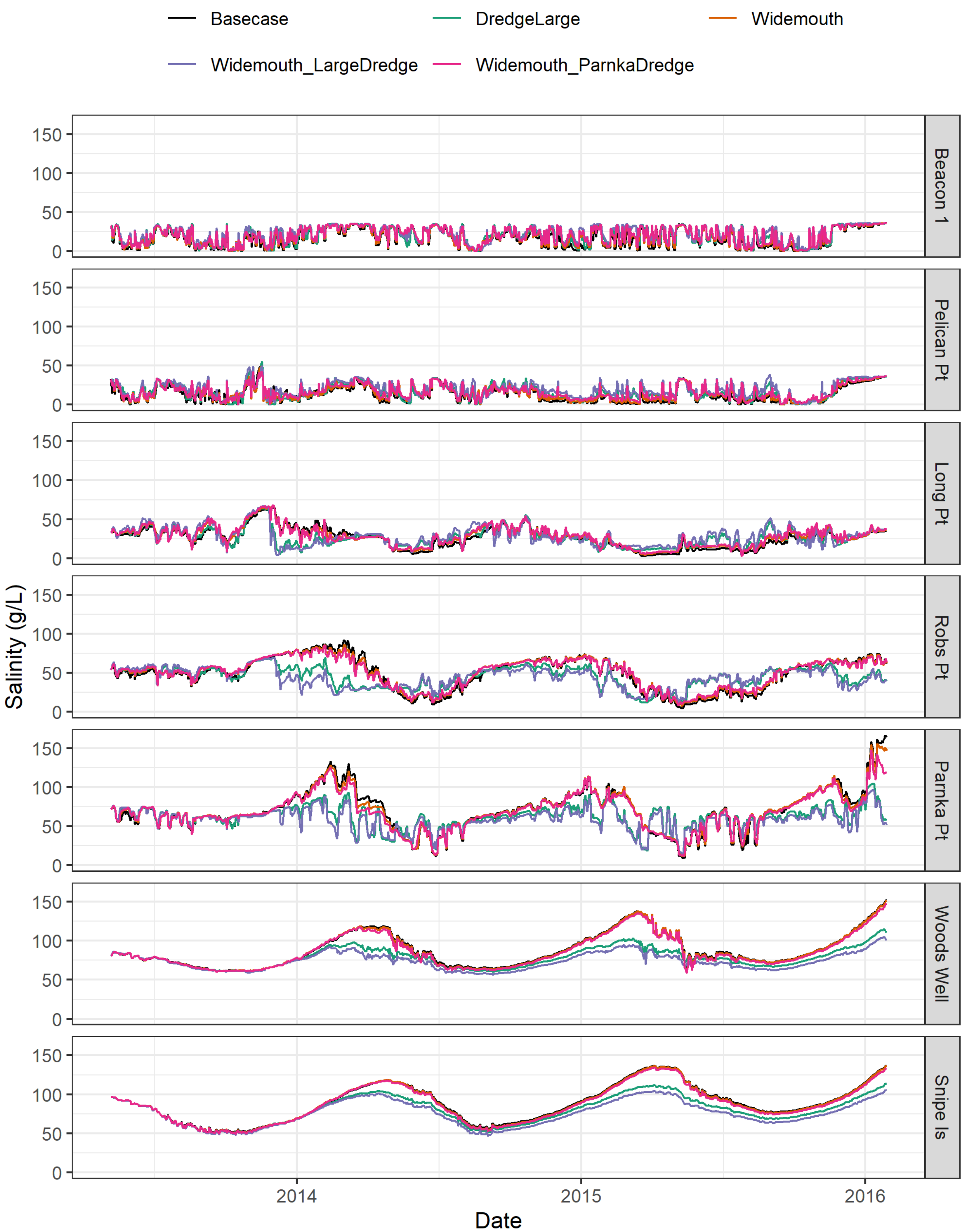

Figure 4-33. Modelled salinity under base case and wide mouth scenarios

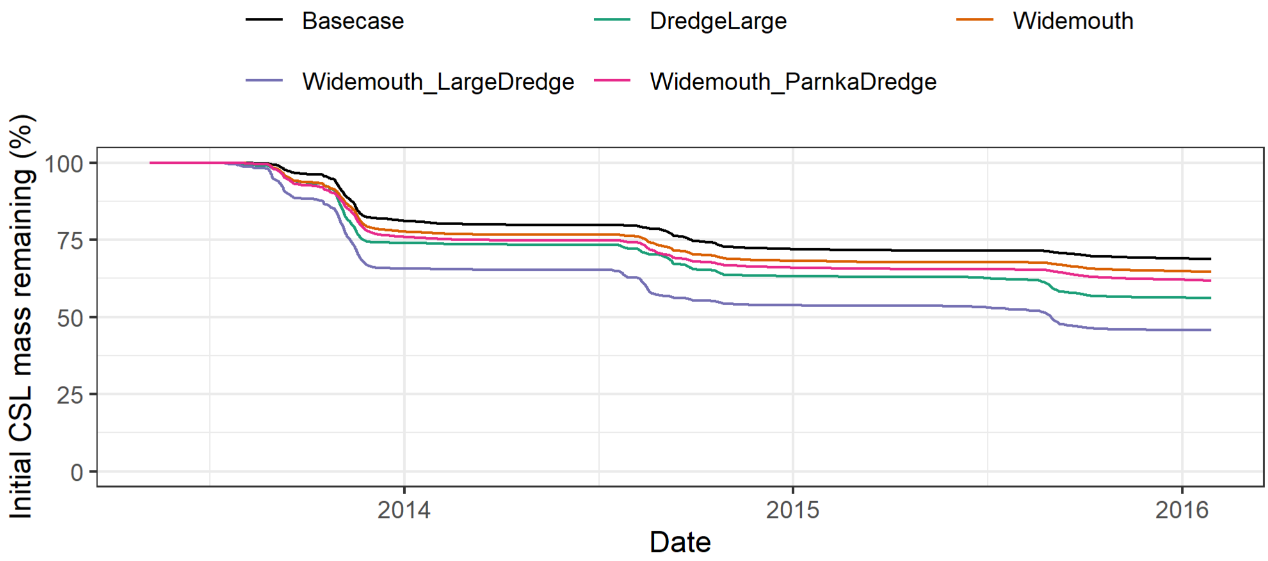

Figure 4-34. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and wide mouth scenarios

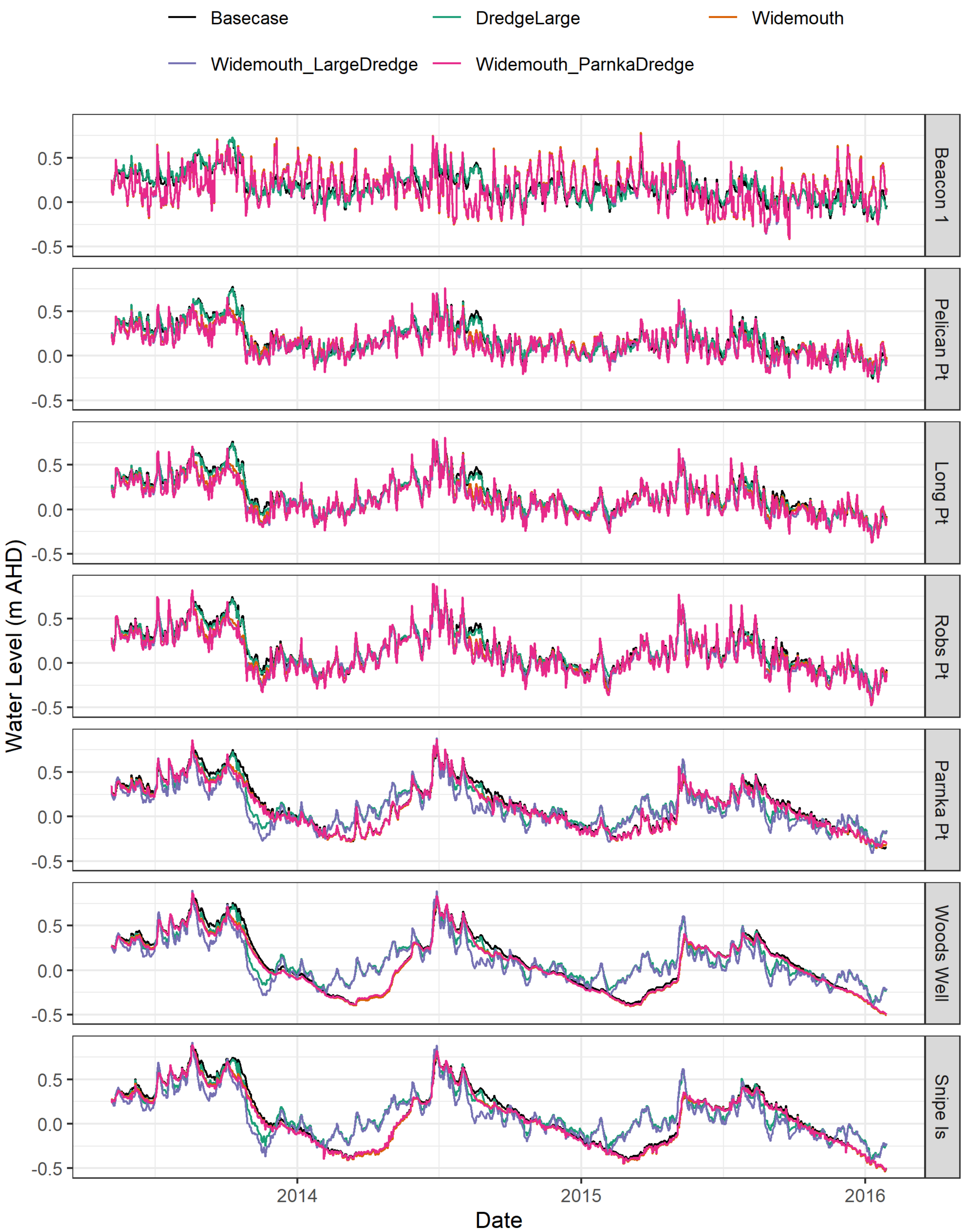

Figure 4-35. Modelled water levels at gauging stations across the Coorong for base case and wide mouth scenarios

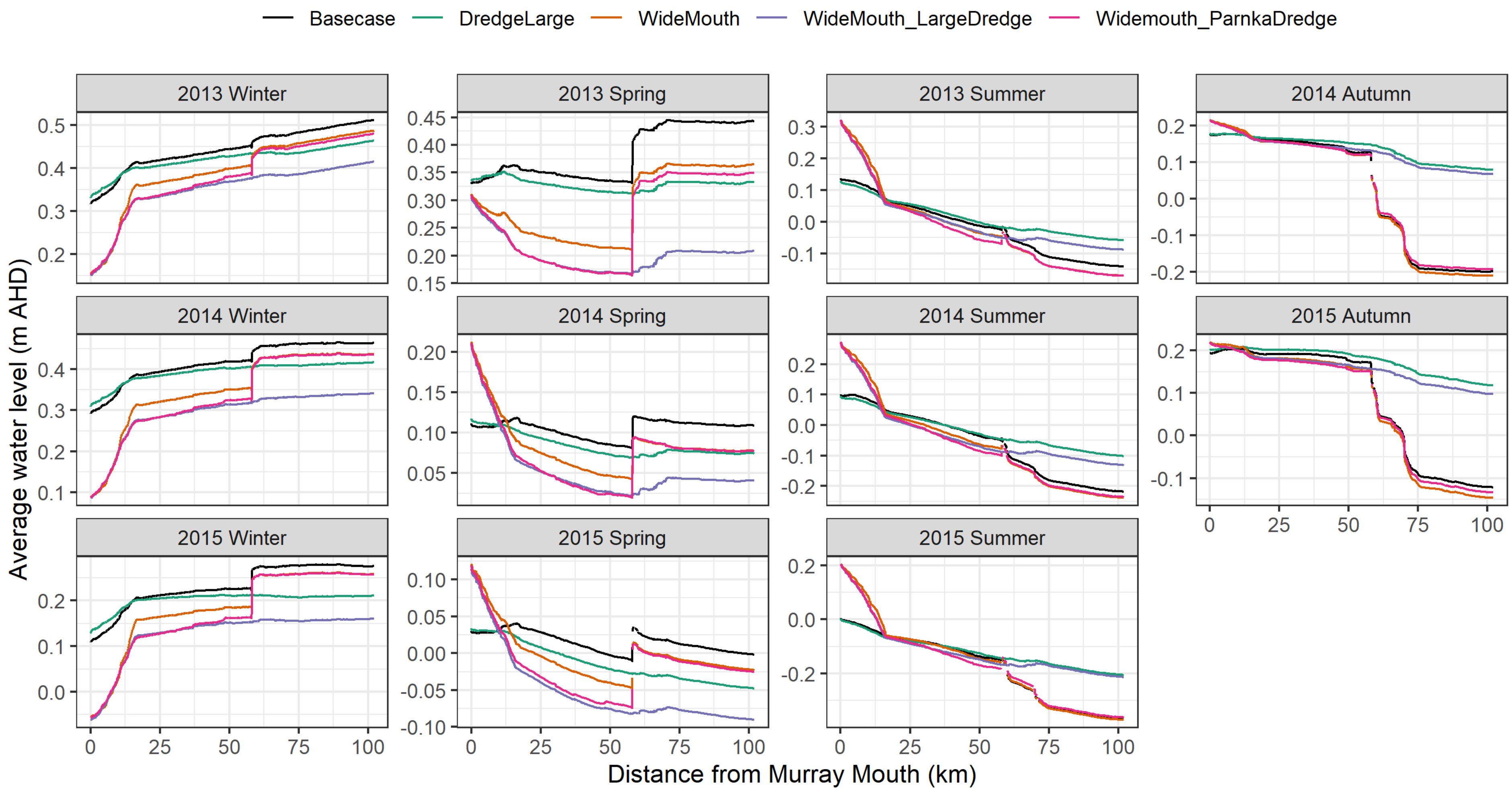

Figure 4-36. Modelled water levels along the length of the Coorong (north to south) for base case and wide mouth scenarios

4.7 Dredging combined with pumping scenarios

4.7.1 Observed inflows

Results for scenarios with a combination of dredging and pumping compared to the base case (normal) scenario are presented in Figure 4-37 to Figure 4-39. The impact of different dredging locations can be seen in Figure 4-40 to Figure 4-42, which shows the combination of pumping out 250 ML/d combined with different dredging scenarios.

