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Combining salinity and water management modelling for the Hawkesbury Nepean Valley

J. Simpson [a], **S. Podger** [a], **C. Li** [b], **J. Nicholls** [a], **K. Kumandur** [b], **P. Dunne** [b], **E. Beling** [b] **and F. Coen** [b]

[a] *Water Analytics, New South Wales Government Department of Planning and Environment*
[b] *Sydney Water*
Email: james.simpson@dpie.nsw.gov.au

Abstract: The NSW Government is required to update water sharing regulations known as Water Sharing Plans every 10 years (NSW Water Management Act 2000) to help optimize outcomes for both the environment and water users. This process has recently been carried out for the Greater Metropolitan Water Sharing Plan, which covers the Hawkesbury-Nepean, Upstream Warragamba and Shoalhaven valleys. Ecological impacts are of key concern with this process and one of the areas with a higher probability of impacts is the tidal pool downstream of Yarramundi Bridge, where freshwater mixes with the saline water from the ocean. Increased salinity in this area is also likely to create issues for irrigators within the tidal pool near Windsor, because an increase in salinity could lead to an inability to extract water for irrigation for periods of time.

To support this work, DPE water has developed a set of eWater Source models to represent catchment scale processes such as runoff, irrigation, environmental water releases and other management rules. In parallel, Sydney Water has developed a suite of models that include a hydrodynamic and water quality model (TUFLOW FV with AED2) to assist in investigations of water quality impacts. Sydney Water's representations of salinity and DPE's representations of the valley management rules were unique to each model set. To investigate impacts to salinity from changes to the management rules, the two models we reused in combined.

While this combination of models relied upon various assumptions and created some challenges in generating useable output, it created longitudinal salinity time series that were otherwise unavailable and could be used to inform decisions about changing the management rules in the Greater Metropolitan Water Sharing Plan. This interagency cooperation highlighted areas of modelling overlap which will help increase efficiency of modelling in the future, as each organization can focus on various aspects of modelling and share their datasets with the other so that work does not need to be repeated.

Keywords: *Collaboration, salinity modelling, water balance modelling, planning and policy*

1. INTRODUCTION

The Department of Planning and Environment (DPE) has been developing and upgrading a range of eWater Source models for the Shoalhaven, Hawkesbury/Nepean and upstream Warragamba valleys to use for various planning purposes. One of these key purposes is to assist in optimizing environmental outcomes and water use that are contingent upon the Greater Metropolitan Water Sharing Plan (GMWSP). The GMSWP is a piece of legislation that defines water access rules and environmental release rules for the Hawkesbury-Nepean, Upstream Warragamba and Shoalhaven valleys. One of the areas of interest for this process was determining the impacts of changes in the implemented management rules on salinity in the tidal pool. Specifically, the impact to salinity from changes to environmental flows and trading of water access licenses that affected the tidal pool were of interest.

The DPE Source model for the Hawkesbury-Nepean valley has representations of irrigators, cease to pump rules, water access licenses, environmental flow releases, sewerage treatment plant discharges, rainfall runoff, instream losses and more. It does not, however, have representations of salinity or other water quality related metrics. Sydney Water (SW) have, however, been developing and upgrading a Water Quality Response Model (WQRM) for the Hawkesbury Nepean River system, which has a Source catchments hydrologic and water quality model used as input into a finite volume hydrodynamic and water quality model developed within the TUFLOW FV and AED2 software.

Sydney Water's models have relatively limited representation of irrigation extractions and do not represent the various water management rules; however, they do simulate salinity dynamics throughout the river system from the Pheasants Nest and Broughton's Pass weirs all the way to the estuary mouth, therefore covering both fresh and saline sections of the rivers. These models were established to allow the evaluation of relevant environmental impacts (detrimental or beneficial) resulting from different catchment conditions ovexj k,r broad spatial and temporal scales. There was an opportunity to assess the impact of changing management rules to salinity by combining the DPE and SW models as this would achieve the necessary combination of representations of both salinity and the changes to management rules. SW and DPE agreed to combine efforts and create this model combination, while thoroughly checking the assumptions and potential downsides of combining our modelling processes.

