Gurra Gurra wetland modelling

Phase 3 scenario modelling

DEW Technical note 2018/54

Government of South Australia
Department for Environment and Water

Gurra Gurra wetland modelling – Phase 3 scenario modelling

Daniel McCullough and Matt Gibbs
Department for Environment and Water

August, 2018

DEW Technical note 2018/54

Government of South Australia
Department for Environment and Water

Department for Environment and Water

GPO Box 1047, Adelaide SA 5001

Telephone National (08) 8463 6946

International +61 8 8463 6946

Fax National (08) 8463 6999

International +61 8 8463 6999

Website www.environment.sa.gov.au

Disclaimer

The Department for Environment and Water and its employees do not warrant or make any representation regarding the use, or results of the use, of the information contained herein as regards to its correctness, accuracy, reliability, currency or otherwise. The Department for Environment and Water and its employees expressly disclaims all liability or responsibility to any person using the information or advice. Information contained in this document is correct at the time of writing.

ISBN 978-1-925805-40-6

Preferred way to cite this publication

McCullough DP and Gibbs M (2018). Gurra Gurra wetland modelling – Phase 3 scenario modelling. DEW Technical note 2018/54, Government of South Australia, Department for Environment and Water, Adelaide.

Acknowledgements

SARFIIP is a $155 million investment program funded by the Australian Government and implemented by the South Australian Government to improve the watering and management of River Murray floodplains in South Australia's Riverland region.

The author would like to acknowledge peer review contributions from Matt Gibbs, Volmer Berens and Glenn Shimmin (Department for Environment and Water) and Luke Mosley (The University of Adelaide).

Contents

List of figures

List of tables

Summary

The condition of the Gurra Gurra wetland complex, located on the River Murray near Berri, has progressively degraded over the years due to river regulation (e.g. construction of locks altering the wetland from ephemeral to permanent), landscape alteration (e.g. construction of roads and banks that impact on flows across the wetland), and irrigation development to the north-east of the wetland that have exacerbated saline groundwater inflows (AWE, 2003; Barnett, 2007). These impacts have contributed to salinisation of the wetland. The South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) has been implemented to improve the condition of adjacent floodplains through inundation management regimes, which has also provided an opportunity to improve the condition of the Gurra Gurra complex.

Modelling was conducted to investigate the effects on wetland salinity (referred to as electrical conductivity, or EC) as a result of realistic long-term operational scenarios in the context of SARFIIP. A baseline ("no change") scenario was compared to scenarios which include weir pool raisings at Lock 4, downstream of the wetlands (0.5 and 1 m raisings) and with a complementary measure of reducing the sill level through the Lyrup flow path in the north of the Gurra Gurra system, to increase the frequency of flushing.

The results indicated that the introduction of modelled weir pool raisings over a 114-year hydrograph provide an average decrease in EC throughout the wetland compared to the baseline condition. For instance, at the pump location, weir pool raisings of 1 m above normal pool provided a mean reduction in EC from the baseline case of approximately 13%, compared to approximately 4% reduction in the case of 0.5 m raisings.

Lowering the Lyrup flow path to a level of 13.3 m AHD in conjunction with weir pool raisings was found to enhance EC reduction benefits in the wetland when compared to weir pool raisings only. The maximum overall benefit to mean EC was achieved when the 1 m (highest) weir pool raisings were combined with a Lyrup lowering, resulting in approximately a 26% mean reduction in EC from the baseline condition at the pump location.

Despite the reduction in mean EC introduced by the management scenarios considered, temporary EC fluctuations relative to the baseline condition were modelled to occur during the weir pool raising events. In the northern sections of the system, these EC fluctuations were typically only decreased relative to baseline EC, whereas at locations further south in the system, such as at the pump location, both increases and decreases in EC from the baseline condition were modelled.

Results for the River Murray channel also displayed increases and decreases in EC relative to baseline under each of the management options, up to a maximum increase of approximately 80 µS/cm. Despite these changes, negligible difference in average river EC was modelled between each of the scenarios. The most frequent and highest magnitude salinity change occurred in the scenario modelled that offered the maximum benefit of wetland EC reduction (i.e. 1 m raisings and Lyrup lowering). Given the repeatable hydrograph used in each of the scenarios, these results indicate the effectiveness of the management options in transporting salt out of the Gurra Gurra system, particularly when introducing a lowering of the Lyrup flow path to SARFIIP operations.

1 Introduction

The Gurra Gurra wetland complex, located on the River Murray in South Australia to the east of Berri and directly upstream of Lock and Weir 4, is a floodplain and wetland complex covering an area of approximately 3000 ha. Refer to Figure 1.1 for locality information. The wetland condition has progressively worsened over the years due to significant hydrological changes that have occurred in the River Murray system since regulation was introduced, including:

- construction of locks in the River Murray, which has altered the hydrology of the wetland from an ephemeral system to a permanently inundated wetland (AWE, 2003)
- alteration of the wetland landscape, such as the construction of roads and banks that have introduced barriers to flow across the wetland (AWE, 2003)
- irrigation development to the north-east of the wetland that have exacerbated saline groundwater inflows (AWE, 2003; Barnett, 2007).

These hydrological changes have resulted in salinisation of the wetlands, particularly in the lakes and northern sections of the system.

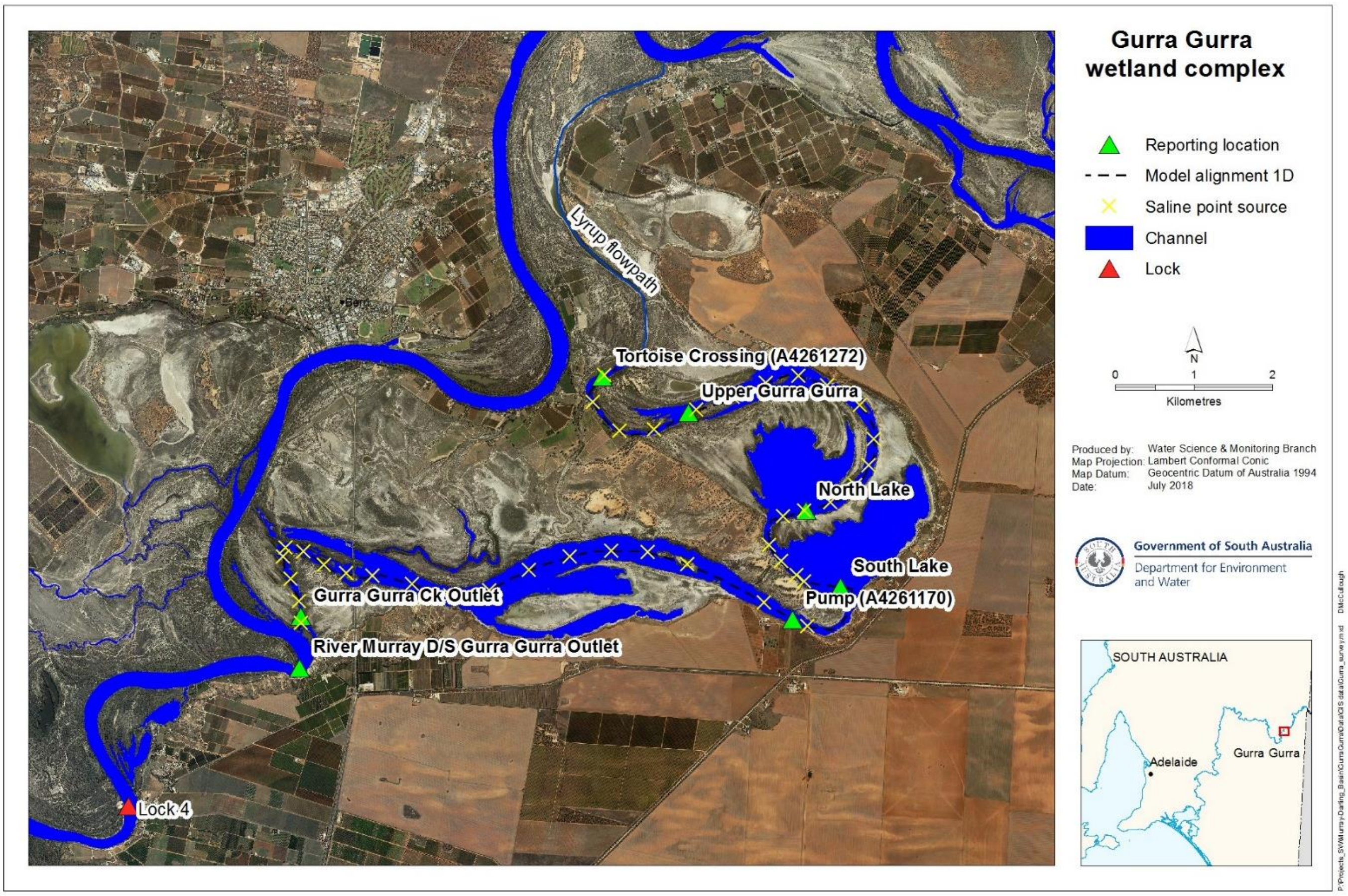


Figure 1.1. Gurra Gurra wetland complex, model reporting locations and modelled saline groundwater discharge sources

The South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) has been developed with a major focus on improving the condition of the neighbouring floodplains in Pike and Katarapko. This program has also included the development of salinity management strategies for Gurra Gurra to assist with the improvement of wetland condition. To support the development of these strategies, models of Gurra Gurra have been developed, and scenarios previously undertaken, over the course of two modelling phases. This modelling is presented in Neilsen (2016) as 'Phase 1' modelling; Neilsen (2017) as 'Phase 2 – Part 1' (model validation); and Montazeri and Gibbs (2017) as 'Phase 2 – Part 2' (scenario modelling).

The following report represents Phase 3 of the modelling work, which investigates the impacts on salinity changes within the wetland of long-term SARFIIP operations, which include weir pool raisings at Lock 4. The impacts of introducing Lyrup flow path lowering in the context of weir pool raisings is also considered as part of the modelling. The results are expected to further inform possible management actions to improve wetland condition.

2 Model calibration refinement

2.1 Calibration refinement details

A previous validation exercise with the Gurra Gurra hydrodynamic model against salinity survey results (collected as electrical conductivity, or EC, in µS/cm), as summarised by Montazeri and Gibbs (2017), indicated that the model was under-predicting salinity concentrations across the wetland, particularly as salinity increased after the 2016 high flow event. This work suggested that the model accuracy in representing observed salinities could be improved with a revision of the saline groundwater discharge sources applied to the model.

Two key parameters were focused on for the calibration refinement exercise for the present modelling work:

- Salinity concentrations at point sources representing groundwater discharge throughout the wetland complex, as indicated in Figure 1.1
- Dispersion factor used in the Advection-Dispersion (AD) module.

Variations tested in the calibration exercises included (i) original salt concentrations at each intrusion location, (ii) double the original salt concentrations at each location, and (iii) triple the original salt concentrations. For each salt concentration, dispersion factors of 1, 5 and 10 were tested to determine the relative impact of each variable on model results. Due to the nature of the present modelling work (i.e. long term simulations that require short simulation times), calibration refinement was only performed on the MIKE 11 (1D) model version of Gurra Gurra.

Observational data used for comparison with the modelled results included:

- Spatial results of boat-mounted EC surveys through the wetlands collected at various River Murray flow conditions since 2016, including September and October 2016, and January, March and August 2017. The surveys were resolved to match the chainage locations of the 1D model for direct comparison.
- Continuous monitoring data at sites located within the wetland, including at the pump location (A4261170) and Tortoise Crossing (A4261272). The nearest model chainages to each monitoring site were used as the basis for comparison.

Note that comparisons between observed and modelled results required conversion of the model results, in Total Dissolved Solids (TDS in mg/L), to EC (in µS/cm). An empirical conversion table, found as a layer in the Hydstra Database Manager (internal Department for Environment and Water), was used to convert modelled salinity to EC, as presented in Figure 2.1.

Simulations were conducted based on observed data for the period encompassing the EC surveys (i.e. June 2016 to August 2017). Lock 4 upstream level was used as the downstream water level model boundary and flow at Lock 4 representing the upstream inflow model boundary. Daily rainfall and evaporation data from BoM archives were also used as time-series data in the model configuration.

Comparisons used to provide a basis for selecting the calibration parameters that provided the best fit with the observational data include:

- Correlation between modelled to observed data (i.e. R correlation coefficient), where a coefficient closer to 1 indicates a better correlation
- Slope and intercept of a line of best fit through the model, where a slope closer to 1 and intercept closer to 0 represents a better representation of modelled to observed data
- Mean magnitude and percentage of difference (based on either each time step or each chainage of the model, depending on the nature of the data) between modelled to observed EC data, where an average or percentage closer to 0 indicate a closer fit of the data.

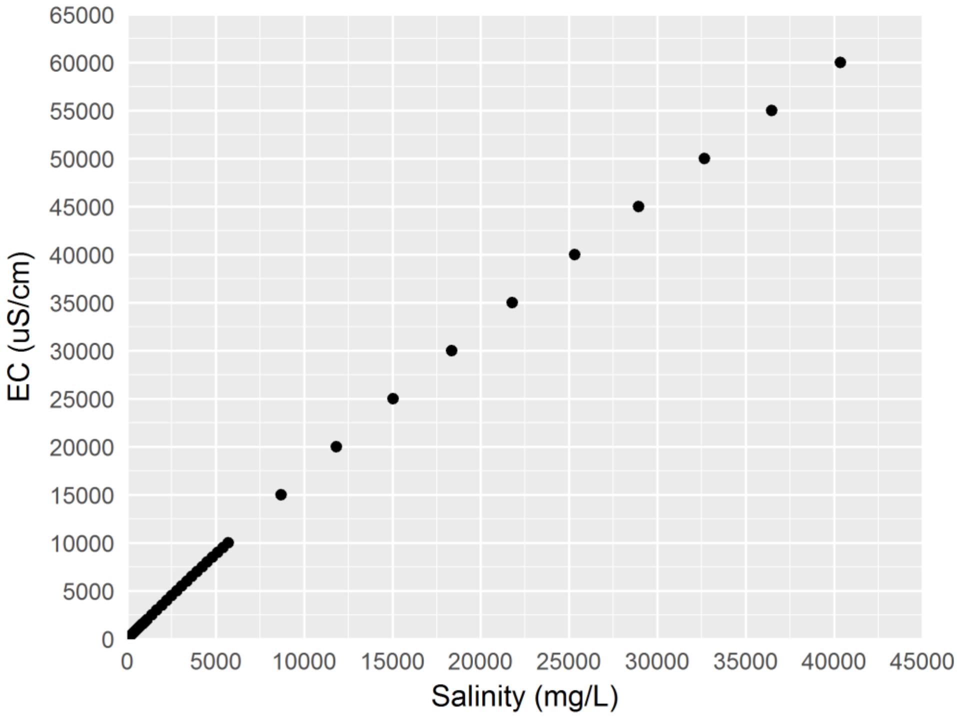


Figure 2.1. Relationship for conversion of salinity (mg/L) to EC (µS/cm)

2.2 Results

Table 2.1 shows the statistical results of modelled versus observed data at monitoring site A4261170, while Table 2.2 shows the statistics at site A4261272. In general, for a given salt influx concentration the statistical parameters tend to improve with increasing dispersion factor, especially at site A4261170. At each monitoring site the combination of doubled point salt concentrations and base dispersion factor of 10 provided the overall best representation of the observed data from the other calibration parameter combinations when considering the closeness of each statistical measurement to the "ideal" values as listed in the preceding introduction section.

Table 2.1. Statistical measurements of modelled to observed results at site A4261170 for each calibration parameter combination tested

Salinity conc	Dispersion factor	R correlation coefficient	Slope of line best fit	Intercept of line best fit µS/cm	Mean difference obs-modelled µS/cm	Mean difference obs-modelled %
Base	Base (10)	0.825	0.908	737	678	39
Base	5	0.791	0.824	781	656	38
Base	1	0.652	0.706	936	683	38
Base x2	Base (10)	0.859[1]	0.953[1]	355	393[2]	22[2]
Base x2	5	0.796	0.834	451	394[2]	22[2]
Base x2	1	0.620	0.677	695	523	27
Base x3	Base (10)	0.817	0.912	131[2]	393[2]	21[2]
Base x3	5	0.722	0.761	313	560	30
Base x3	1	0.526	0.579	656	798	41

1 Statistical measurement value approximately closest to 1 (ideal value) of all calibration parameters tested

2 Statistical measurement value approximately closest to 0 (ideal value) of all calibration parameters tested

Table 2.2. Statistical measurements of modelled to observed results at site A4261272 for each calibration parameter combination tested

Salinity conc	Dispersion factor	R correlation coefficient	Slope of line best fit	Intercept of line best fit µS/cm	Mean difference obs-modelled µS/cm	Mean difference obs-modelled %
Base	Base (10)	0.834	1.324	505	1053	46
Base	5	0.960[1]	1.202	451	796	38
Base	1	0.878	0.813	679	438	27
Base x2	Base (10)	0.924	0.906[1]	273[2]	286[2]	20[2]
Base x2	5	0.902	0.700	488	599	27
Base x2	1	0.744	0.408	864	1845	67
Base x3	Base (10)	0.867	0.617	399	1022	40
Base x3	5	0.816	0.461	639	1658	59
Base x3	1	0.680	0.266	969	3528	121

1 Statistical measurement value approximately closest to 1 (ideal value) of all calibration parameters tested

2 Statistical measurement value approximately closest to 0 (ideal value) of all calibration parameters tested

Hydrographs of the continuous EC data recorded at monitoring sites A4261170 and A4261272, plotted against the simulated results of the various calibration runs, are shown in Figure 2.2 and Figure 2.3, respectively. Modelled flow and water level hydrographs at each site are shown in the respective figures to provide context on the behaviour of EC through the simulated period. Note that the EC monitoring station at site A4261272 commenced operation mid-October 2016, and hence no data was available prior to this for comparison with simulation results.

Visual inspection of the hydrographs confirmed that, in general, the modelled EC with a dispersion factor of 10 and double the original salt concentrations provided a reasonable representation of actual EC for the period simulated. The largest departure of modelled to observed EC using these model parameters occurred at site A4261170 between November and December 2016, where observed EC was in the order of 1000 µS/cm higher than modelled at times during the period, although the minimum observed EC during this period corresponded relatively well with the modelled value. Note that this occurred on the rising limb of the 2016 high flow event, during which flow direction was predominantly from the river into the wetland (prior to the Lyrup flow path activating), while observed EC behaved relatively erratically during this period. This discrepancy of modelled to observed EC may therefore be a result of effects such as floodplain surface salt mobilisation under rising water levels, as well as other nuances such as wind effects, minor level changes and mixing processes that may not be fully accounted for in the model. A closer correspondence between modelled and observed EC with the selected model parameters occurred following the peak of the high flow event for the remainder of the simulation period.

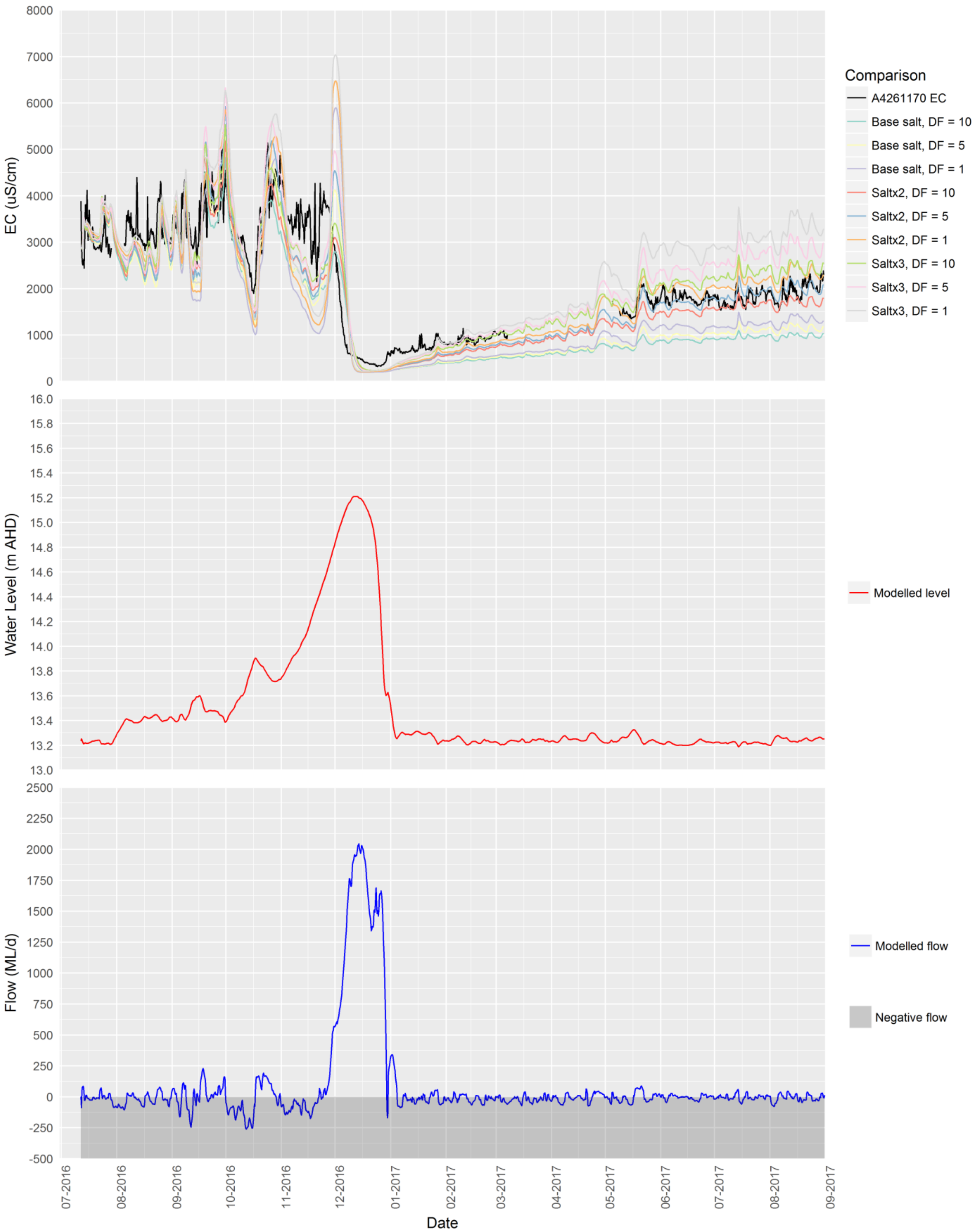


Figure 2.2. Continuously monitored EC at site A4261170 against the EC results of all calibration runs. Modelled water level and flow at the site location are presented for context of EC behaviour. Positive flow direction from wetland to River Murray through Gurra Gurra outlet