The combination of dredging and pumping provides improved benefits, with an even larger reduction in salinity in the south lagoon (when comparing the same pumping rate, or dredging alone), except in the case of dredging only at Pelican Point. The improved connectivity between the north and south lagoons as a result of dredging prevents low water levels occurring in the south lagoon over late summer, that was evident in the pumping alone scenarios (Figure 4-41).

Water levels in the south lagoon recede quickly over spring (Figure 4-39), which may be problematic for the ability of key species (e.g. Ruppia) to complete their annual life cycle. This is due to the enhanced connection between north and south lagoon, in addition to pumping. The circular pumping (pumping in and out based on water level triggers) reduces the impact of this rapid recession in Spring.

4.7.2 Extreme dry conditions

A combination of dredging and pumping scenarios were modelled to understand the implications of extreme drought conditions on their performance. The results are provided in Figure 4-43 to Figure 4-44.

The results indicate that a constant pumping out flow rate of 250 ML/d is sufficient to reduce salinity in the southern lagoon over time, even with no additional inflow, however 125 ML/d was not. It is almost as effective as pumping in 500 ML/d combined with dredging at Parnka narrows and Policeman Point, but without the impact of increasing salinity in the north lagoon.

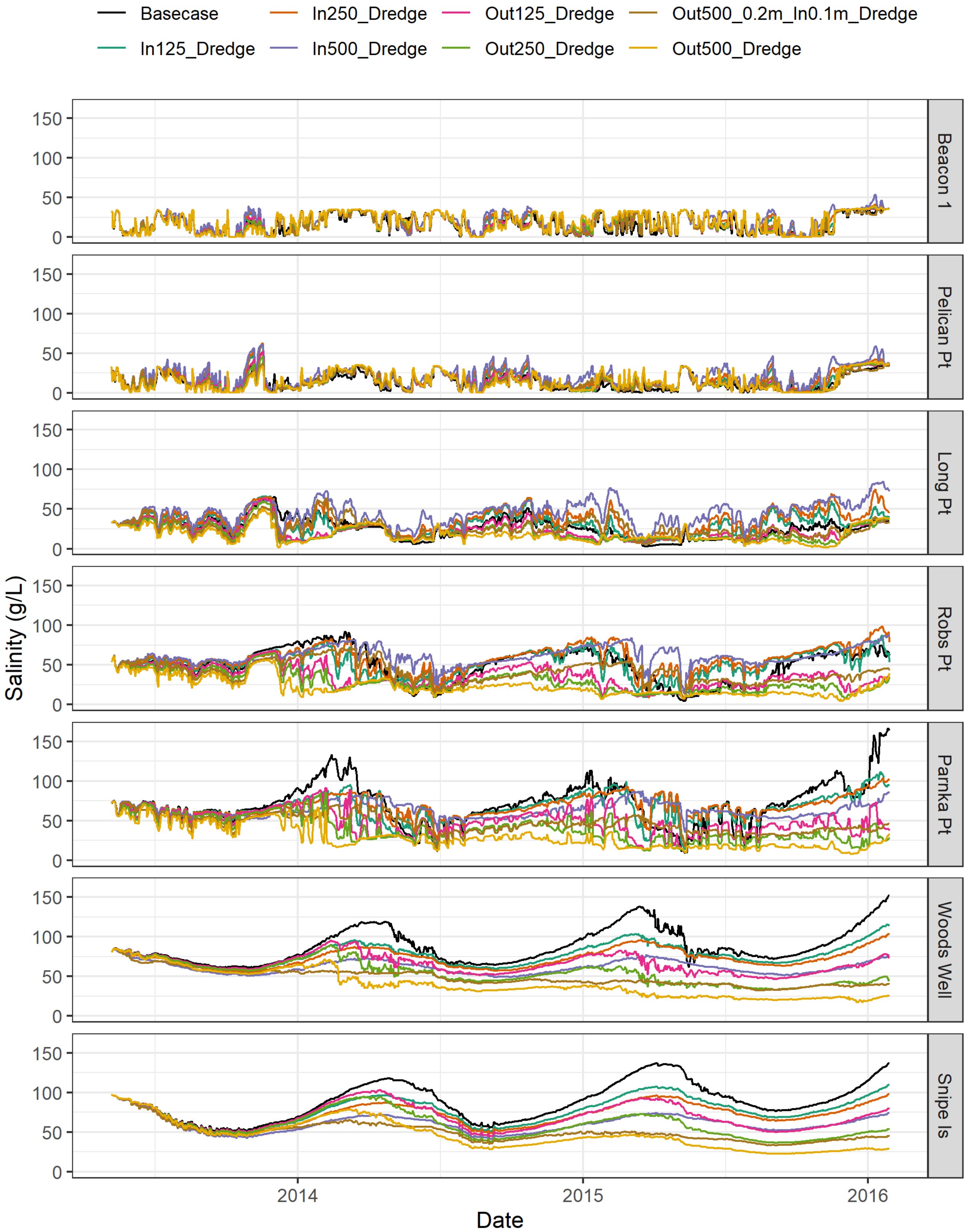

Figure 4-37. Modelled salinity under base case and combined dredging - pumping scenarios

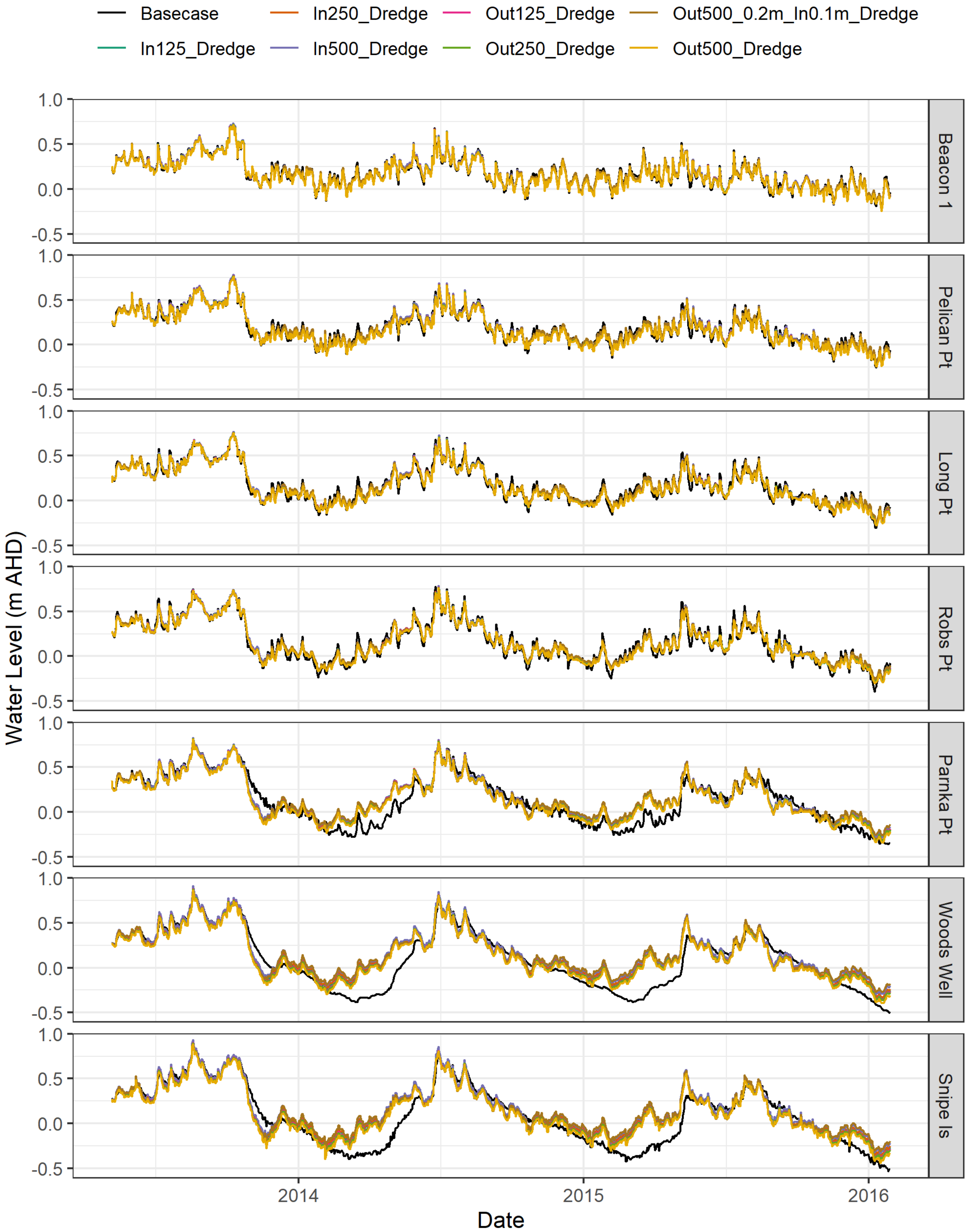

Figure 4-38. Modelled water levels at gauging stations across the Coorong for base case and combined dredging - pumping scenarios

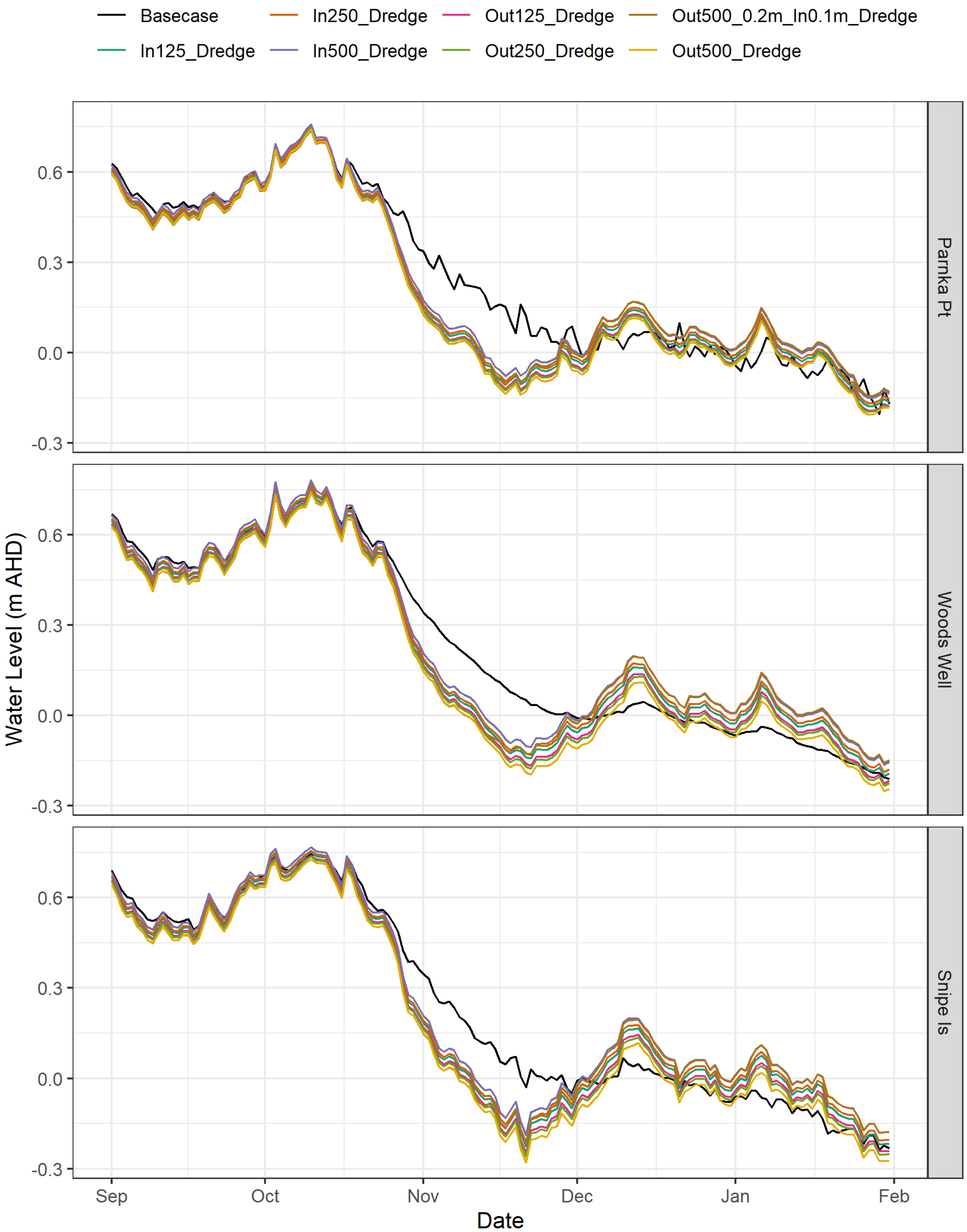

Figure 4-39. Modelled water levels at gauging stations in the Coorong south lagoon for base case and combined dredging - pumping scenarios for 2013/14