2. BACKGROUND / MODEL OVERVIEWS

2.1. Sydney Water WQRM

The WQRM was originally developed for Sydney Water in 2014 as part of the water quality modelling of the Hawkesbury Nepean River System project. The purpose of the modelling was to inform Sydney Water and associated stakeholders of the potential changes in hydrology, water quality and inform ecological response under different scenario settings and through the application of a coupled catchment and receiving water quality model system. A major upgrade completed in 2021 includes updated calibration and validation based on focused field monitoring data and the application of the latest innovation in the software platforms.

The WQRM simulates three dimensional hydrodynamic and biogeochemical processes (including salinity, nutrients, pathogens and algal growth) at a sub-hourly time step. Detailed catchment inflows and constituent runoff parameters inputs were applied to the hydrodynamic components based on various land use types simulated in SW's own eWater Source catchment models. Extractions from the waterways were based on a synthetic time series of irrigation extractions taken from the Hawkesbury-Nepean IQQM Irrigator Models.

The SW WQRM simulation period adopted for this project was from 01/07/2013 to 01/07/2015. These years were selected as they were deemed representative of a relatively dry year and a wet year respectively, based on decile analysis of rainfall over a 25-year period from 1994 through to 2019.

2.2. DPE eWater Source Model

The DPE water balance model's primary purpose was to replicate water balance at a daily interval in a one-dimensional water balance model. The model was calibrated using observed climate data and observed flow data typically for the years 1990 – 2021. This calibration period was chosen as it contained the best quality data, a range of climate events and variability and was found to be representative of current behaviour. The model is best suited to reproducing flows over this period and periods with similar climatic and development conditions.

Management rules and users are also dynamically applied within the Source model. The dynamically applied management rules for irrigators and users which impact diversions (based on entitlements and cease-to-pump rules) and operation and releases of storages and weirs. The location of the DPE and SW water balance outputs which were introduced into the WQRM TUFLOW model are presented in Figure 1.

The simulation period for the DPE model was from 01/07/1889 through to 30/06/2020.

