APPENDIX H5.3

Comparison of Olympic Dam EIS and Kaempf models

H5.3 COMPARISON OF OLYMPIC DAM EIS AND KAEMPF MODELS

H5.3.1 INTRODUCTION

Modelling studies were undertaken by BMT WBM Pty Ltd, in conjunction with the Centre for Water Research (CWR) of the University of Western Australia, for both the Draft and Supplementary EIS. For the Draft EIS, this comprised a high-resolution model of Upper Spencer Gulf (for simulating plume dispersion over hours to days), nested within a lower-resolution model of the entire Spencer Gulf for simulating long-term salinity changes over years (refer Appendices O11.2 and O11.4 of the Draft EIS). For the Supplementary EIS, BHP Billiton commissioned BMT WBM Pty Ltd to upgrade all modelling tools used in that study to account for recent advances in modelling technologies, and also to collect additional targeted field data to support validation of the upgraded modelling tools. This ensured the ongoing delivery of robust and rigorous modelling outcomes. High- and low-resolution models were both developed to cover the entire gulf, with the former adopting a spatially variant horizontal grid resolution (decreasing with distance from the diffuser) and the latter using the same spatial resolution as the Draft EIS low-resolution model (see Appendices H5 and H7 of the Supplementary EIS). Specific modelling of the diffuser was also undertaken for the both the Draft and Supplementary EIS to capture the initial dilutions before the plume dispersion beyond the immediate influence of the diffuser. For the Supplementary EIS, a suite of diffuser arrangements using a range of techniques was applied (see Appendices H6 and H7 of the Supplementary EIS).

After the release of the Draft EIS, a modelling study of the South Australian gulfs was published by Kaempf and others (2009). That study developed and employed low (spatial) resolution modelling tools to simulate and describe the long-term, broad-scale oceanographic behaviour of Spencer Gulf and Gulf St Vincent. It also deployed a higher-resolution modelling tool to investigate dispersion of desalination return water released at Point Lowly (and Port Stanvac, but this is not of direct relevance here), but no diffuser modelling was reported by Kaempf and others (2009).

Given the relevance of this modelling study to the Olympic Dam Expansion EIS investigations, it was considered important to compare and contrast the study methodologies and outcomes of Kaempf and others (2009) to those undertaken for the Draft and Supplementary EIS modelling studies. This allows the BHP Billiton studies to be benchmarked against modelling acceptable for publication in international journal-standard literature.

H5.3.2 COMPARISON OF MODELLING STUDIES

Modelling framework

The modelling studies for the Draft and Supplementary EIS have a similar hierarchical structure to that of Kaempf and others (2009), with the exception of the detailed diffuser modelling.

The overall two-tier modelling paradigm of the Draft EIS, Supplementary EIS and Kaempf and others (2009) is essentially the same in that all studies have constructed, executed and in varying ways linked, low and high (spatial) resolution numerical models. This approach has been adopted across all studies to support investigation of commensurately scaled processes – that is, low-resolution models have generally been used to investigate long-term, broad-scale processes (such as flushing times, for example) and higher-resolution models have been used to investigate shorter-term local-scale processes such as return water dispersion near Point Lowly.

The exception to the above is the consideration of a third tier for detailed diffuser simulations across the studies. Both the Draft EIS and Supplementary EIS studies paid attention to diffuser simulation and its impacts on (and linkage to) hydrodynamic modelling, whereas Kaempf and others (2009) do not report diffuser modelling studies. A sensitivity analysis provided in Appendix H7.2 of the Supplementary EIS has shown that this third tier of modelling, and the method by which it is integrated into high-resolution hydrodynamic models, can play an important role in the subsequent prediction of brine dilutions beyond the immediate influence of the diffuser.

The low- and high- resolution modelling comparisons are presented separately below, with reference to diffuser modelling included within the high-resolution modelling discussion.

