A Decision Support Framework for identifying optimal water supply portfolios: Metropolitan Adelaide Case Study

Volume 2: Appendices

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Foreword

This report is a companion document to Volume 1: Main Report,[1] and is to be read in conjunction with that report. It has been prepared as a separate document to allow for ease of publication.

[1] Maheepala, S., Dandy, G., Marchi, A., Mirza, F., Wenyan, W., Daly, R., Hewa, G., Neumann, L. Holger Maier, He, Y. and Shaun Thomas (2014), *A Decision Support Framework for identifying optimal water supply portfolios: Metropolitan Adelaide Case Study: Volume 1: Main Report*, Goyder Institute for Water Research Technical Report Series No. 14/17, Adelaide, South Australia.

Contents

List of Figures

List of Tables

Appendix 1 Rebuild of Metropolitan Adelaide Source Catchment Model

The catchment model developed as part of the Adelaide Coastal Water Quality Improvement Plan (WBM BMT, 2008), was chosen for the Optimal Water Resource Mix (OWRM) project to compute stormwater runoff from urban areas. This catchment model covered the entire study area of the OWRM project (Apx Figure 1-1). It was developed in the E2 modelling platform, which was the same platform used in the Source model used by the OWRM project. However, the following limitations were identified with regard to the catchment model of WBM BMT (2008):

- Sub-catchment boundary delineation was wrong in some areas;
- Node-link networks were not correct in the Sturt River and Brown Hill Creek catchments;
- Hydrology was calibrated using a single gauging station with factors applied for other regions which led to large areas with a poor hydrological calibration;
- Land use data needed to be updated to 2012 to better reflect the base scenario and current hydrological conditions; and
- Given the simulation model was setup to for a period of 50 years, climate data needed to be extended to 50 years.

Given the above limitations, a rebuild of the existing catchment model was considered necessary. This Appendix describes the model rebuild and calibration of the catchment model developed as part of the OWRM project.

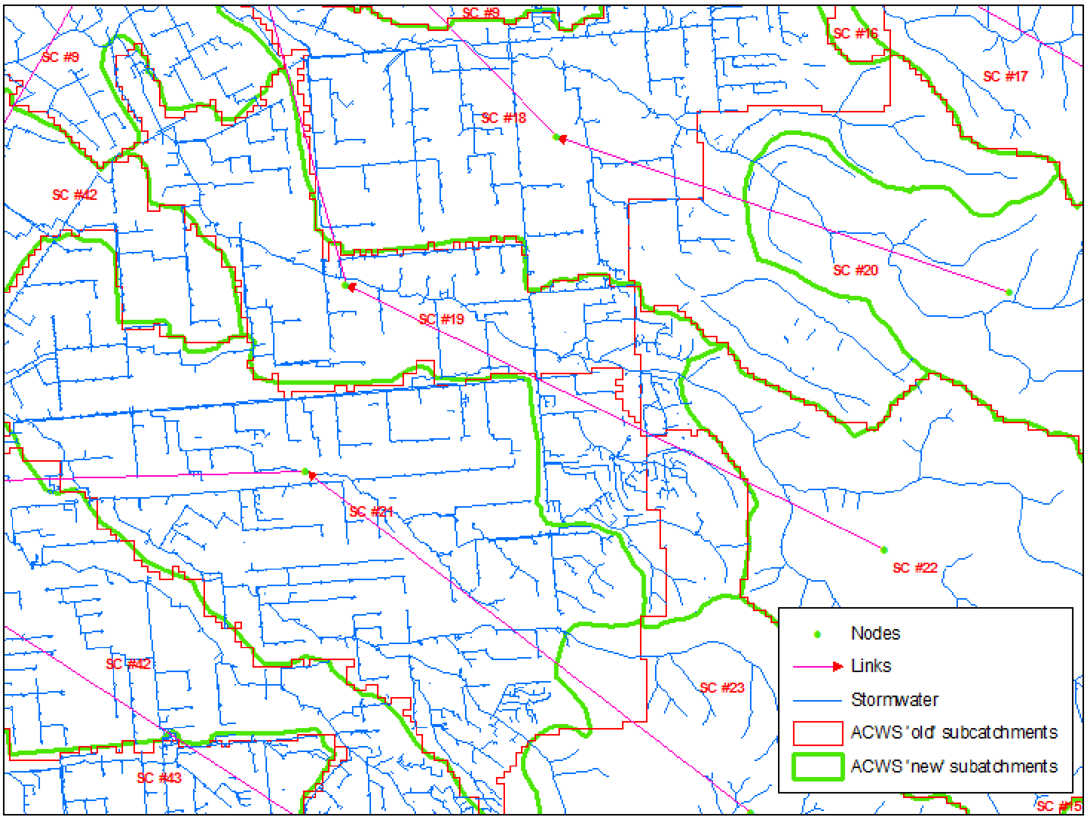
1.1 Catchment boundaries

The sub-catchments layer of catchment model developed by WBM BMT (2008) was derived from the GIS data available for major rural catchments from the Department of Environment, Water and Natural Resources (DEWNR). For the urbanised parts of the catchment, the sub-catchment boundaries were defined by using a hand-drawing method based on the stormwater drainage network. Upon reviewing the model, it was found that the sub-catchment boundaries in some areas were incorrectly defined. Additionally, there were several topological errors, such as gaps between adjacent polygons resulting in errors in catchment area. Apx Figure 1-2 and Apx Figure 1-3 highlights some of the issues identified in the existing sub-catchment boundaries (Apx Figure 1-1).