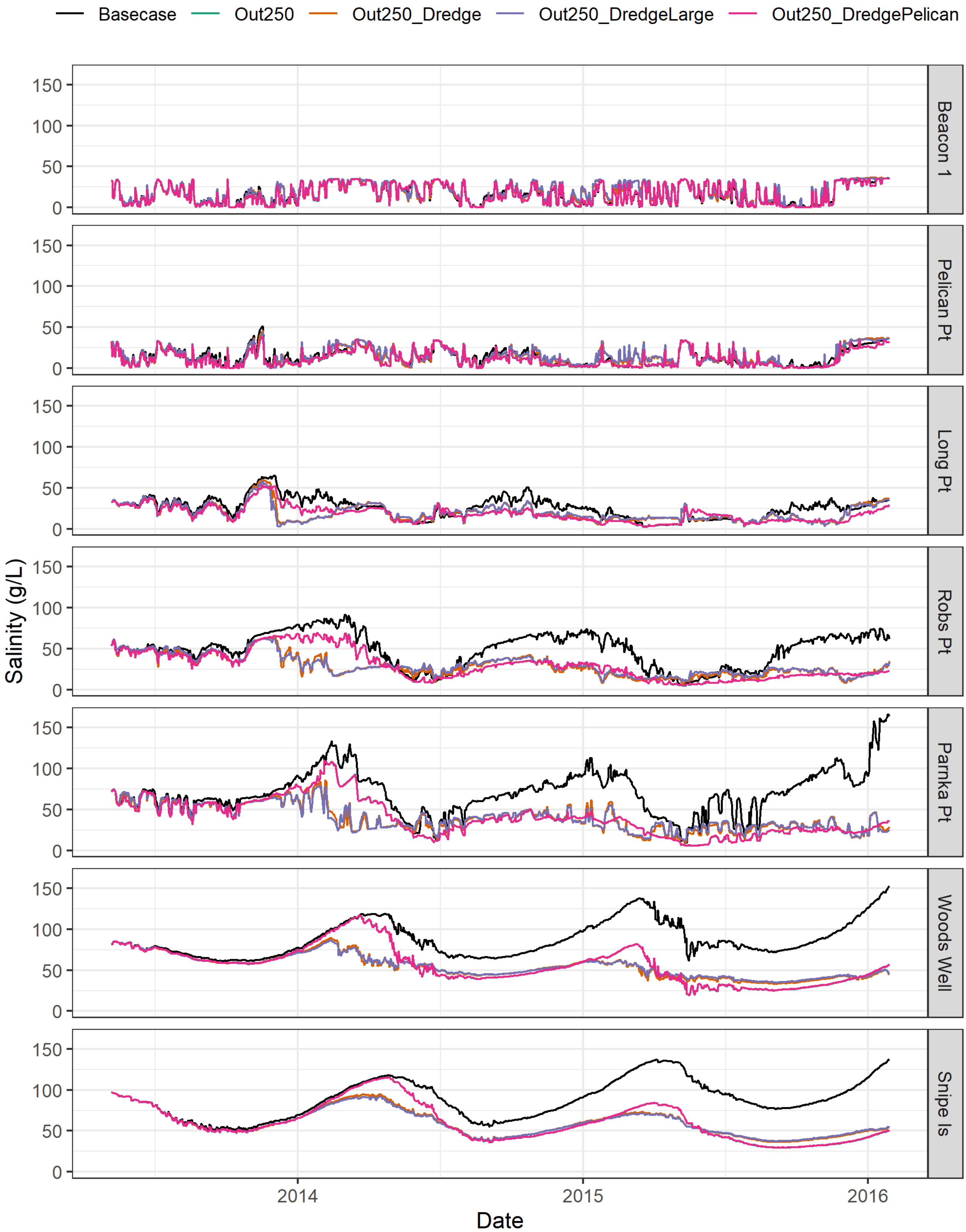

Figure 4-40. Modelled salinity under base case and 250 ML/d pumping out scenarios with variable dredging locations

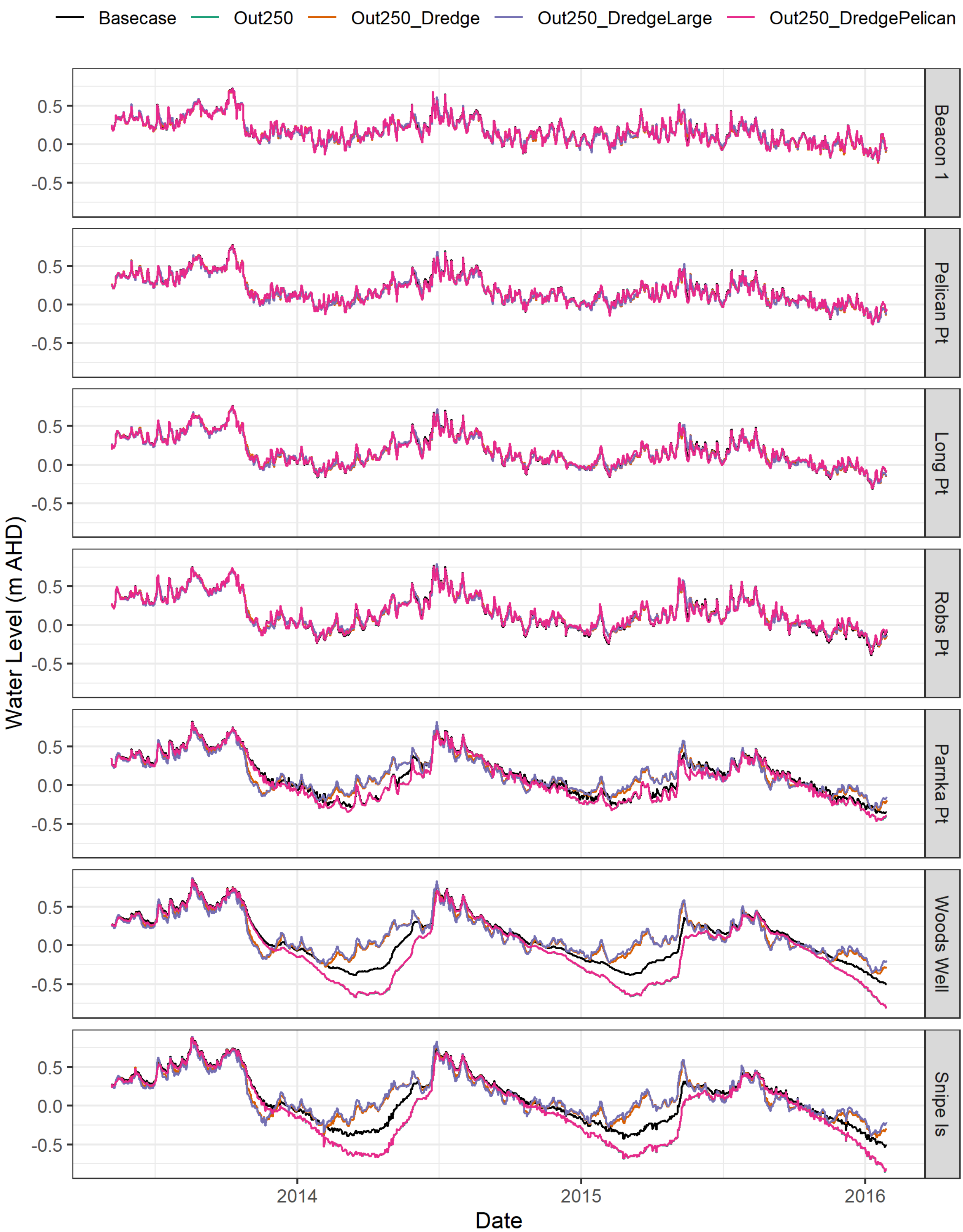

Figure 4-41. Modelled water levels under base case and 250 ML/d pumping out scenarios with variable dredging locations

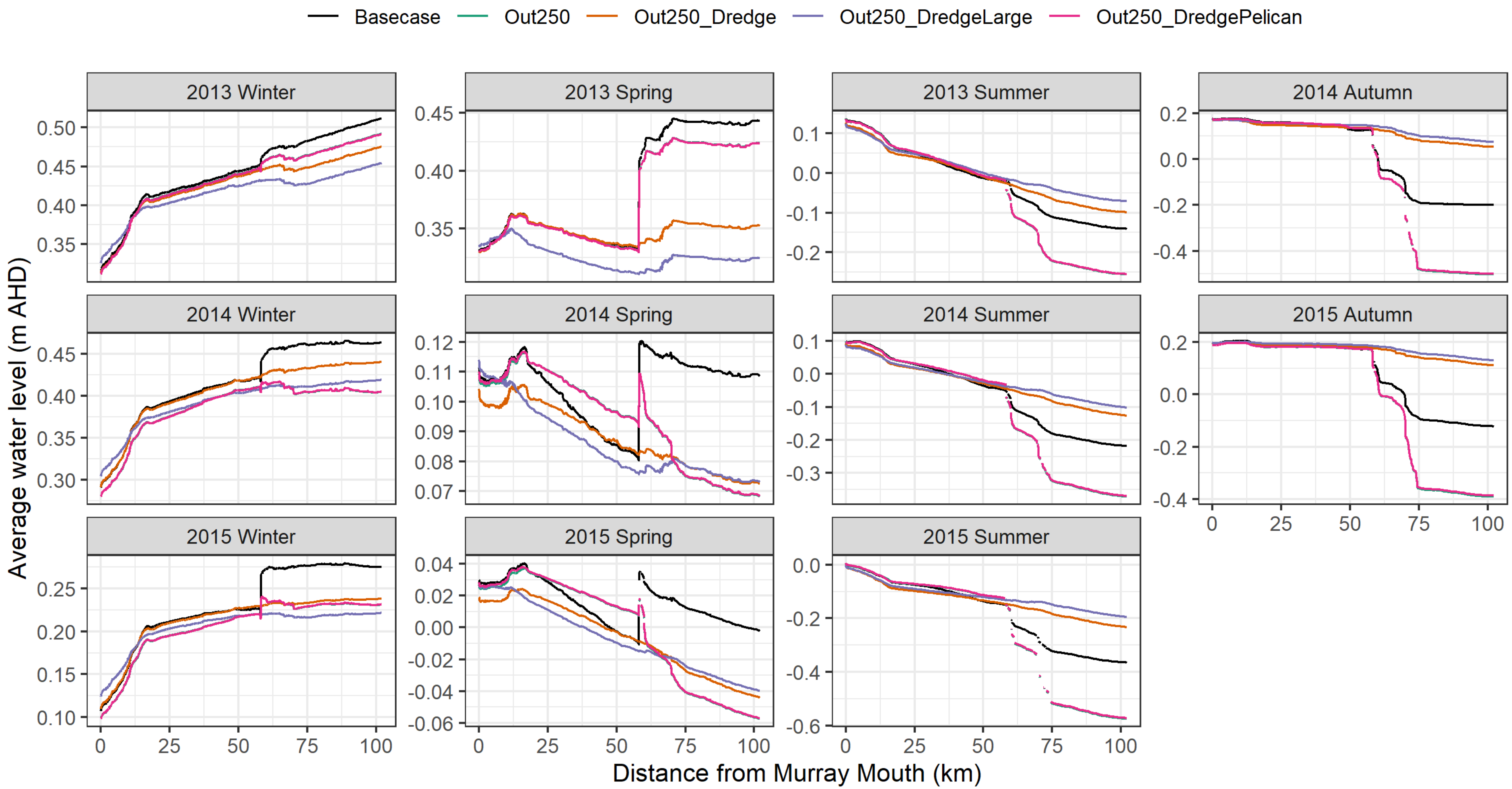

Figure 4-42. Modelled water levels along the length of the Coorong (north to south) for base case and 250 ML/d pumping out scenarios with variable dredging locations