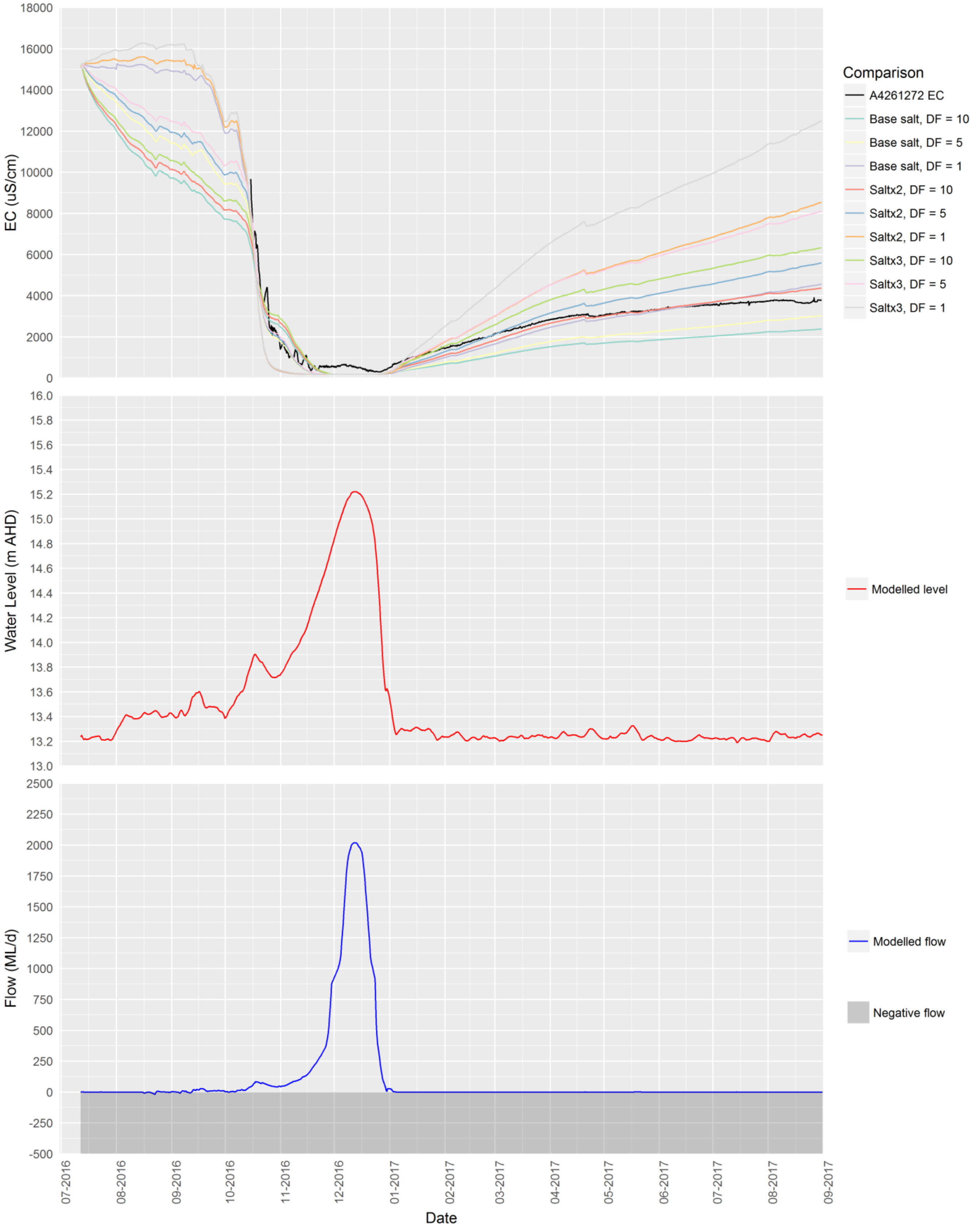


Figure 2.3. Continuously monitored EC at site A4261272 against the EC results of all calibration runs. Modelled water level and flow at the site location are presented for context of EC behaviour. Positive flow direction from wetland to River Murray through Gurra Gurra outlet

Table 2.3 shows mean difference (by magnitude and percentage) between modelled and surveyed EC along the length of the wetland complex. Comparison plots of each EC survey against model results, normalised to the modelled distances, are presented in Appendix A. The results indicated the most appropriate calibration parameters based on a difference analysis between modelled to surveyed data varied depending on the survey date. For instance, on the rising limb of the 2016 event, the base model salinity concentrations used tended to more closely follow the EC survey results, whereas at the end of the recession (i.e. 24 January 2017 survey) the highest salt concentrations tested (i.e. triple the original groundwater intrusion concentrations) tended to better represent the EC survey results. However, the combination of double the original groundwater discharge salinity concentration and dispersion factor of 10 generally possessed mean percentage differences in EC between measured and modelled results that were amongst the lowest calculated under both high and low flow conditions, providing further confidence to this calibration parameter combination as found with the preceding EC monitoring station analysis.

2.3 Validation

Validation of the selected calibration parameters of a dispersion factor of 10 and doubled base salt concentration was performed by simulating existing conditions in the River Murray from approximately 1990 to 2009. Figure 2.4 provides a comparison of the modelled EC concentrations at the Gurra Gurra outlet (at the bridge) and north of the Gurra Gurra Lakes to a series of intermittent observational EC readings collected during the period at each location. A visual comparison of observed to modelled results indicate an effective representation of EC at the two locations measured, indicating the selected calibration parameters are suitable for performing further scenario modelling using the Gurra Gurra MIKE 11 model.

2.4 Model limitations and uncertainty

Simulation of the 2016–17 period with the selected model calibration parameters indicated a mean difference between observed and modelled EC in the order of 22% at the pump location and 20% at Tortoise Crossing to the north of the wetland. It should be noted however that the discrepancy between modelled to observed EC is highly dependent on factors such as hydrodynamics within the wetland, evapoconcentration rates, salt deposition/ washoff, and variability in groundwater inflows, all of which may not be fully accounted for within the model for a given simulation. These processes combine with other dependencies including the frequency of wetting events, climatic variables, river flows (e.g. the meeting of Basin Plan targets) and river salinity to increase the uncertainty of modelled EC at a given point in time. Thus, the simulation results of differing management options may be compared to a "do nothing" scenario with some confidence as to the overall merits of the alternative actions, however the exact magnitude of EC changes will be highly dependent on the aforementioned factors.

Representation of saline groundwater discharge remains one of the main limitations of the MIKE hydrodynamic model given that they may only be specified on a basic level of constant values. This does not allow for more complex groundwater–surface water interactions to be taken into account that may be encountered with rising and falling hydrographs, e.g. saline intrusions may differ on a rising limb of a flood compared to the falling limb for a given river flow. This indicates that a single set of calibrated variables may not optimally represent salinity within the wetlands under all conditions. The final calibrated variables chosen therefore provided the best fit against the observed data for the period investigated.

Additional floodplain surface salt mobilisation also represents a potential limitation of the model, which may account for some of the discrepancy between modelled and observed EC as identified in section 2.2. This limitation may therefore provide a greater impact on modelled EC during wetting events following extended periods of low flow, where salt may accumulate on the floodplain via evapoconcentration, than during periods of increased wetting frequency.

Salinity concentrations for a given location in the MIKE 11 model are based on an average of the cross-section and do not account for stratification or mixing processes, and thus may not provide the maximum salinities on a spatial basis for a given case. This presents a limitation in the modelling compared to the MIKE FLOOD model version, which can provide salinity distribution on a 2D spatial basis, although stratification is also not accounted for in this model version. This may be particularly relevant to the River Murray section of the model downstream of Gurra Gurra outlet, which has a relatively small flow from Gurra Gurra into a large river cross-section.

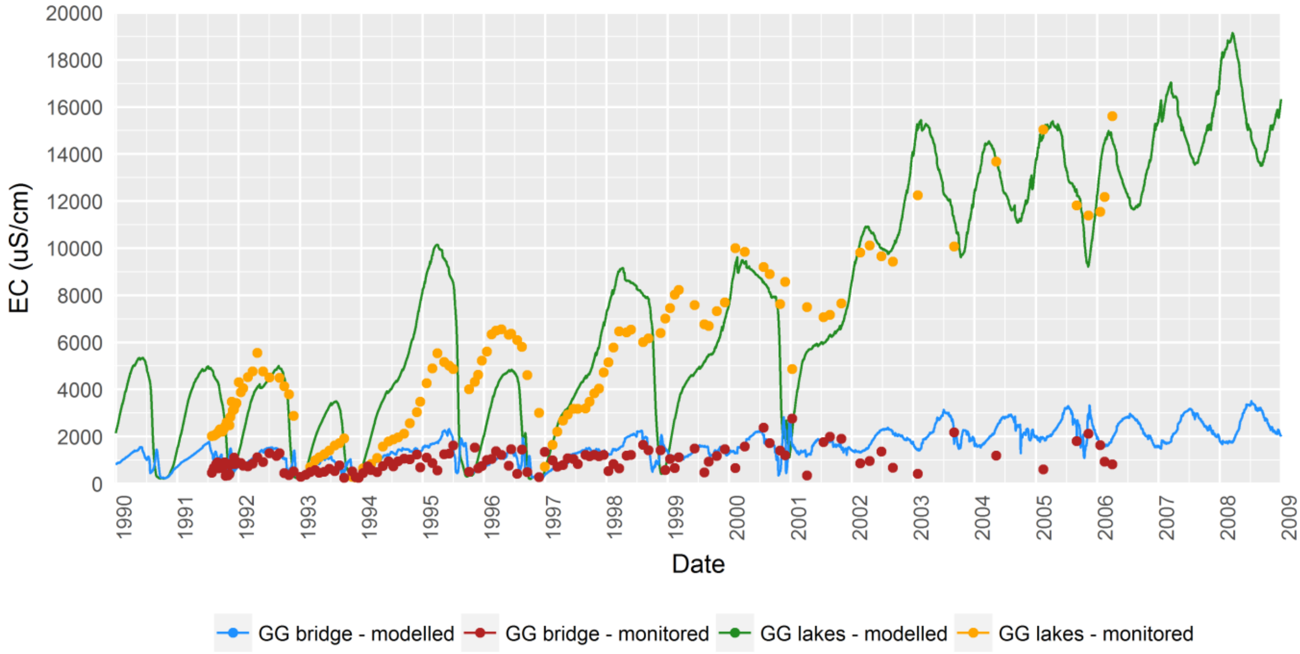
Another limitation of the MIKE 11 model is that definition of the potential flow paths throughout the wetland is mainly restricted to the main flow path due to the nature of the 1D model. This may therefore not account for some flood runners that activate under high flow conditions, which in turn may impact on the passage and distribution of salt under these conditions. Given that lower salinity conditions may generally persist under higher river flows however, this may represent only a minor limitation of the model.

Table 2.3. Mean difference (absolute and by percent) of EC across all model chainages between modelled and observed EC survey data

Salinity conc	Dispersion factor	Survey 20 Sept 2016		Survey 14 Oct 2016		Survey 24 Jan 2017	
		Mean diff obs-modelled	Mean % diff obs-modelled	Mean diff obs-modelled	Mean % diff obs-modelled	Mean diff obs-modelled	Mean % diff obs-modelled
Base	Base (10)	743	15[1]	721	11	536	54
Base	5	515[1]	17	533[1]	10[1]	522	52
Base	1	1218	27	1121	20	495	49
Base x2	Base (10)	694	15[1]	623	10[1]	350	35
Base x2	5	641	18	575	10[1]	325	33
Base x2	1	1460	29	1259	20	291	30
Base x3	Base (10)	698	17	584	10[1]	172	18[1]
Base x3	5	846	21	685	11[1]	159[1]	17[1]
Base x3	1	1709	32	1433	22	160[1]	17[1]

Salinity conc	Dispersion factor	Survey 7 Mar 2017		Survey 28 Aug 2017	
		Mean diff obs-modelled	Mean % diff obs-modelled	Mean diff obs-modelled	Mean % diff obs-modelled
Base	Base (10)	675	48	856	36
Base	5	635	46	597	27
Base	1	579	44	372[1]	22[1]
Base x2	Base (10)	247	20	374[1]	22[1]
Base x2	5	183	16	744	32
Base x2	1	223[1]	19	1319	46
Base x3	Base (10)	216[1]	14[1]	1305	60
Base x3	5	324	20	2003	85
Base x3	1	499	30	2838	102

1 Statistical measurement value approximately closest to 0 (ideal value) of all calibration parameters tested



(a)

(b)

Figure 2.4. (a) Validation results comparing modelled to observed EC readings at Gurra Gurra bridge (at Gurra Gurra outlet) and north of the Gurra Gurra lakes, with (b) the monitoring locations indicated

3 Modelled scenarios

Scenarios were designed in the context of SARFIIP operations within the adjacent Pike and Katarapko floodplains, and potential on-ground works in the Lyrup flow path to lower the commence to flow of the wetland complex inlets.

The operating conditions tested for the scenarios are as follows:

1. No change (baseline)
2. 0.5 m weir pool raisings. This uses water level at Lock 4 as Scenario 1 but superimposes a 0.5 m weir pool raising at Lock 4 in any month where either Pike or Katarapko structures are operated (for a partial or full event)
3. 1 m weir pool raisings. Similar to Scenario 2 but applying a 1 m weir pool raising
4. 0.5 m weir pool raisings with Lyrup flow path lowering. Similar to Scenario 2 but applying a lowering of the Lyrup flow path to 13.3 m AHD, as conducted in Montazeri and Gibbs (2017)
5. 1 m weir pool raisings with Lyrup lowering. Similar to Scenario 4, but weir pool raisings to 1 m

Further details on the assumptions used are outlined below.

3.1 Scenario period and upstream inflow

The flow in the River Murray was derived from Murray–Darling Basin Authority (MDBA) MSM BIGMOD outputs, representing the Basin Plan following implementation of SDL Adjustment Supply Measures. The modelling simulates a 114-year period from 1895 to 2009. The scenario adopted was an interim output available at the time of this study, representing an environmental water recovery of 2110 GL. The flow modelled downstream of Lock 5 was used as the upstream flow boundary. Given the extended time period used in the modelling, only the MIKE 11 (1D) version of the model was use for the analysis due to simulation time constraints.

Salinity outputs are only available from MSM BIGMOD from 1975. The salinity at Lock 5 presented in these outputs was used as the upstream salinity for these scenarios where available, and earlier salinities were estimated based on a relationship with flow. This was achieved using an exponential line of best fit through a salinity versus flow plot to derive the relationship for converting EC from flow, as shown in Figure 3.1. This methodology provides only an approximate estimate of EC given that EC is not exclusively dependent on flow, thereby returning salinities that are effectively mean values for a given flow. Subsequently, the extent of variation in modelled EC is potentially reduced to that encountered in reality, thereby representing a limitation in the modelled scenarios. However, for the purposes of comparing simulations in the present modelling work, the relationship (in the absence of other data) is considered acceptable for relative comparisons across a range of scenarios.

Figure 3.1. EC versus flow data from MSM BIGMOD outputs with approximated line of best fit relationship

3.2 Downstream water level

For the downstream model boundary, Lock 4 was held at 13.2 m AHD under low flow conditions, and increased in line with flow where the lock loses its capacity to regulate water levels (i.e. from approximately 45 000 ML/d Flow to South Australia (QSA)). To derive a water level when the water level increased above pool level based on the MSM BIGMOD modelled flow, a downstream water level boundary was synthesised from historical backwater curves linking Lock 4 water levels to peak QSA data, providing water levels for flows up to the 1956 event peak flow (i.e. approximately 340 GL/d). An approximate mathematical relationship was then determined from lines of best fit through the data (see Figure 3.2), which were then used to convert flow at the inflow boundary data to the downstream water level boundary.

For Scenarios 2 to 5, which include weir pool raisings coinciding with operation, outputs from MSM BIGMOD were used to identify when the Pike or Katarapko structures would be operated, and hence when weir pool raisings should occur. When this was the case, the downstream water level was raised, held and lowered, and superimposed on the base (no change) water level data hydrograph to form the downstream model boundary.

This approach does not include additional weir pool raisings for the purpose of the Lock 4 weir pool independent of the structures. However, given the frequency of inundation, from both natural and weir pool events, it could be expected that this may occur infrequently. The flow and water level hydrographs, with weir pool raisings (0.5 and 1 m above normal pool) specified based on MSM BIGMOD outputs, is shown in Figure 3.3. Note that weir pool raising of Lock 4 occurs whenever Pike and/or Katarapko managed inundation operation occurs.

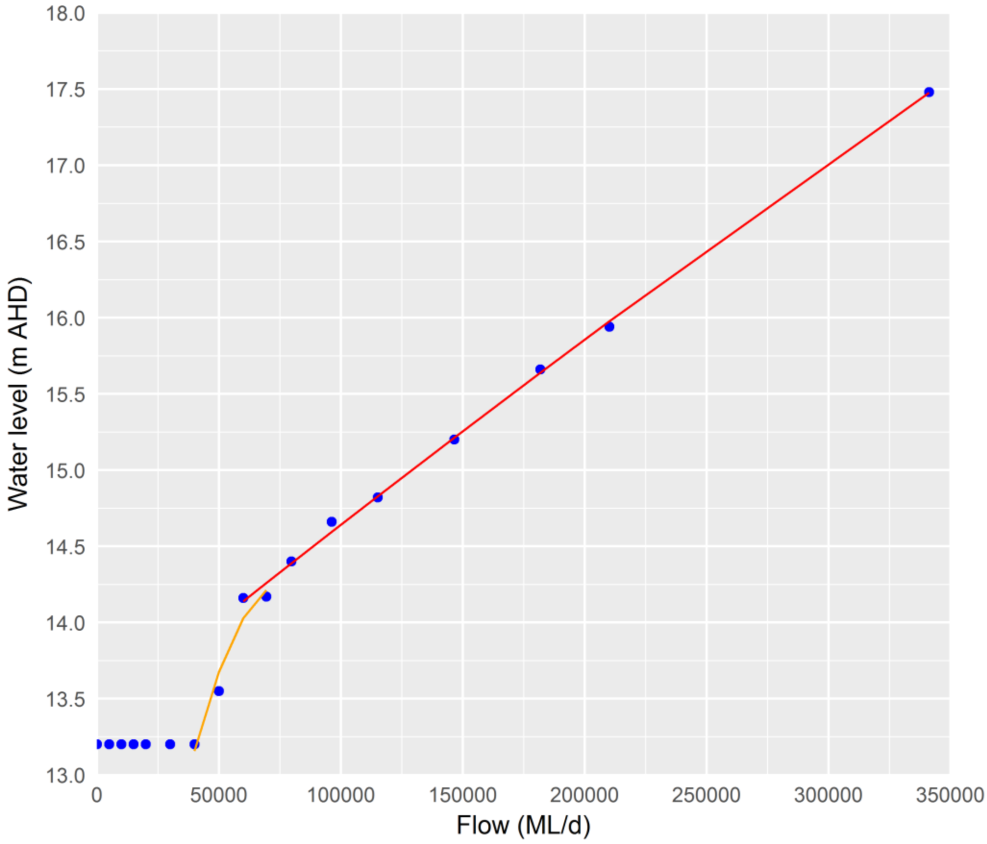


Figure 3.2. Backwater curve water levels at Lock 4 upstream versus QSA with approximated line of best fit relationships (red for high flows and orange for mid-range flows above normal Lock 4 weir pool level)

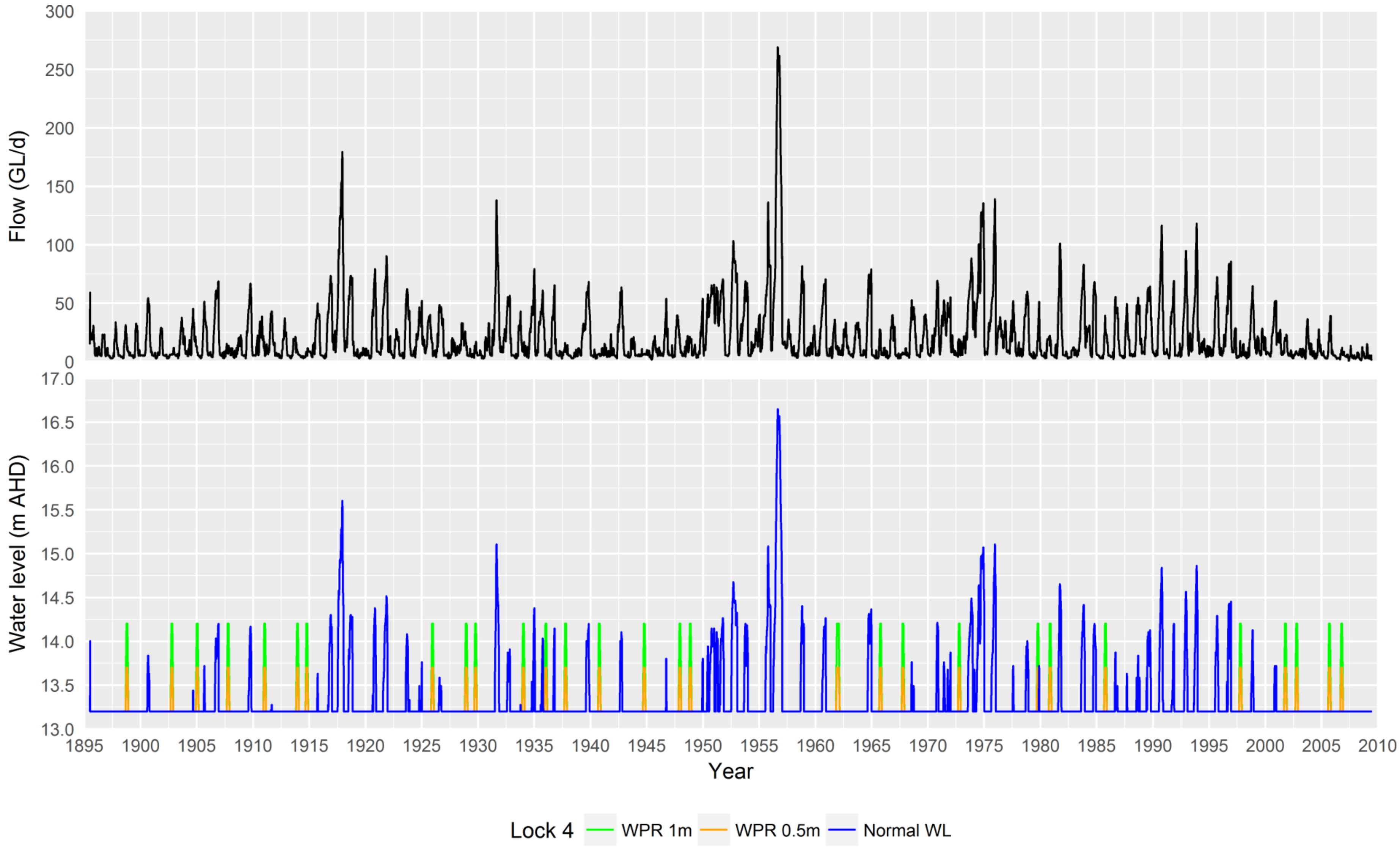


Figure 3.3. River Murray flow and Lock 4 water levels for natural (blue), 0.5 m weir pool raising (orange) and 1.0 m weir pool raising

3.3 Climate data

A suitable representation of net evaporation is important to represent the evapoconcentration of salts within the Gurra Gurra wetland complex. Historical daily rainfall and evaporation data at Loxton (SILO 2017) were additionally applied as model boundary conditions in a variable time-series file for the duration of the simulation period.

3.4 Output locations

Modelling results were focused on the same locations as used in Neilsen (2016) for Phase 1 of the Gurra Gurra modelling work and presented in Figure 1.1, namely:

- Upper Gurra Gurra (upstream of the lakes)
- North Lake
- South Lake
- Pump location (Gurra Gurra creek)
- Gurra Gurra Creek outlet
- River Murray downstream of Gurra Gurra outlet

For each model location the following results were obtained:

- EC hydrographs for the entire simulation period for each scenario relative to the baseline EC
- Mean EC and EC difference from baseline conditions for each hydrograph
- Frequency analysis of the simulation periods in the form of percentile analysis for 10^{th}, 50^{th} and 90^{th} percentiles, as used in Neilsen (2016).

Results are presented in both tabular and graphical form as applicable.

4 Scenario results

4.1 EC Hydrograph comparisons

The modelling results indicated that, on a long term basis, an overall reduction in mean EC from the baseline (i.e. Scenario 1) EC condition occurred across the wetland complex when implementing a weir pool raising program, with the higher weir pool raisings causing a greater reduction in mean EC. A further reduction in EC was also modelled when implementing a lowering of the Lyrup flow path in combination with weir pool raising, with the greatest percentage reductions in EC from baseline EC modelled with a 1 m weir pool raising and a lowering of Lyrup flow path to 13.3 m AHD across all locations. Table 4.1 shows the mean EC and mean EC difference from baseline at each location and scenario modelled over the simulation period. EC hydrographs at each location for each scenario are shown in Appendix B, with comparison in each case to the baseline condition (Scenario 1).