Low-resolution modelling

The low-resolution modelling studies of the EIS, and Kaempf and others (2009) are similar, however the former studies employ more detailed forcing data (e.g. meteorological data) and include key hydrodynamic processes (e.g. wetting and drying). A detailed comparison of the low-resolution models developed for the EIS modelling studies and by Kaempf and others (2009) is provided in Table H5.3.1. Key elements of this comparison are:

- the Draft EIS and Supplementary EIS domains spanned Port Augusta to approximately Port Lincoln (at a horizontal resolution of two kilometres), while the Kaempf and others (2009) domain extended further southwards to the shelf and included Gulf St Vincent (at a horizontal resolution of three kilometres). Validation of the Draft and Supplementary EIS models has shown, however, that including shelf areas in the model domain is not required for robust and defensible simulation of the processes of concern

- the Draft EIS and Supplementary EIS models use spatially distributed meteorological forcing (up to 15 km gridded resolution in the Supplementary EIS) at a high temporal resolution (hourly in the case of the Supplementary EIS); Kaempf and others (2009) used single-point monthly average meteorological forcing
- the Draft EIS and Supplementary EIS used wetting and drying of intertidal areas; Kaempf and others (2009) did not include wetting and drying and set a minimum water depth of five metres, affecting 38% of Upper Spencer Gulf (north of the Whyalla shipping channels)
- the Draft EIS and Supplementary EIS were validated to tidal measurements from 2005 supplied by Flinders Port Corporation; Kaempf and others (2009) compared to measurements collected before 1980
- similar durations were applied (five to seven years) for the Draft EIS and by Kaempf and others (2009), while the Supplementary EIS model was executed for approximately 70 years to assess long-term behaviour of the gulf
- broad-scale, long-term predicted behaviours of Spencer Gulf were broadly consistent

In summary, the low-resolution modelling approaches, set-ups, calibration philosophies, execution periods and broad-scale predictions are generally similar for the models developed for the Draft and Supplementary EIS, and by Kaempf and others (2009). Nevertheless, several aspects of the EIS modelling studies are more detailed in nature: e.g. higher model grid resolution; more temporally and spatially resolved meteorological forcing; longer simulations; inclusion of wetting and drying; and simulation of all water depths.

High-resolution modelling

The EIS and Kaempf and others (2009) high-resolution modelling studies are not similar, with the former studies focusing in greater detail on diffuser and return water dilution matters. This has driven some recent progress in scientific methods and applications to deliver robust and thorough modelling outcomes. In particular, the detailed diffuser modelling approach (and injection method) has built on work by Okely and others (2007) and provided significant improvements to that reported to date in published literature.

High-resolution modelling studies are intended to simulate short-term, small-scale processes. In particular in this comparison, they have been used to assess the likely fate and transport of discharged return water. Despite this similarity in intent, in general the Draft EIS, Supplementary EIS and Kaempf and others (2009) high-resolution modelling studies are quite different, as described below.

A detailed comparison of the high-resolution models developed for the EIS modelling studies and by Kaempf and others (2009) is provided in Table H5.3.1. Key elements of this comparison are:

- the Draft and Supplementary EIS domains span Upper Spencer Gulf and the entire Spencer Gulf, respectively, with a horizontal resolution near Point Lowly of 200 m and 40 m respectively; the Kaempf and others (2009) domain is similar to the Draft EIS but it is rectangular and has a resolution of approximately 500 m
- the Draft and Supplementary EIS models used spatially distributed meteorological forcing (up to 15 km gridded resolution in the Supplementary EIS) at a high temporal resolution (hourly in the case of the Supplementary EIS); Kaempf and others (2009) used none (air-sea fluxes were ignored)
- the Draft and Supplementary EIS models used spatially distributed initial conditions derived from the low-resolution model for temperature and salinity; Kaempf and others (2009) used uniform conditions
- the Draft EIS and Supplementary EIS included full wetting and drying of intertidal areas; Kaempf and others (2009) did not include wetting and drying and set a minimum water depth of 5 m.
- the Draft EIS and Supplementary EIS were calibrated to targeted local hydrodynamic measurements; Kaempf and others (2009) presented no calibration of the high-resolution model.
- the Draft EIS and Supplementary EIS studies considered diffuser modelling in some detail, using a range of techniques including advanced computational fluid dynamics (CFD) approaches; Kaempf and others (2009) did not present diffuser modelling studies
- the Draft EIS used a conservative approach to introduce return water into the model ('injection technique'), whereas the Supplementary EIS reviewed existing approaches and developed a state-of-the-art injection technique using diffuser field modelling predictions (from CFD); Kaempf and others (2009) used a flux-based injection technique which does not take account of the use of a diffuser; and there are uncertainties about the impact of this method on predictions of dilutions beyond the immediate influence of the diffuser.