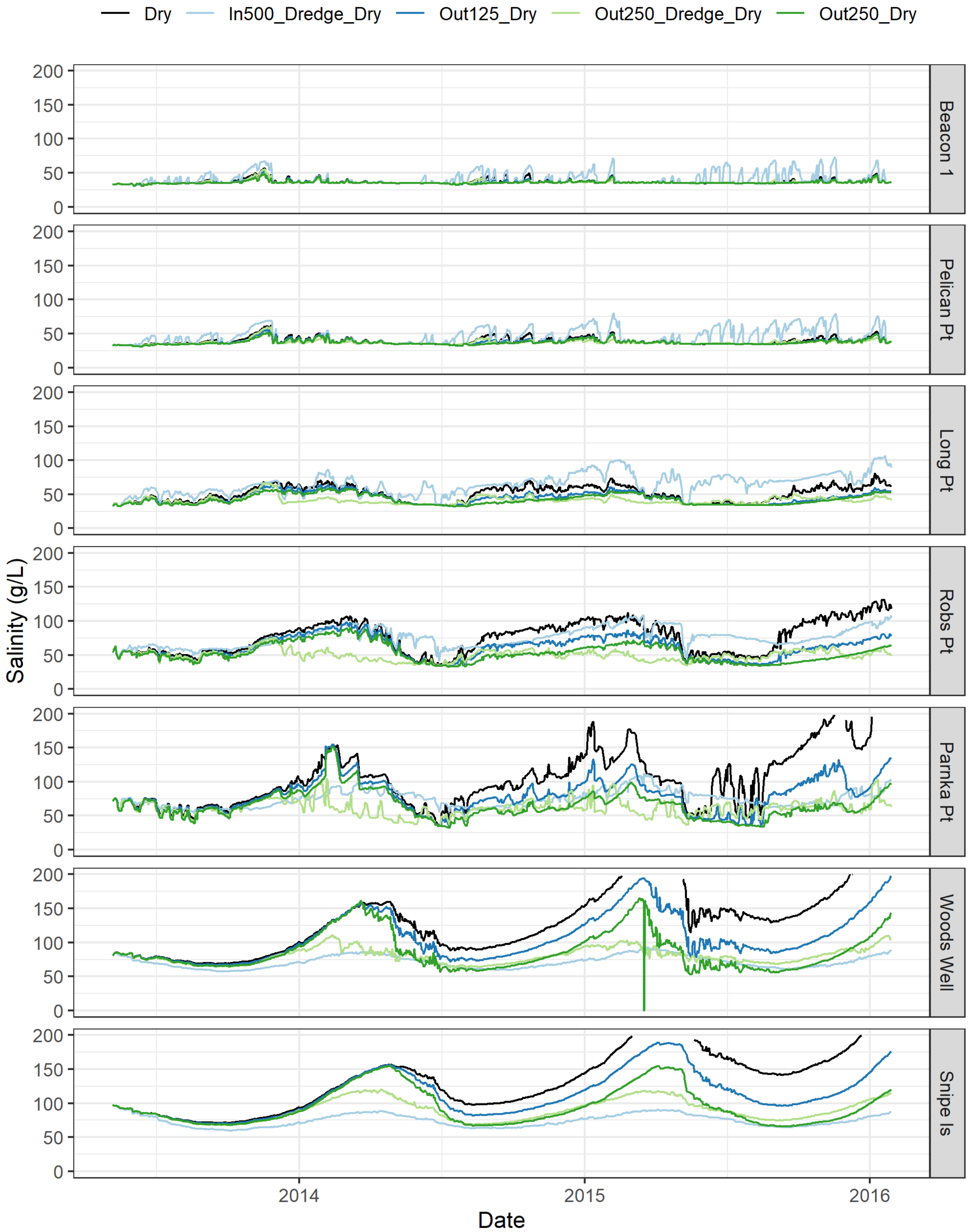

Figure 4-43. Modelled salinity for extreme drought scenarios

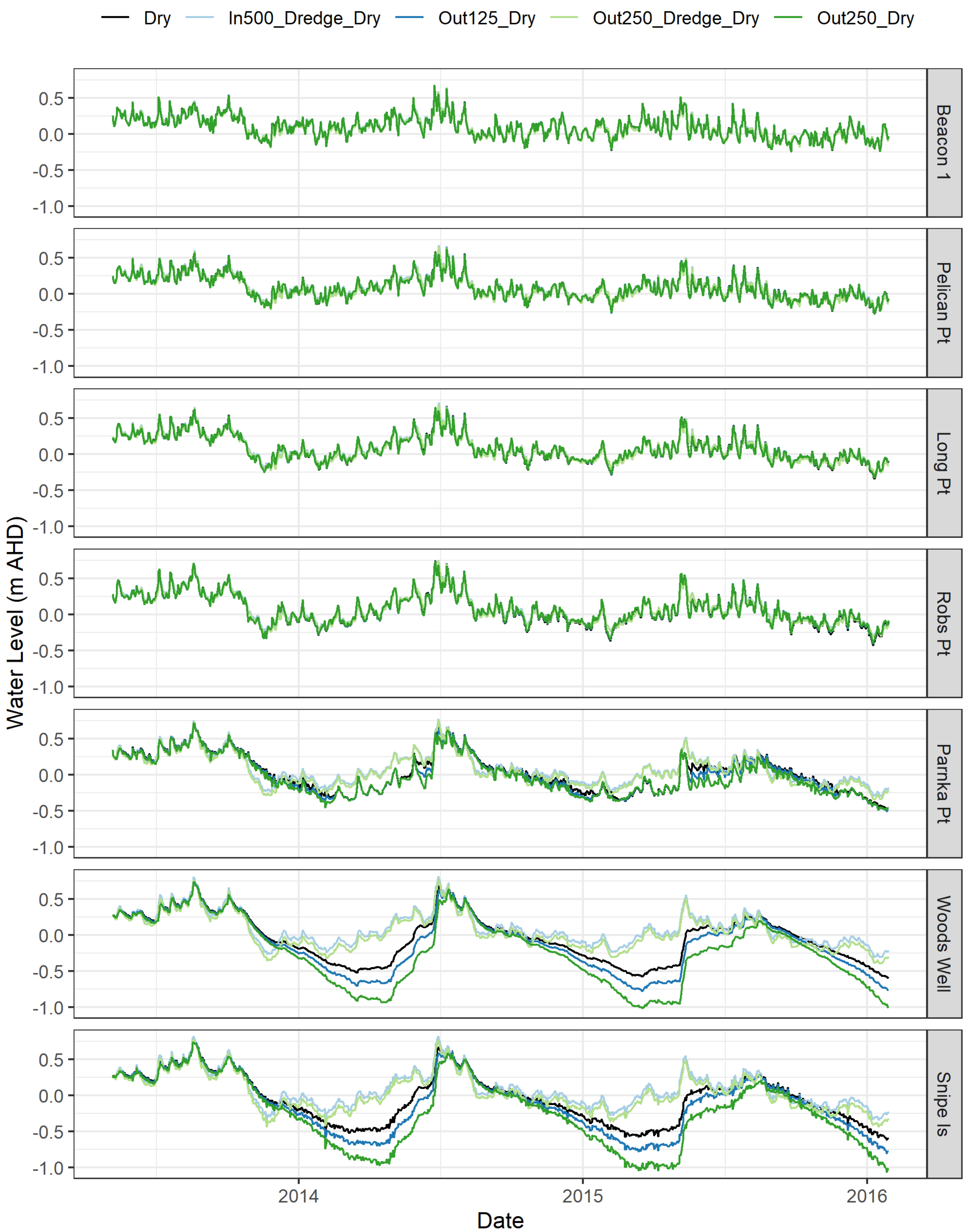

Figure 4-44. Modelled water levels at gauging stations across the Coorong for extreme drought scenarios

4.8 Lake Albert connector scenarios

Results for scenarios which incorporate a connection between the Coorong south lagoon and Lake Albert, compared to the base case (normal) scenario are presented in Figure 4-45 to Figure 4-47.

The Lake Albert connector aids in reducing salinity in the southern lagoon, with results only marginally better with the additional 1 GL/d scenario or the incorporation of dredging at Parnka narrows and Pelican Point. The circulation of water is not as effective as pumping out 250 ML/d or in 500 ML/d at Policeman Point, as indicated by the remaining initial mass.

The assumption that the first 1 GL/d of barrage flow available will be diverted through the Lake Albert connector may not reflect actual operations, and hence may overstate the benefit from the connector, as indicated by the performance of the more realistic scenario. The impact is insufficient to reduce salinity at the far south end of the CSL to below 100 g/L across the entire simulation period.

The effectiveness of the Lake Albert connector is dependent on the availability of river flow and priorities for barrage flow across the site. Hence, this option provides no benefit in the extreme dry scenario, where there is no barrage flow available.

It is anticipated that diverting flow through Lake Albert will aid in freshening of waters in Lake Albert. In the long term, the provision of fresher water through the Lake Albert connector to the Coorong may show more benefit to maintaining desirable salinity levels than identified in this preliminary modelling, which assumes a constant lake salinity of 1500 EC.

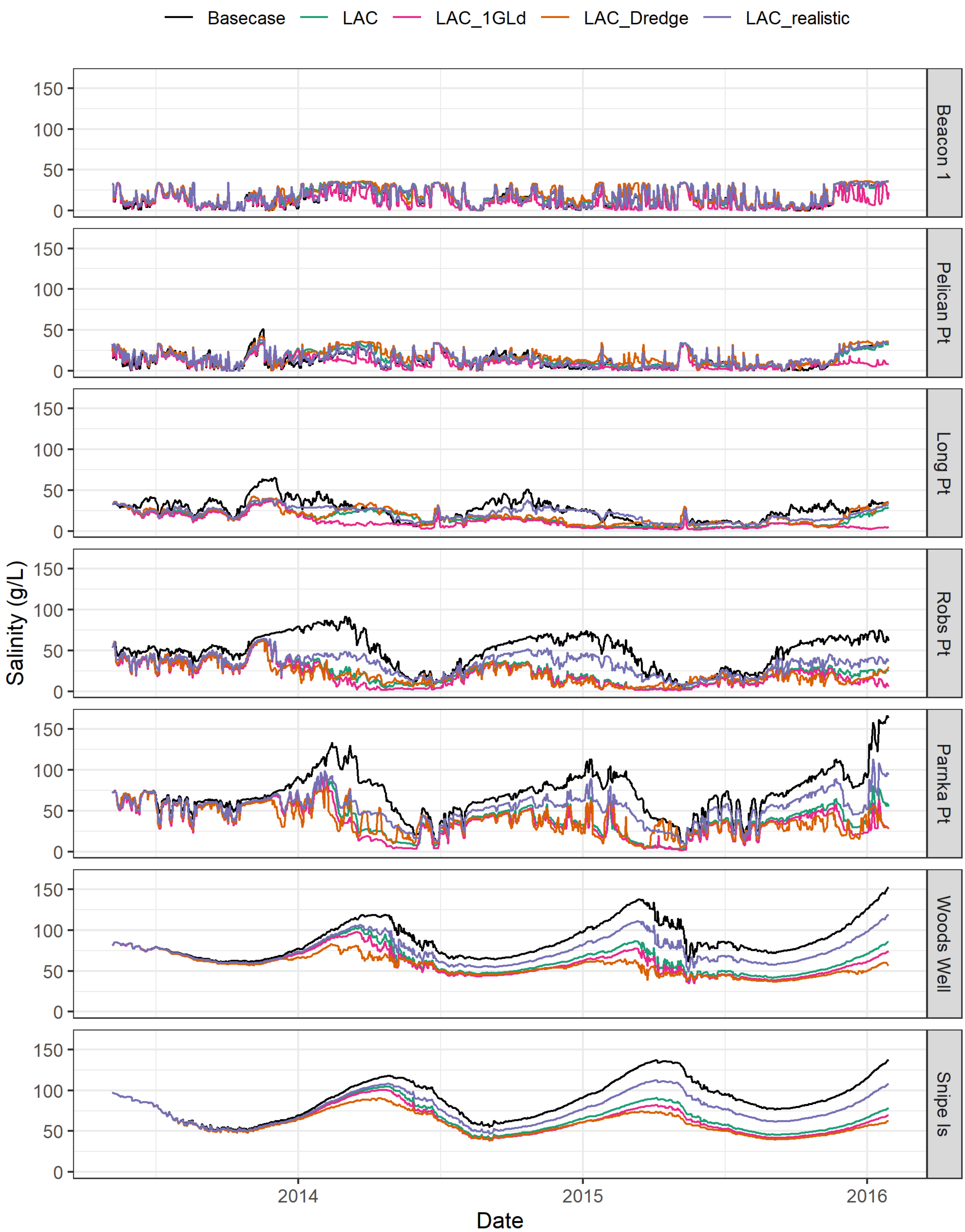

Figure 4-45. Modelled salinity under base case and Lake Albert connector scenarios

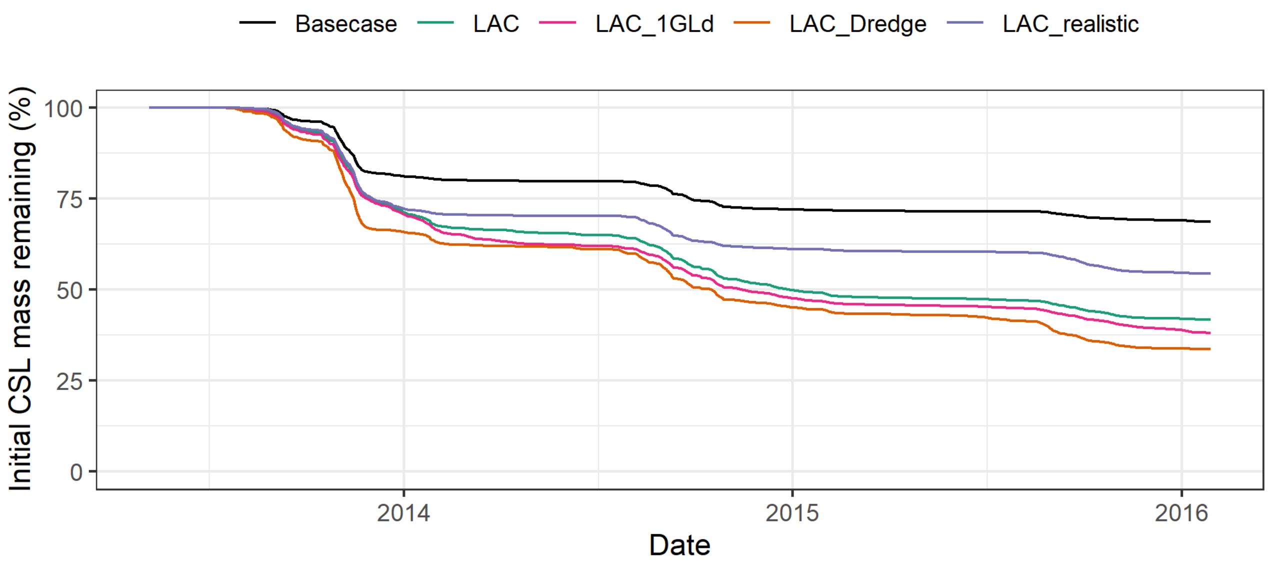

Figure 4-46. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and Lake Albert connector scenarios