Apx Figure 1-1: Geographic extent of the study area

To better represent the actual catchment characteristics, a new sub-catchment layer was created by filling the gaps and correcting the boundaries. Also, several sub-catchments were split to enable the hydrological calibration. For example, the gauge A5040529 is located nearly end of the Torrens catchment, which captures most of the Torrens flow. As such, it was necessary to split the catchment above the gauge.

Apx Figure 1-4 illustrates the change in sub-catchments between the two versions of the catchment boundary layers. The existing layer (blue line) has 57 sub-catchments, while the new layer has 78 sub-catchments, with the additional catchments outlined with in red. It is important to note that the new sub-catchment ID number is different from the old sub-catchment ID (Apx Table 1-1).



Apx Figure 1-2: Issues related to sub-catchment boundaries definition (e.g. see SC#19 and SC#21)

1.2 Stream node-link network

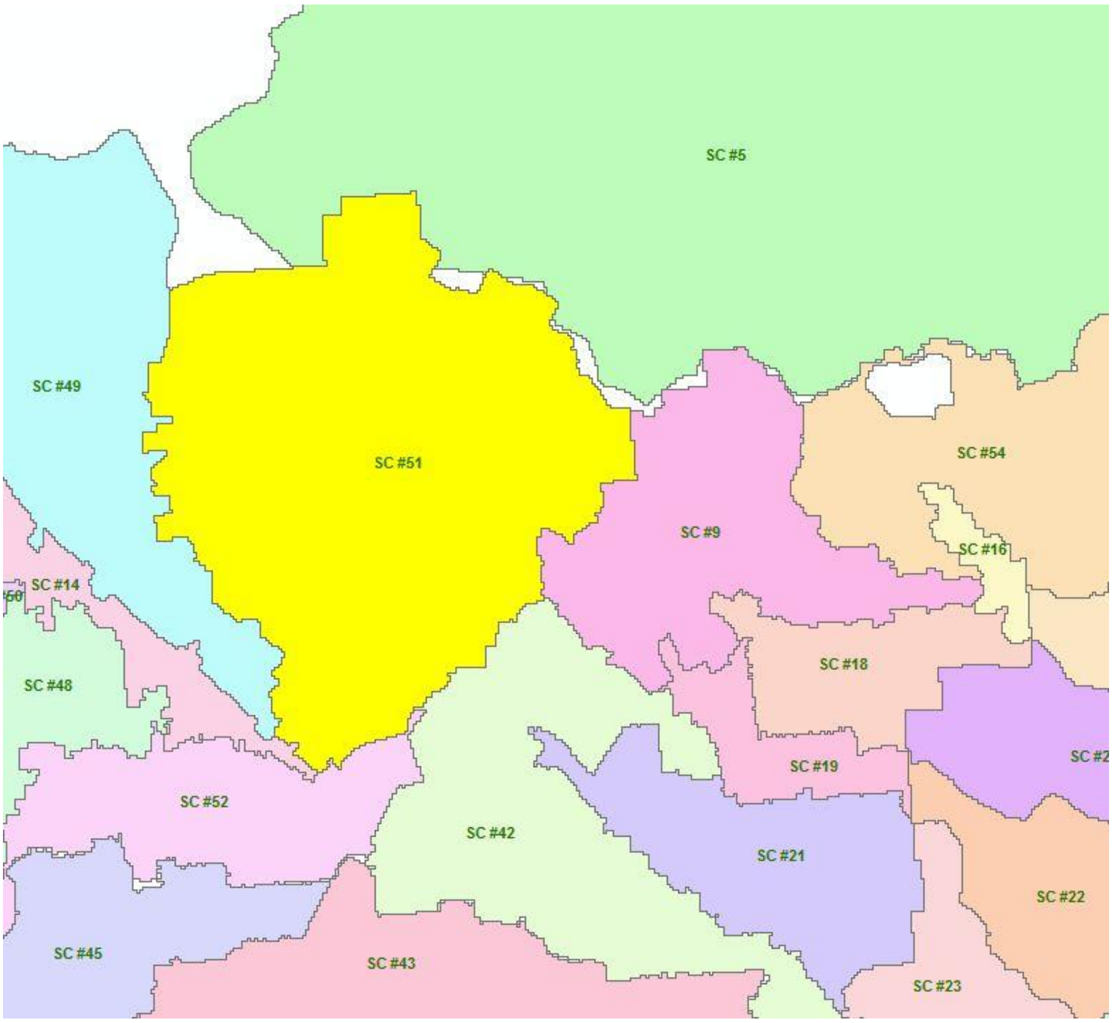
The stream node-link network of the Catchment model of WBM BMT (2008) was generated using the manual drawing method. However, issues were identified in the Sturt River and Brownhill Creek catchments, with a mismatch between the flow direction from gauge A5040583 and the node-link network on the old model (see Apx Figure 1-5). The flow direction of the Brownhill Creek is from SC#26 to SC#46 rather than to SC#53. Also, water should flow from SC#46 to the outlet. Thus, a modified node-link network was generated, shown in Apx Figure 1-6, to more accurately reflect the actual node – link network.

1.3 Updating land uses

The land use dataset used in the Catchment model of WBM BMT (2008) was the 2003 land uses. To represent the current land use condition, an update to the land use data was essential. Hence the most recent land use dataset that represented 2012 land uses was obtained from the Department of Planning, Transport and Infrastructure (DPTI). This layer was created based on the valuation information and the valuation parcel boundaries, thus a parcel can have multiple valuations over it. It means one polygon can have multiple land use classes associated which could result in a duplicated area calculation. For catchment modelling purposes, each polygon can only have one land use type associated with it. To fix this issue, the most recent aerial photo obtained from Nearmap (http://nearmap.com/au) was used to identify and ground truth the main land use, leading to the extra land use classes being manually deleted in ArcGIS.