- despite Kaempf and others (2009) using a return water discharge rate less than half of the proposed rate, the minimum dilution predictions for the Draft EIS and by Kaempf and others (2009) are broadly similar (approximately 1:10), although Kaempf and others (2009) suggested that dilutions might even be as low as 1:3. The Supplementary EIS provides an improved diffuser design and modelling (particularly the injection technique), resulting in minimum dilution predictions exceeding 1:40. Importantly, the Supplementary EIS studies demonstrate a clear and defensible link to diffuser model predictions, and as such the high-resolution model predictions of dilutions beyond the immediate influence of the diffuser are responsive to material diffuser design and configurational changes. Kaempf and others (2009) did not model the diffuser and hence have not taken into account the initial dilutions thus achieved.

In summary, the EIS and Kaempf and others (2009) high-resolution modelling approaches, set-ups, calibration philosophies and outcomes are different. In particular, the Supplementary EIS model has been calibrated to targeted and comprehensive field data, has a high horizontal resolution in the vicinity of the proposed diffuser outfall, includes meteorological forcing at high spatial and temporal resolution, includes wetting and drying, sets no minimum water depths, and, most importantly, takes direct and defensible account of detailed diffuser modelling outcomes. These features provide a modelling tool that delivers robust predictions of return water dispersion, including interaction with sensitive receptors.

Tabular comparison

A detailed comparison of the Draft EIS, Supplementary EIS and Kaempf and others (2009) studies is provided in Table H5.3.1. Low- and high-resolution models have been considered together.

H5.3.3 CONCLUSIONS ABOUT ECOLOGICAL OUTCOMES

Kaempf and others (2009) concluded that return water discharge might have severe and irreversible negative impacts on the marine and benthic environments due to:

- stress in adjacent marine ecosystems, citing Seddon and others (2000)
- the sheltered nature and associated slow flushing of the receiving environment, citing Lattemann and Hoepner (2008) and Fernandez-Torquemada and others (2005).

The following provides further information about the references cited by Kaempf and others (2009).

- Seddon and others (2000) studied an isolated seagrass dieback event from south of Port Pirie to south of Port Broughton in 1993, concluding that there was compelling evidence that the dieback was due to negative tide levels, associated with a wide-scale climatic event, resulting in desiccation. Stress of this nature is considered to be completely unrelated to, and unlikely to be exacerbated by, elevated salinity levels. It should be noted that salinity hindcasts for that period are among the lowest for that decade (see Appendix H8.1 of the Supplementary EIS).
- Lattemann and Hoepner (2008) provided a synopsis of the key environmental concerns of desalination. They stated that enclosed and shallow sites with abundant marine life can generally be assumed to be more sensitive to desalination plant discharges than exposed, high-energy, open-sea locations, assuming a higher capability to dilute and disperse the discharges. One of their key recommendations, however, was for a project- and location-specific environmental impact assessment study. The Draft (and Supplementary) EIS provide such a study, which shows that the action of a diffuser and fast currents near Point Lowly can provide adequate dispersion. The Draft EIS was peer-reviewed by Dr Sabine Lattemann (a co-author of the cited publication), who considered the work to have been undertaken thoroughly and to a high technical level, with reasonable conclusions reached (refer Appendix O of the Draft EIS).
- Fernandez-Torquemada and Sanchez-Lizaso (2005) presented preliminary results of monitoring return water discharge from a Mediterranean desalination plant, and the disappearance (potentially migration) of urchins. This discharge, apparently without the use of a diffuser, was into a very-low-energy receiving environment – with a typical tidal range of 0.1–0.15 m (UKHO 2010), compared with typical tide ranges of 0.5–2.3 m at Point Lowly (see Figure 17.15b of the Supplementary EIS). It is possible that Kaempf and others (2009) considered this environment to be relevant to Point Lowly, as they reported maximum current speeds in Spencer Gulf of 0.1–0.5 m/s, with a virtual disappearance of tidal currents and associated mixing for dodge tide periods lasting two to three days. Field data collected at Point Lowly for the Draft and Supplementary EIS, however, show that current speeds reached 1.5 m/s and dropped below 0.1 m/s for only 16% of the time, with a maximum period of five hours.