Table 4.1. Mean EC and difference from baseline EC over the simulation period at each model location

Location	Scenario	Mean EC µS/cm	Mean EC Difference from no change µS/cm	EC reduction from baseline %
Gurra Gurra outlet	1	475	-	-
	2	472	-3	1
	3	467	-8	2
	4	467	-8	2
	5	461	-14	3
Pump location	1	2799	-	-
	2	2675	-124	4
	3	2446	-353	13
	4	2296	-502	18
	5	2081	-718	26
South Lake	1	5311	-	-
	2	4894	-417	8
	3	4342	-969	18
	4	3994	-1317	25
	5	3530	-1781	34
North Lake	1	6085	-	-
	2	5568	-517	9
	3	4910	-1174	19
	4	4447	-1638	27
	5	3911	-2174	36
Upper Gurra Gurra	1	7058	-	-
	2	6420	-639	9
	3	5629	-1429	20
	4	4955	-2103	30
	5	4350	-2708	38
River Murray	1	372	-	-
	2	372	0	0
	3	372	0	0
	4	371	0	0
	5	371	0	0

The greatest benefits of weir pool raising combined with Lyrup flow path lowering in terms of percentage EC reduction from baseline EC was modelled to occur in the northern parts of the wetland. For instance, Upper Gurra Gurra (north of the Gurra Gurra lakes) showed almost a 40% mean reduction in EC when considering weir pool raising to 1 m and Lyrup flow path lowering, compared to a 26% mean reduction at the pump site under the same conditions (see Table 4.1).

The benefits of Lyrup flow path lowering to mean EC reduction at each wetland location are additionally highlighted when comparing to weir pool raising–only cases (i.e. Scenarios 2 and 3). For example, mean EC at the pump site was reduced by approximately 13% from baseline EC under 1 m weir pool raisings, while lowering the flow path at the same weir pool raising approximately doubled the mean EC reduction (i.e. 26% reduction from baseline EC). Considering mean EC at the pump site under 0.5 m weir pool raisings, a 4% mean EC reduction was modelled with no lowering compared to 18% with lowering. Note that River Murray mean EC shows little to no change across all 5 scenarios tested.

Despite a reduction in mean EC for each of the operating scenarios, positive and negative fluctuations in EC compared to the baseline condition occurred during the simulation period. Figure 4.1 shows an example of the impacts on EC difference from baseline for 0.5 m weir pool raisings and lowered Lyrup flow path at the pump location and North Lake, compared to Lock 4 water levels (with normal operations indicated). The 1940 to 1950 period is shown given it contains an example of alternating mid-range river flows (i.e. ~60 GL/d) with intermediate weir pool raisings. At each weir pool raising event in the example plot, EC at the pump site initially reduced relative to baseline EC due to dilution from the River Murray through the Gurra Gurra outlet, before increasing above baseline as higher salinity water from the northern parts of the wetland were drawn towards the river through lowering of Lock 4 back to normal pool level. High flow events showed a different behaviour in EC however, with an initial spike in EC at the pump due to high salinity water being pushed from the north of the wetland through earlier activation of the Lyrup flow path, before reducing to a negative EC difference as lower salinity river water reached the pump site, again due to the earlier flushing of the system. In the North Lake however, both managed and unregulated Lock 4 level increases caused a decrease in EC from baseline, with EC generally maintained at or below the baseline EC through the simulation period.

An example of the changes during an unregulated event is presented in Figure 4.2, showing the EC at the pump location for each scenario during an unregulated flow event in the period from ~1942 to 1944. At the start of the period considered, all management scenarios have a lower salinity than the baseline Scenario 1, representing the long term benefits from increasing the salt export from the Gurra Gurra system. During the unregulated flow event, the reduction in modelled EC was similar in Scenarios 1 to 3 (i.e. baseline and weir pool raisings of 0.5 and 1.0 m, respectively) during the period, given that the conditions (water levels and Lyrup flow path sill level) in each system are the same. In Scenarios 4 and 5 the Lyrup flow path is lower and departure in EC was modelled, with EC remaining higher than baseline EC initially as river flow increases and higher salinity water from the Gurra Gurra lakes flushes past the pump location, before reducing below baseline as peak flow was reached, and then returning to an EC slightly below the scenarios that use the current Lyrup flow path sill level as river flow returns to normal flows.

Figure 4.3 shows a further example of EC behaviour at the pump location, in this case for a managed weir pool raising event for the period of ~1944 to 1946. In all management scenarios for the period, EC decreased below baseline as the managed raising reached its peak, as lower salinity water from the River Murray flows past the pump location into the wetland. As the water level recedes on the back of the weir pool raising event, there is an increase in EC above baseline for approximately 2 to 3 months, as high salinity water from the Gurra Gurra wetland flows out of the system past the pump location. Following the weir pool manipulation event this net export of salt from the system results in EC being below baseline for the remainder of the period. In contrast to an unregulated event, EC differed depending on the scenario configuration, where a 1 m weir pool raising produced the greatest reduction of EC below baseline, while the 0.5 m raising produced an intermediate EC reduction. For the river flows during this event (approximately 6000 ML/d) the Lyrup sill lowering had a minimal influence on the connection through this flow path for the 0.5 m raising scenario. However, for the 1 m raising scenario, following the raising event the salinity in Scenario 5 can be seen to be lower than Scenario 3, indicating that the combination of weir pool raising and sill lowering resulted in increased flushing of the Gurra Gurra wetland via the Lyrup flow path for this event.

While mean EC in the River Murray did not change across the scenarios tested, fluctuations from baseline EC were also modelled to occur, as indicated in Figure 4.4. The smallest and least frequent EC changes were modelled to occur in the case of the 0.5 m weir pool raising with no Lyrup flow path lowering, while the greatest frequencies and magnitudes of fluctuations were modelled to occur under the 1 m weir pool raising case with Lyrup lowering. These results may be expected due to the additional exporting of salt from the system that is encountered with maximised Lock 4 raising and lowered flow path compared to lesser measures of dilution. The maximum increase of EC above baseline was approximately 80 µS/cm across all scenarios, with the duration of the increases in the order of 3 to 4 weeks.

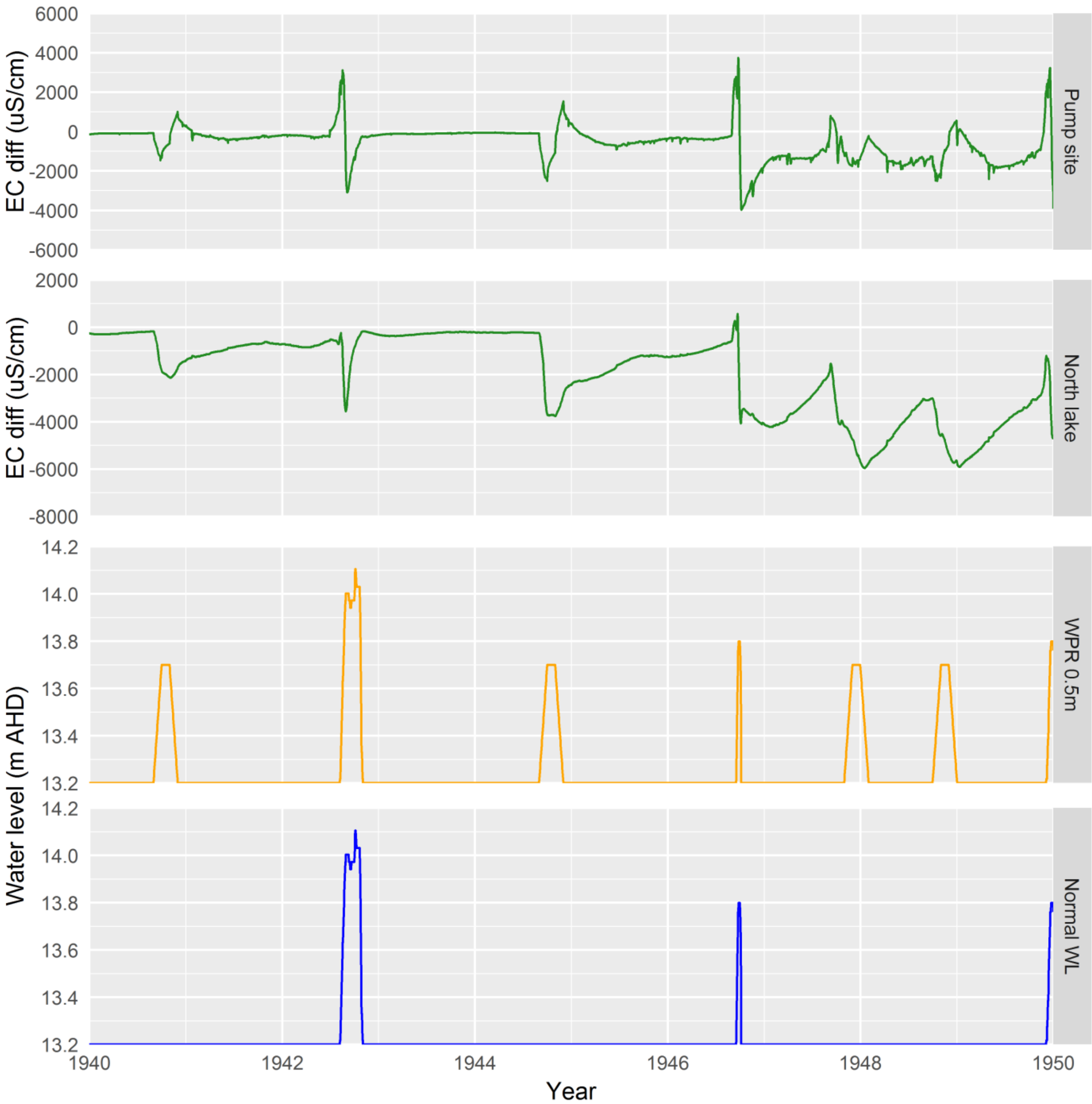


Figure 4.1. EC for the pump site and North Lake for 0.5 m weir pool raising and lowered Lyrup flow path. Modelled Lock 4 water levels (orange) and levels attributed to normal river operations (blue) indicated

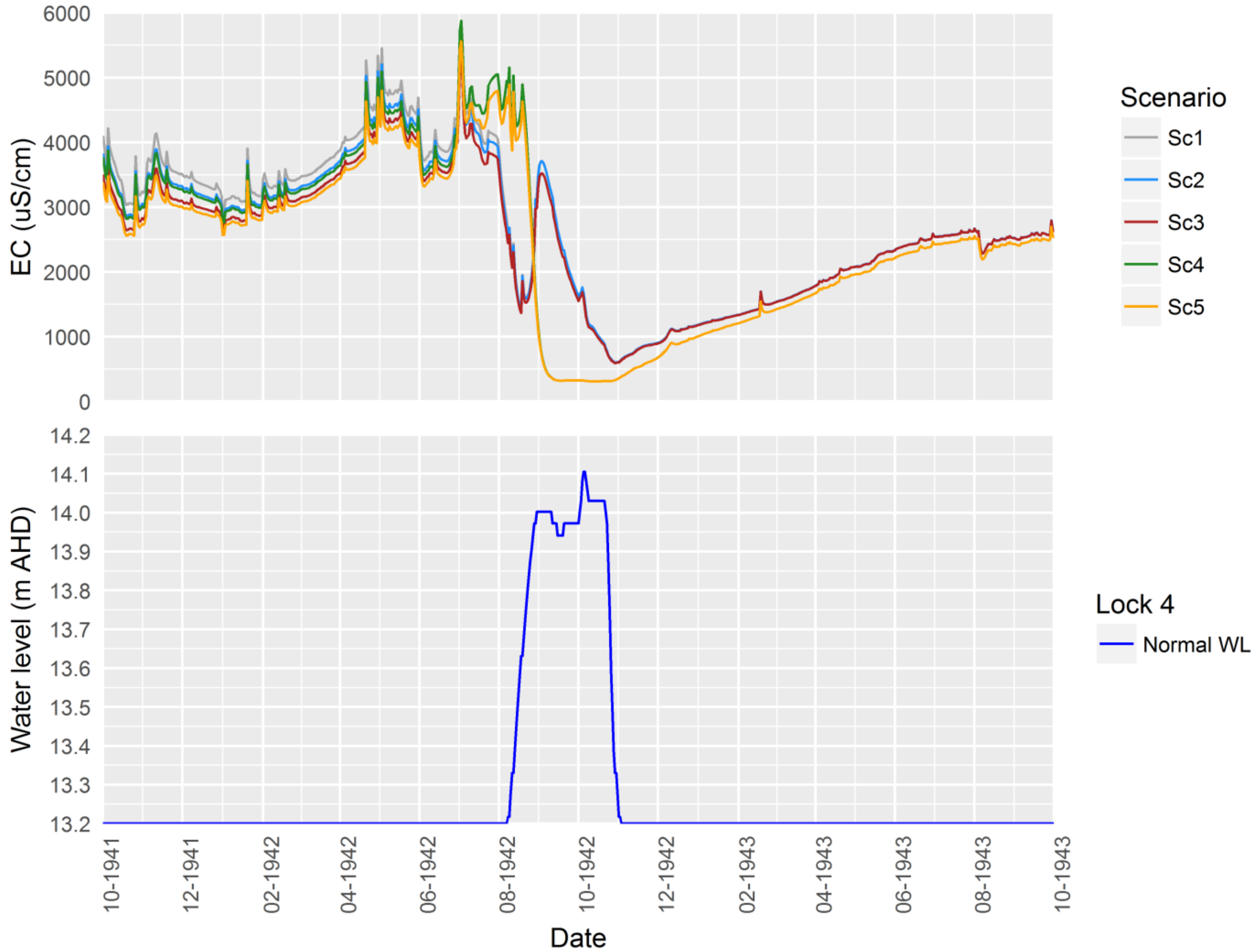


Figure 4.2. EC for the pump site from 1942 to 1944 for Scenarios 1 to 5, with modelled Lock 4 level during unregulated flow event indicated

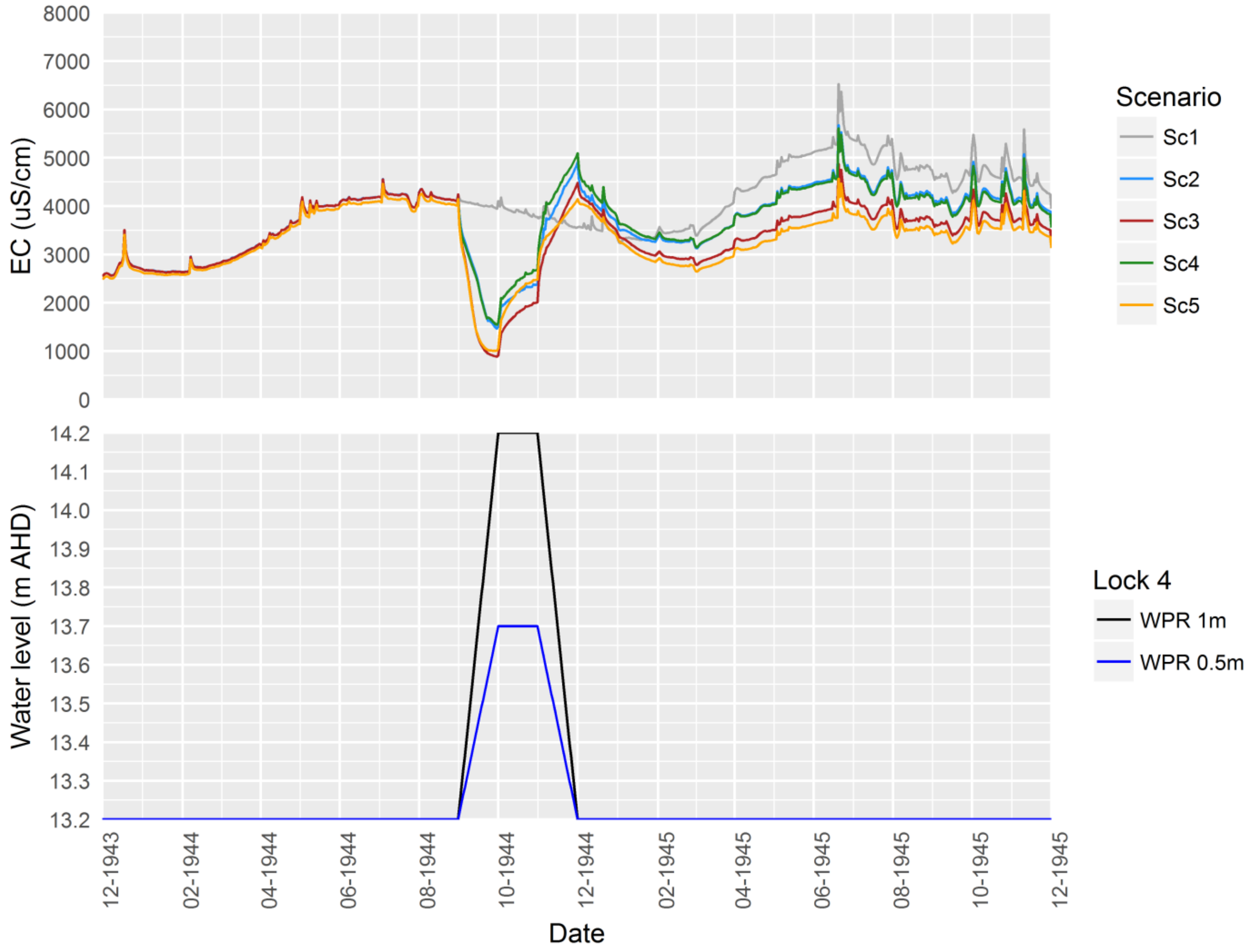


Figure 4.3. EC for the pump site from 1944 to 1946 for Scenarios 1 to 5, with modelled Lock 4 level during managed weir pool raising events of 0.5 and 1.0 m indicated

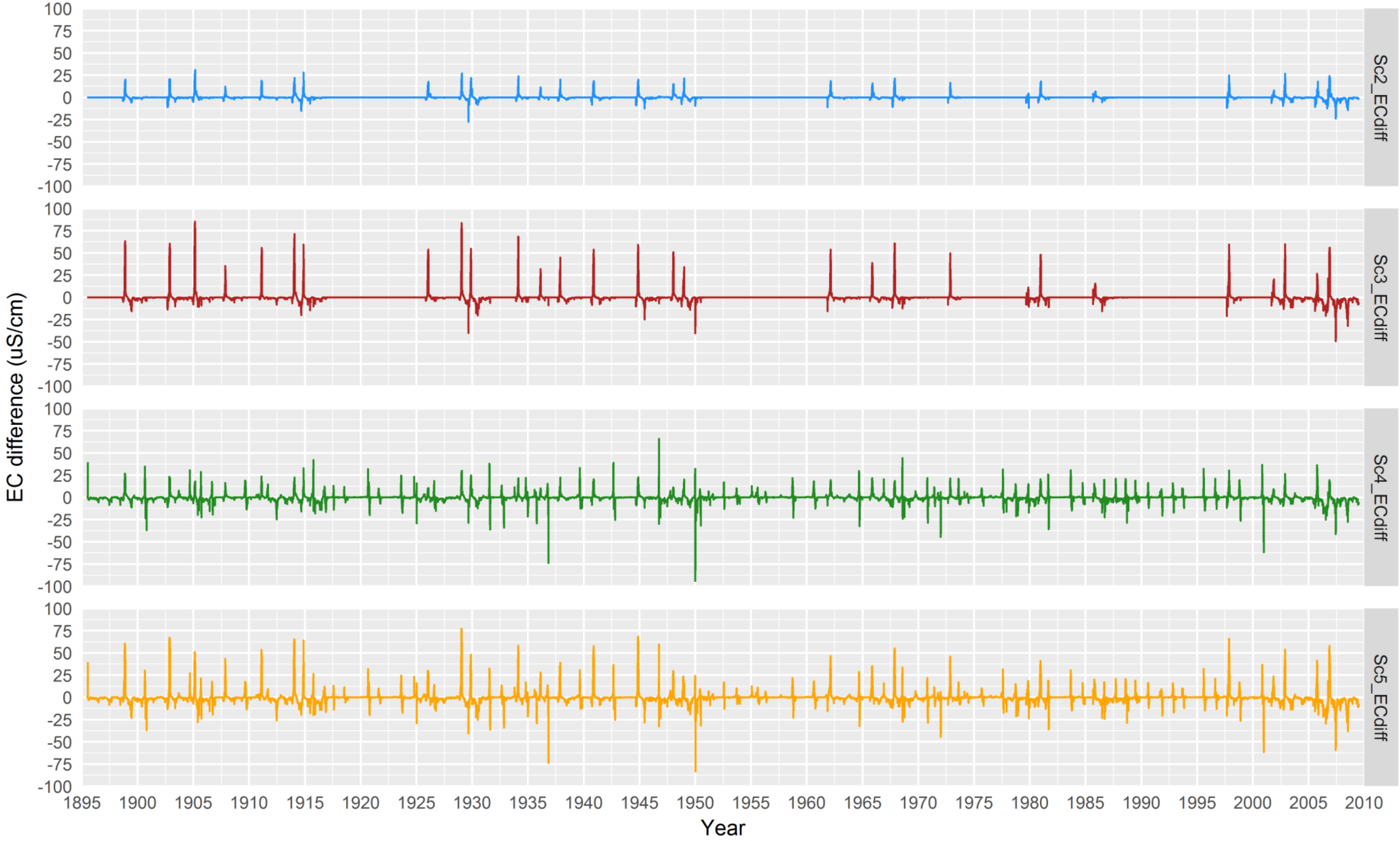


Figure 4.4. EC difference from baseline EC for Scenarios 2 to 5 at River Murray downstream Gurra Gurra outlet

4.2 Percentile analysis

Percentile analysis results of the EC at each of the wetland locations is shown in Table 4.2, indicating 10th, 50th and 90th percentile EC values under each scenario. Supporting percentile plots for each location are shown in Figure 4.5 to Figure 4.10. The results indicate that for each location (with the exception of Gurra Gurra outlet and River Murray locations) a generally decreasing trend in EC at each percentile is modelled as the extent of management measures increases (i.e. from baseline conditions in Scenario 1 to 1 m weir pool raisings and Lyrup lowering in Scenario 5). For both the Gurra Gurra outlet and River Murray downstream of Gurra Gurra, little change in EC is apparent across all scenarios compared to the other locations. Note that River Murray EC values may be impacted by estimations of EC in the pre-1975 period that were not included in the MSM BIGMOD hydrograph (See Section 3.1). However, the relative differences in EC between the scenarios are not expected to change.