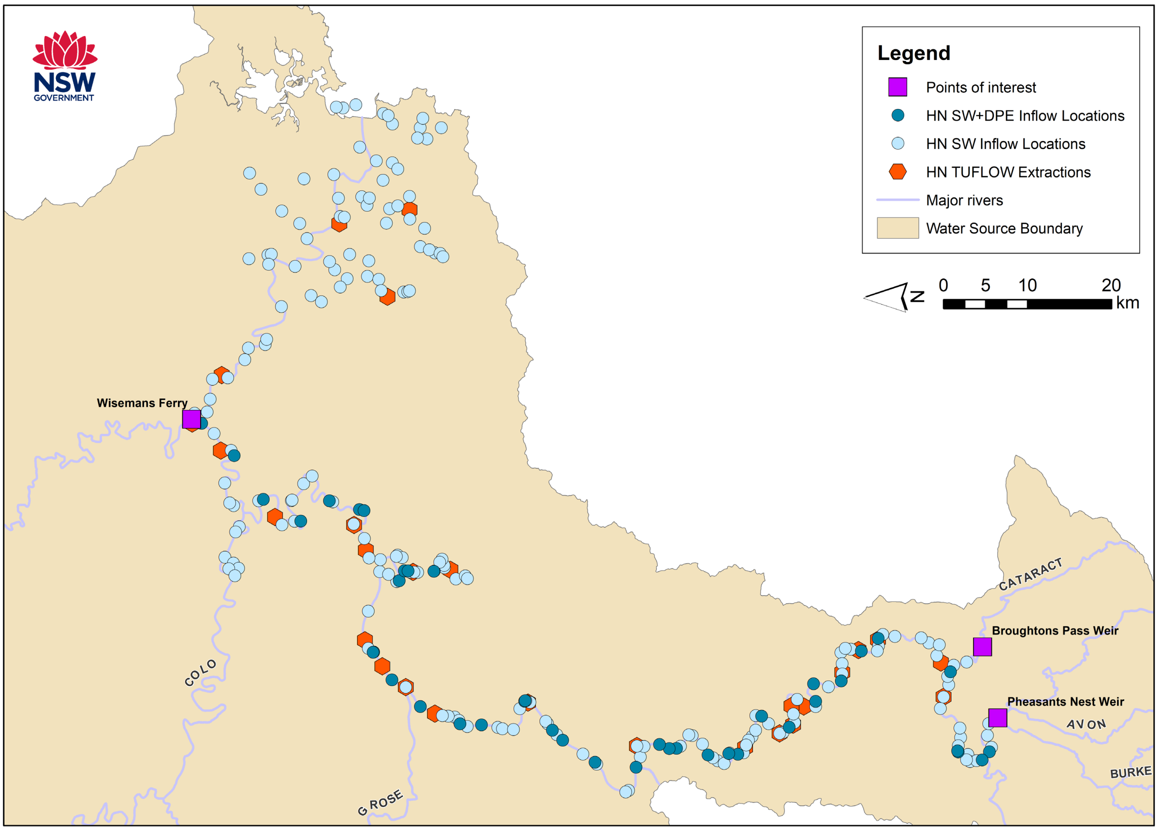

Figure 1. Hawkesbury-Nepean model inflow and outflow locations used in the TUFLOW model

3. SCENARIOS

A series of model runs using the model combination were completed to supplement the WSP development. The model combination developed by the DPE, and SW teams provided context to determine what impact extractions and trading have on the salinity profile in the tidal pool of the Nepean River.

In this work for the WSP development the following model scenarios were run:

- SWBaseline – the HN EIS baseline scenario model finalised in June 2021
- DPEBaseline – Catchment inflow, dam releases, WWTP discharges and extraction volumes updated based on DPE's water balance model
- DPETrade – Operation of DPE's trading scenario (S3B)
- DPENoExt – a sensitivity test with all extractions switched off

The first two scenarios relate to best estimates of current conditions in the valley. The purpose of the DPETrade scenario was to determine what the impacts may be of trading entitlements from upstream into the tidal pool. This involved moving 2GL of entitlements from irrigators in the section from Penrith Weir to Yarramundi Bridge and evenly distributing them across irrigators downstream of Yarramundi Bridge. Since there is higher water availability, higher crop demands and less cease to pump events downstream of Yarramundi Bridge, this resulted in 0.8GL/yr increase in valley wide irrigation diversions. This increase would remove water from the system that would otherwise be available for the environment.

Previous DPE modelling results had highlighted that cease to pump rules were less restrictive in the tidal pool than those upstream of Yarramundi Bridge, allowing water users more frequent access to flows. There were also more points of inflow down to the tidal pool, which allowed for a greater volume of water to be accessed. This increased frequency and volume of water available resulted in increased water extractions for the valley, leading to less flow passing through the tidal sections of the river.

The DPENoExt scenario was created as a contextual benchmark sensitivity analysis to compare the impacts of the more realistic scenarios to the extreme situation in which all irrigation extractions were removed from the valley.

3.1. Comparison of inputs

A comparison of scenario inputs into the TUFLOW salinity model between SW and DPE scenarios is presented in Table 1. From this data it is observed that the total flow volume between the SW and DPE baseline scenario are relatively similar for the selected model period (<1%). As each model was calibrated and conceptualized differently it is expected that there will be differences in model results, however this close correlation in total volume potentially reduces the level of risk and uncertainty in combining these models.

The main difference that can be seen is that DPE models have higher estimates of losses and the SW have higher estimates of inflows. This was due to the different processes that have been undertaken to represent the model water balance. The DPE model incorporates surface water losses prior to calibration by finding periods of no or low rainfall and drawing a relationship between reach losses and upstream flows. Residual inflow calibration is then done with these assumed losses in place. By contrast, the SW model utilises the net catchment discharges as hydrology boundary conditions, which include both groundwater and surface water contributions.

Although the total volumes between the DPE and SW models were estimated to be similar, differences could lead to more salinity being lost or introduced compared to the other model. This could create differences in metrics for sections upstream of the tidal pool, however where there is highly saline water mixing with fresh water, the total volume is expected to be the driving factor, which makes these combinations of models more suitable and fit for purpose.