While acknowledging that the long-term steady-state concentrations of return water seemed relatively low, Kaempf and others (2009) concluded that long-term exposure and potential accumulation of pollutants in bed sediment is of ecological concern. These concerns were not substantiated and made no reference to the composition of the return water or desalination process.

The studies undertaken by BMT WBM Pty Ltd (and CWR) are focused exclusively on hydrodynamic modelling and have not attempted to draw conclusions about the ecological impacts associated with particular model predications. They have provided one of the many tools used in the impact assessment of the proposed desalination plant, which interpreted the model predictions within the context of natural variability, the composition of the return water, ecotoxicology study results, and the desalination process.

The findings of the Supplementary EIS are that close to the diffuser (within 100 m) there may be minor effects on approximately 5% of species, with a possible shift in community structure similar to that 10–20 km north of Point Lowly.

The Draft and Supplementary EIS concluded that beyond the immediate area of impact there would be negligible impact on the marine environment of Upper Spencer Gulf, with key considerations including:

- long-term salinity increases of 0.1–0.15 g/L are approximately one tenth of the natural variability in salinity within the same day, across spatial scales of a few kilometres, and between bottom and mid-water depths in the vicinity of Point Lowly (see Appendix H5.4 of the Supplementary EIS), and one 20th of the seasonal variation (3 g/L)
- freshwater loss through natural causes is more than 300 times the loss due to desalination (refer Section 16.4.4 of the Draft EIS)
- the return water contains few ‘pollutants’ as the toxicity of anti-scalants to aquatic life is very low (Lattemann and Hoepner 2008), and all other chemicals that may be present in trace concentrations are commonly used in traditional domestic water treatment plants and discharged with treated wastewater (refer Section 16.4.1 of the Draft EIS)
- the long-term concentration of return water near Point Lowly would be several times more dilute than the species protection trigger value derived from ecotoxicology studies (refer Section 16.4.2 and 16.4.3 of the Draft EIS)
- the desalination plant would result in a net loss of heavy metals in Upper Spencer Gulf (refer Section 16.4.1 of the Draft EIS), and gain of dissolved oxygen (see Appendix H7.2 of the Supplementary EIS).

Table H5.3.1: Detailed comparison of models by Kaempf and others (2009) and models used for the Draft and Supplementary EIS