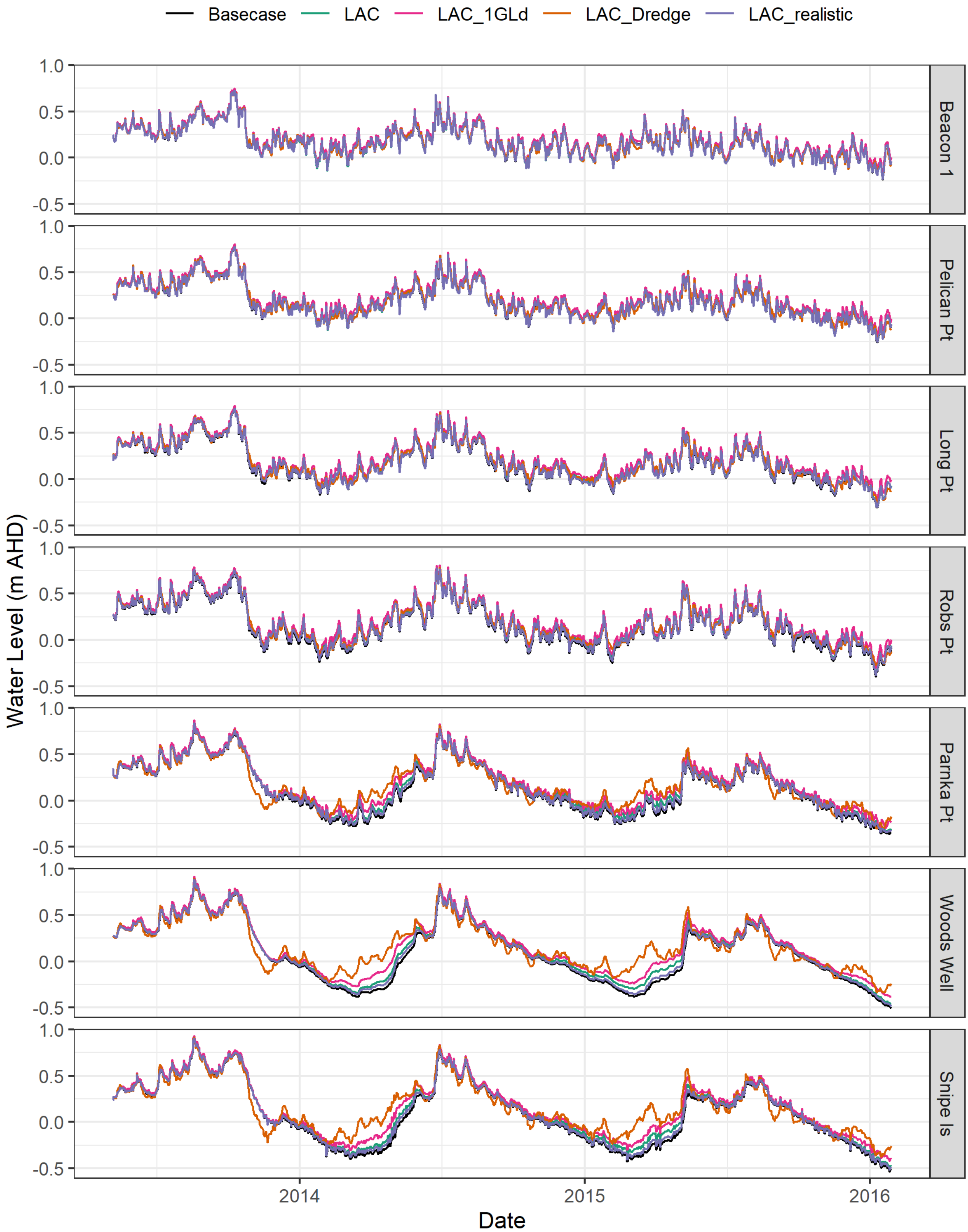

Figure 4-47. Modelled water levels at gauging stations across the Coorong for base case and Lake Albert connector scenarios

4.9 South east flows scenarios

Results for scenarios which include flows from the south east drainage catchments, compared to the base case (normal) scenario are presented in Figure 4-48 to Figure 4-50.

The 1975 current SE flows is very similar to the base case scenario in terms of salinity levels in the CSL, with the 1943 current conditions SE inflow slightly fresher. Figure 4-49 indicates that the 1975 SE inflow base case results in less export of the initial south lagoon water out of the system, but given the salinity concentrations are very similar indicates that the south east inflow is providing a dilution function. In both instances, the augmented flow (i.e. with input from Drain L and K) helps freshen the CSL, but salinity does not reduce substantially. For the 1975 event, the augmented flows do not reduce salinity consistently below 100 g/L.

Water levels in the CSL are not changed significantly but are slightly higher with augmented flows over the spring months, but otherwise there is negligible change.

For the SE flow scenarios with additional infrastructure options, i.e. dredging and the Lake Albert Connector, only the 1975 augmented flow scenarios have been presented, in Figure 4-51 to Figure 4-53. The scenario with augmented flows, dredging *and* the LAC options performs best in reducing salinity levels at the South Coorong, to less than 100 g/L across the entire simulation period. However, even this combination of infrastructure options does not reduce salinity as much as the pumping scenarios.

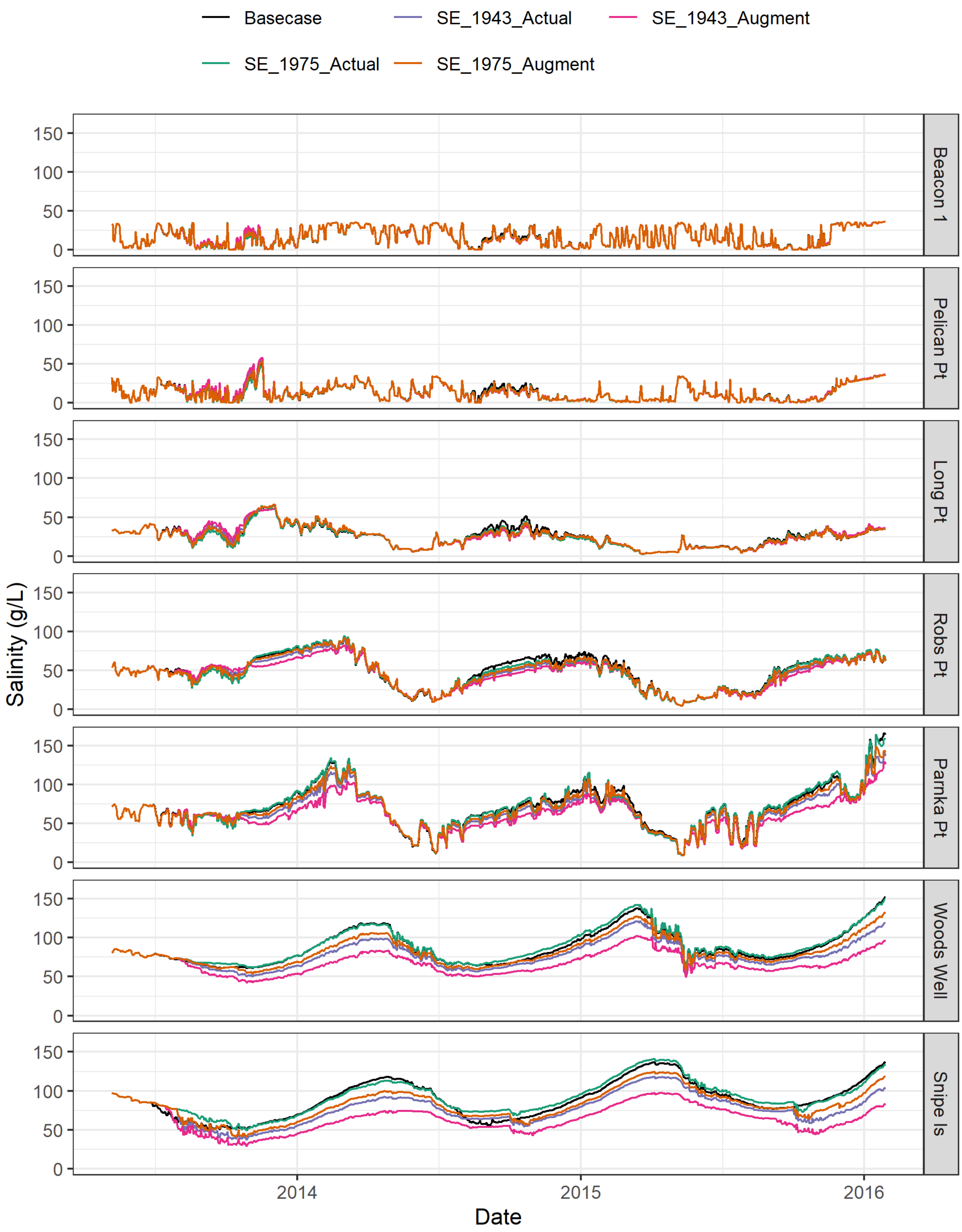

Figure 4-48. Modelled salinity under base case and SE flows scenarios

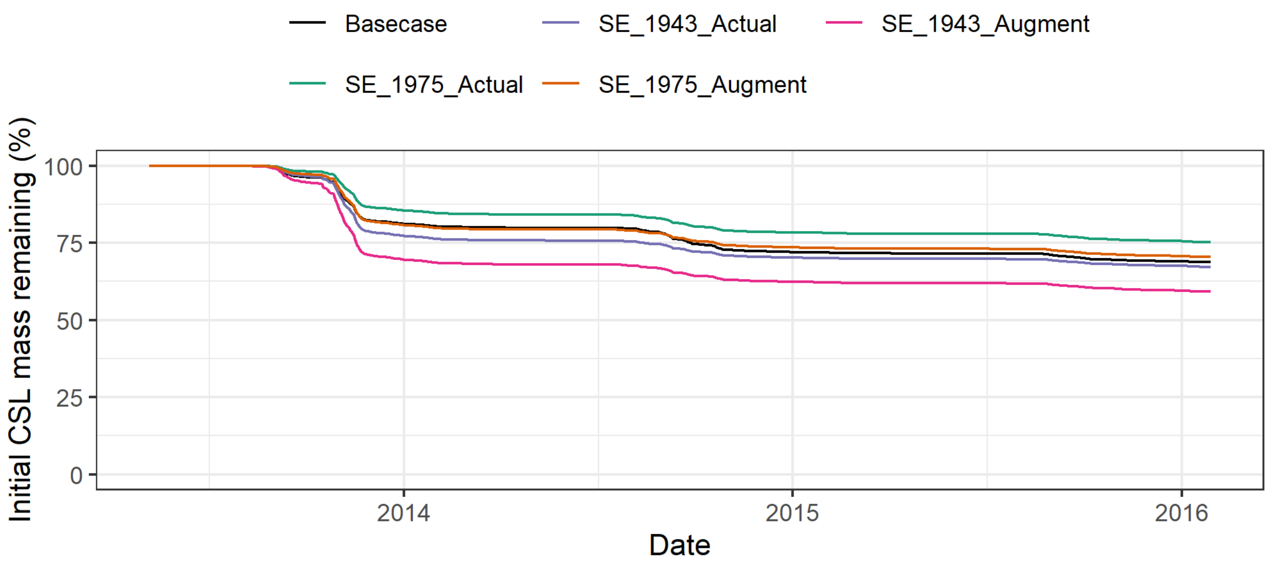

Figure 4-49. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and SE flows scenarios

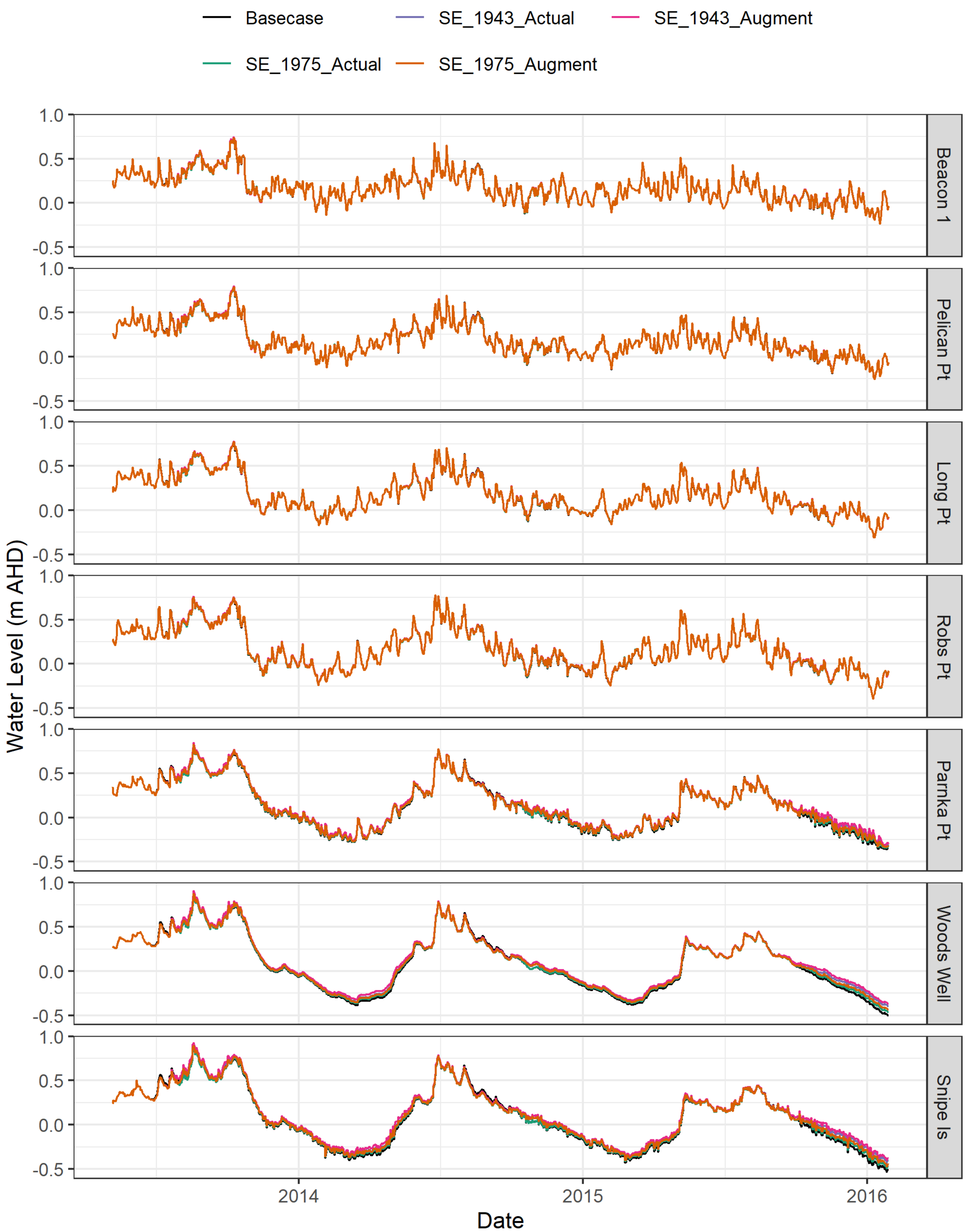

Figure 4-50. Modelled water levels at gauging stations across the Coorong for base case and SE flows scenarios