Further to the above, since the SW model included salinity conditions from headwater and residual reach inflows as an input, these needed to be generated for the DPE version of input. As salinity was not explicitly represented in the DPE model, average salinity values were taken from the SW model and were scaled linearly to the inflows in the DPE inputs.

Table 1. Comparison of scenario inputs for model run period (2013–2015)

	SW_Baseline	DPE_Baseline (m^3)	DPE_NoExtractions (m^3)	DPE_TradingScenario (m^3)
Boundary inflows	184,014	175,068	199,568	175,068
Residual inflows	47,654	71,894	72,567	71,912
Extraction + Losses	-6,220	-23,535	-22,011	-23,817
Net inflows	225,448	223,427 (-1%)	250,124 (+11%)	223,163 (1%)
Number of inflow nodes	156	40	40	40

The resultant channel fluxes extracted from model scenarios are present in Table 2. The largest differences between the SW_Baseline and DPE_Baseline scenarios are in the sections of Sackville and US_SouthCreek. These sections of the models have lower accuracy in irrigation, flow and loss estimates due to lack of data availability, which could explain some of the differences in the DPE and SW models. These differences are, however, all within expected error ranges for differing hydrologic model calibrations.

Table 2. Comparison of channel fluxes (m^3/s) for model scenarios

	SW_Baseline	DPE_Baseline	DPE_NoExtractions	DPE_TradingScenario
Sackville	23.4	27.4	27.3	32.2
US SouthCreek	16.4	19.6	19.5	24.1
US GroseRiver	14.2	15.7	15.7	19.6
Penrith	12.7	13.5	13.5	17.4

4. RESULTS

A set of key outputs are presented in this section. Figure 2 presents the predicted salinity time series at Wisemans Ferry for the SW baseline, DPEBaseline and the DPENoExt scenario. From these model results it can be observed that the salinity time series response is predicted to be similar between all the scenarios, the climate providing the strongest response. The difference in response between SW and DPE is expected as the total salinity load arriving at the tidal pool varies as does the flows and other inputs. The difference between the DPEBaseline and SW baseline is dependent on the point in the time series as there were only small differences predicted from May 2015 to November 2015.

These outputs highlight that while there is a difference in model outputs, there is a relatively similar response down to the end of the area of interest.