Aspect of study	Kaempf model (Kaempf et al. 2009)	Draft EIS models (Appendices O11.2, O11.4 of the Draft EIS)	Supplementary EIS model (Appendices H5 to H7)	Comparison/Comment
Peer review	*Desalination and Water Treatment* journal review process.	Independent experts from two internationally recognised marine engineering companies – HR Wallingford Ltd in the UK and Cardno (NSW) Pty Ltd (trading as Cardno Lawson Treloar Pty Ltd), – and by oceanographer Dr Rick Nunes-Vaz, an author of some of the definitive papers on Spencer Gulf oceanography. The model calibration and assessments were reviewed separately.	As for Draft EIS.	The level of peer review applied to the EIS studies is considered to be to at least the same standard as an international journal, and included domestic experts.
Model configuration and parameters				
Model extents	Low-resolution model extends from 10 km south of Port Augusta to near the shelf and includes Gulf St Vincent. High-resolution model centred at Point Lowly (and one other high-resolution model at Port Stanvac, but this has not been considered here).	Low-resolution model extends from Port Augusta to approximately Port Lincoln. High-resolution model extends from Port Augusta to just south of Point Lowly.	Low- and high-resolution models both extend over the entire Spencer Gulf to approximately Port Lincoln.	BHP Billiton modelling has shown that inclusion of shelf areas is not required to appropriately simulate relevant processes (such as temperature and salinity seasonality) for the purposes of investigating return water dispersion.
Processes	Low-resolution model includes parameterisation of shelf processes.	Processes within Spencer Gulf.	As for Draft EIS.	As above.
Horizontal resolution	Nested COHERENS model with grids of approximately 3 km x 3 km (low resolution) and 500 m x 500 m (high resolution) near outfall.	Nested ELCOM models with grids of 2 km x 2 km (low resolution) and 200 m x 200 m (high resolution).	High-resolution model has grids of 40 m x 40 m near outfall. Low-resolution model has grid of 2 km x 2 km.	The models adopted for the Draft and Supplementary EIS are more finely resolved than those of Kaempf et al. (2009).
Vertical resolution	Low-resolution model grid used 10 evenly spaced terrain-following layers; high-resolution model used 10 layers for the bottom 2 m and 10 layers for the remainder of the water column.	Low-resolution model grid used 2 m layers down to approximately 40 m depth, 4–10 m thereafter. High-resolution model grid used 2 m layers down to 24 m, then 5 m thereafter. Cell heights are variable at the bottom during grid construction and at the sea surface during simulation.	High- and low-resolution model layers were 2 m down to 4 m depth, progressively decreased to 1 m at 14 m depth, and from 23 m depth were progressively increased to 12 m. Cell thicknesses are variable at the bottom during grid construction and at the sea surface during simulation.	All low-resolution models are broadly comparable. Kaempf et al. (2009) used 20 cm resolution in the bottom 2 m of the high-resolution model. BHP Billiton Computational Fluid Dynamics (CFD) modelling has shown that this level of resolution is not necessary and if a robust injection technique is used then it is not required and vertical resolutions adopted in the Draft and Supplementary EIS studies are sufficient.
Wetting and drying	Excluded.	Included.	Included.	Draft and Supplementary EIS models include wetting and drying, which is a process characterising inter-tidal areas in Upper Spencer Gulf.

Table H5.3.1: Detailed comparison of models by Kaempf and others (2009) and models used for the Draft and Supplementary EIS (cont'd)

Aspect of study	Kaempf model (Kaempf et al. 2009)	Draft EIS models (Appendices O11.2, O11.4 of the Draft EIS)	Supplementary EIS model (Appendices H5 to H7)	Comparison/Comment
Minimum water depth	Set to 5 m, affecting 38% of Upper Spencer Gulf (north of the Whyalla shipping channels) for the low-resolution model.	None set.	None set.	Draft and Supplementary EIS studies place no restrictions on water depths.
Bathymetry	Based on a data set provided by Geoscience Australia at a spatial resolution of approximately 1 km x 1 km.	Digital Elevation Model (DEM) of Spencer Gulf produced from a combination of local navigation charts and targeted echo soundings performed in the region of Point Lowly as part of studies undertaken for the Draft EIS.	As for Draft EIS, but enhanced with acoustic mapping data from Point Lowly.	The Draft EIS and Supplementary EIS models adopted the approach of sourcing and digitising boating charts and survey data in the areas of interest and creating a high-resolution DEM, which was then sampled to the model resolution.
Temporal resolution	Time step of 30 seconds.	Time step of eight minutes for mid-field model, 50 minutes for far-field model.	Time step of 24 seconds for high-resolution model, 30 minutes for low-resolution model (long-term runs).	Both the model by Kaempf et al. (2009) and the high- resolution Supplementary EIS model are of similar temporal resolution. Lower temporal resolution in the low-resolution Supplementary EIS model was required for manageable long-term (approximately 70-year) simulations.
Diffuser modelling	Not reported.	Separate quasi-2D diffuser (CORMIX) modelling.	Three-dimensional Computational Fluid Dynamics (CFD) modelling used to determine initial concentrations for ELCOM plume dispersion model. Sensitivity and comparative analyses undertaken using Cormix and Roberts equations.	The Supplementary EIS modelling studies considered multiple diffuser simulation techniques and have shown that accurate predictions of plume dilution due to the action of a diffuser are essential to seed hydrodynamic models. In particular, CFD diffuser modelling showed that re-entrainment and overlap between plumes within a diffuser can significantly influence diffuser performance. Kaempf et al. (2009) did not present diffuser modelling.
Injection method	A flux approach. Discharge is released using this technique evenly over the lowermost 2 m of the water column for the low-resolution model and 1 m of the water column for the high-resolution model.	CORMIX and ELCOM model results combined conservatively.	A novel scientific technique developed to link CFD and ELCOM models to ensure robust connection between diffuser and hydrodynamic modelling, with commensurate increase in predictive certainty. Described in detail in BMT WBM modelling assessments report.	The Supplementary EIS modelling has developed a novel technique to appropriately inject return water to the high- (and low-) resolution models so the action of a diffuser can be defensibly accounted for in dilution predictions in these models. A sensitivity analysis presented in the Supplementary EIS has shown that dilution predictions away from a diffuser (in a high-resolution hydrodynamic model) are dependent on the injection technique used. Kaempf et al. (2009) do not report how their hydrodynamic model predictions of dilution relate to diffuser design or injection method.