In addition, the 2012 land use layer has unmapped areas. The 2008 land use dataset from DEWNR was applied to fill the gaps.

The functional units used for the new Catchment model are similar to the Catchment model of WBM BMT (2008), with only a few minor changes to categories. For example, Commercial/High Density was changed to Commercial; 'Unspecified_OpenSpace' was changed to 'Open Space'; a new functional unit – 'WWTP' was created. Apx Table 1-2 outlines the functional units applied in the new Catchment model. In addition, the areal calculation for each land use class shown in the Catchment model of WBM BMT (2008) was incorrect, see Table 4-1 on Page 19 (WBM BMT, 2008).



Apx Figure 1-3: Topologic errors, such as gaps between SC#5 and SC#51

Apx Table 1-1: New sub-catchment ID vs Old sub-catchment ID

CATNAME	SUBNAME	NewSUBID	OldSUBID
Smith & Adams Creeks	Smith & Adams Creeks	SC# 1	SC #3
Dry & Cobbler Creeks	Dry & Cobbler Creeks	SC# 2	SC #5
Port Adelaide	Port Adelaide	SC# 3	SC #6
Holdfast Bay	Holdfast Bay	SC# 4	SC #56
Hallett Cove	Hallett Cove	SC# 5	SC #32
Field River	Field River	SC# 6	SC #31
Curlew Point	Curlew Point	SC# 7	SC #34
Christie Creek	Christie Creek	SC# 8	SC #35
Pedler Creek	Peder Creek	SC# 9	SC #37
Ingleburne Creek	Wirra Creek	SC# 10	SC #38
Willunga Creek	Willunga Creek	SC# 11	SC #39
Silver Sands	Silver Sands	SC# 12	SC #40
Black Hill	Black Hill	SC# 13	SC #41

CATNAME	SUBNAME	NewSUBID	OldSUBID
Gawler River	Turretfield	SC# 14	SC #55
Gawler River	Greenock Creek	SC# 15	SC #55
Gawler River	Duck Ponds Creek	SC# 16	SC #55
Gawler River	Baraossa Valley	SC# 17	SC #55
Gawler River	Flaxrran Valley	SC# 18	SC #55
Gawler River	Taunda Creek	SC# 19	SC #55
Gawler River	Jacob Creek	SC# 20	SC #55
Gawler River	Lyndoch Creek	SC# 21	SC #55
Gawler River	Gawler River Channel	SC# 22	SC #55
Gawler River	South Para	SC# 23	SC #2
Gawler River	Tenafeate Creek	SC# 24	SC #2
Little Para River	Lower Little Para River	SC# 25	SC #4
Salt & Templers Creeks	Salt & Templers Creeks	SC# 26	SC #1
Onkaparinga River	Scott Creek	SC# 27	SC #29
Onkaparinga River	Chandlers Hill	SC# 28	SC #33
Onkaparinga River	Clarendon Weir	SC# 29	SC #33
Onkaparinga River	Lower Onkaparinga River	SC# 30	SC #33
Onkaparinga River	Peter Creek	SC# 31	SC #36
Torrens River	Sixth Creek	SC# 32	SC #15
Torrens River	Fifth Creek	SC# 33	SC #17
Torrens River	Fourth Creek	SC# 34	SC #20
Torrens River	Third Creek	SC# 35	SC #22
Torrens River	Second Creek	SC# 36	SC #23
Torrens River	First Creek	SC# 37	SC #25
Patawalonga Basin	Upper Brownhill Creek	SC# 38	SC #26
Patawalonga Basin	Upper Sturt River	SC# 39	SC #57
Patawalonga Basin	Central Sturt River	SC# 40	SC #57
Patawalonga Basin	Chambers Creek	SC# 41	SC #57
Patawalonga Basin	Brownhill Creek #1	SC# 42	SC #43
Torrens River	Lower Second Creek	SC# 43	SC #21
Patawalonga Basin	Sturt River	SC# 44	SC #53
Patawalonga Basin	Airport Drain	SC# 45	SC #45
Torrens River	Lower Sixth Creek	SC# 46	SC #10
Torrens River	Torrens River #1	SC# 47	SC #8
Torrens River	Torrens River #2	SC# 48	SC #54
Torrens River	Lower Fifth Creek	SC# 49	SC #16
Torrens River	Torrens River #3	SC# 50	SC #54