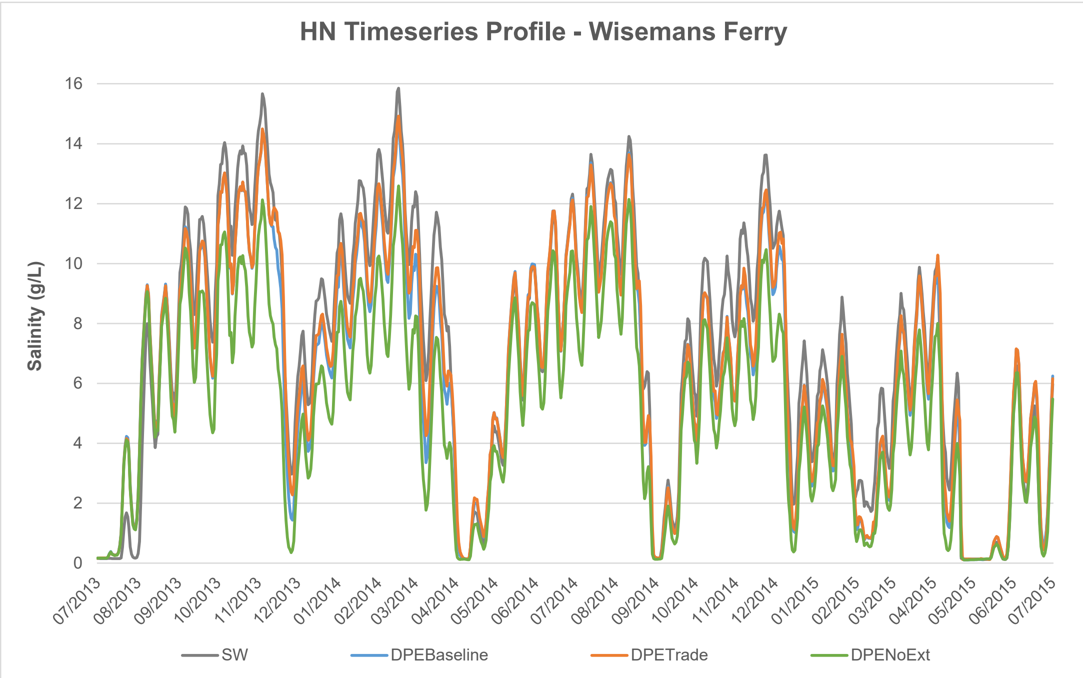

Figure 2. Hawkesbury Nepean – salinity time series at Wiseman's Ferry

Figure 3 presents the longitudinal median of the entire timeseries of salinity along the tidal pool for the SW baseline, DPEBaseline, DPETrade and the DPENoExt scenario. As it can be seen, the difference in annual median salinity between the SW Baseline and the DPEBaseline is similar in magnitude (but different in direction) to DPEBaseline and DPENoExt.

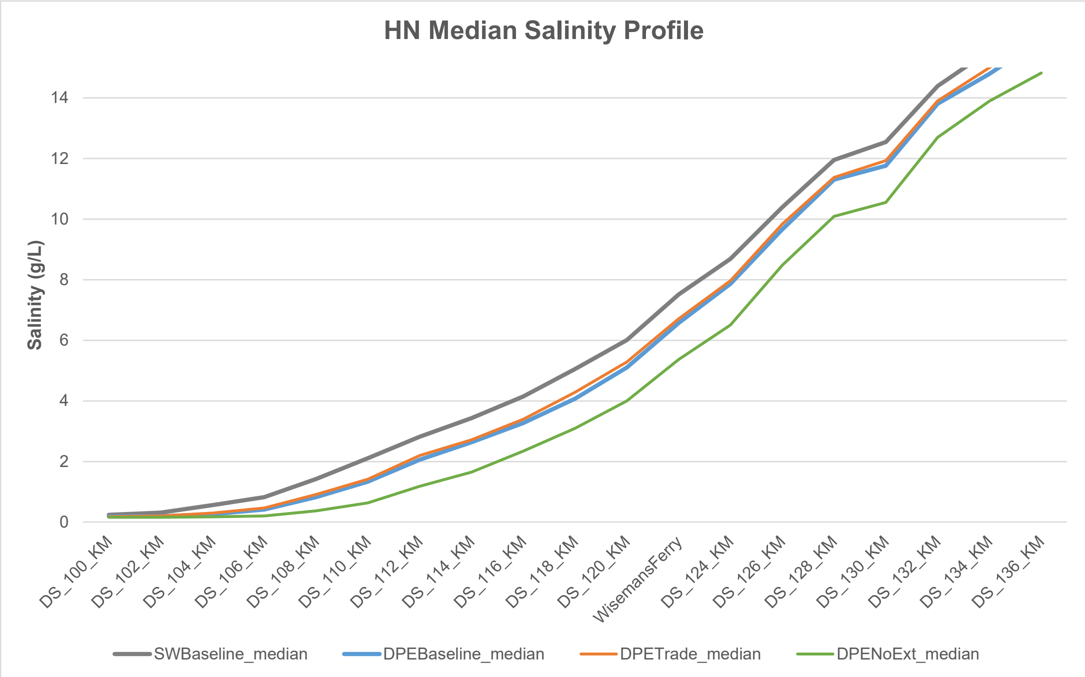

Figure 3. Hawkesbury Nepean – Longitudinal Median salinity. The x-axis refers to chainages along the Hawkesbury-Nepean River starting from Wallacia Weir

While the DPE Baseline predicts lower salinity levels in the tidal pool, estimates are within < 2km of the annual median salinity estimates of the SW Baseline. Since the differences in salinity estimates between the SW and DPE baselines are not significant, this increases confidence that the combination of SW and DPE models is appropriate for assessing impacts to irrigators and the environment. For other purposes which don't focus on this measure, there will be lower confidence in the accuracy of results.