Table H5.3.1: Detailed comparison of models by Kaempf and others (2009) and models used for the Draft and Supplementary EIS (cont'd)

Aspect of study	Kaempf model (Kaempf et al. 2009)	Draft EIS models (Appendices O11.2, O11.4 of the Draft EIS)	Supplementary EIS model (Appendices H5 to H7)	Comparison/Comment
Discharge rate modelled	140 ML/d	370 ML/d (peak)	370 ML/day (peak rate applied to plume dispersion predictions), 309 ML/day (average discharge rate applied to long-term predictions). Results based on reduced discharge rates (with no SA Government component) have also been provided (see Appendix H7.3).	Kaempf et al. (2009) used a return water flow rate of 38% of the peak and 45% of the average flow rates used for the Draft and Supplementary EIS.
Salinity of return water	80 g/L	75 g/L	As for Draft EIS models.	Kaempf et al. (2009) used slightly elevated return water salinity.
Temperature of return water	Ambient	Ambient +1 °C	As for Draft EIS models.	Draft and Supplementary EIS studies included an increase in return water temperature.
Atmospheric forcing (including air temperature, wind speed and direction, humidity, short- and long-wave radiation)	Monthly means from a global model, supplemented by relative humidity data from Adelaide Airport Bureau of Meteorology site, were calculated for the period 1978–1998. The average of two time series was used to represent the entire gulf in the low-resolution model. Wind stresses and other air-sea fluxes were ignored for the high-resolution model.	Both low- and high-resolution models used were compiled at hourly intervals in five zones along the north-south gradient corresponding to local meteorological stations. Half-hourly short- and long-wave radiation data for Adelaide were adapted to reflect the natural north-south gradient typical of the Gulf.	Compiled at hourly intervals over a grid of approximately 15 km x 15 km using the Weather Research and Forecasting (WRF) global atmospheric model as boundary conditions to develop a targeted and high-resolution WRF sub-model, thus providing atmospheric data at a spatial resolution beyond that of the publicly available WRF model outputs. The data were validated against satellite observations and data obtained from the meteorological station deployed as part of the EIS studies. The same data were employed for low- and high-resolution models.	The spatially and temporally variant meteorological forcing applied within the Draft and Supplementary EIS modelling studies allows for the capture of a wide range of processes in the associated hydrodynamic models, particularly those at higher temporal frequency. These might include daily and sub-daily processes that occur due to wind mixing (or its temporary cessation) or development of density fronts in response to pronounced (but short-lived) atmospheric forcing variations. The influence of these processes on the long-term hydrodynamic predictions are likely to be less than on the high-resolution modelling, where such atmospheric variations are potentially significant. This is supported by the broad predictive agreement of the Draft and Supplementary EIS and Kaempf et al. (2009) low-resolution models in terms of salinity and temperature variation on a seasonal basis. Conversely, the Supplementary EIS high-resolution study includes forcing by high spatial and temporal resolution meteorological data, ensuring robust prediction of relevant local and short-term hydrodynamic processes (such as local return water discharge), especially with regards to their potential impact on return water dispersion. Kaempf et al. (2009) turned off atmospheric forcing in their high-resolution model.