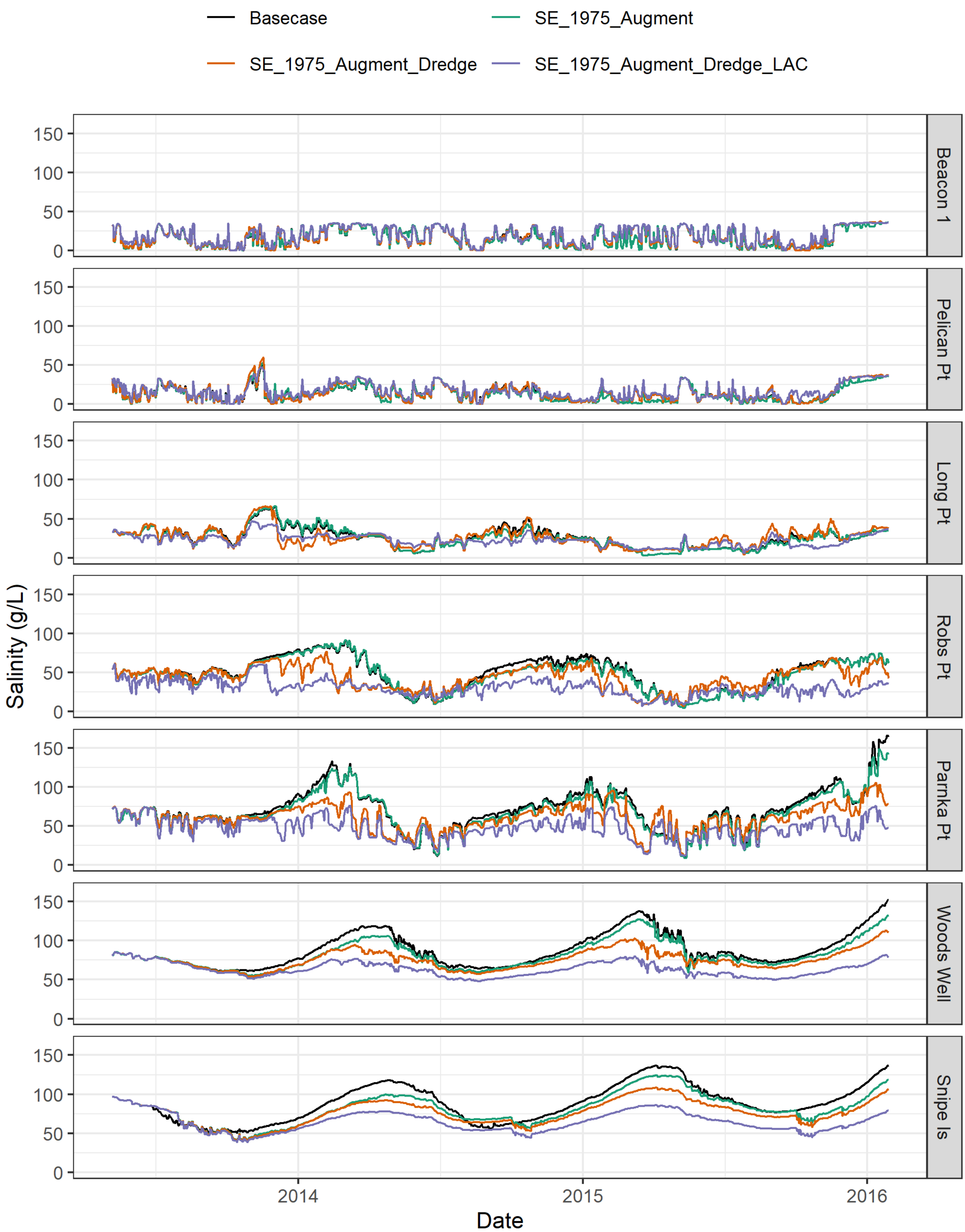

Figure 4-51. Modelled salinity under base case and SE flows scenarios with dredge or LAC options

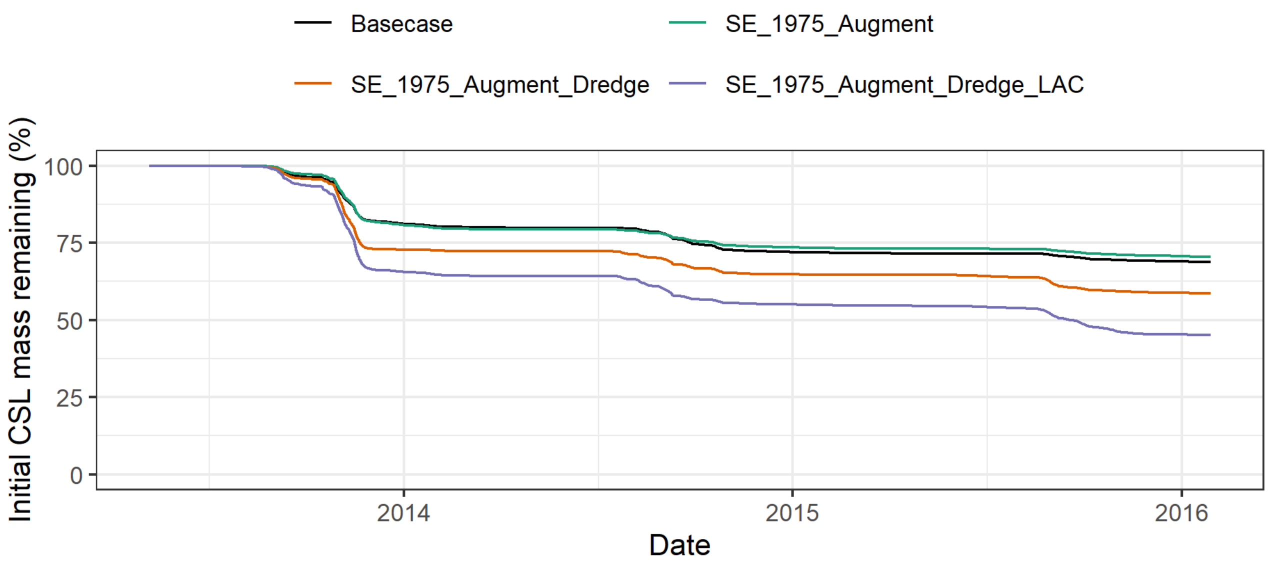

Figure 4-52. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and SE flows scenarios with dredge or LAC options

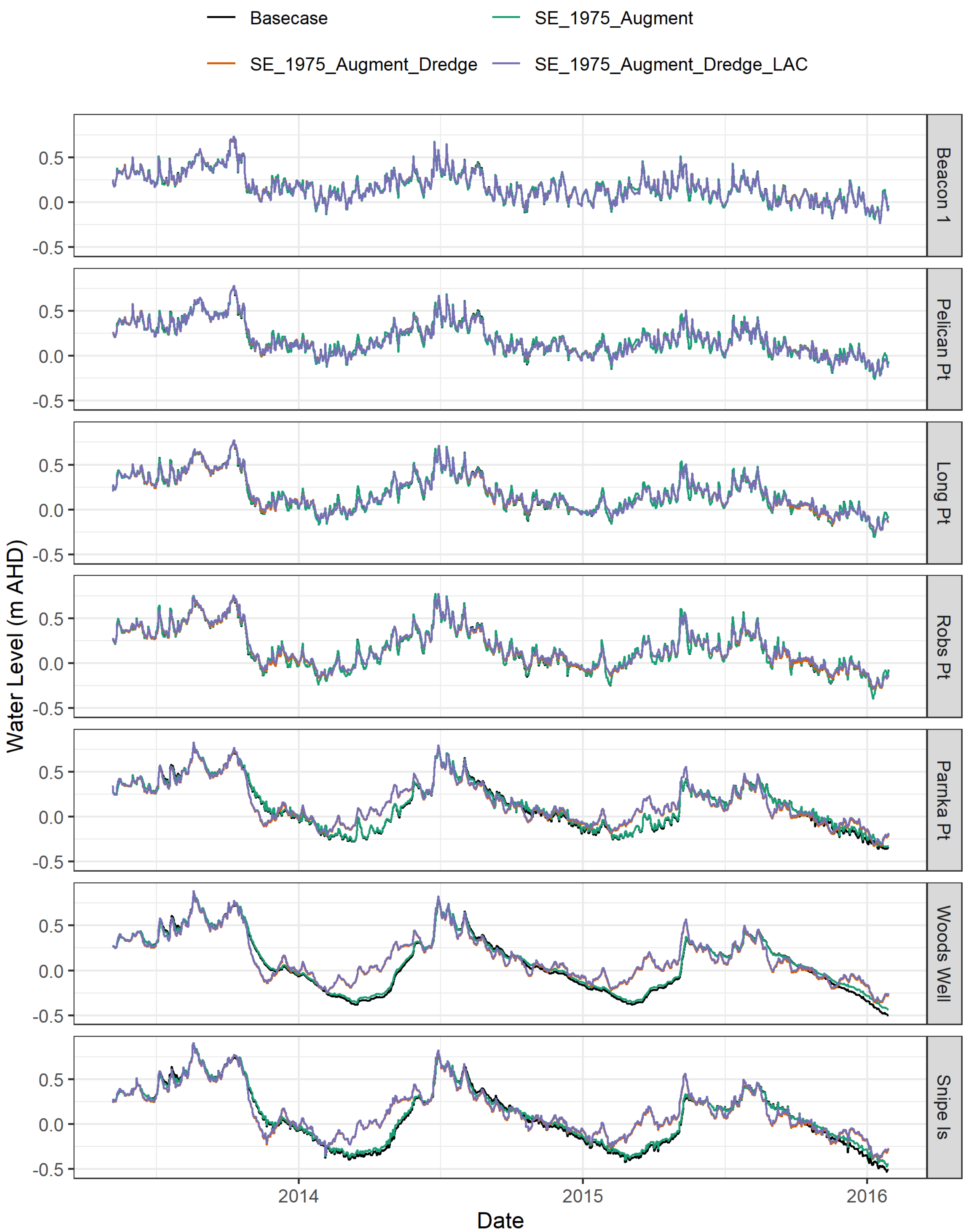

Figure 4-53. Modelled water levels at gauging stations across the Coorong for base case and SE flows scenarios with dredge or LAC options

4.10 Automated barrage flow scenarios

Results for scenarios which include pulsing barrage flows representing the functionality of additional automated gates at Tauwitchere barrage, compared to the base case (normal) scenario, are presented in Figure 4-54 to Figure 4-57.

None of the operational rules for automation were able to reduce salinity in the Coorong South Lagoon, as indicated in Figure 4-54 and Figure 4-57. Some differences are apparent in the north lagoon (Figure 4-54), but this relatively short term and local freshening did not tend to have an influence on the southern end of the water body.

Pulsing through on a fortnightly basis had the largest impact of all operational rule scenarios, though this is likely not practical operationally, and the impact is insignificant. The initial mass remaining in the Coorong south lagoon after three years of simulation is only a few percent lower.