For the DPETrade scenario results showed increases in median salinity along the tidal pool by approximately 0 - 0.2g/L. In effect causing the median salinity to travel upstream < 0.25km. For DPENoExt scenario this caused decreases in median salinity along the tidal pool by approximately 0.2 - 1.2g/L, and causing the predicted median salinity to travel downstream approximately < 2km.

5. LIMITATIONS

To more optimally model salinity levels and other quality measures in tandem with irrigation and management rules, the SW WQRM and the DPE Source models would need to be recalibrated so that they were better aligned. This would be very onerous and time consuming and was not deemed possible in this instance given time and budget constraints. If the environment or irrigators are in future deemed at risk of high impacts from salinity movement, this recalibration should be done to increase confidence in the modelling results.

Some of the differences that would need to be addressed to minimise the inaccuracy of integrating the modelling are:

- Finer representation of sub-catchments in the Sydney Water Source model
- Water management rules are included in the DPE model (such as: implementation of water allocations, cease to pump rules, management rules and irrigator behaviours) compared to the timeseries irrigation extractions in the Sydney Water model
- Representation of water quality inputs in the Sydney Water model that are not represented in the DPE model and assumed for the purposes of this study

When either model is being recalibrated, some of the easiest differences to rectify would be copying DPE management rules and placing them in Sydney Water modelling and to implement some salinity inputs into DPE rainfall runoff modelling with the help of the Sydney Water model.

6. DISCUSSION AND CONCLUSIONS

There were many metrics used to assess the impacts of the GSWSP scenarios, which includes environmental flows, impacts to diversions and access, salinity etc. DPE models were developed to best compare to those metrics but have no representations of instream water quality or salinity. There was an opportunity to understand the approximate impacts that the GSWSP scenarios would have on the salinity profiles by utilizing the SW model. It is assumed that upstream movement of salinity within the tidal pool could confer negative impacts to either the environment or irrigators extracting from the tidal pool. That the DPETrade scenario predicted reduced freshwater flows through the tidal pool, the possibility that this could cause upstream movement of salinity further motivated this work. Detailed irrigator or environmental impacts with salinity movement has not been investigated but could be a focus for future work.

Conceptualizing and building water resource models that can accurately simulate salinity, requires significant investment of time and effort. The work completed in this paper describes the challenges and the opportunity of comparing the utility of different models. The results from combining the models from DPE and SW were useful in illustrating the impacts of the GMWSP scenarios. The numerical outputs were not ultimately used in the WSP development; however, the conceptual impacts were used to assist in decision making in place of assuming what the impacts would be.

The combination of SW and DPE modelling highlighted that trading water access licenses to give more access to users within the tidal pool (and less access upstream) did not cause significant changes to salinity. While detailed ecological and economic impacts of this change are not known, the work has assisted to contextualize the scope of potential changes, which assisted in informing planners and stakeholders about the risks associated with trading entitlements into the tidal zone.

Both models will be improved in future iterations thanks to the effective collaboration between the modellers at DPE and SW. Areas where SW modelling have developed more significantly include water quality processes and representation of wastewater treatment plants. These developments have allowed DPE to upgrade their modelling. Similarly, areas where DPE modelling have focused on could be used to help future SW model improvements.

It was confirmed that both sets of modelling are important and should remain separate, however continued collaboration will assist in model improvements and minimizing repetition of work between agencies. When future recalibrations and model improvements are made, it will be of great value to further integrate these models and narrow the gap between their uses so both models better suit the needs of their respective agencies.

REFERENCES

Murray-Darling Basin Authority., 2012. Hydrologic modelling to inform the proposed Basin Plan: Methods and results.

New South Wales. Department of Planning and Environment., 2023. Draft Water Sharing Plan: Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources, accessed 01 Feb 2023.

Sydney Water., 2021. Hawkesbury Nepean and South Creek TUFLOW FV and AED2 Model Calibration Report.