Table H5.3.1: Detailed comparison of models by Kaempf and others (2009) and models used for the Draft and Supplementary EIS (cont'd)

Aspect of study	Kaempf model (Kaempf et al. 2009)	Draft EIS models (Appendices O11.2, O11.4 of the Draft EIS)	Supplementary EIS model (Appendices H5 to H7)	Comparison/Comment
Tidal forcing at open boundaries	Low-resolution model tides at the eastern and western boundaries were generated from the four dominant tidal constituents sourced from the National Tidal Centre of the Bureau of Meteorology, and applied uniformly across the boundaries. Low-resolution model predictions were used to force high-resolution models.	Low-resolution model tides were generated each hour from 22 tidal constituents for sections along the boundary and compared with field-collected measurements(with necessary adjustments being made). Low-resolution model predictions were used to force the high-resolution model.	The tidal elevation dataset was sourced from a global tidal model which has been validated with reference to approximately 5000 tidal stations and 15 years of satellite radar altimeter, supplemented by the HYbrid Coordinate Ocean Model (HYCOM), a global model which assimilates all available satellite altimeter, salinity and temperature data from free-drifting floats. Applied equally to both low- and high-resolution models.	The Draft and Supplementary EIS modelling studies used a large number of tidal constituents for forcing and/or validation.
Salinity and temperature at boundaries	Salinity maintained at a constant value at low-resolution model boundary; temperatures sourced from monthly means of CSIRO data. Both were assumed to be uniform within high-resolution model domain.	Monthly means (depth-averaged) published for Port Lincoln used for low-resolution model. High-resolution model forced with two-dimensional boundary predictions from low-resolution model.	Two-dimensional salinity and temperature profiles were sourced from the HYCOM model database at 24-hour intervals. Applied equally to both low- and high-resolution models.	The HYCOM model provides temperature and salinity boundaries in two spatial dimensions, and at hourly temporal resolution.
Other boundaries	None reported.	A power station outfall at Port Augusta and salt lake inflow from north of Port Augusta were both included in the simulations.	As for Draft EIS.	The models adopted for the Draft and Supplementary EIS have considered natural and power plant discharges.
Calibration/ validation data				
Tidal levels	Comparison with tidal levels from 30 to 40 years ago for the low-resolution model. High-resolution model calibration not reported.	Time-series tidal water levels from Port Lincoln, Whyalla and Port Augusta (supplied by Flinders Ports), measured at five-minute intervals for several day periods including spring and neap tides; day of year comparison with additional long-term (five to 12 month) historical data sets at three locations (R Nunes-Vaz, unpublished data; RK Steedman & Associates, unpublished data).	Tidal levels from 2009 field data, in addition to data used to calibrate Draft EIS models. Full tidal decomposition comparative analysis undertaken.	The Supplementary EIS models were validated against tidal modulation and amplification in Spencer Gulf using a wide variety of independent sources, including targeted field data.