Table 4.2. 10th, 50th and 90th percentile ECs at each model location for the simulation period

Location	Scenario	10th percentile EC µS/cm	50th percentile EC µS/cm	90th percentile EC µS/cm
Gurra Gurra outlet	1	315	477	623
	2	313	473	619
	3	311	467	605
	4	313	466	607
	5	311	460	594
Pump location	1	812	2741	4658
	2	811	2668	4421
	3	790	2505	3928
	4	420	2308	4011
	5	419	2134	3554
South Lake	1	951	5148	9747
	2	950	4754	8600
	3	946	4176	7574
	4	420	3753	7584
	5	419	3375	6825
North Lake	1	900	5910	11394
	2	898	5424	9971
	3	889	4658	8837
	4	382	4076	8715
	5	381	3669	7855
Upper Gurra Gurra	1	646	6841	13612
	2	645	6204	11875
	3	640	5361	10477
	4	310	4523	10198
	5	308	4042	9185
River Murray[1]	1	265	385	436
	2	264	384	436
	3	264	384	440
	4	264	384	434
	5	264	384	438

1 River Murray EC percentiles may be impacted by EC estimations required pre-1975.

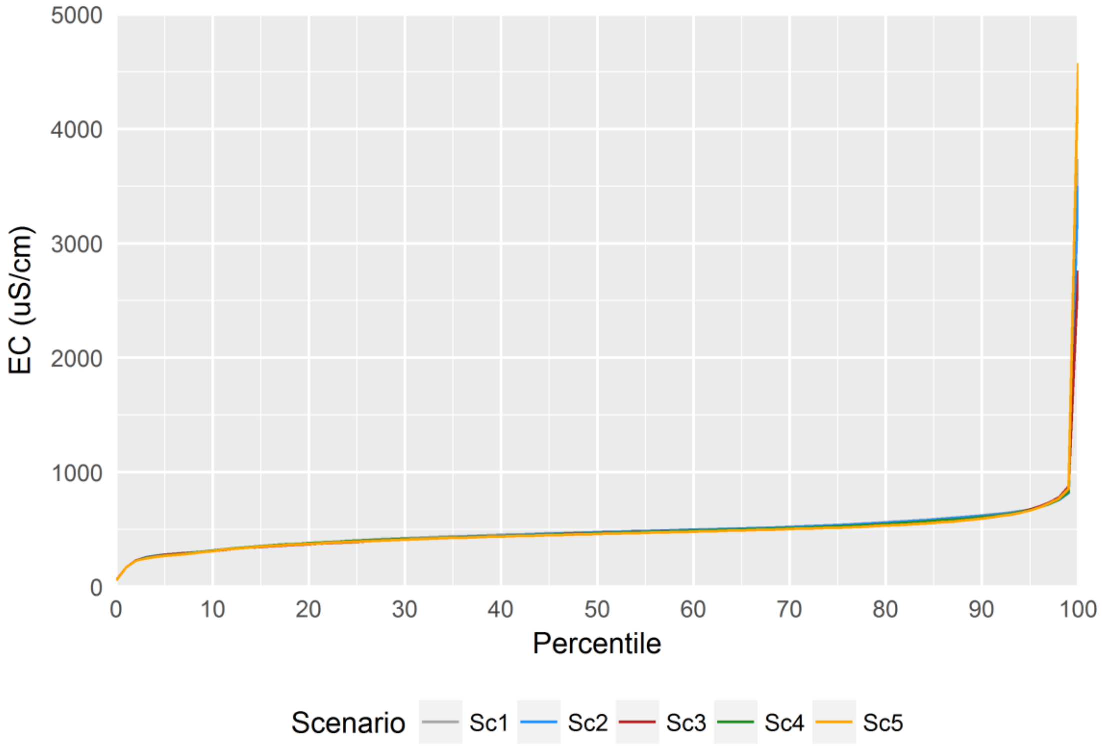


Figure 4.5. EC percentiles for the Gurra Gurra outlet under Scenarios 1 to 5

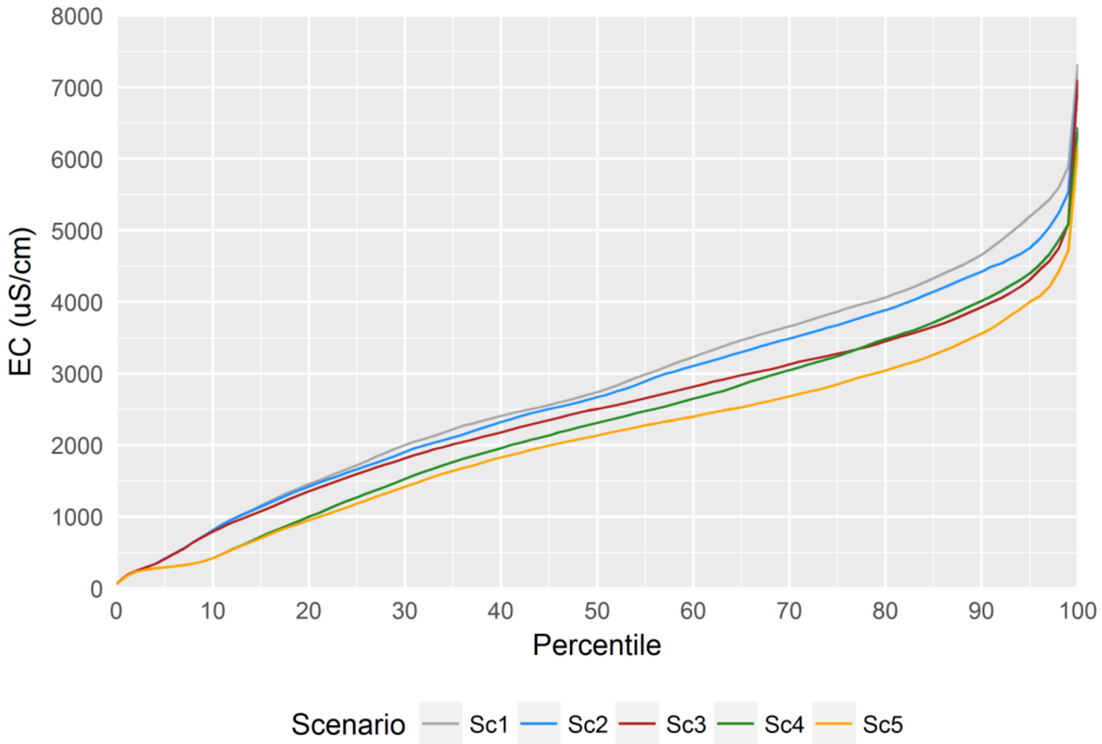


Figure 4.6. EC percentiles for the pump location under Scenarios 1 to 5

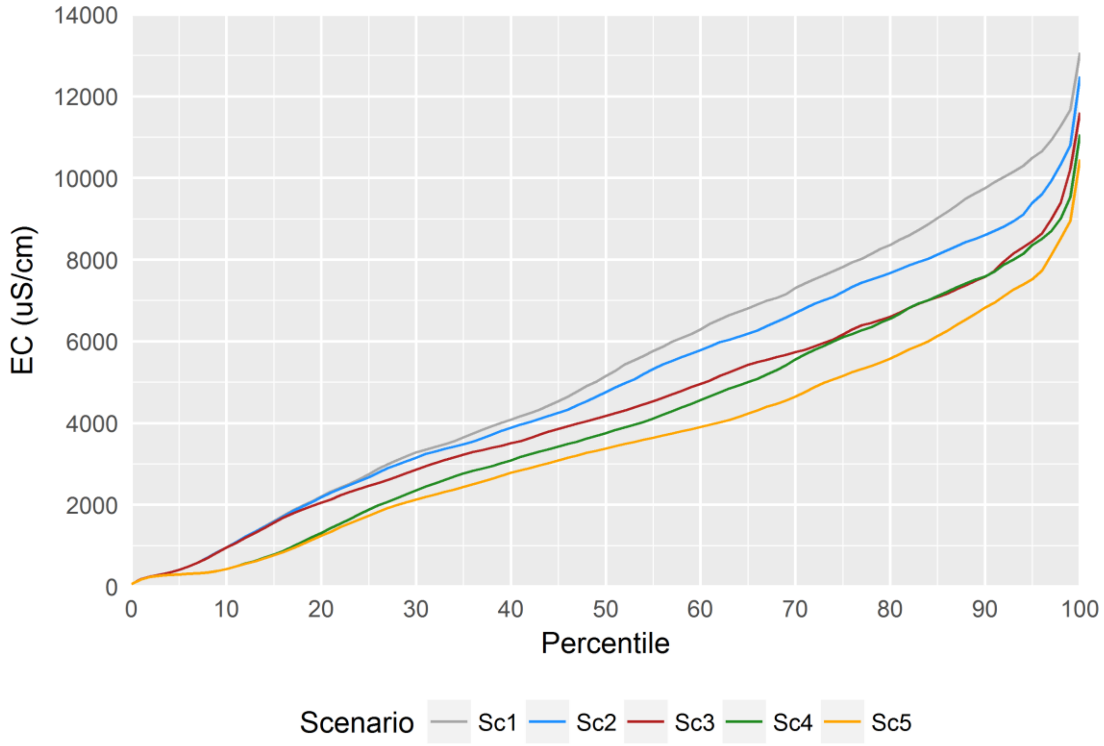


Figure 4.7. EC percentiles for the South Lake under Scenarios 1 to 5

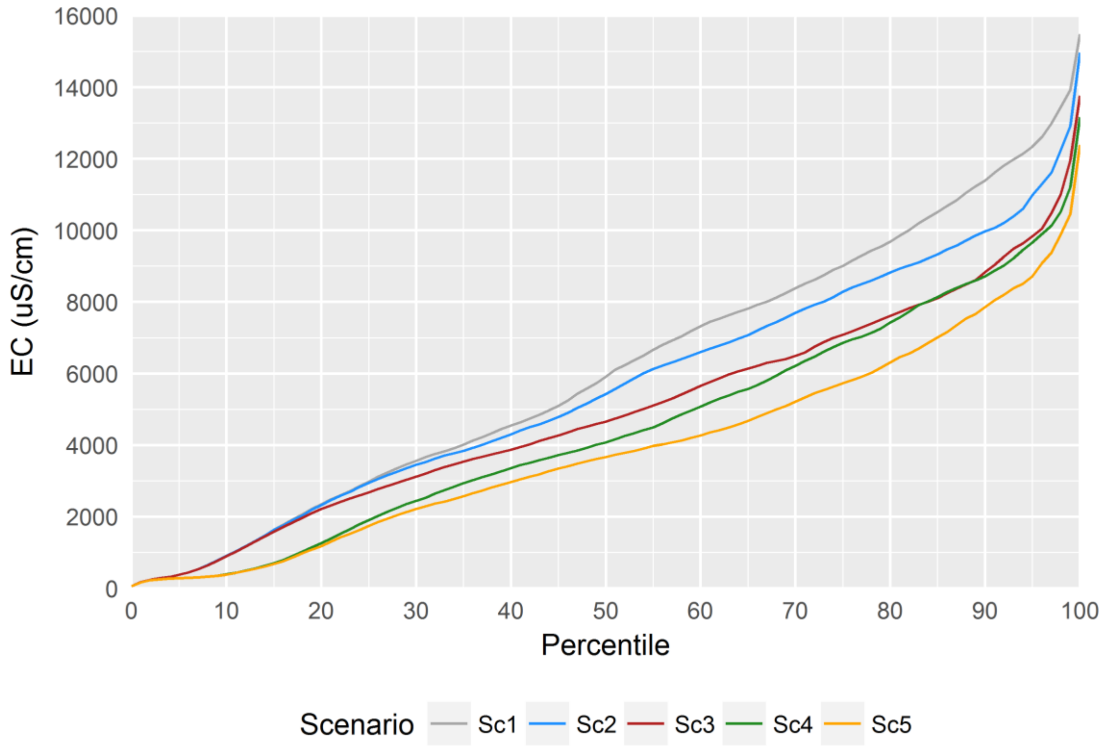


Figure 4.8. EC percentiles for the North Lake under Scenarios 1 to 5

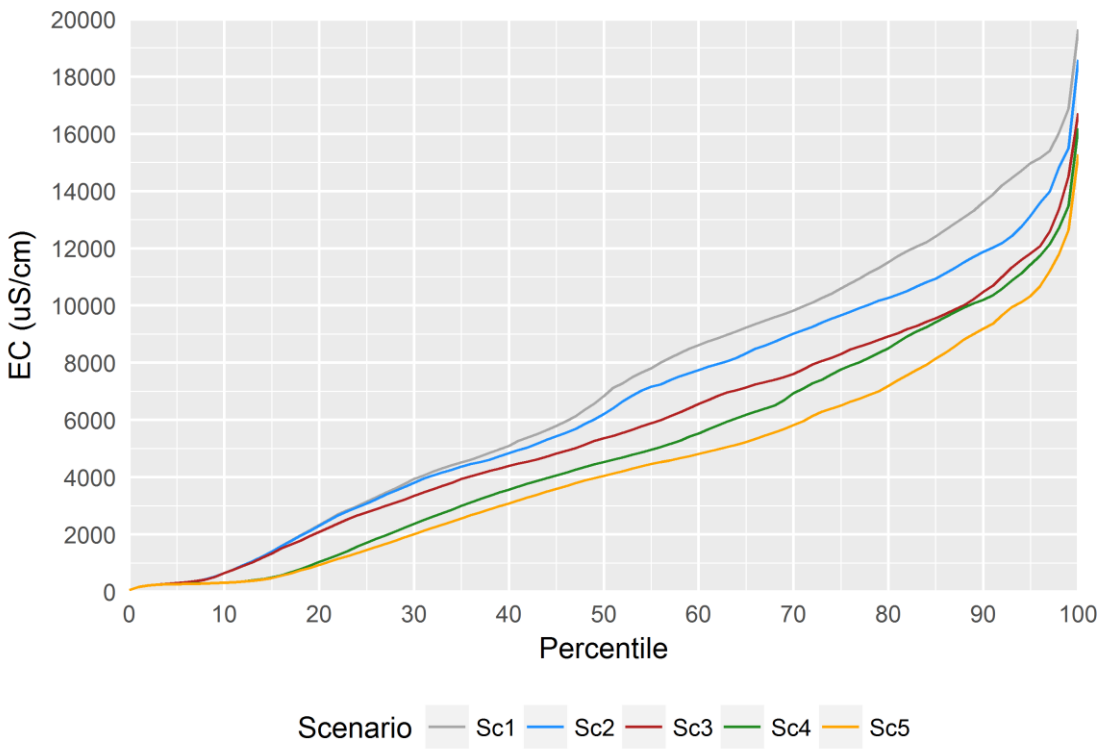


Figure 4.9. EC percentiles for Upper Gurra Gurra under Scenarios 1 to 5

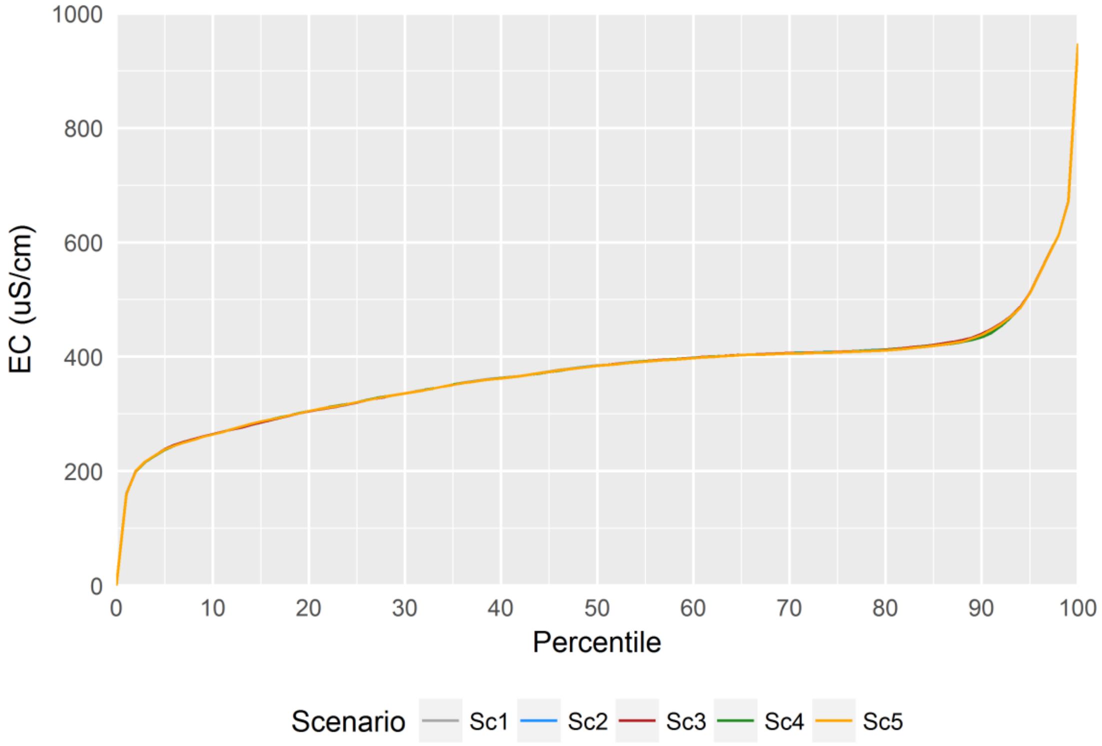


Figure 4.10. EC percentiles for River Murray downstream of Gurra Gurra outlet under Scenarios 1 to 5

5 Conclusions

Hydraulic modelling was conducted to assess the long term behaviour of salinity (as EC) in Gurra Gurra wetland under a number of different River Murray operational scenarios. A long term baseline scenario of one representation of an implemented Basin Plan was considered as the “no change”/baseline condition. Scenarios representing SARFIIP operations were considered, with temporary 0.5 m and 1 m weir pool raisings superimposed on the baseline hydrograph. Finally, a lowering of the Lyrup flow path was applied to each weir pool raising scenario to increase the frequency of flushing of the Gurra Gurra wetland. The following conclusions were derived from the modelled scenarios:

1. A long term baseline scenario of one representation of an implemented Basin Plan has been considered as the “no change”/baseline condition. Scenarios representing SARFIIP operations and the associated weir pool raisings were considered, with 0.5 m and 1 m weir pool raising, and each with a lowering of the Lyrup flow path to increase the frequency of flushing of the Gurra Gurra wetland.
2. The results indicated an average decrease in EC throughout the wetland for each management scenario compared to the “no change”/baseline condition. Raisings of 1 m above the normal pool level of 13.2 m AHD were modelled to provide a greater mean reduction in EC compared to 0.5 m raisings.
3. Implementing a lowering of the Lyrup flow path to a level of 13.3 m AHD, in conjunction with weir pool raisings was found to provide a greater benefit to EC reduction in the wetland than when considering weir pool raisings only. A 0.5 m raising with Lyrup lowering provided a greater benefit to EC reduction than 1 m weir pool raisings without sill lowering, while the maximum benefit was obtained with 1 m raisings and Lyrup lowering.
4. Although mean EC was reduced under the management options modelled, temporary EC fluctuations (both as increases and decreases relative to baseline EC conditions) were modelled when Lock 4 level was raised above normal weir pool level. In the northern sections of the wetland the fluctuations in EC were generally decreased compared to baseline, i.e. the EC was improved throughout the simulation period. Locations further south, such as at the pump location, encountered some increases in EC from management events relative to baseline. These increases were a result of higher EC water from the north of the system being drawn out towards the river when lowering Lock 4 level following a managed event, and/or higher EC water being pushed down from the north of the system through the Lyrup flow path by river water under higher flow conditions.
5. In all management options considered, River Murray EC downstream of the Gurra Gurra outlet was modelled to undergo temporary fluctuations from the baseline condition – including minor EC increases up to ~80 µS/cm – at each Lock 4 level raising. Where weir pool raising-only was considered, the EC increases were limited predominantly to weir pool raising events. The introduction of a Lyrup flow path lowering to weir pool raisings resulted in an increase in the frequency of River Murray EC fluctuations from baseline, due to a reduction in the commence to flow threshold creating more frequent inflows through the north of the wetland. These results indicate the effectiveness of the management options in transporting salt out of the Gurra Gurra system.

6 References

AWE, 2003, Gurra Gurra wetland complex – suitability for drying trials assessment, Australian Water Environments report ref 42397 prepared for Wetland Care Australia, February 2003.

Barnett S, 2007, Gurra Gurra wetland complex – groundwater data review, DWLBC Technical note 2007/17, Government of South Australia, Department of Water, Land and Biodiversity Conservation, Adelaide.

Montazeri M and Gibbs M, 2017, Gurra Gurra wetland modelling – Phase 2 scenario modelling, DEWNR Technical note 2017/29, Government of South Australia, Department of Environment, Water and Natural Resources, Adelaide.

Neilsen, C, 2016, DEWNR Gurra Gurra Lyrup Forest Modelling – Final report, DHI Water & Environment, prepared for Government of South Australia, Department of Environment, Water and Natural Resources, Adelaide.

Neilsen, C, 2017, DEWNR Gurra Gurra Lyrup Forest Modelling – Phase 2 Model Validation, DHI Water & Environment, prepared for Government of South Australia, Department of Environment, Water and Natural Resources, Adelaide.

SILO, 2017, Queensland Government, accessed 15 November 2017, <https://silo.longpaddock.qld.gov.au>

Appendix A – Comparison plots of EC survey to modelled results

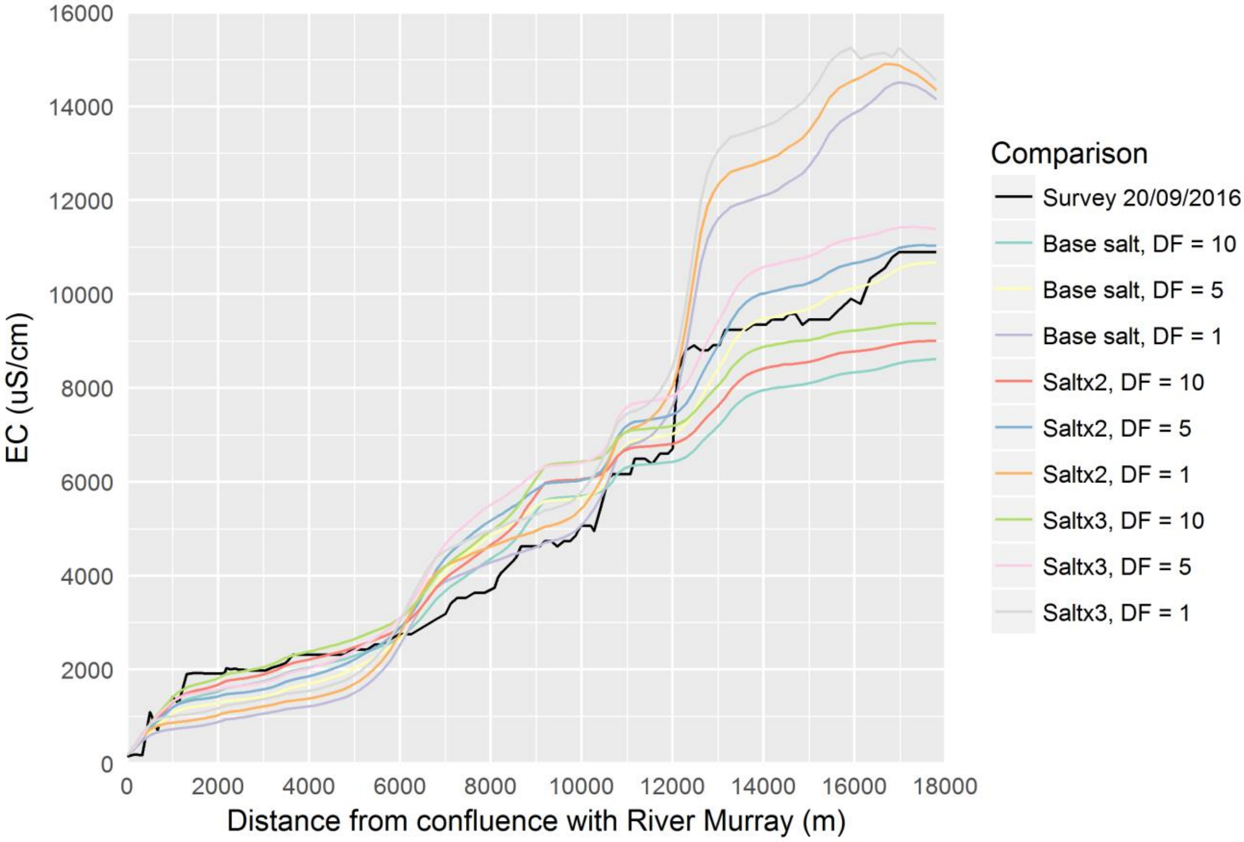


Figure A.1. Comparison of model calibration results to survey data from 20 September 2016