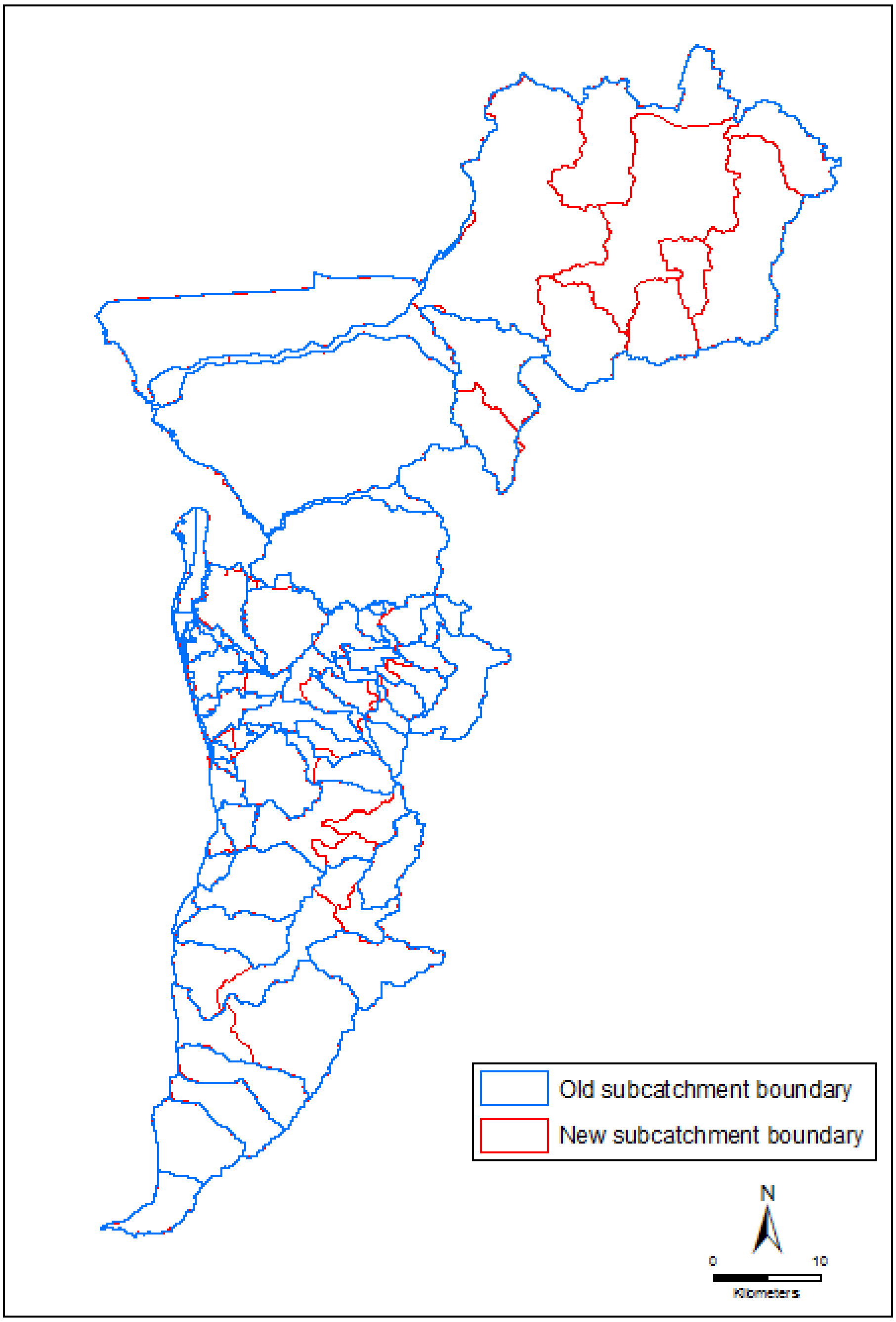
CATNAME	SUBNAME	NewSUBID	OldSUBID
Torrens River	Lower Fourth Creek	SC# 51	SC #18
Torrens River	Torrens River #4	SC# 52	SC #9
Port Adelaide	Port Adelaide #1	SC# 53	SC #51
Torrens River	Lower Third Creek	SC# 54	SC #19
Torrens River	Torrens River #5	SC# 55	SC #52
Port Adelaide	Port Adelaide #2	SC# 56	SC #49
Port Adelaide	Port Adelaide #3	SC# 57	SC #48
Port Adelaide	Port Adelaide #4	SC# 58	SC #14
Port Adelaide	Port Adelaide #5	SC# 59	SC #50
Torrens River	Lower First Creek	SC# 60	SC #42
Port Adelaide	Port Adelaide #6	SC# 61	SC #7
Port Adelaide	Port Adelaide #7	SC# 62	SC #13
Port Adelaide	Port Adelaide #8	SC# 63	SC #12
Patawalonga Basin	Centre Brownhill Creek	SC# 64	SC #26
Patawalonga Basin	Brownhill Creek #2	SC# 65	SC #44
Patawalonga Basin	Lower Brownhill Creek #1	SC# 66	SC #46
Patawalonga Basin	Patawalonga Basin #1	SC# 67	SC #28
Patawalonga Basin	Lower Sturt River	SC# 68	SC #53
Holdfast Bay	Holdfast Bay #1	SC# 69	SC #30
Holdfast Bay	Holdfast Bay #2	SC# 70	SC #47
Patawalonga Basin	Patawalonga Basin #2	SC# 71	SC #24
Patawalonga Basin	Patawalonga Basin #3	SC# 72	SC #27
Torrens River	Torrens River #6	SC# 73	SC #52
Port Adelaide	Port Adelaide #9	SC# 74	SC #11
Gawler River	Gawler River	SC# 75	SC #55
Patawalonga Basin	Lower Brownhill Creek #2	SC# 76	SC #46
Pedler Creek	Lower Peder Creek	SC# 77	SC #37
Onkaparinga River	Onkaparinga River Outlet	SC# 78	SC #33