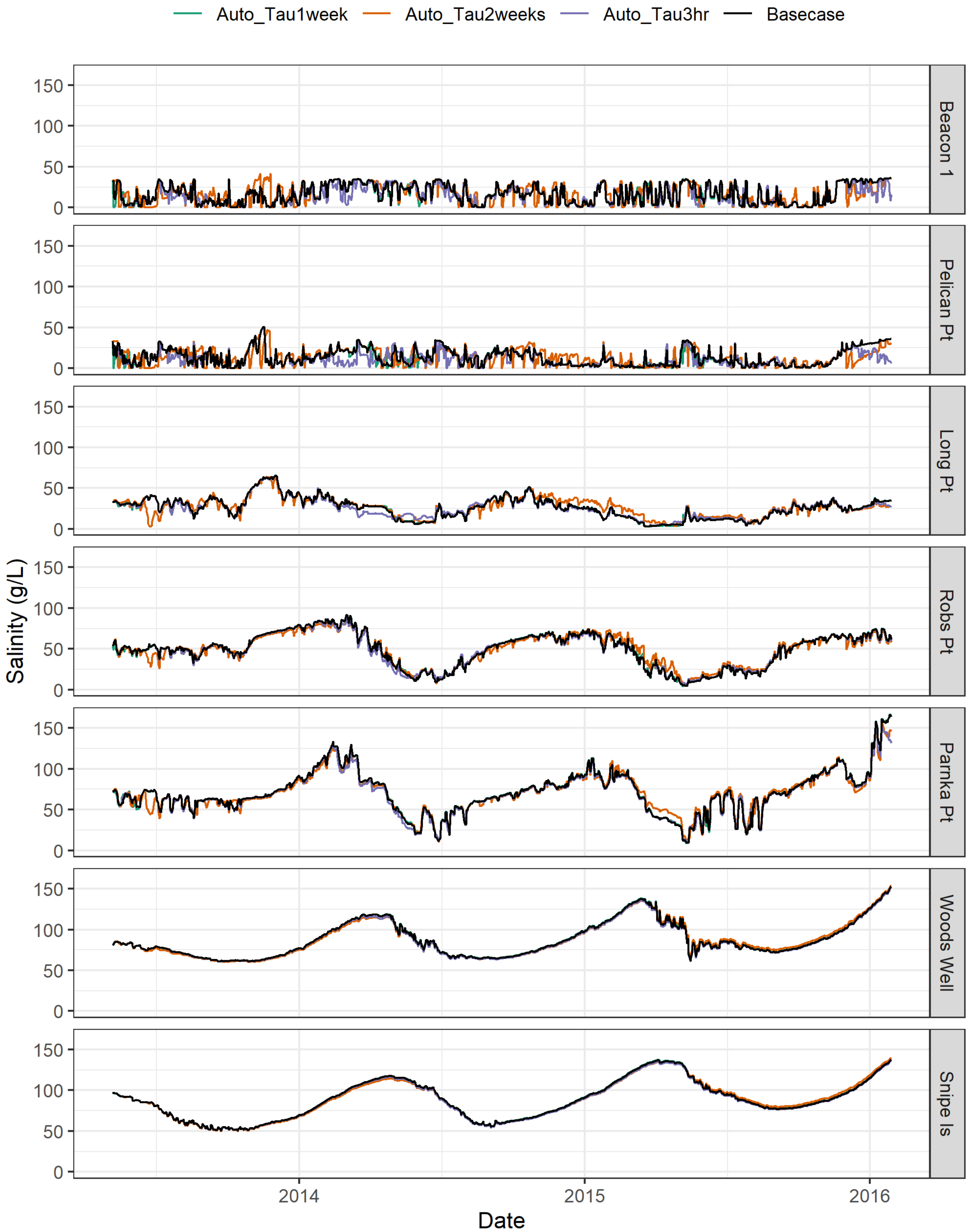

Figure 4-54. Modelled salinity under base case and automated barrage scenarios

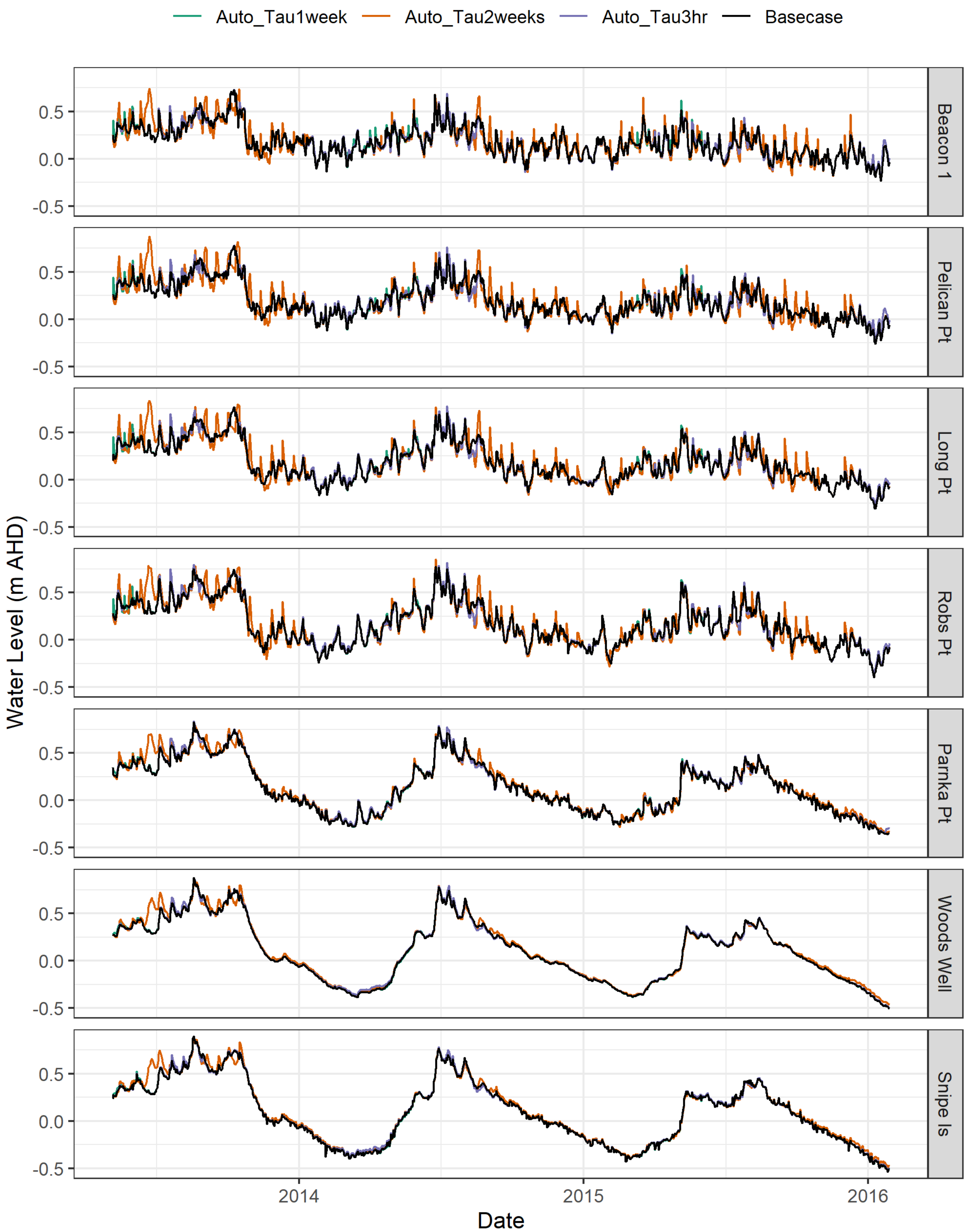

Figure 4-55. Modelled water levels under base case and automated barrage scenarios

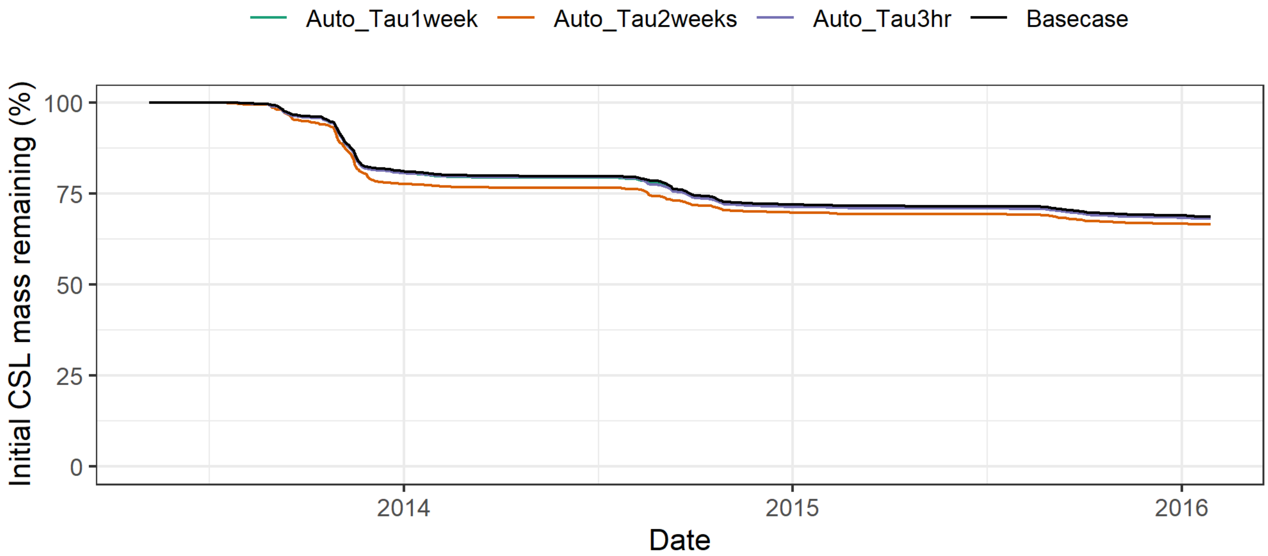

Figure 4-56. Modelled proportion of initial mass (water) remaining in the Coorong south lagoon for base case and automated barrage scenarios

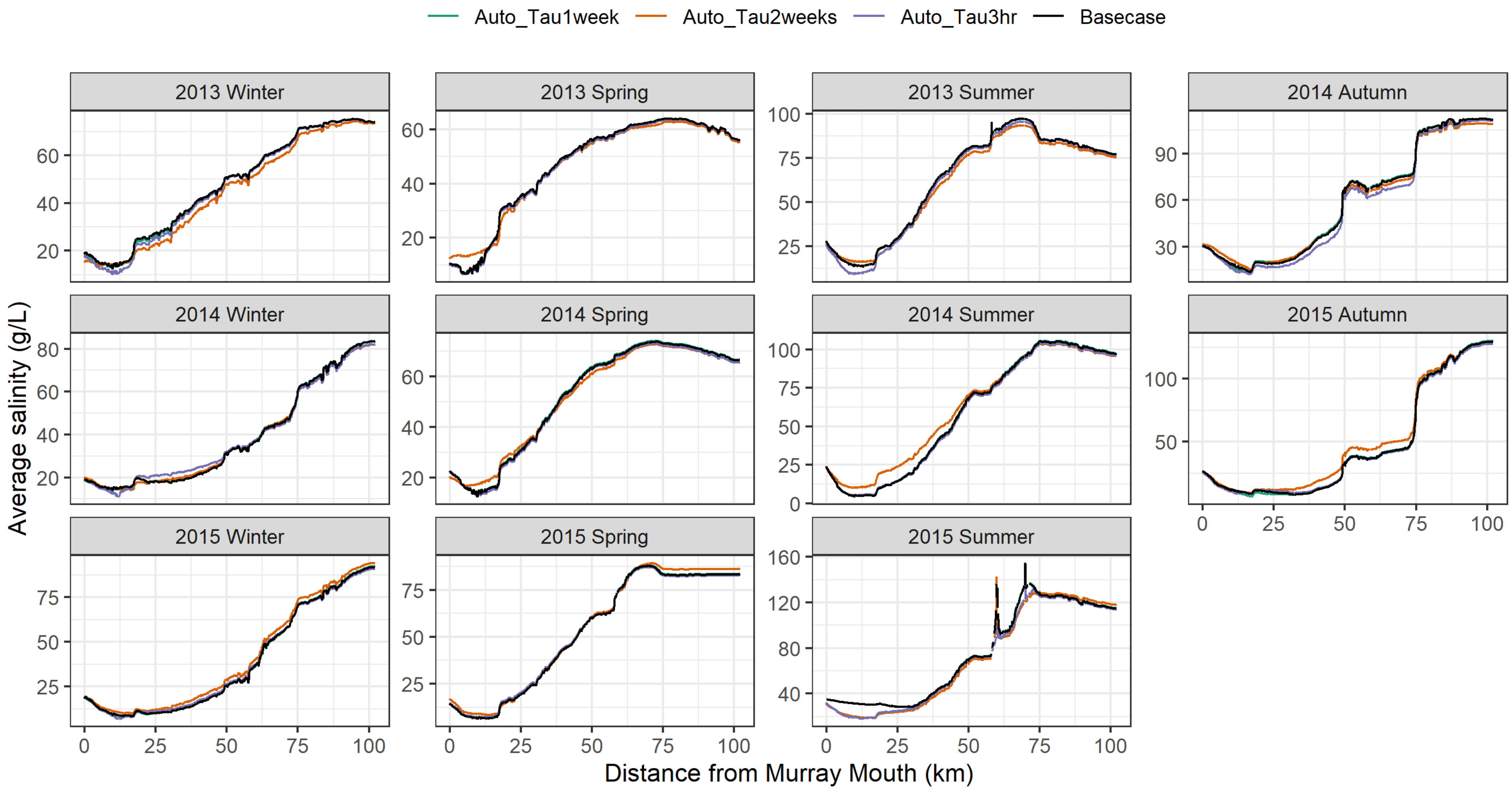

Figure 4-57. Modelled salinities along the length of the Coorong (north to south) for base case and automated barrage scenarios

5 Discussion

5.1 Summary of results

A total of 60 model scenarios have been undertaken to evaluate the expected changes in water level, salinity and flushing in the Coorong from various configurations of shortlisted infrastructure options considered by the Coorong Infrastructure Investigations Program. The preliminary modelling results indicate the following:

- Climate change scenarios show a marked reduction in salinity in the CSL, with concentrations dominated by the increased flux of tidal water into the lagoon. The north and south lagoons are near permanently connected, with water levels in summer generally greater than 0.2 mAHD, and in winter greater than 0.5 mAHD. This suggest a very different base case in the next 30 years based on high emission (RPC 8.5) sea level rise projections for 2050.
- Pumping seawater into the south lagoon is less efficient than pumping water out of the south lagoon, and results in high salinity water being exported to the north lagoon, exceeding management triggers, even in the third year of operation.
- Pumping out of the south lagoon is an effective method to reduce retention time and salinity, however low water levels over late spring and summer must be mitigated. This may be achieved with; a higher pumping out rate only when water levels are above a threshold; the combination of pumping water in as well as out of the lagoon; or with a combination of dredging. However, the previous Salinity Reduction Scheme investigations found that a higher pumping rate for shorter period would have a larger negative impact on the marine environment.
- A pumping solution has the benefit of being independent of water availability in the River Murray or south east drainage network. A constant 250 ML/d pumping rate was sufficient to reduce salinities even under a no inflow scenario. At the south lagoon average water level (0.25 m AHD) the volume of the south lagoon is 133 GL and in north lagoon (including Murray mouth) is 117 GL. Hence, a constant pumping rate of 362 ML/d will remove the full volume of the south lagoon each year (without considering evaporation).
- Pumping out at the southern end of the south lagoon results in slightly greater salinity benefit than at the northern end, however the difference is minimal. Hence, other factors (e.g. power source, site access, vegetation clearance, cultural sites) are likely to be more important drivers of pump location than salinity benefit to the Coorong.
- Dredging (at Parnka point and Pelican Point) increases water levels in the south lagoon, and hence the available mudflat area, over late summer, at a critical time for shorebirds. This dredging, however, also reduces water levels in the south lagoon faster in spring (of the first year), which may be detrimental to Ruppia in completing its life cycle.
- Dredging at Pelican Point alone, or deeper bathymetry at the mouth had very little impact on the Coorong water levels or salinities in the model.
- Dredging in combination with pumping has a greater reduction in salinity in the south lagoon, particularly over autumn, than pumping or dredging alone. The impact on water levels in the south lagoon is less than pumping alone.
- The benefits of the Lake Albert connector are limited to times when there is sufficient flow in the river. This was not the case over the Millennium drought. Nonetheless, salinity reductions resulted from the modelled options. The 'best case' was sufficient to reduce salinities in the south lagoon below 100 g/L,

whereas the more realistic operational scenario achieved approximately half of the volume directed through the Lake Albert connector, and a similar reduction in salinities in the south lagoon.