Table H5.3.1: Detailed comparison of models by Kaempf and others (2009) and models used for the Draft and Supplementary EIS (cont'd)

Aspect of study	Kaempf model (Kaempf et al. 2009)	Draft EIS models (Appendices O11.2, O11.4 of the Draft EIS)	Supplementary EIS model (Appendices H5 to H7)	Comparison/Comment
Tidal currents	Not reported.	Data from bottom-mounted ADCP deployed for 40 days at Port Bonython; seven transects, up to 3.3 km long, in the vicinity of the jetty. Applied to high-resolution model.	Data from bottom-mounted ADCP deployed at Point Lowly for 70 days in summer 2007–2008; three bottom-mounted ADCPs deployed for 40 days at Point Lowly and three other locations (concurrently) in late autumn 2009; five transects of a boat-mounted ADCP, each from Point Lowly to Ward Spit, during different tides (including dodge). Applied to high-resolution model.	Data collected for the EIS shows there are considerable tidal currents during dodge tides. Comparisons between modelled and measured currents included in the Draft EIS show that location-specific data are important for model calibration. Such data were collected and incorporated into the Supplementary EIS model and validation processes.
Salinity and temperature	Monthly means at three locations (including one in Upper Spencer Gulf), sourced from Nunes and Lennon (1986) for the low-resolution model. High-resolution model calibration not reported.	CTD data from four locations, (including three in Upper Spencer Gulf) sourced from Nunes (1985); day of year comparison with additional long-term (five to 12 month) historical data sets from bottom, surface and mid-depth measurements at three locations (R Nunes-Vaz, unpublished data; RK Steedman & Associates, unpublished data). Applied to low-resolution model.	As for Draft EIS (i.e. low-resolution model detailed calibration) plus concurrent deployments of CTD sensors over 40 days in May-June 2009 at Point Lowly, three nearby locations (one with two depths) and in Flinders Channel, south of Port Augusta (six in total). CTD data was validated and corrected using grab samples measured with highly accurate instruments. All data applied to high-resolution model.	The Supplementary EIS model, in particular, was shown to resolve salinity variations at the tidal time scale and rates of changes of salinity in 'the rip'.
Meteorological data	No local data collected.	Local meteorological data collected in 2006.	Additional local meteorological data collected in 2009 and used to validate the data sourced from the high-resolution WRF global atmospheric model.	Draft and Supplementary EIS studies collected local meteorological data for comparative purposes.
Outcomes				
Flushing times	12–24 months across mouth of gulf based on water age analysis.	Eight or 12 months across mouth of gulf (from water age and e-folding methods respectively).	High-resolution Supplementary EIS model showed flushing times of about 300 days based on water age.	Flushing assessments are broadly comparable in terms of water age.
Far-field concentrations (and/or salinity increases)	Steady long-term return water concentrations of 0.3% within 20 km of Point Lowly. No results presented for further north.	Long-term average increases in salinity 0.17% (0.07 g/L) near Point Lowly, 0.06% (0.03 g/L) at Port Augusta and Yatala Harbour, and 0.03% (0.01 g/L) at Wallaroo and in the gulf as a whole.	Long-term average salinity increases between 0.05 and 0.14 in the northern gulf and 0.01 in the gulf as a whole.	The results of the Supplementary EIS and Kaempf et al. (2009) appear similar but Kaempf et al. have modelled a discharge rate less than half of the proposed rate.

Table H5.3.1: Detailed comparison of models by Kaempf and others (2009) and models used for the Draft and Supplementary EIS (cont'd)

Aspect of study	Kaempf model (Kaempf et al. 2009)	Draft EIS models (Appendices O11.2, O11.4 of the Draft EIS)	Supplementary EIS model (Appendices H5 to H7)	Comparison/Comment
Worst-case return water dilutions (and salinity increases), high-resolution model	1:11–1:5 (4–10 g/L)	1:9 (4 g/L)	1:43 (0.7 g/L)	The supplementary EIS model provided the most precise linking of near-field inputs (based on CFD modelling) and long-term salinity increases. Importantly, the Supplementary EIS ensured that dilutions delivered by diffuser arrangements (as predicted by CFD modelling) were directly translated to high- (and low-) resolution modelling studies. This ensured that artificially low (and unrealistic) dilutions were not predicted by the Supplementary EIS ELCOM models. The modelling by Kaempf et al. (2009) did not consider the initial dilutions achieved by a diffuser, and the influence of this on hydrodynamic model predictions of dilutions beyond the immediate influence of the diffuser is unclear.

H5.3.4 REFERENCES

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