Apx Table 1-2: Functional unit classification

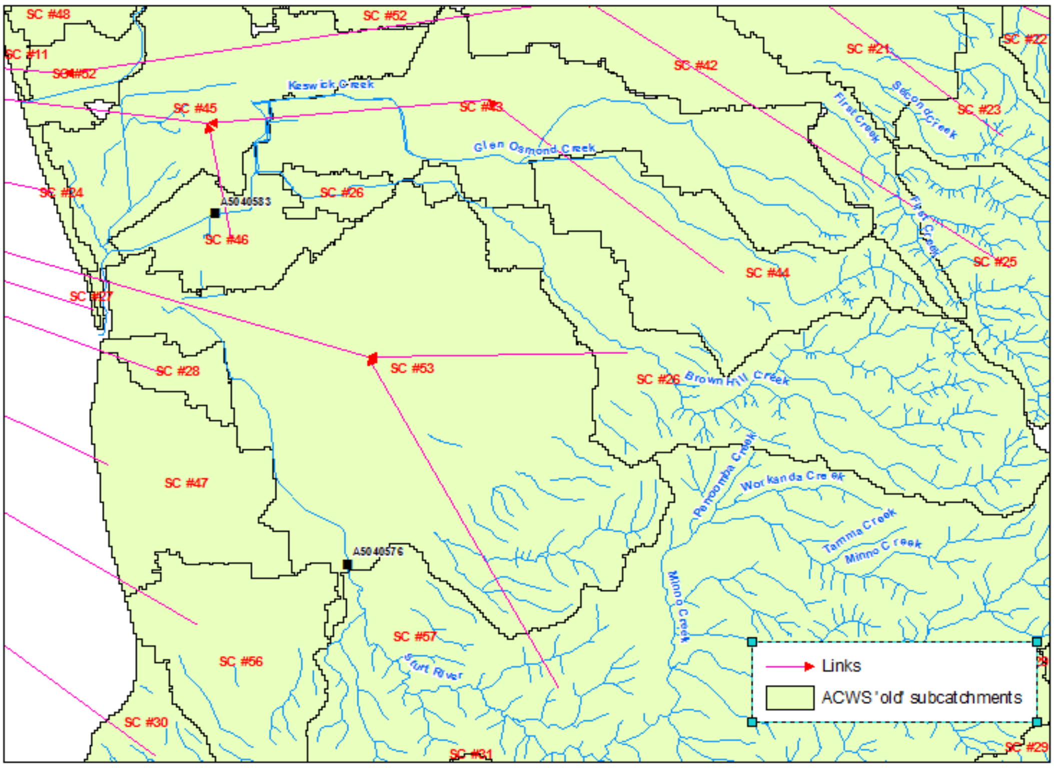
Landuse Class	Functional Unit	Area (ha)	% of Land use
COMMERCIAL	Commercial	2699	1.01
EDUCATION	Commercial	2209	0.82
PUB_INSTITUTION	Commercial	2703	1.01
RET_COMMERCIAL	Commercial	1581	0.59
SERVICES	Commercial	59	0.02
FORESTRY	Forestry	28274	10.54

Landuse Class	Functional Unit	Area (ha)	% of Land use
RESERVE	Forestry	5970	2.23
AGRICULTURE	Horticulture/Ag	26574	9.91
HORTICULTURE	Horticulture/Ag	30244	11.28
FOOD_INDUSTRY	Industry	849	0.32
INDUSTRIAL	Industry	17	0.01
UTIL_INDUSTRY	Industry	5804	2.16
LIVESTOCK	Livestock	62128	23.17
MINE_QUARRY	Mining	2443	0.91
GOLF	Open space	1206	0.45
RECREATION	Open space	3299	1.23
VACANT	Open space	3147	1.17
RESIDENTIAL NATIVE COVER	Open space	50	0.02
ROAD	Road	21679	8.08
RURAL_RESID	Rural living	24860	9.27
NONPRIVATE_RESID	Urban	564	0.21
RESIDENTIAL	Urban	30984	11.55
VACANT_RESID	Urban	3719	1.39
WWTP	WWTP	1178	0.44
BEACH	Water	10	0.00
RESERVIORS	Water	241	0.09
WATER	Water	5657	2.11
Total		268,151	100.00

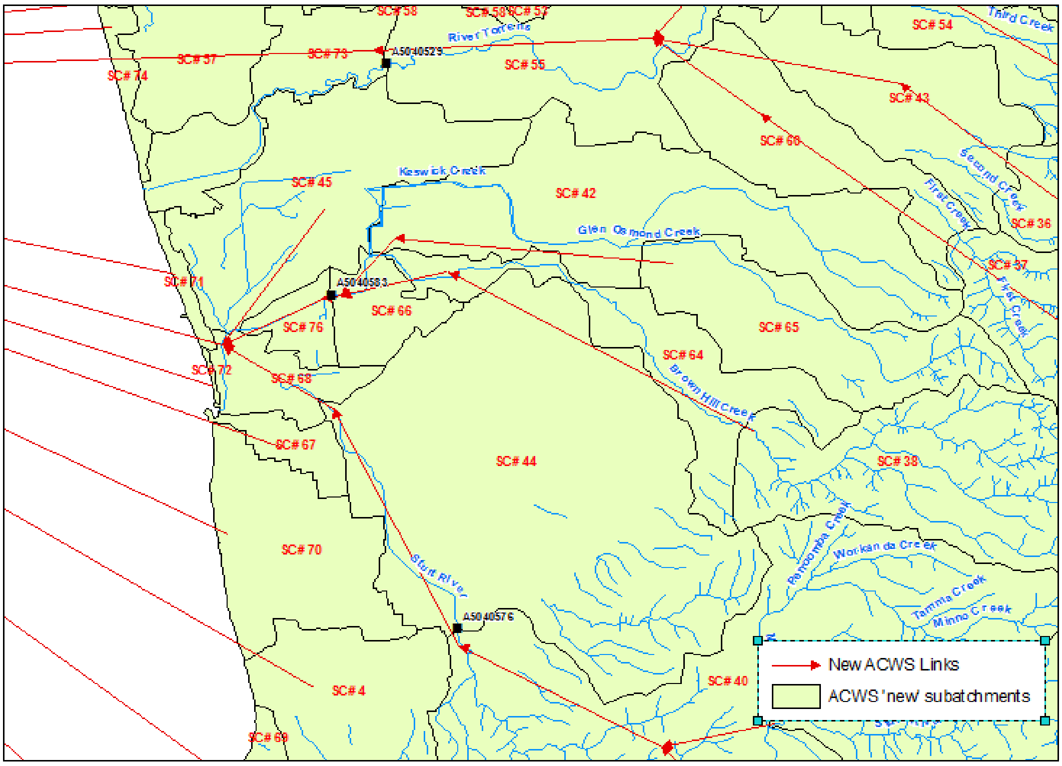
In addition, for future land-use scenarios (2025 and 2050), the urban growth area was required. This information was based on the GIS layer supplied by DPTI which was created for the Greater Adelaide 30 years Plan project and provides growth scenarios for 2025 and 2040. For this project the 2040 data was used for the 2050 scenario. Apx Figure 1-7 shows the future urban growth area in the study area, mainly located in the northern sub-catchments. This GIS layer was integrated with the 2012 land-use data to generate the 2025 and 2050 urban areas in relevant sub-catchments, as shown in Apx Figure 1-7.