- The modelled options for automating the barrages tested three 'best case' operational scenarios, none of which were able to significantly reduce salinities in the Coorong, despite doubling the number of automatic gates. Positive benefits to operating the gates in this way may be experienced at a local scale in the north lagoon.

5.2 Comparison to previous work

Many of the infrastructure options considered in this work have been assessed previously, most commonly with the 1D Coorong Hydrodynamic Model, which has the advantage of much faster simulation times enabling multi-decadal simulations. The salient studies are outlined below, and all of which are in agreement with the results presented in this work.

Lester et al. (2009) considered pumping the southern lagoon to the ocean, in combination with dredging. Pumping rates of 150 ML/d and 450 ML/d were considered, including differences in the duration and start date of pumping. The 450 ML/d discharge was subsequently considered to pose too high a risk to the receiving marine environment. The study was undertaken in the context of the Millennium drought, and hence no barrage flow scenarios were considered, with simulation periods of 8 years. It was found that approximately three years of pumping was required for the salinities in both lagoons to settle down to a new equilibrium, a similar duration of time to the scenarios used in this work. The results aligned with this study, in that: 1) the salinities reductions from dredging alone were the least effective of the options considered by Lester et al. (2009), and 2) that the pumping scenarios with the greatest benefit to salinity also had the largest impact on water level. Based on these findings, a second round of scenarios that included dredging in combination with pumping to offset water level impacts was considered. This second round of scenarios found that without a return of barrage flows, the 150 ML/d pumping rate considered was not sufficient to reduce salinities below 60 g/L at any time in the simulation period, again in line with the results presented here.

BMT WBM (2009 and 2010) also considered pumping out of the Coorong scenarios with a higher resolution numerical model, a RMA10s finite element numerical model, which preceded the development of the TUFLOW FV model used in this work. Similar scenarios and results to those presented here were considered. Under a no barrage flow scenario, a 150 ML/d pumping rate was not sufficient to reduce peak summer salinities in the south lagoon, however a 250 ML/d pumping rate did show reductions in the peak. BMT WBM (2010) found that moving the pump location from near Woods Well to slightly further south at Seagull Island had minimal impact on the salinity benefit derived, with the location further south providing a slightly greater salinity reduction, aligning with the work undertaken here.

Increasing flow from the South East drainage network has been considered by multiple previous studies. Sims (2017) used the 1D Coorong Hydrodynamic Model to assess changes to the Coorong and subsequent Ruppia and fish habitat suitability from augmentation of the SEFRP project, and also included a structure between the north and south lagoons to manage water levels. The 114 year simulations assumed barrage flows that represented implementation of the Basin Plan and adopted a rule to not divert additional south east inflows when the south lagoon was below 60 g/L. Based on these assumptions, the higher Basin Plan barrage flow time series resulted in limited need for additional flows from the South East Flows Restoration Project (SEFRP), however, the results did indicate that these extra flows from south east drainage network reduced peak salinities to a small degree.

Lester et al. (2012) used 25 year, steady state, modelling scenarios to investigate the impact of flow volume, timing and quality from the barrages and south east drainage network on the Coorong. Both barrage and Salt Creek flow volumes were found to influence salinity, in particular, with Salt Creek flows having a greater impact when barrage flows were low. Sims (2017) presented a comparison of annual volumes from the barrages and south east drainage network, to identify how frequently substantial volumes may be available from the drains when barrage flow is low, and found that while the two inflow annual volumes were highly correlated, there were some years in the 114 year modelled period where higher south east flows could be available. Lester et al. (2012) presented their results as contour plots that could be used to derive average and maximum south lagoon salinities for a given combination of repeating barrage flow and south east inflow volume (reproduced in Figure 5-1). The change in maximum annual salinity that can be derived from Figure 5-1 based on the average barrage flow and south east inflows assumed in this work are in agreement with that presented in Figure 4-48 above.

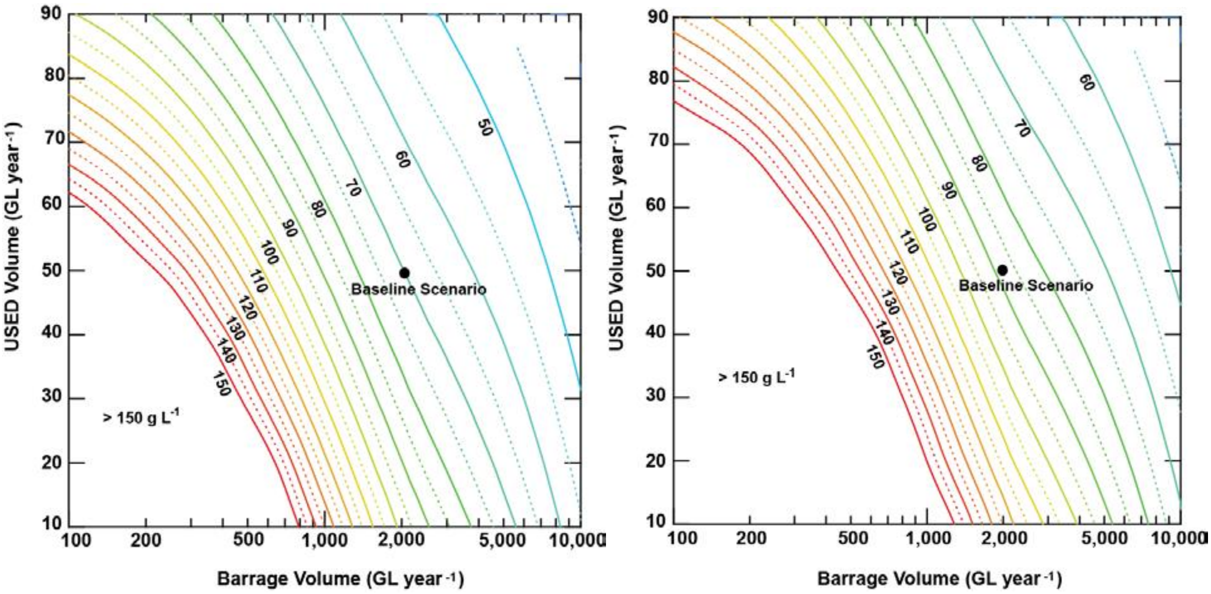

Figure 5-1 Average (left) and maximum (right) salinity in the South Lagoon as a function of USED and barrage flow volumes. Reproduced from Lester et al. (2012).

6 Recommendations

The preliminary results have indicated that further investigation of some options is required. This includes:

- Further ecological interpretation of these results via the ecological risk assessment framework.
- Investigation of the response of the system under base case and shortlisted CIIP scenarios for long term simulations, to capture the full extent of the impact of the interventions and interannual variability that could be expected from the forcing conditions of inflows, tide, wind and climate.
- Investigate habitat response for key species such as Ruppia Tuberosa under base case and shortlisted CIIP option scenarios.
- Investigate the water quality impacts in the south lagoon from the different water sources, i.e. increased south east drain inflows, River Murray water via a Lake Albert connector, and sea water through pumping.
- Investigation of mitigation options for water level impacts from pumping scenarios, which could include:
    - Only pumping out of the south lagoon under some conditions, for example not pumping after flows between the south and north lagoon are constricted, at approximately 0.2 - 0.3 mAHD,
    - Pumping seawater in to maintain a water balance,
    - Dredging for an improved connection to the north lagoon,
- Further optimisation of pumping rates to inform design of infrastructure.
- Investigate the system response to a broader range of inflow conditions for base case and shortlisted CIIP option scenarios.

7 References

Asanopoulos, C and Waycott, M (2020) The growth of aquatic macrophytes (Ruppia spp. and Althenia) and the filamentous algal community in the southern Coorong. Goyder Institute for Water Research Technical Report Series No. 20/11.

BMT (2019) Murray Mouth Model Status Report. Report to SA Water. Reference R.B23126.001.00. August 2019.

BMT WBM (2009) COORONG SALINTY MODELLING (Update six out of six scenarios modelled). Memo to SA DEH, available from: https://data.environment.sa.gov.au/Water/Data-Systems/CLLMM/Shared%20Documents/CLLMM_612_Coorong%20Pumping%20EPBC%20Referral%20Appendix%20F1_2010.pdf

BMT WBM (2010) Coorong Model / South Lagoon Pumping Simulation Update. Memo to SA DEH, available from: https://data.environment.sa.gov.au/Water/Data-Systems/CLLMM/Shared%20Documents/CLLMM_625_Coorong%20Pumping%20salinity%20impact%20modelling_b_2010.pdf

Collier C, van Dijk K, Ertemeijer P, Foster N, Hipsey M, O'Loughlin E, Ticli K and Collier M (2017) Optimising Coorong Ruppia habitat. Strategies to improve habitat conditions for Ruppia tuberosa in the Coorong (South Australia) based on literature review, manipulative experiments and predictive modelling. University of Adelaide, Department of Environment Water and Natural Resources, University of Western Australia and DAMCO Consulting.

Gibbs, M (2020) Scenario modelling of the Lower Lakes during the Millennium Drought. DEW Technical report 2020/04, Government of South Australia, Department for Environment and Water, Adelaide.

Green G and Pannell A (2020) Guide to Climate Projections for Risk Assessment and Planning in South Australia, Government of South Australia, Department for Environment and Water, Adelaide.

Hobbs TJ, O'Connor J, Gibbs M (2019) Improved elevation and bathymetry models for the Coorong. A Healthy Coorong, Healthy Basin project, DEW Technical report 2019/23, Government of South Australia, Department for Environment and Water, Adelaide.

Inside Infrastructure (2017) Augmenting the South East Flows Restoration Project – Hydrological modelling – stage 1 review. Technical Report to Department of Environment, Water and Natural Resources. Adelaide.

Lester, R, Webster, I, Fairweather, P, and R, Langley (2009) Predicting the ecosystem response of the Coorong to the South Lagoon Salinity Reduction Scheme. A report prepared for the South Australian Murray-Darling Basin Natural Resource Management Board.

Lester, R, Quin, R, Webster, I and Fairweather, P (2012) An investigation into interactions between the proposed Upper South East Drainage (USED) Scheme and Barrage Flows. A report prepared for the South Australian Department for Environment and Natural Resources

Mosley LM, Priestley S, Brookes J, Dittmann S, Farkaš J, Farrell M, Ferguson AJ, Gibbs M, Hipsey M, Huang J, Lam-Gordillo O, Simpson SL, Teasdale PR, Tyler JJ, Waycott M, Welsh DT (2020) Coorong water quality synthesis with a focus on the drivers of eutrophication. Goyder Institute for Water Research Technical Report Series No. 20/10.

Sharma S, Benger S, Tanner J and Webster I (2009) Spatial modelling of mudflat availability and fish habitat in the Coorong, in The CLLAMM Dynamic Habitat: Habitat mapping and dynamic modelling of species distributions, CSIRO: Water for a Healthy Country National Research Flagship and South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Sims, C (2017) Long term Coorong hydrodynamic modelling – Coorong Investigations Project, DEWNR Technical report 2017/17, Government of South Australia, Department of Environment, Water and Natural Resources, Adelaide.

Taylor, B, Gibbs, M, Hipsey, M, Lewis, M, Sharath, I, Brookes, J, Nicol, J, Clarke, K, Dalby, P, Clark, M and Bice, C (2014) Investigations to inform diversion rules for the South East Flows Restoration Project in the Drain L catchment, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide.

Paton, DC, Paton, FL and Bailey, CP (2018) Monitoring of Ruppia tuberosa in the southern Coorong, summer 2017-18

Webster IT (2012) The Application of Hydrodynamic Modelling to Assess the Impact of Supplementary Flow Releases on Coorong Water Levels and Salinities: Water for a Healthy Country National Research Flagship.

Government
of South Australia

Department for
Environment and Water