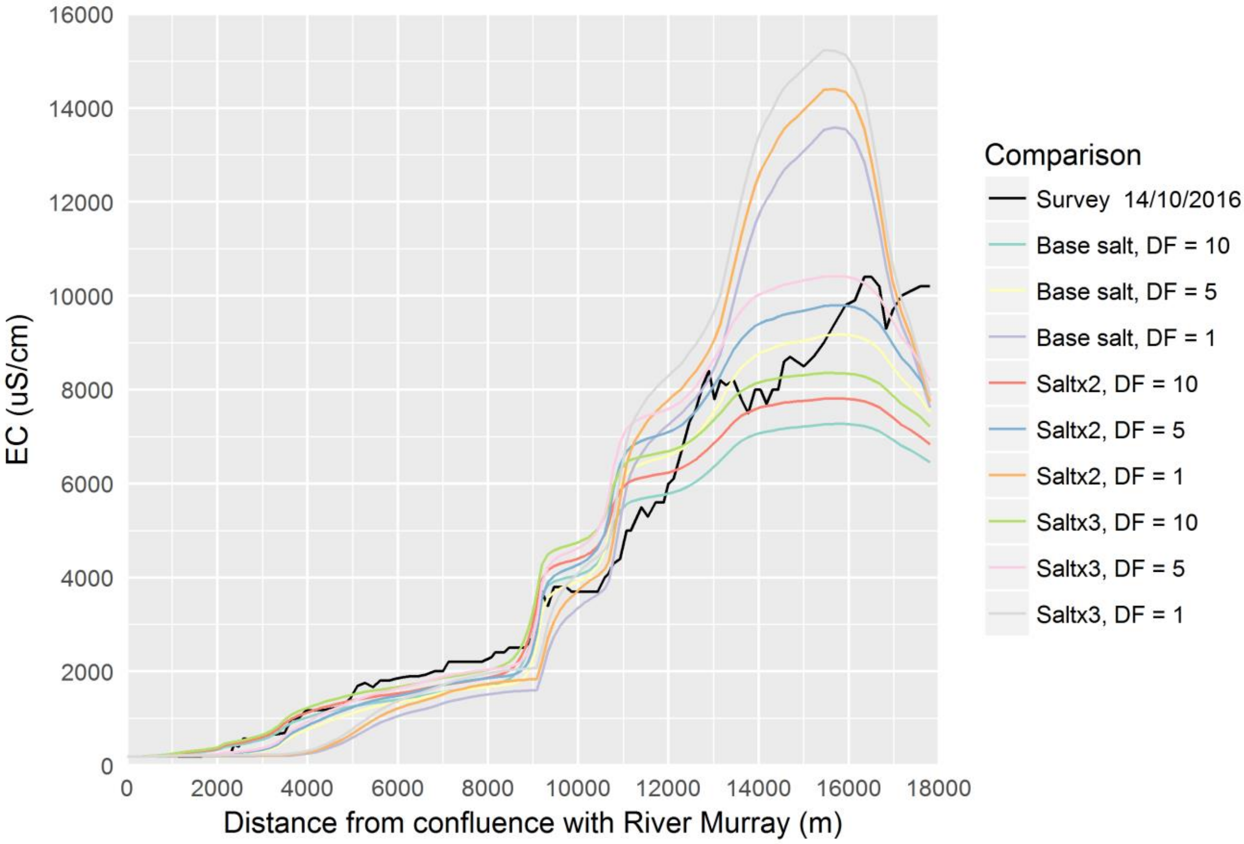


Figure A.2. Comparison of model calibration results to survey data from 14 October 2016

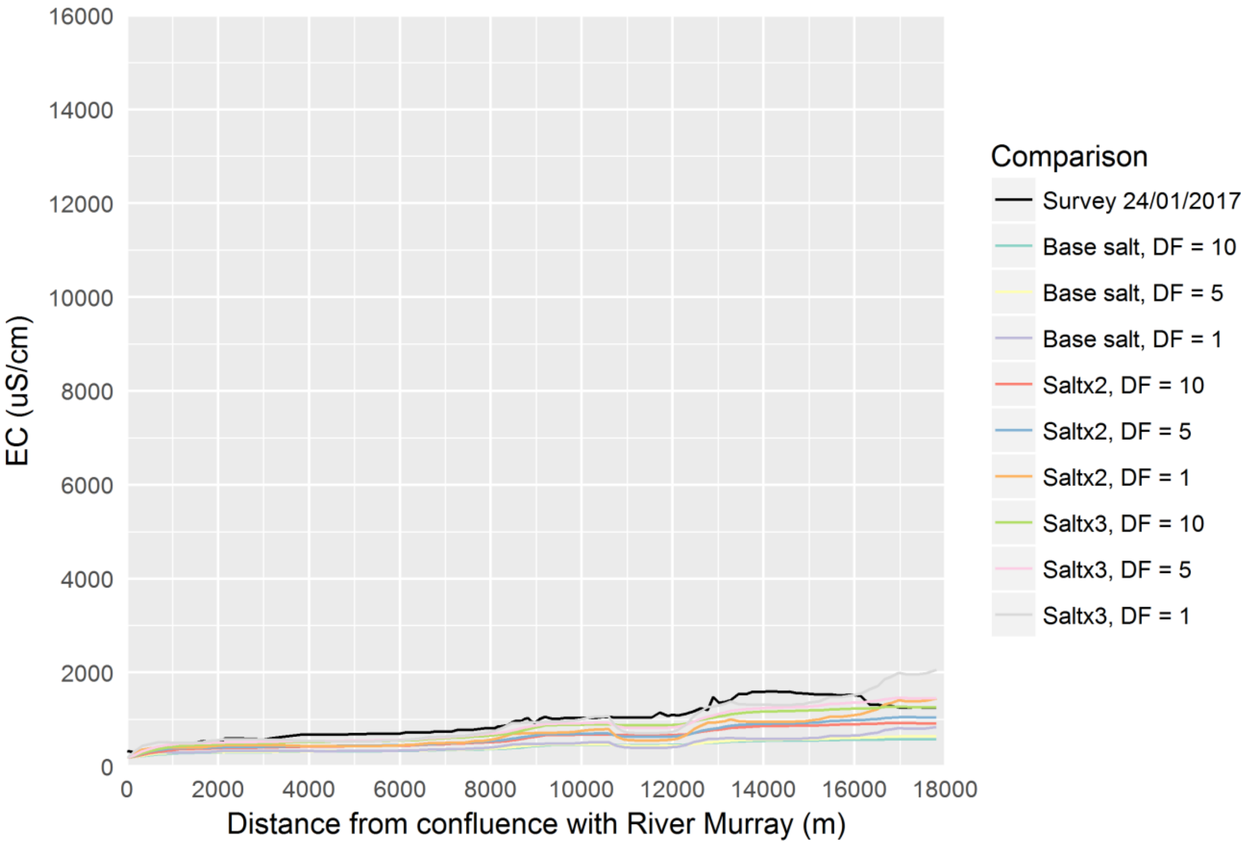


Figure A.3. Comparison of model calibration results to survey data from 24 January 2017

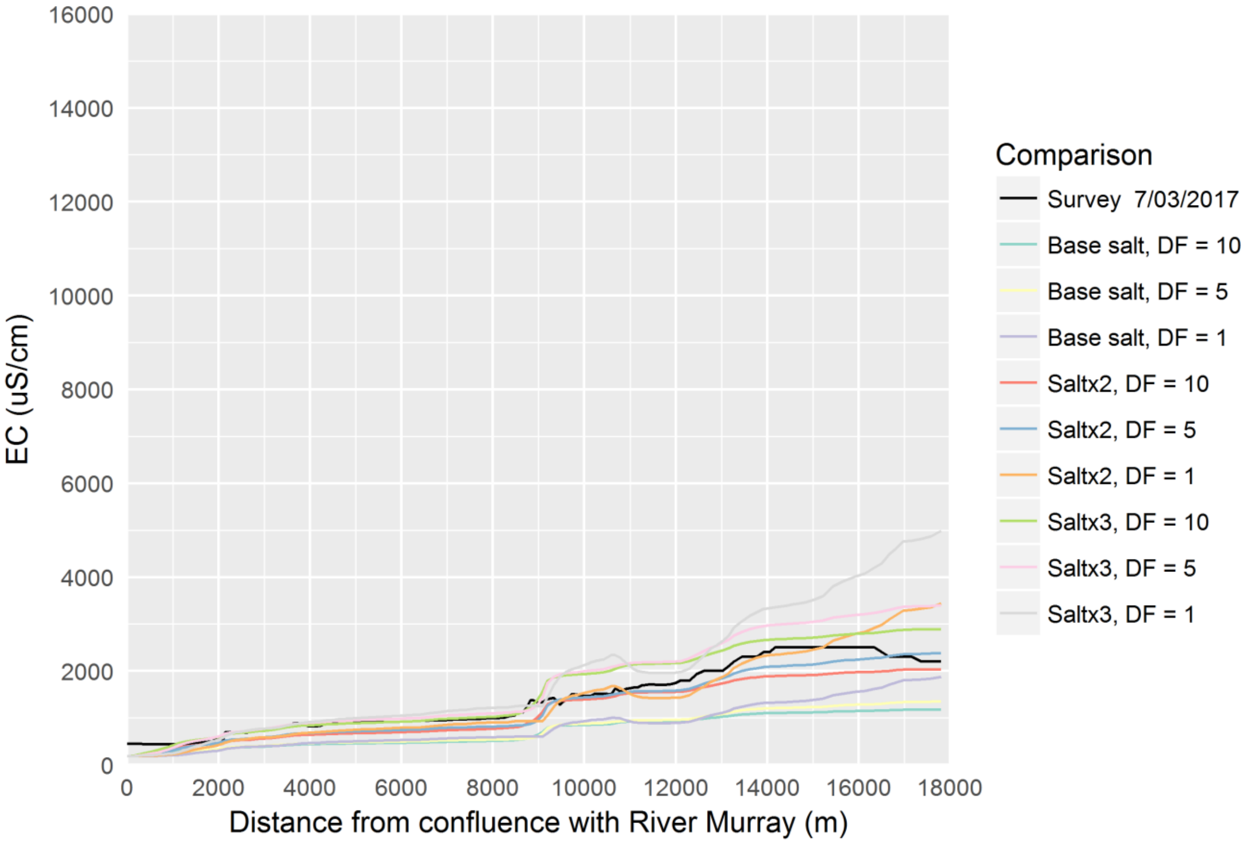


Figure A.4. Comparison of model calibration results to survey data from 7 March 2017

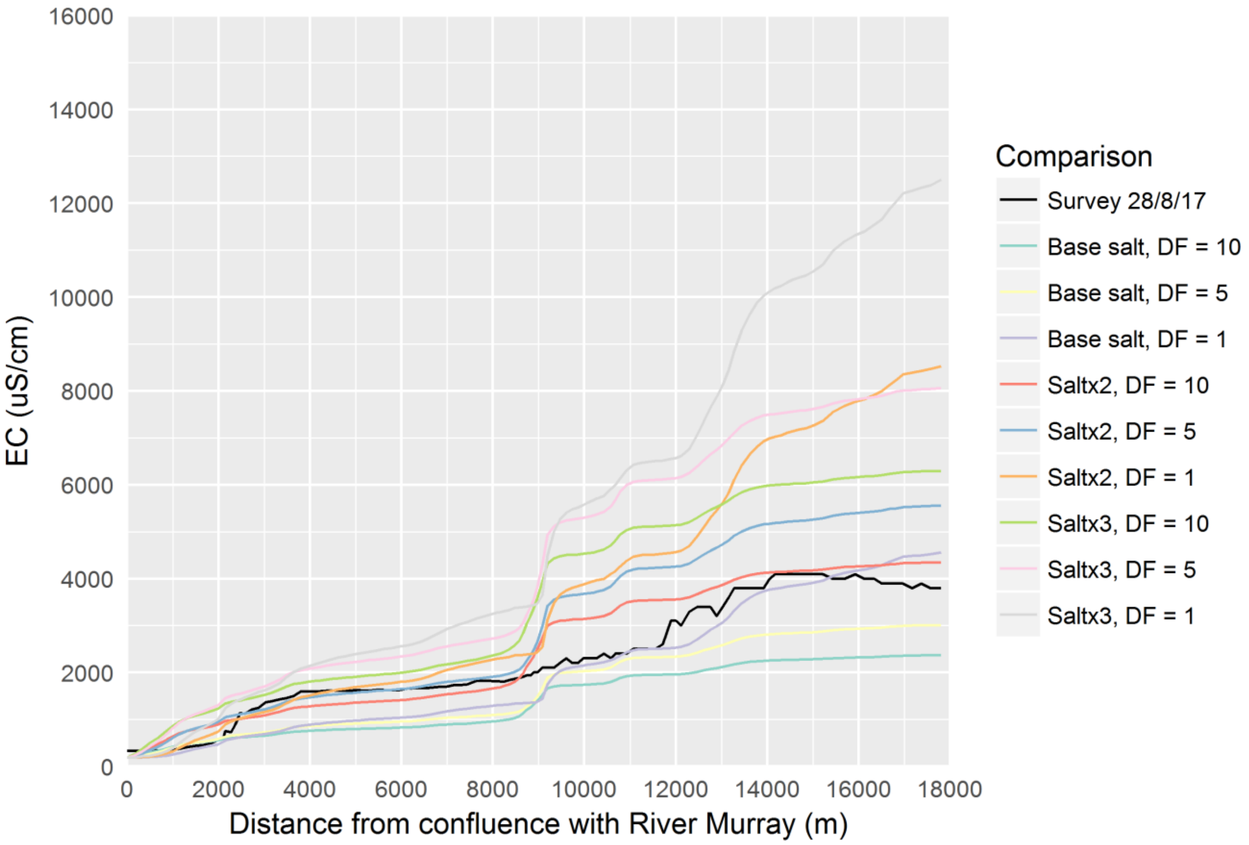


Figure A.5. Comparison of model calibration results to survey data from 28 August 2017

Appendix B – EC hydrograph comparisons

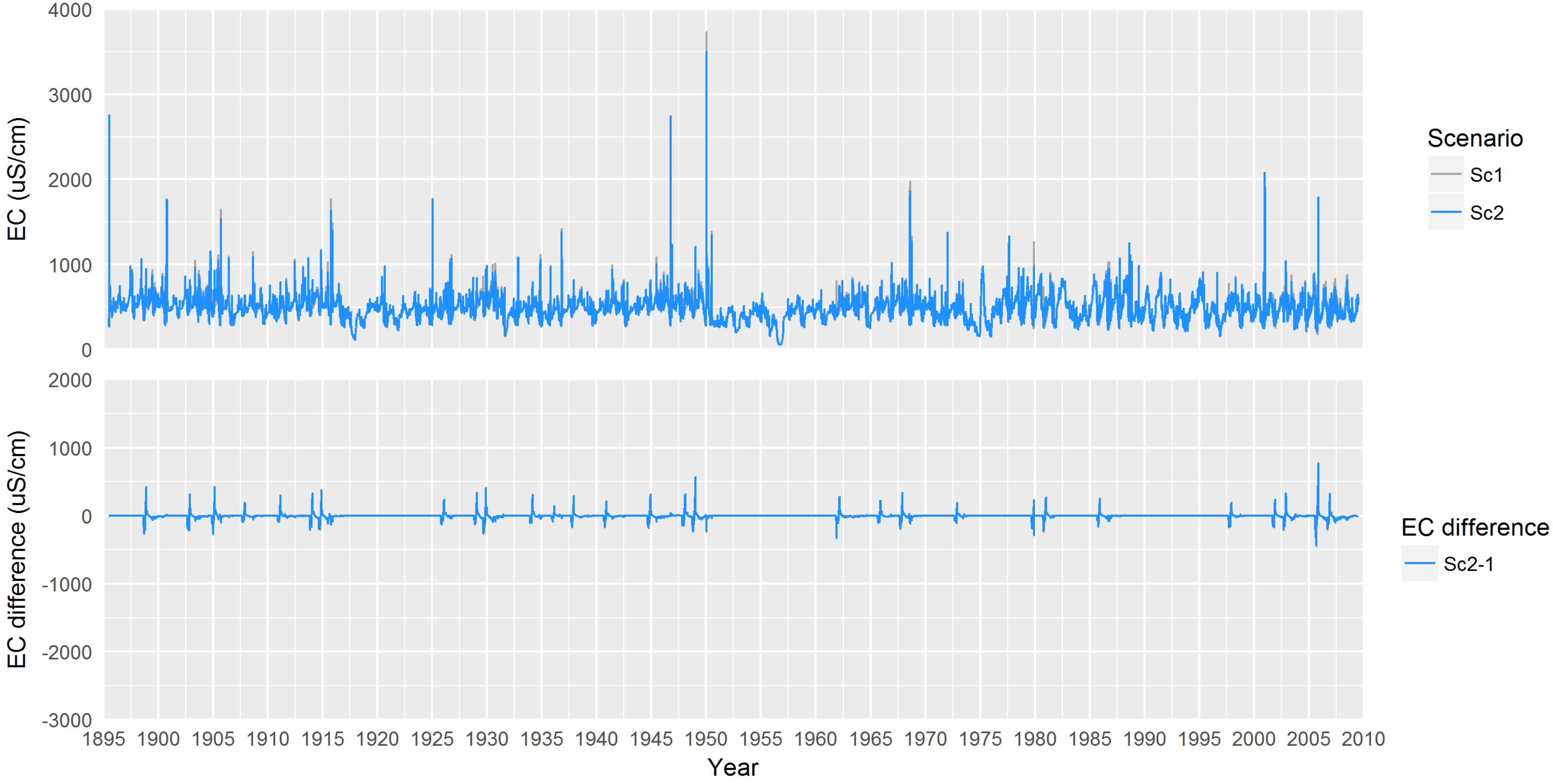


Figure B.1. Comparison of Scenario 2 (0.5 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at Gurra Gurra outlet

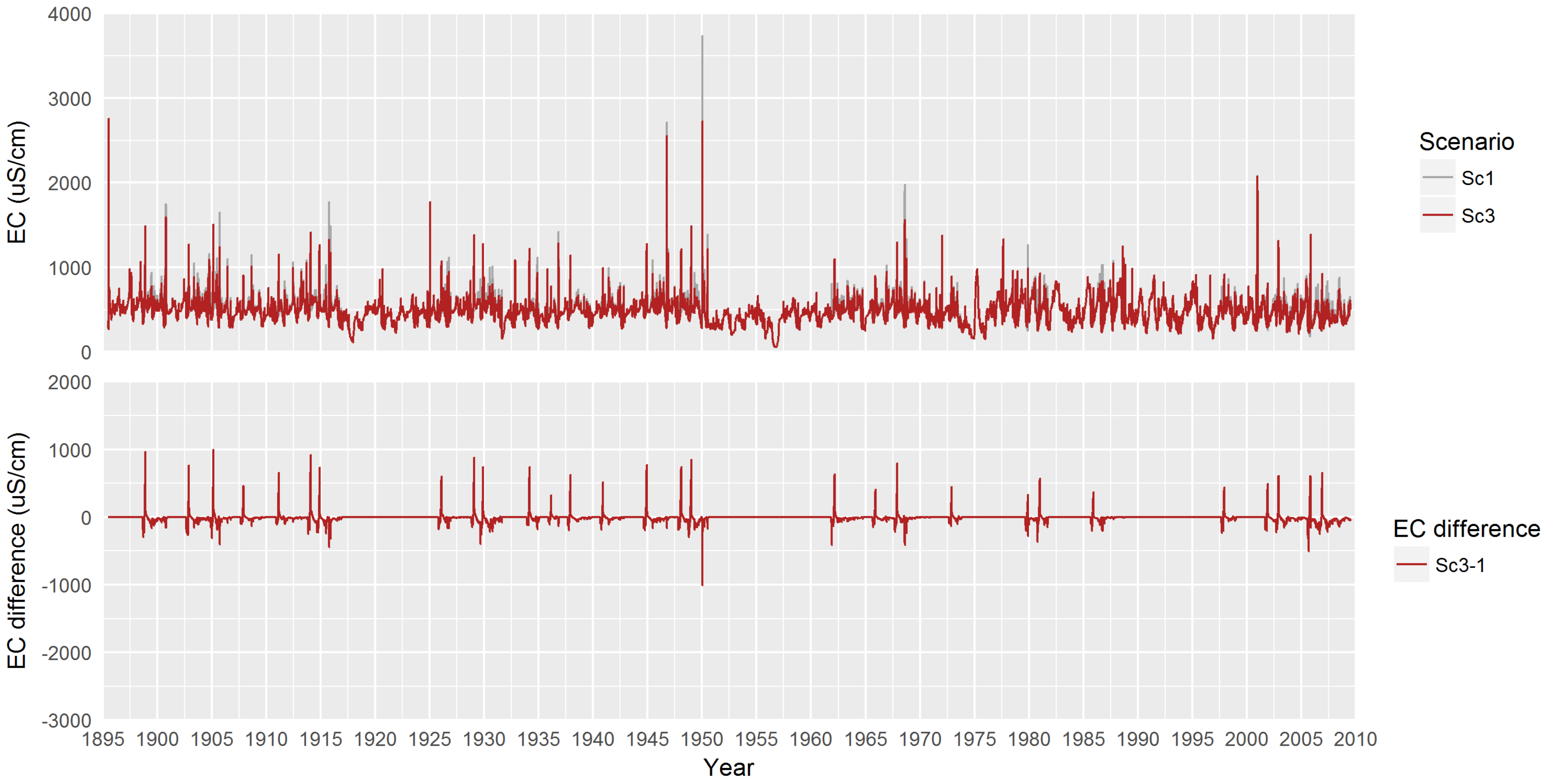


Figure B.2. Comparison of Scenario 3 (1 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at Gurra Gurra outlet

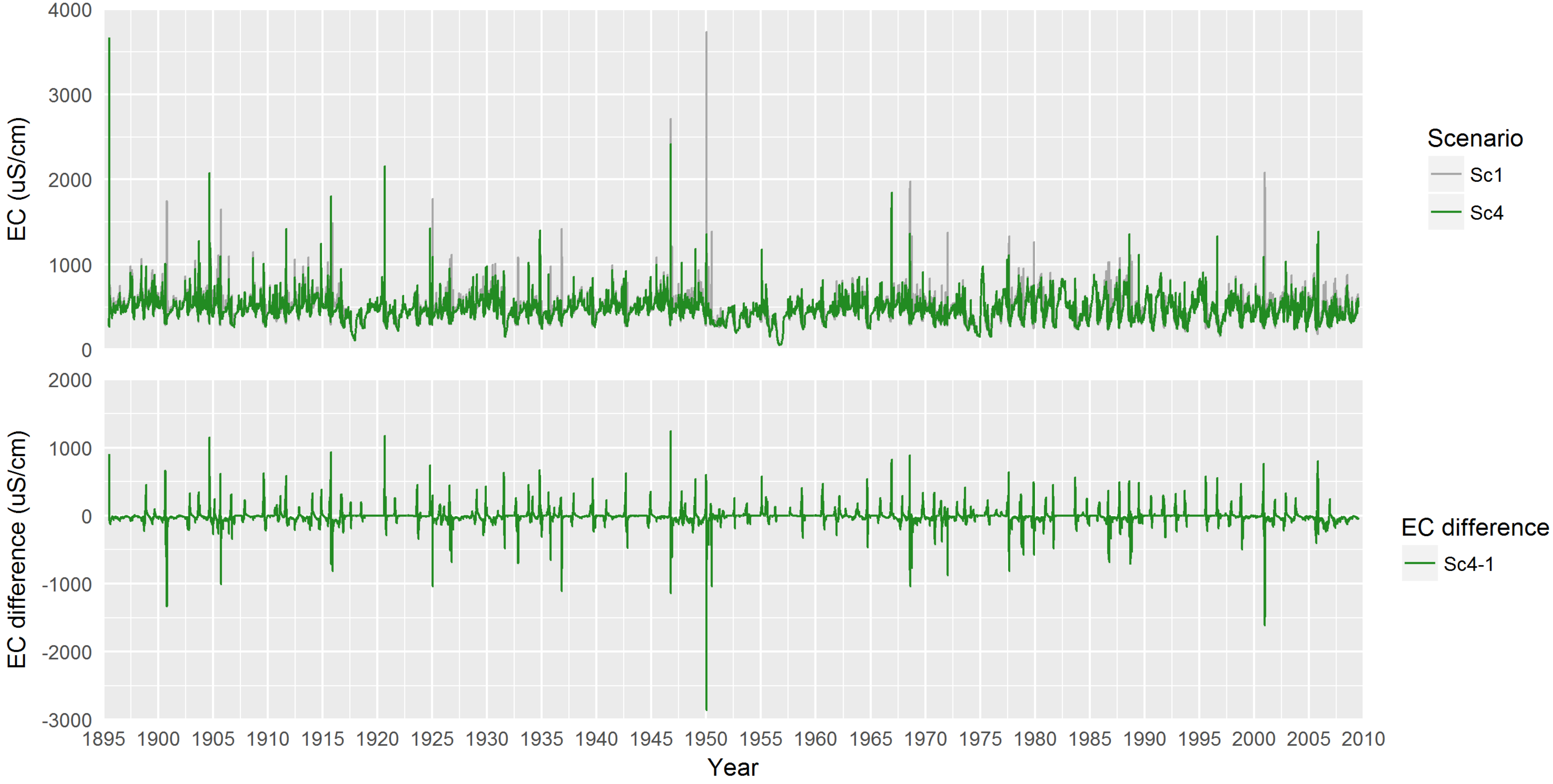


Figure B.3. Comparison of Scenario 4 (0.5 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at Gurra Gurra outlet