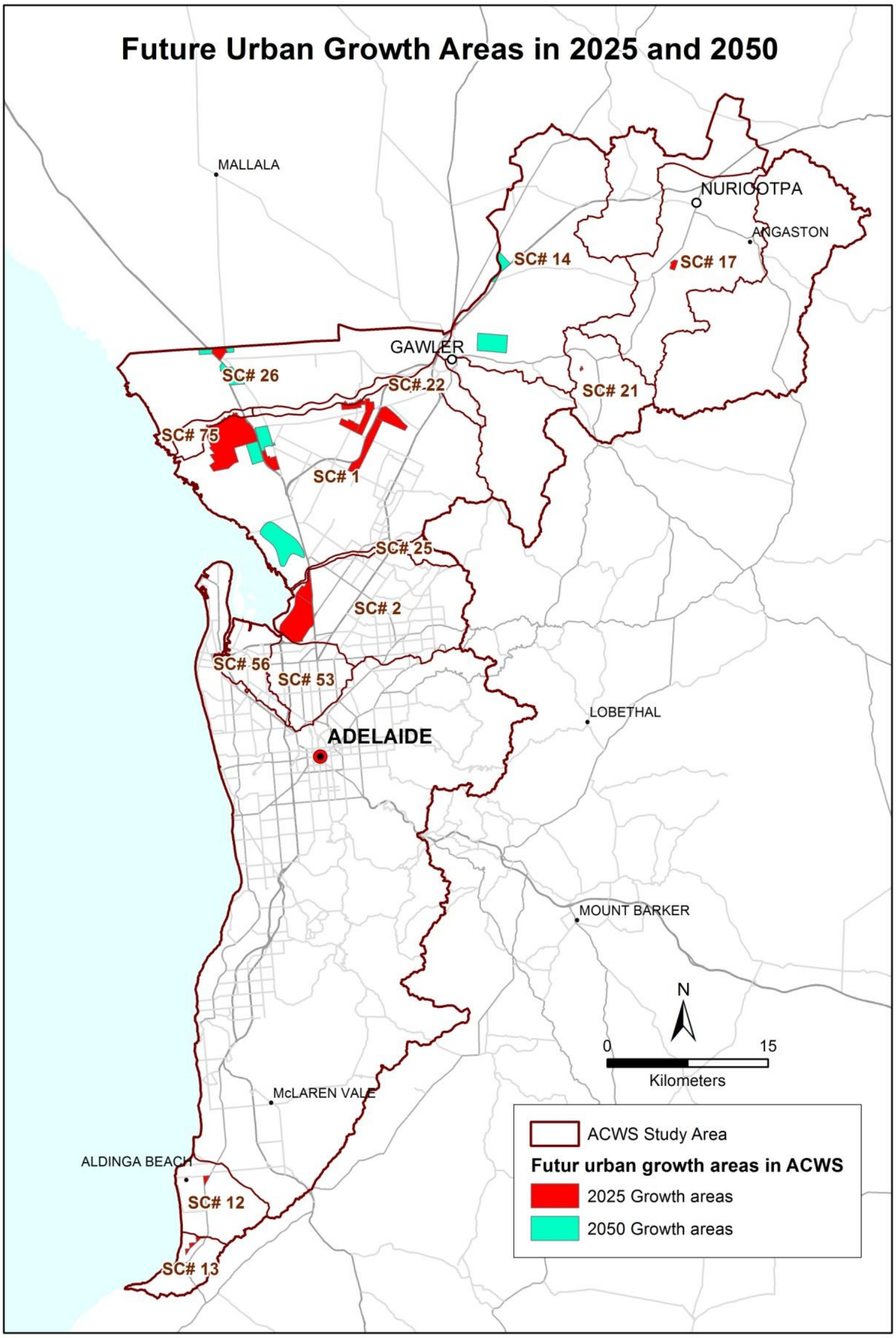
Apx Figure 1-4: Difference in the two versions of sub-catchments layers