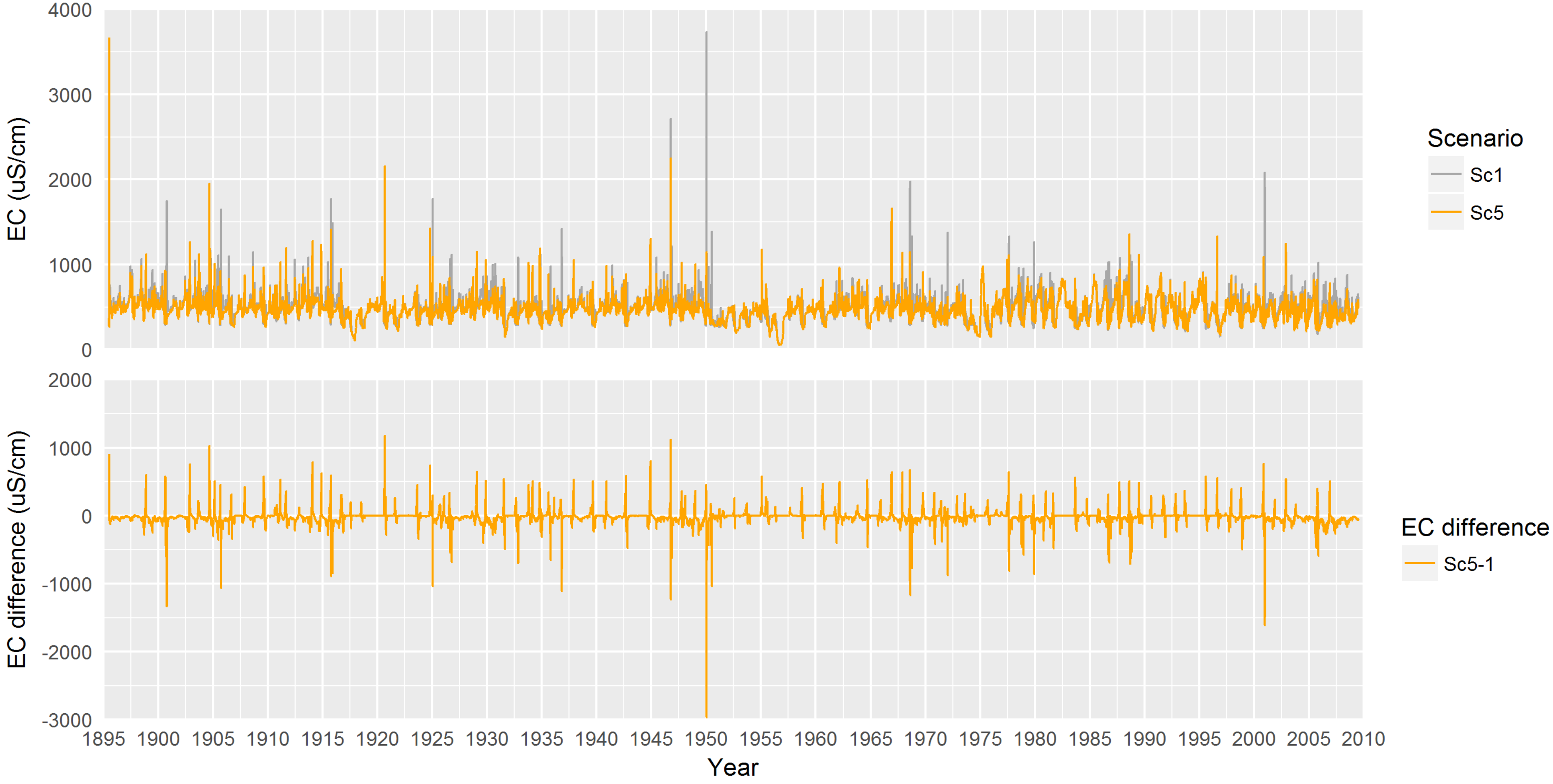


Figure B.4. Comparison of Scenario 5 (1 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at Gurra Gurra outlet

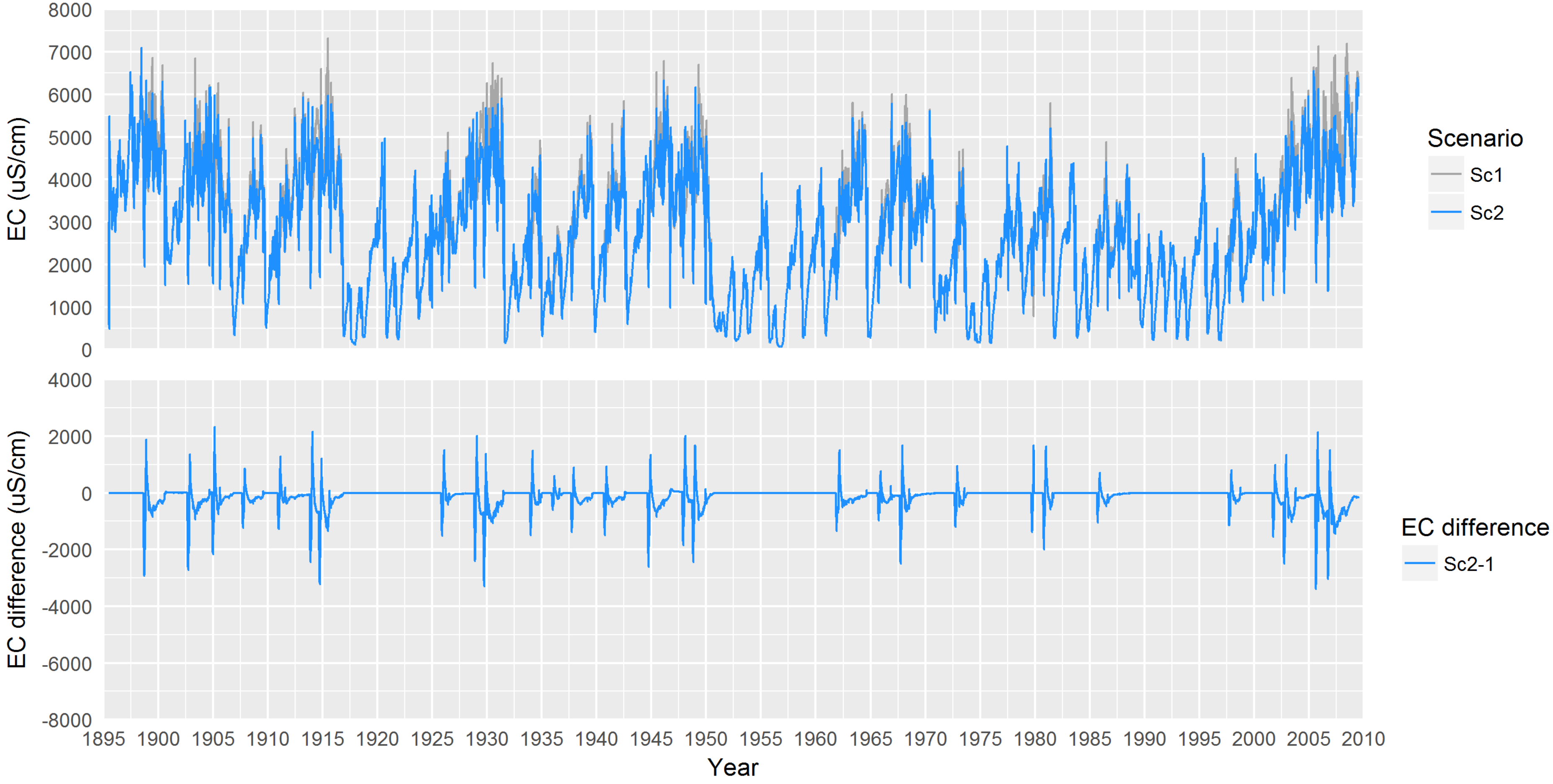


Figure B.5. Comparison of Scenario 2 (0.5 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at pump location

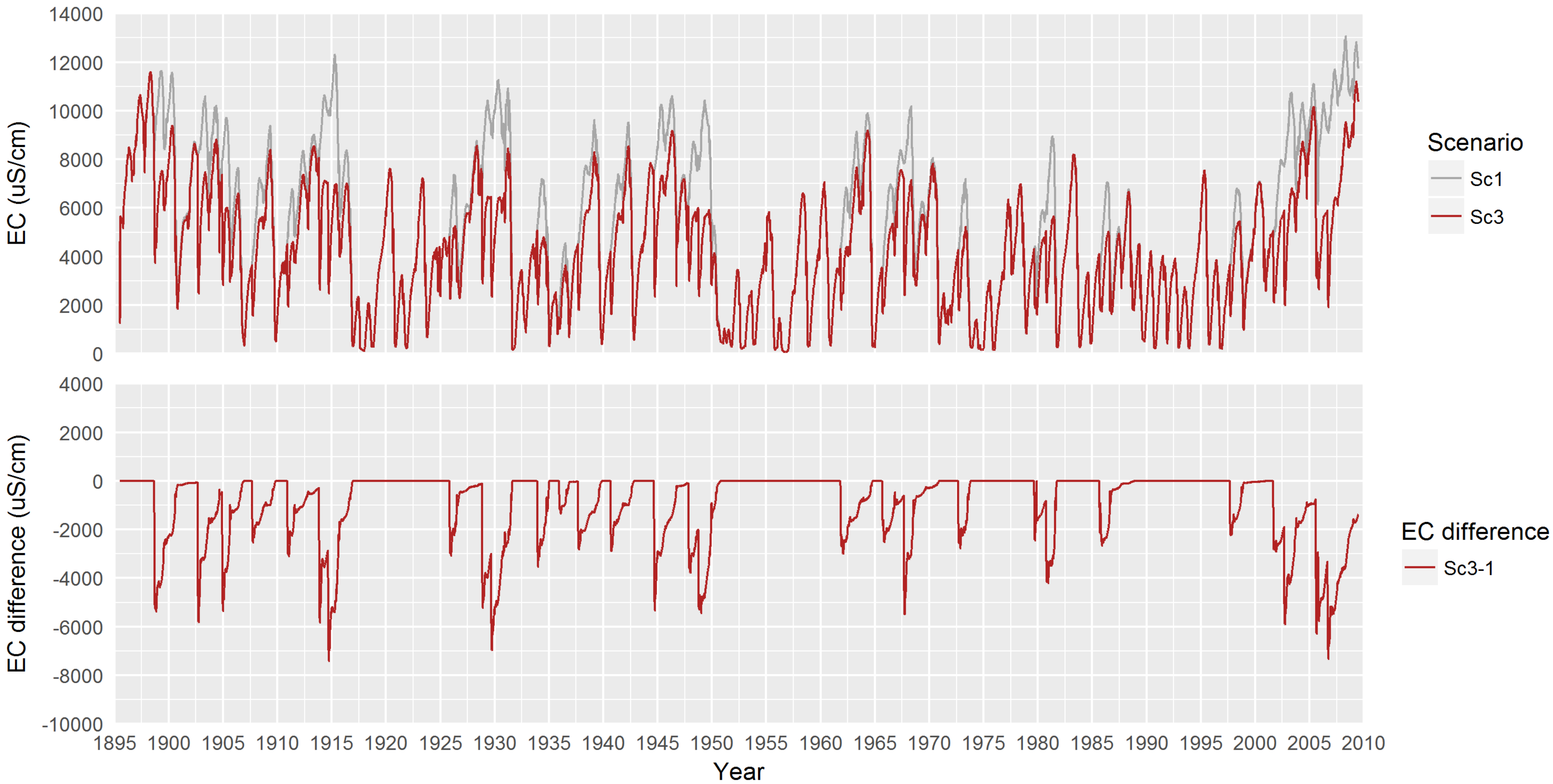


Figure B.6. Comparison of Scenario 3 (1 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at pump location

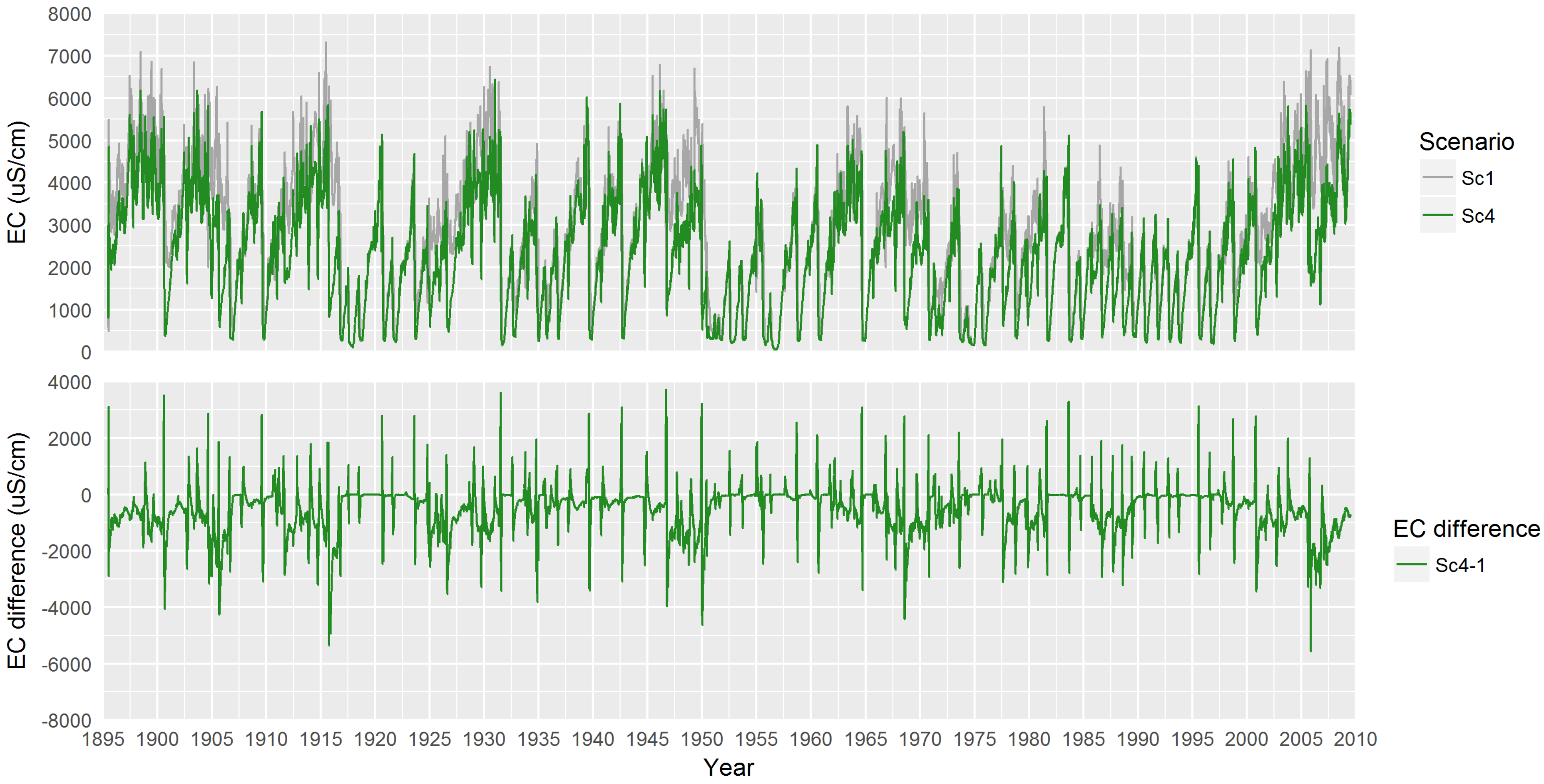


Figure B.7. Comparison of Scenario 4 (0.5 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at pump location

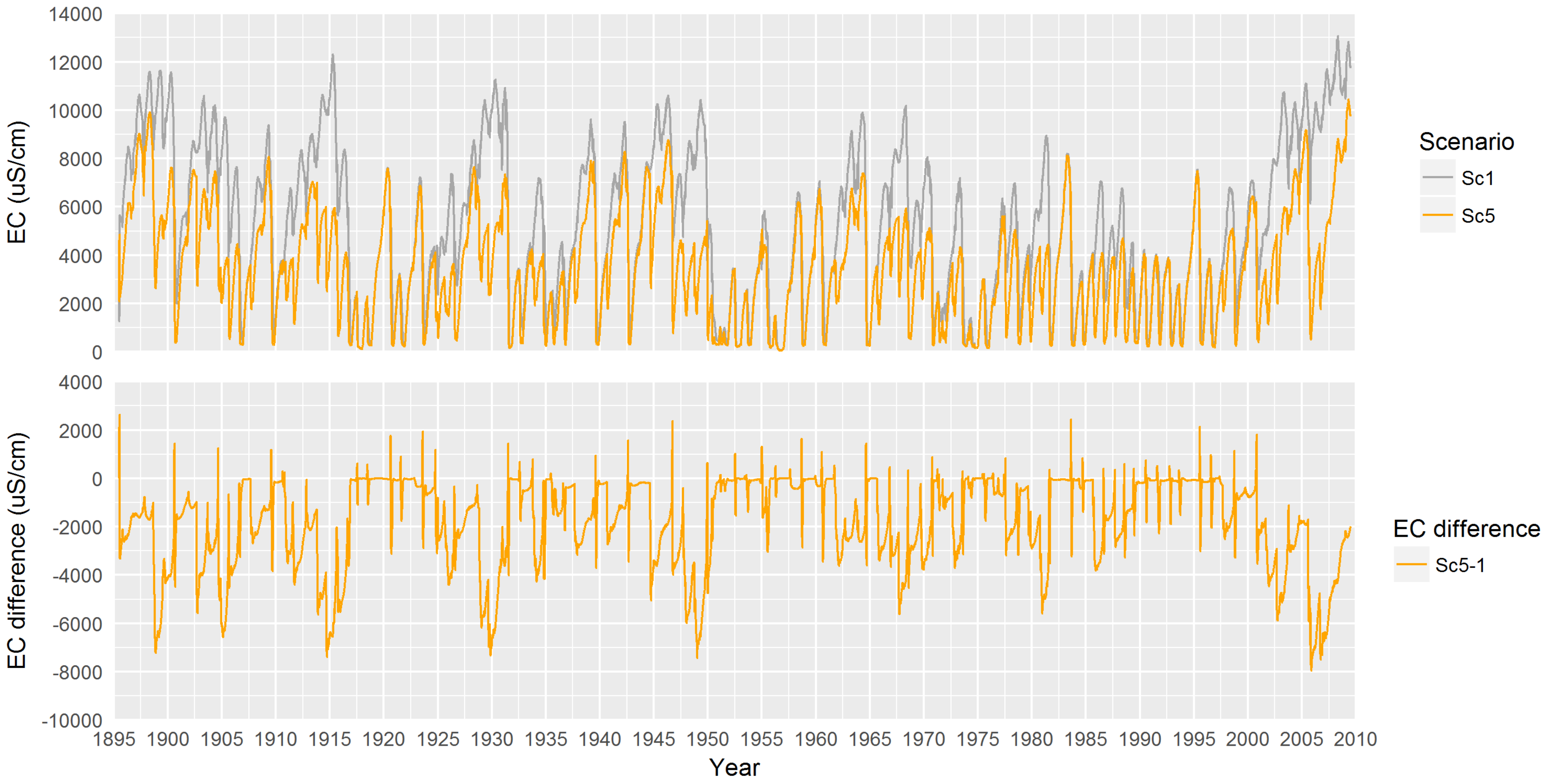


Figure B.8. Comparison of Scenario 5 (1 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at pump location

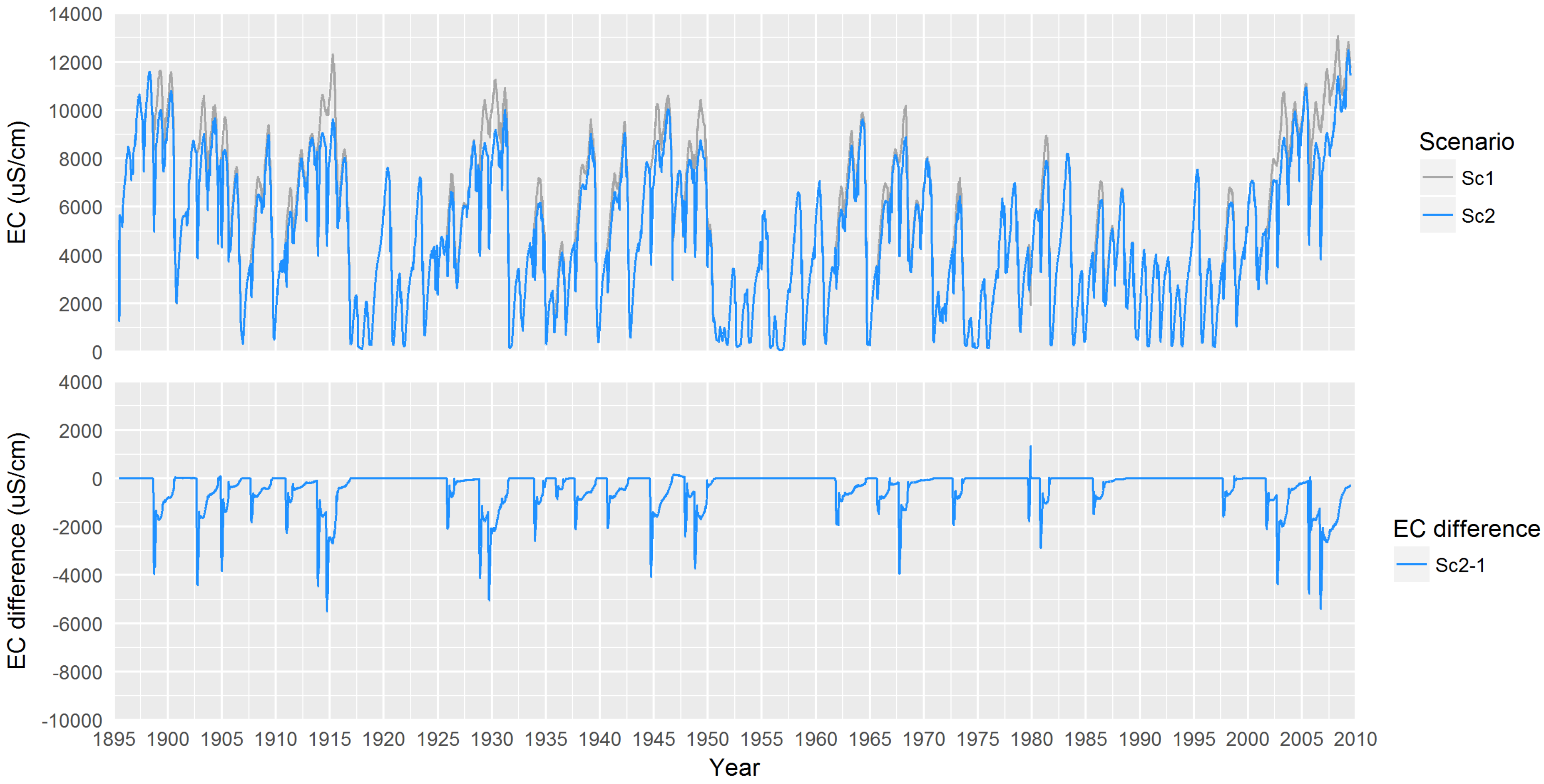


Figure B.9. Comparison of Scenario 2 (0.5 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at South Lake