Apx Figure 1-5: Incorrect Node-Link network



Apx Figure 1-6: Modified Node-Link network



Apx Figure 1-7: Future urban growth areas

1.4 Hydrological calibration: existing model

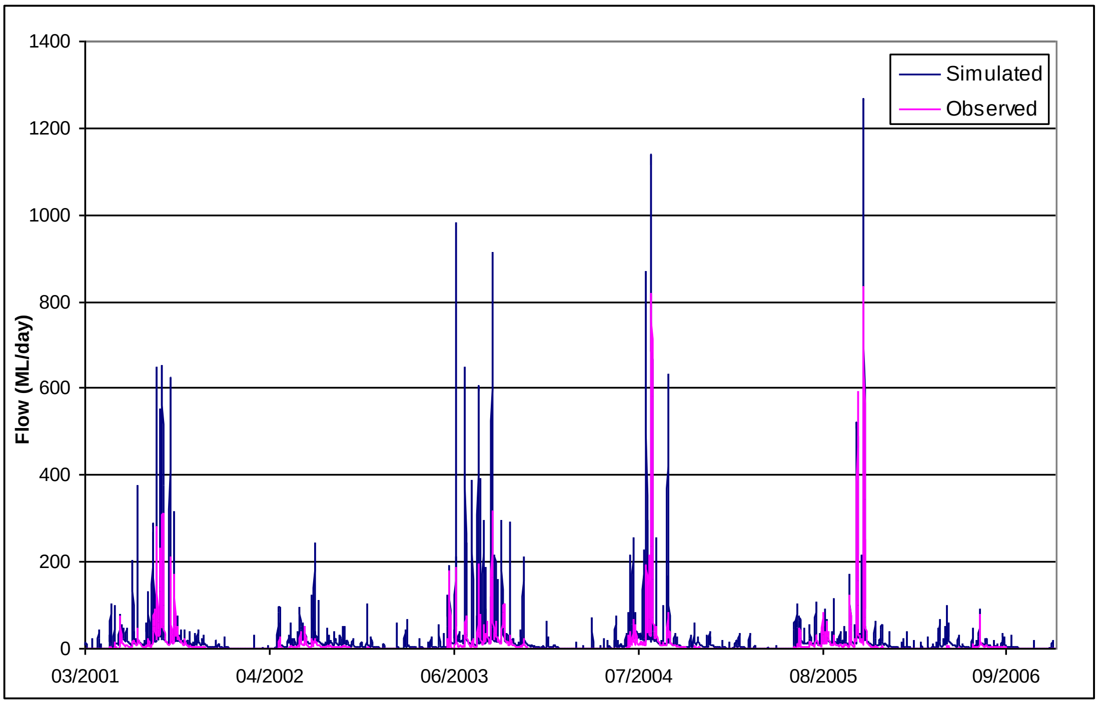
The Catchment model of WBM BMT (2008) was calibrated using the Rainfall-Runoff Library (RRL) tool with only one functional unit based on the monthly flow time series. When revisiting the model, several newer gauges were available and were chosen to validate the model performance. The daily Nash Sutcliff Efficiency (NSE) (Nash and Sutcliff, 1970) values for validation of the gauges and the difference in the flow volumes are shown in Apx Table 1-4, while Apx Figure 1-8 shows the daily observed and predicted stream flow from the gauge A5030503.

It can be seen from the above results that the calibration was unsatisfactory at most of the gauges, with poor NSE values and significant flow biases between observed and simulated flow volume. Therefore, in addition to rebuilding the model, a new hydrological calibration was undertaken to improve the model performance at several gauges.

Apx Table 1-3: Future urban growth areas

Location[1]	2012 Urban (ha)	2025 Urban (ha)	Urban Growth in 2025 (%)	2050 Urban (ha)	Urban Growth in 2050 (%)
SC #1	3596	6327	8.29%	7540	11.97%
SC #2	4952	6001	7.38%	6001	7.38%
SC #75	0	63	5.64%	63	5.64%
SC #14	478	492	0.06%	1079	2.58%
SC #26	107	218	0.66%	518	2.44%
SC #13	73	117	1.79%	117	1.79%
SC #22	307	346	1.39%	346	1.39%
SC #12	385	419	0.73%	419	0.73%
SC #25	216	222	0.47%	222	0.47%
SC #17	639	684	0.29%	684	0.29%
SC #21	108	118	0.16%	118	0.16%
SC #53	1832	1836	0.09%	1836	0.09%
SC #56	1045	1046	0.02%	1046	0.02%

Note 1: the location is defined in terms of the sub-catchment



Apx Figure 1-8: Observed vs simulated (existing model) flow for Gauge A5030503

Apx Table 1-4: Validation results from the existing model

Gauge	Location	Daily NSE	Total volume difference (%)	Validation Period
A5050505	Gawler River	0.24	104%	1/01/1987 -01/07/2004
A5031005	River Torrens	-7.23	73%	25/05/2006-30/04/2007
A5040583	Brown Hill Creek	0.5	-32%	13/03/1997-1/03/2007
A5040576	Sturt River	0.51	4%	1/1/1995-01/03/2007
A5030503	Onka River	-1.15	125%	24/03/2001-31/12/2006

1.5 Hydrological calibration: new model

In order to maintain a similar structure to WBM BMT (2008)'s model, SIMHYD (Chiew *et al.*, 2002) was used as the hydrological model for streamflow modelling. SIMHYD is a lumped daily rainfall–runoff model with 7 parameters which uses a series of interconnected water stores and algorithms to represent the hydrological processes responsible for the movement of water into and out of the stores and the production of runoff as quick flow or baseflow. Previous studies in the neighbouring Mount Lofty Ranges catchments have shown that SIMHYD perform well for most catchments in that study (Fleming *et al.*, 2012).

1.5.1 Gauge data

Gauged data for model calibration were obtained from the Adelaide and Mount Lofty Ranges (AMLR) Natural Resources Management Board[2] and from DEWNRs WaterConnect website[3]. As the AMLR data is accumulated to 9 am and the WaterConnect data is accumulated to 6 am, a dataset accumulated to 9 am (also supplied by request to WaterConnect) was used. In addition to the gauges used in the calibration and validation, the model for the Torrens River calibrated at GA5040529 uses gauged streamflows from the Gorge Weir at its upstream end to capture storage releases.

1.5.2 Climate data

The hydrological models require rainfall and potential evapotranspiration (PET) as inputs and both variables were sourced using daily ASCII grids from the climate surfaces available in the SILO climate database[4]. The PET surfaces were based on the Morton estimates as recommended for hydrological modelling in the Source platform (eWater, 2013). The SILO climate surfaces were clipped to contain only data for the Adelaide region and then imported using the Climate import Tool in the Source modelling platform.