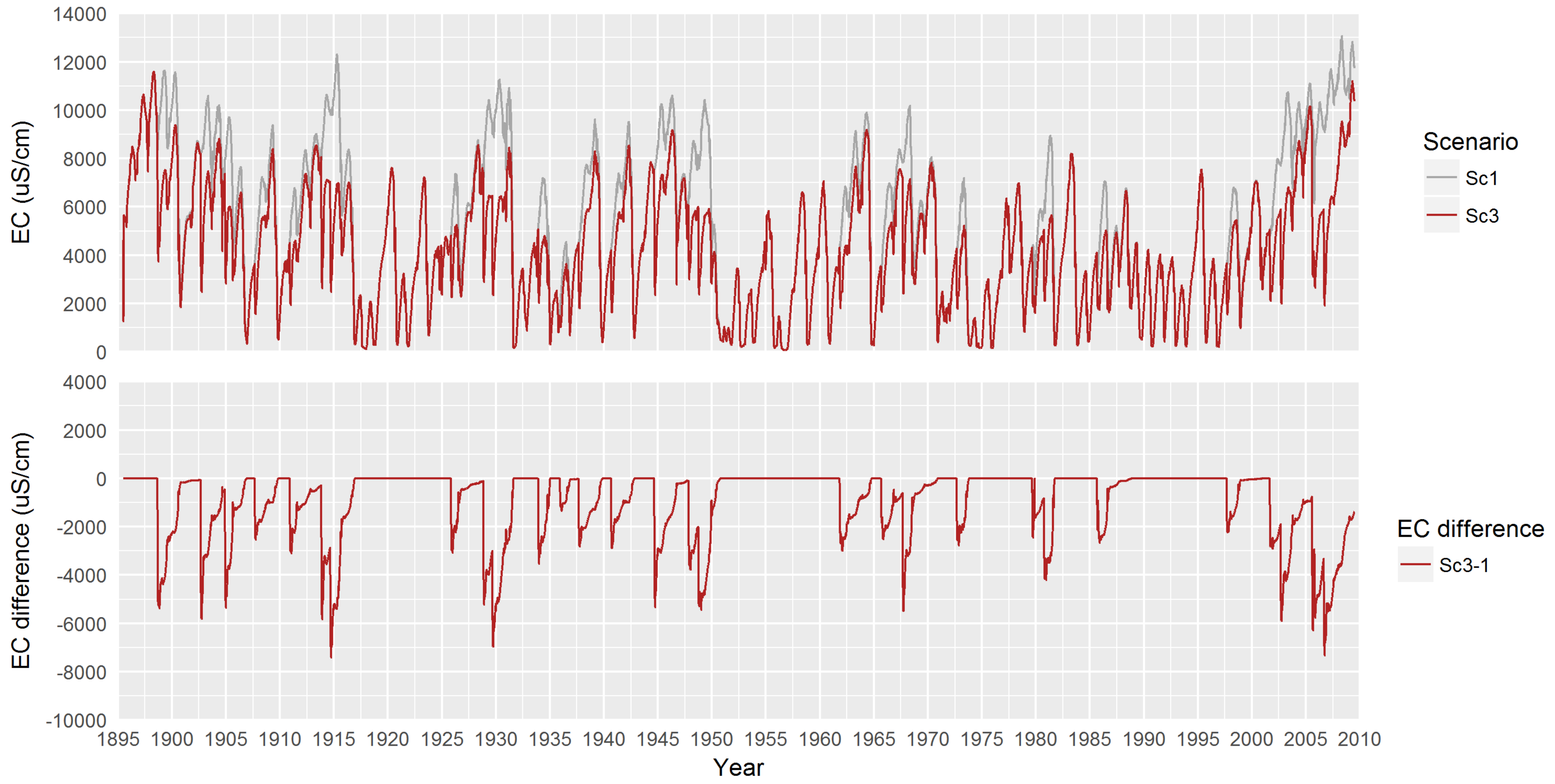


Figure B.10. Comparison of Scenario 3 (1 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at South Lake

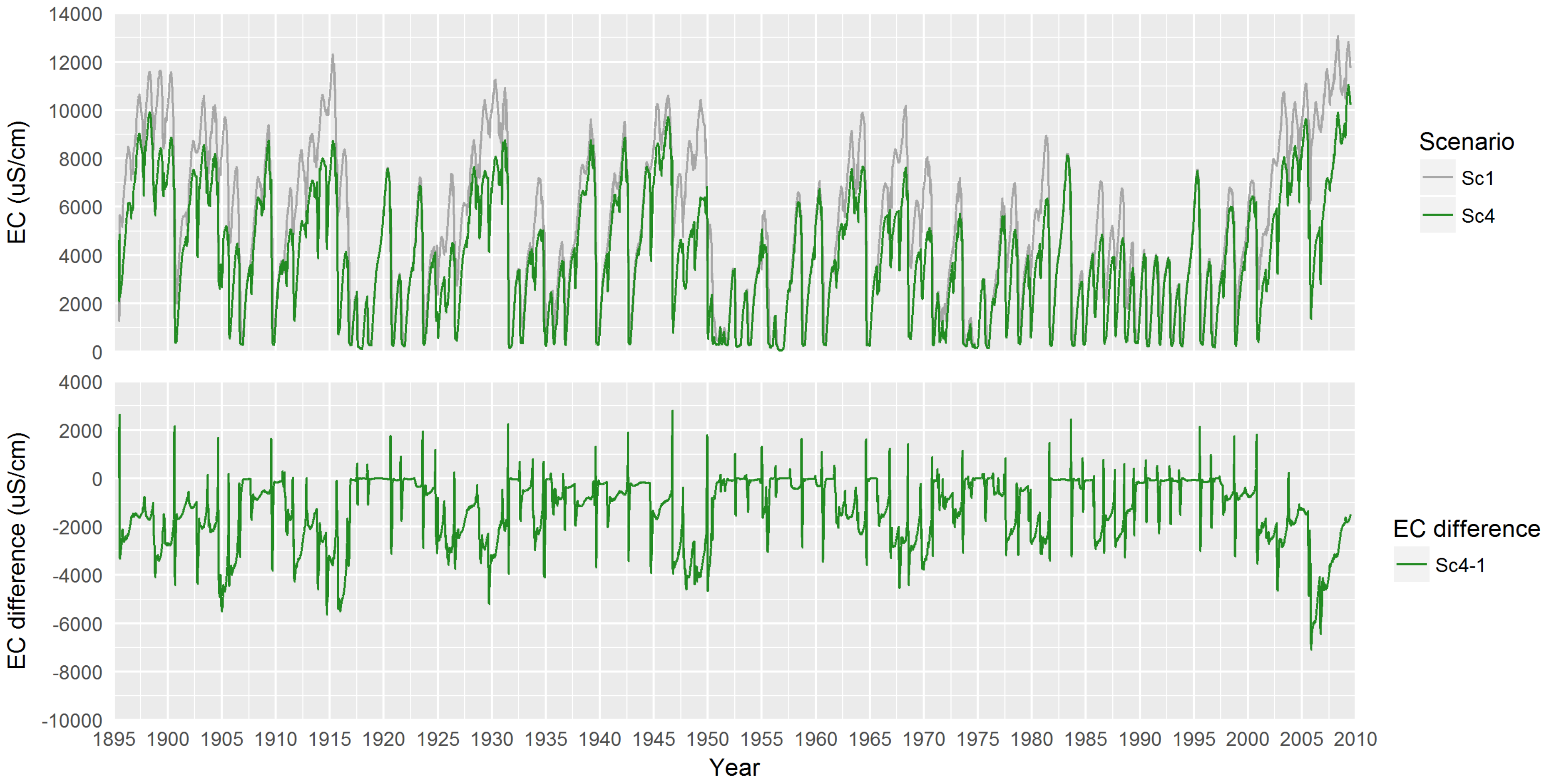


Figure B.11. Comparison of Scenario 4 (0.5 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at South Lake

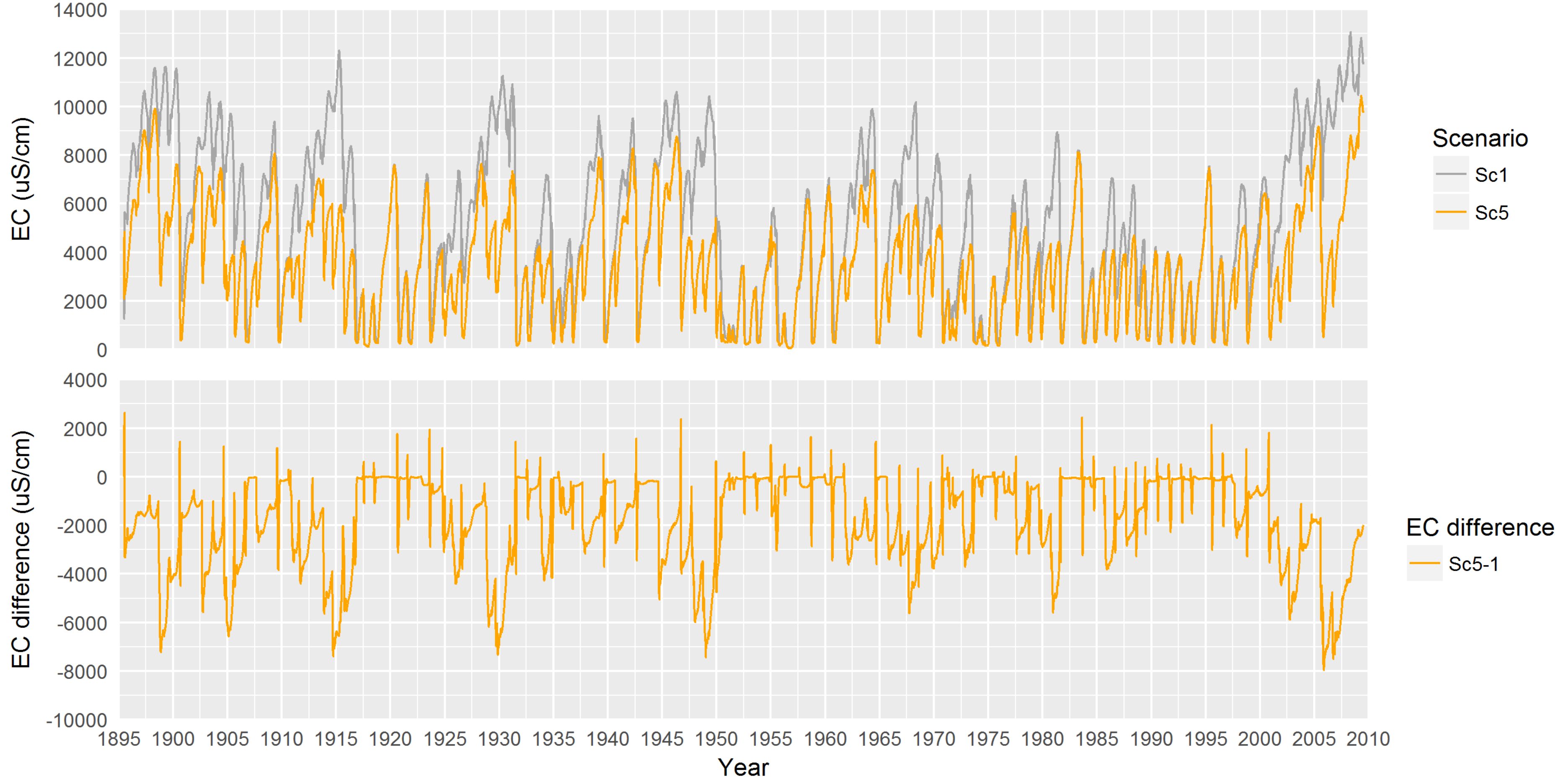


Figure B.12.Comparison of Scenario 5 (1 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at South Lake

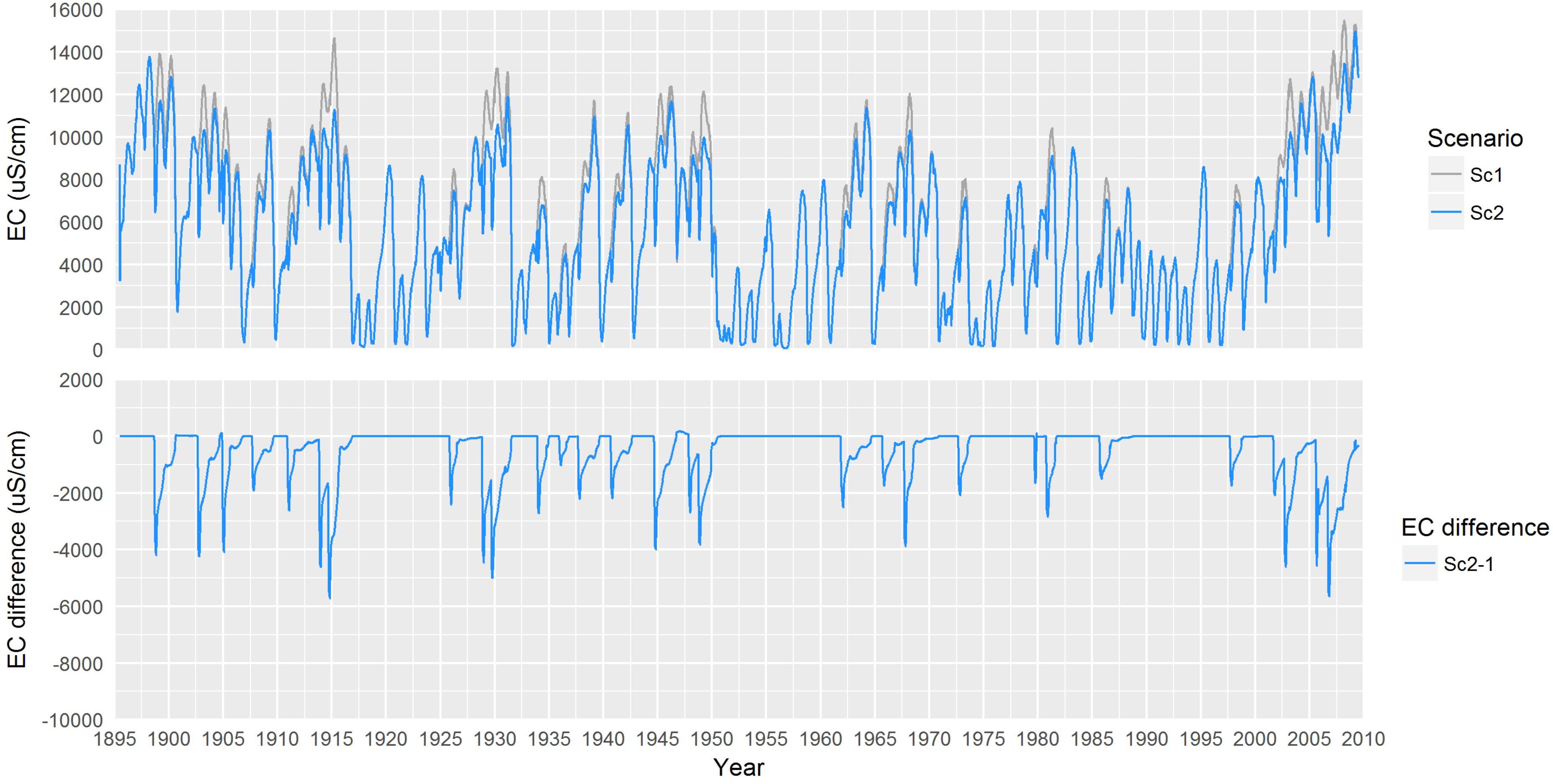


Figure B.13.Comparison of Scenario 2 (0.5 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at North Lake

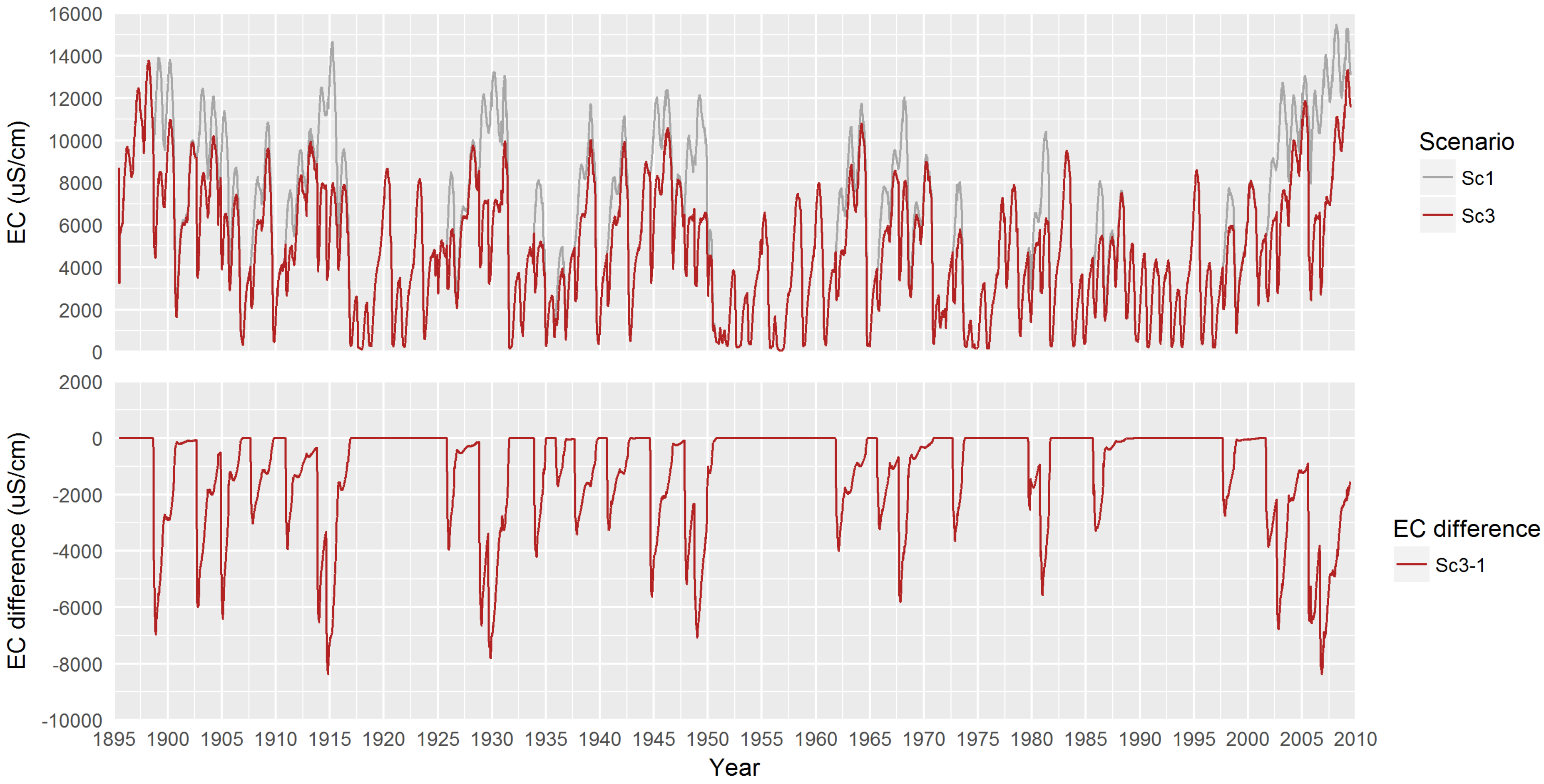


Figure B.14. Comparison of Scenario 3 (1 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at North Lake

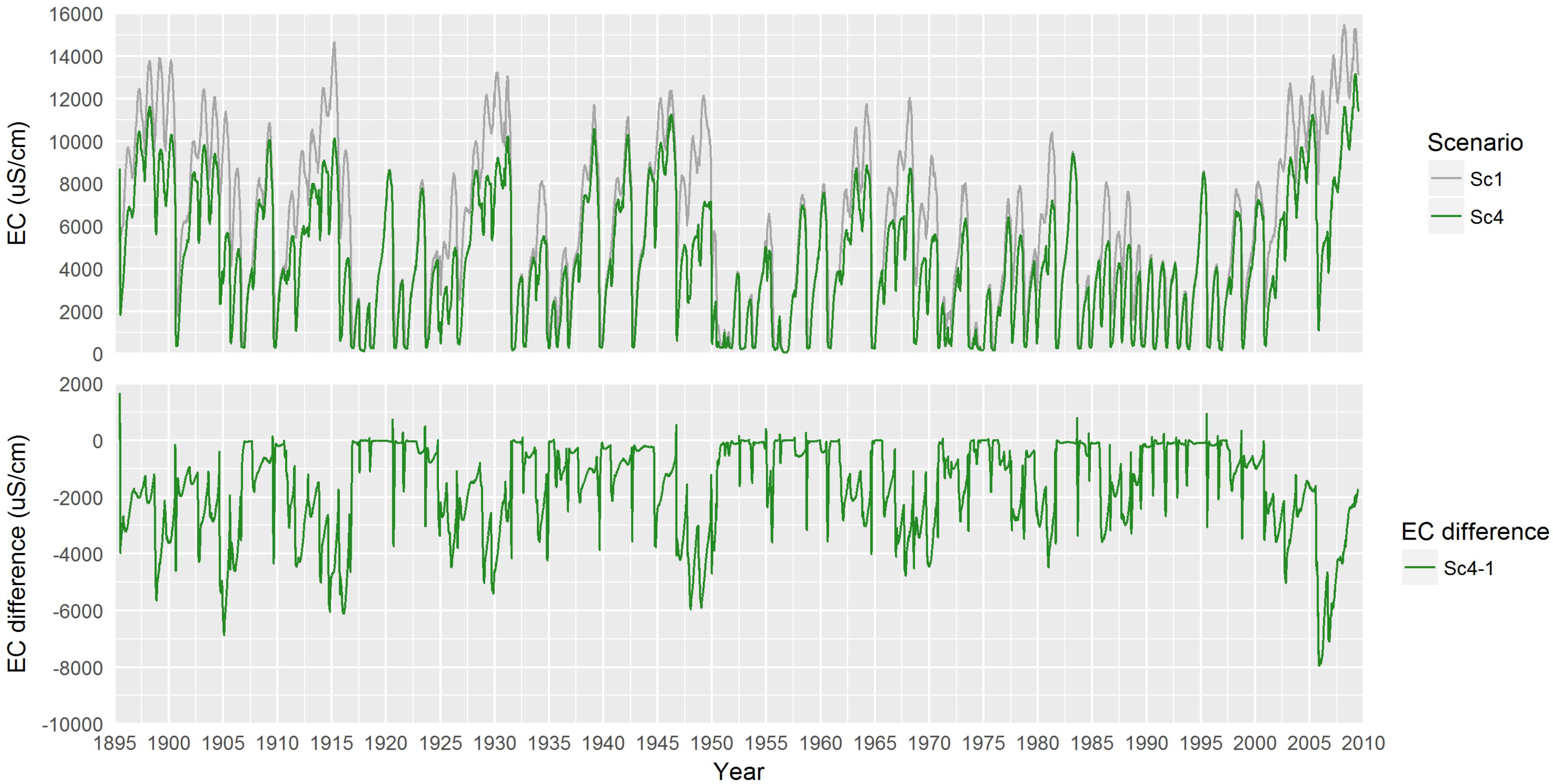


Figure B.15. Comparison of Scenario 4 (0.5 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at North Lake

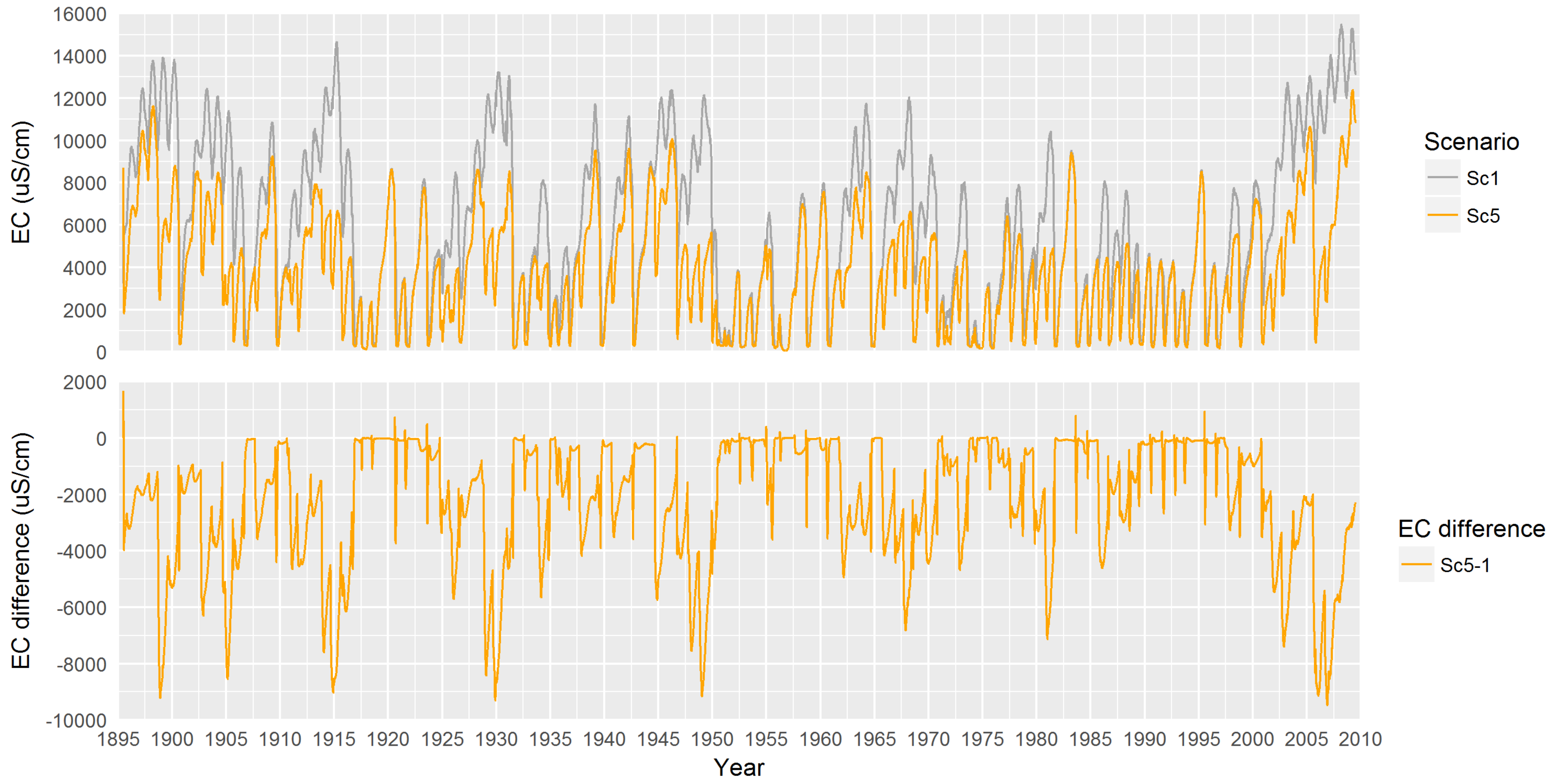


Figure B.16. Comparison of Scenario 5 (1 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at North Lake

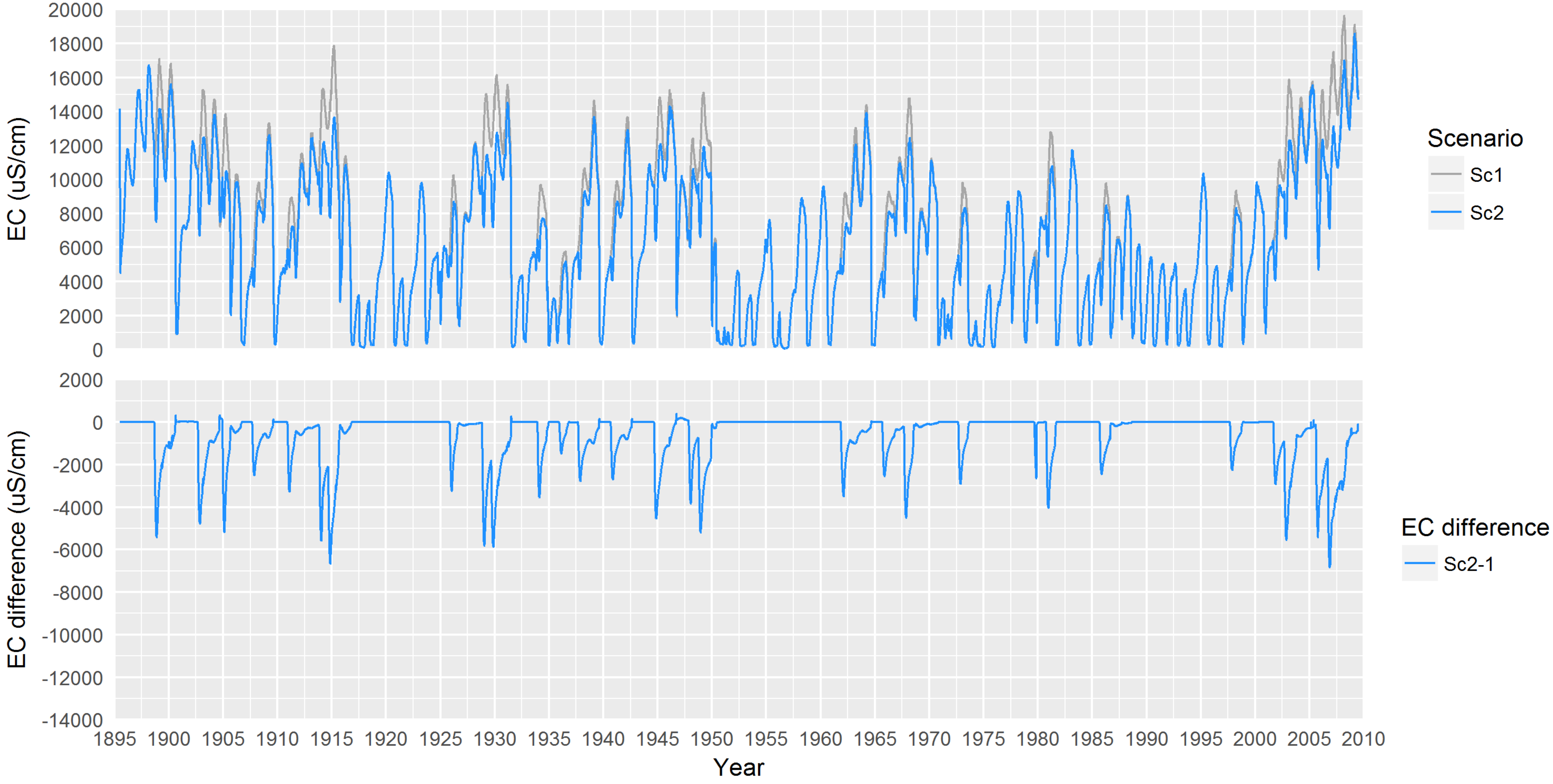


Figure B.17. Comparison of Scenario 2 (0.5 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at Upper Gurra Gurra

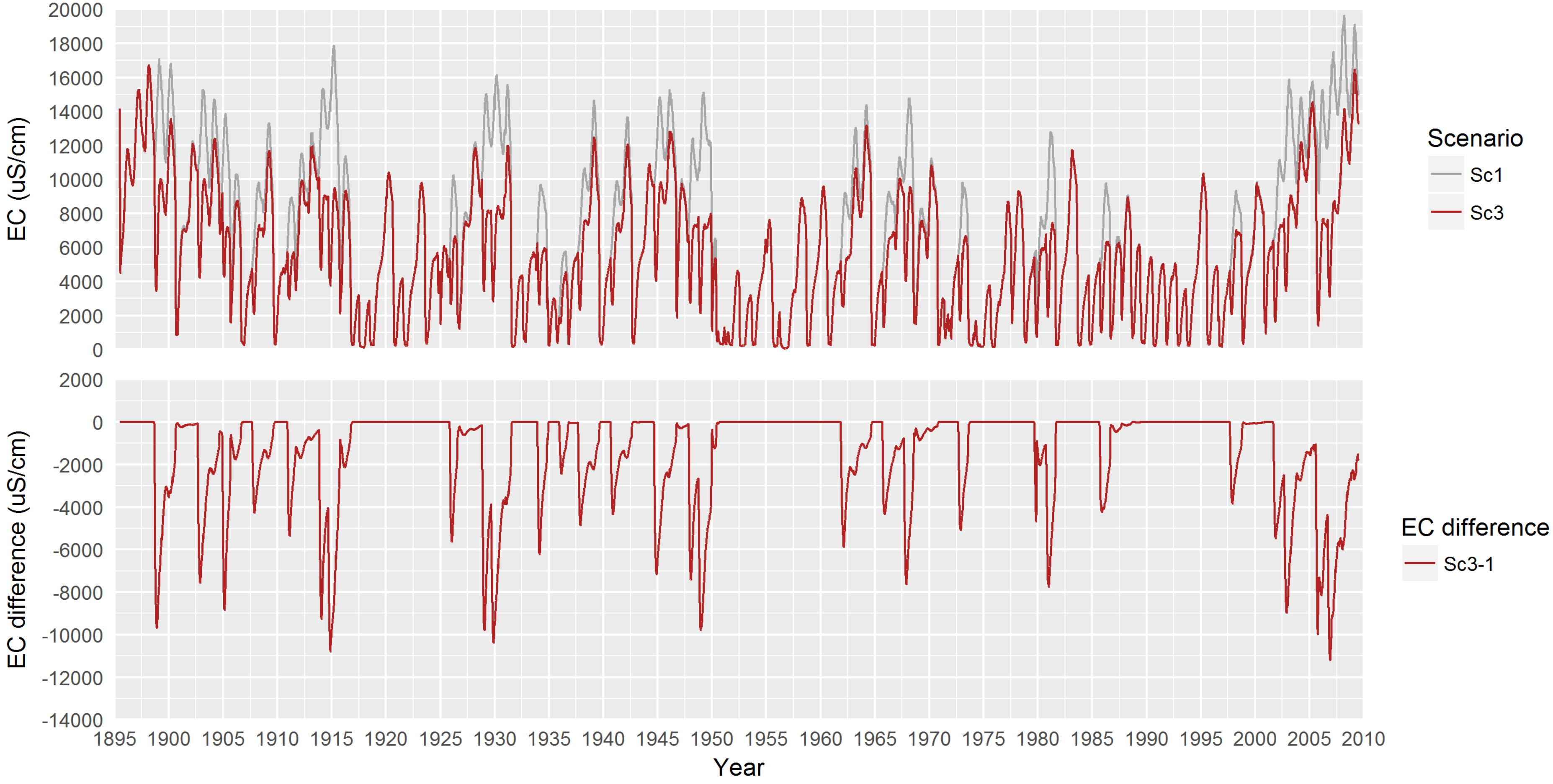


Figure B.18. Comparison of Scenario 3 (1 m weir pool raisings) with Scenario 1 (baseline) modelled EC results at Upper Gurra Gurra

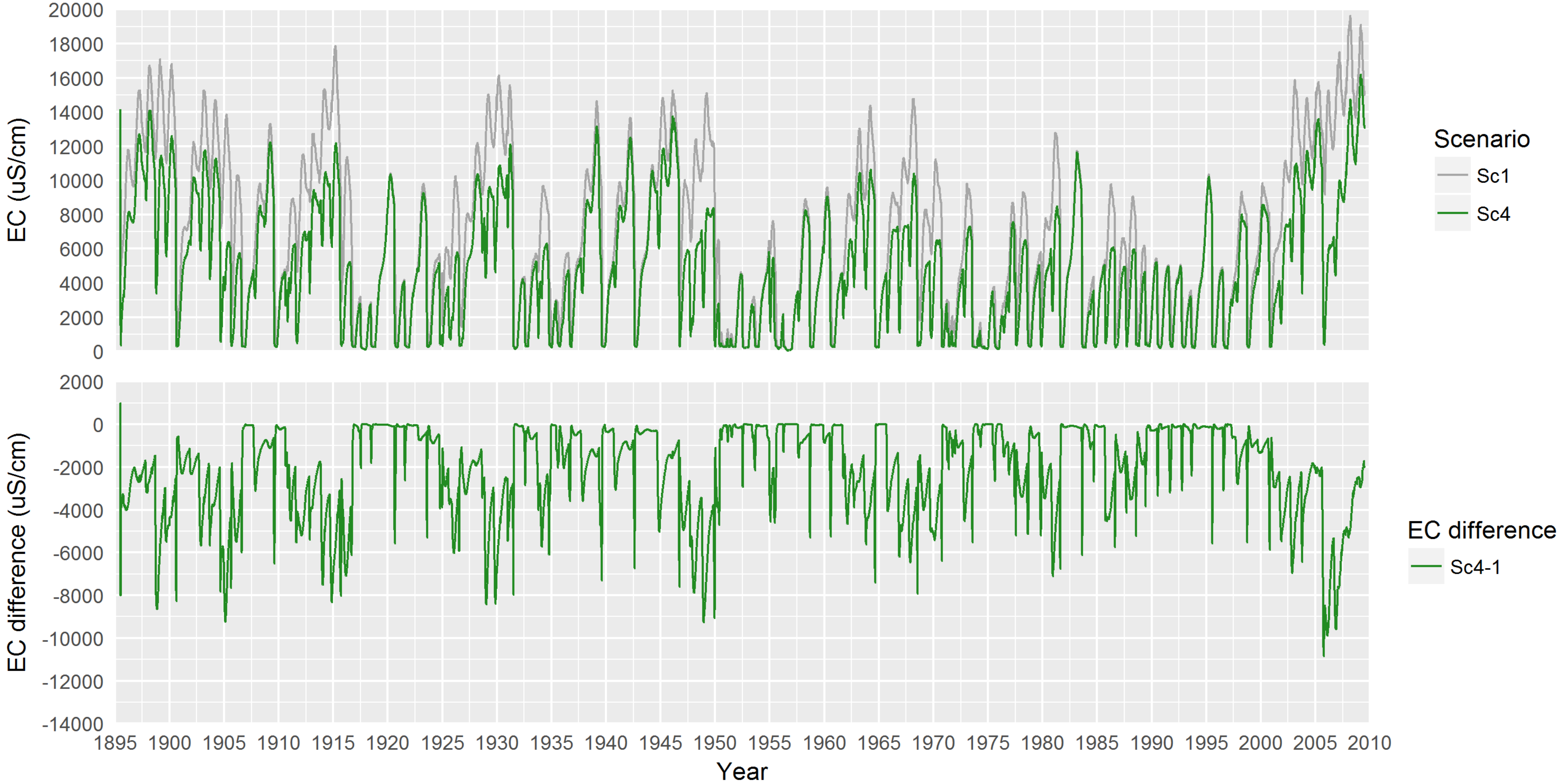


Figure B.19. Comparison of Scenario 4 (0.5 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at Upper Gurra Gurra

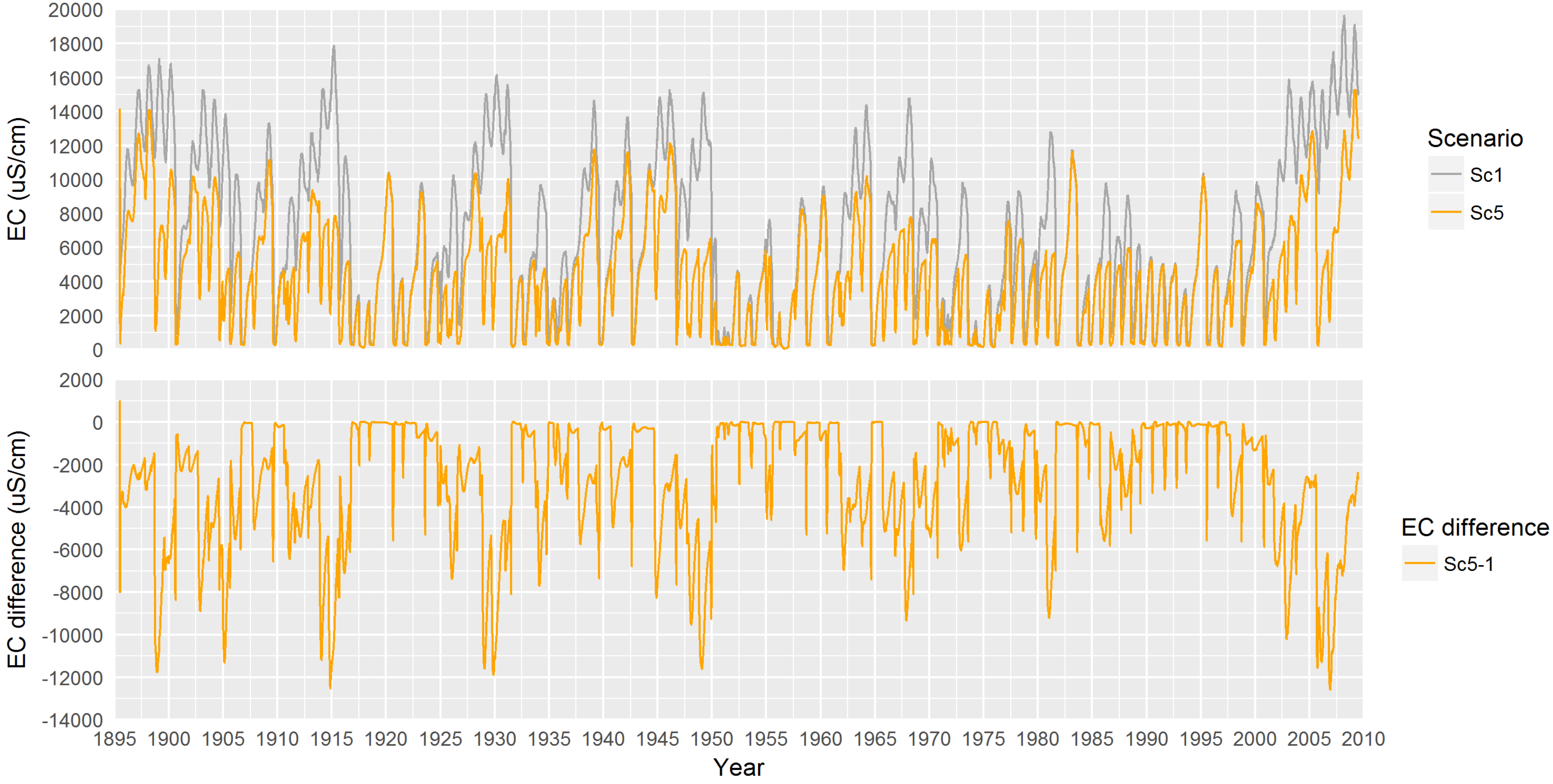


Figure B.20. Comparison of Scenario 5 (1 m weir pool raisings, Lyrup lowering) with Scenario 1 (baseline) modelled EC results at Upper Gurra Gurra

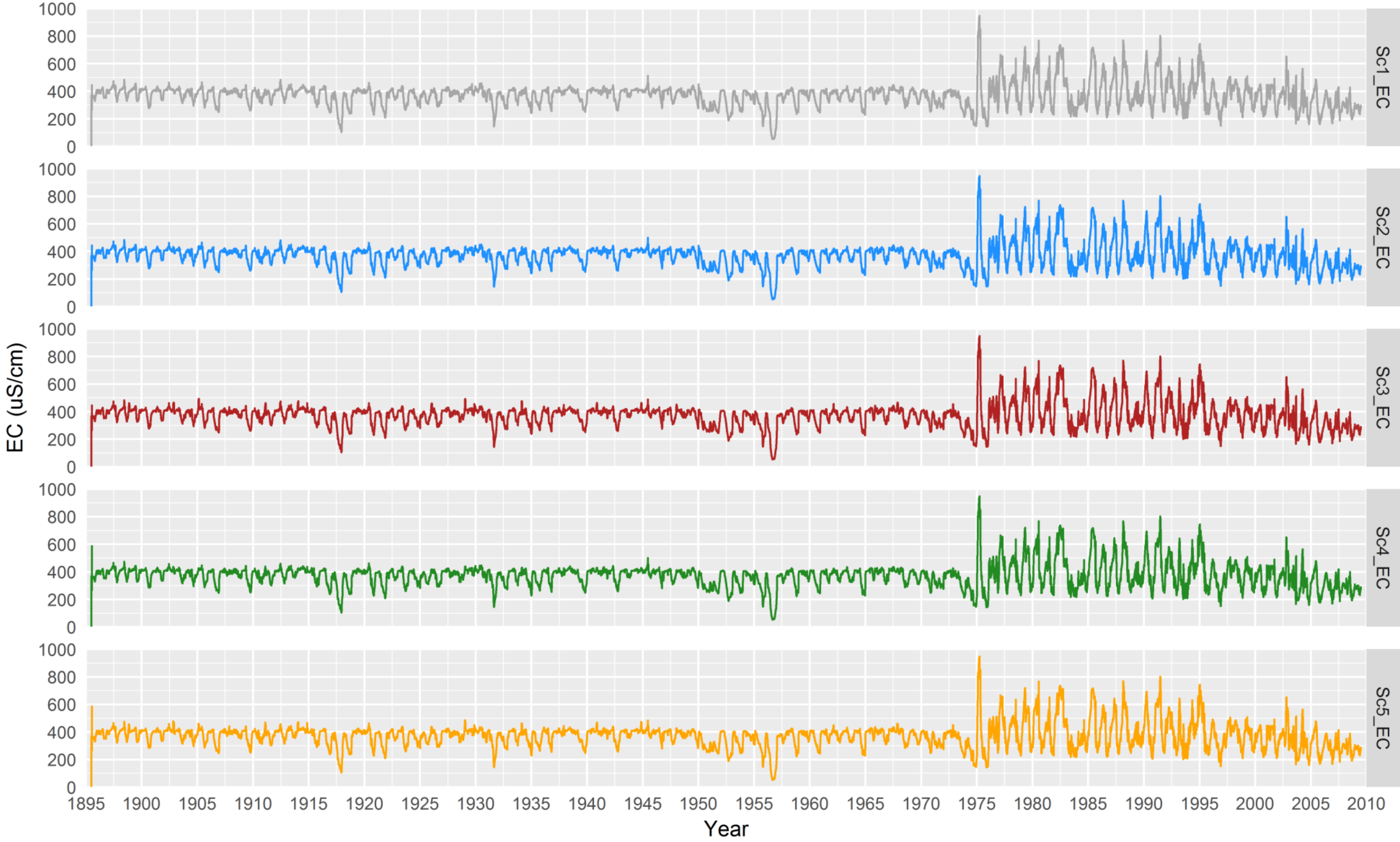


Figure B.21. Comparison of Scenario EC results at River Murray downstream of Gurra Gurra outlet