1.5.3 Calibration and validation

The model was calibrated and validated for seven gauges in the Adelaide Coastal Water catchments as shown in Apx Figure 1-9. The gauges were selected based on their spatial distribution and the availability of observed data that the calibration was based on. The calibration for each catchment was done using Source's Calibration Wizard which provides a series of objective functions and search algorithms for model calibration. The wizard also allows for the use of multiple gauges with different weights placed on the importance of different gauges for the overall calibration.

Optimisation algorithms include in Source include Uniform Random Sampling, Rosenbrock, manual calibration, Shuffled Complex Evolution (SCE) and SCE-Rosenbrock. The calibration was performed using the SCE-Rosenbrock optimizer, as it uses the SCE algorithm (Duan *et al.*, 1993) which has been shown to be an efficient global optimizer (eWater, 2013), followed by the local optimizer Rosenbrock.

The Calibration Wizard also offers a series of possible objective functions to be minimized by the optimization algorithms (eWater, 2013):

- NSE - optimisation method that aims to maximise the Nash and Sutcliffe (1970) efficiency (NSE), calculated as a mean squared error and varying between $-\infty$ and +1. NSE close to

[2] <http://amlr.waterdata.com.au/Amlr.aspx>

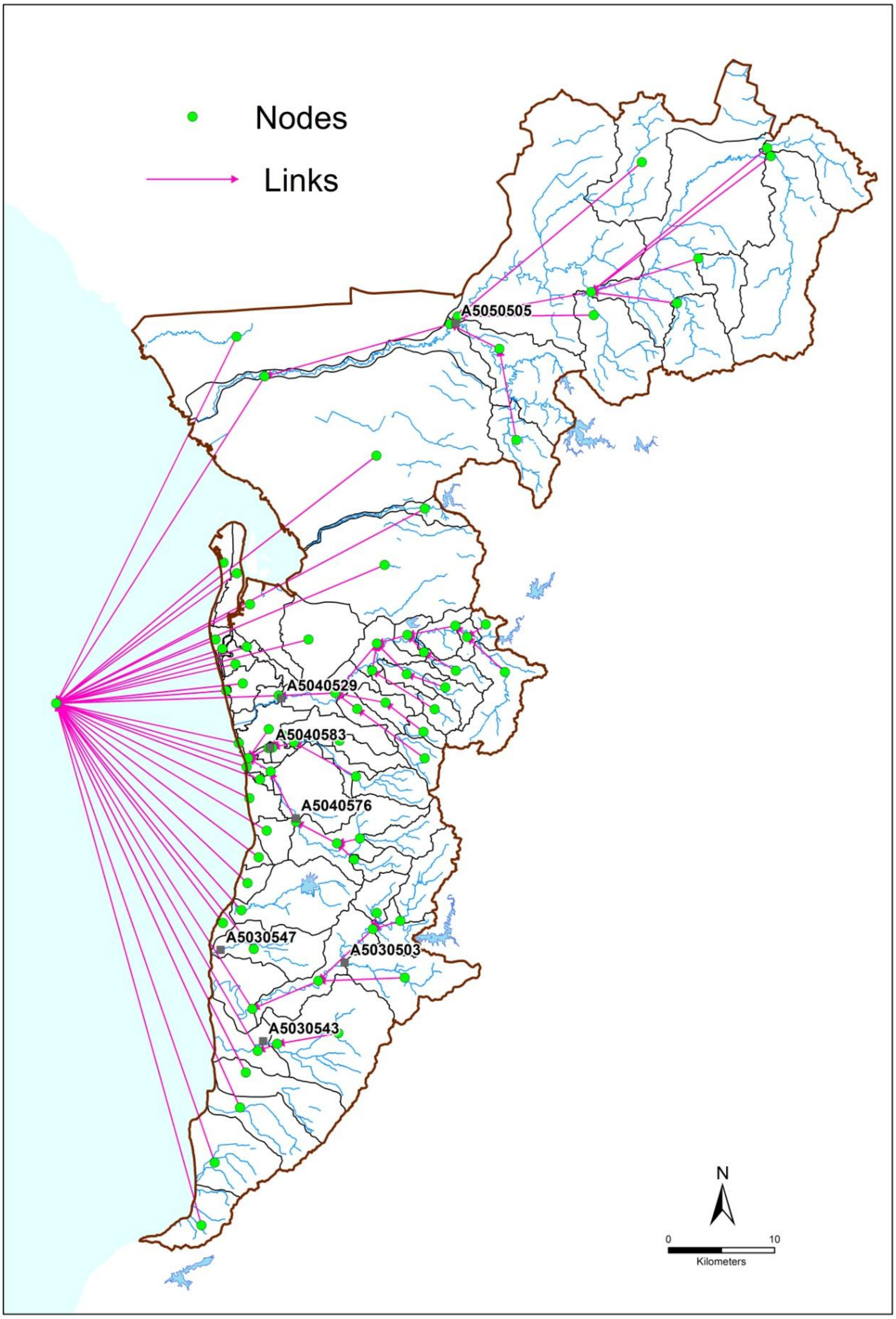
[3] <https://www.waterconnect.sa.gov.au/Systems/SWD/SitePages/Home.aspx>

[4] <http://www.longpaddock.qld.gov.au/silo/>

one indicate good agreement between the modelled and observed daily streamflow, while an NSE value of less than zero indicates that mean observed daily streamflow is a better predictor than the modelled streamflow. It is possible to use the NSE either at a monthly or daily time step;

- Absolute Bias – this method tries to minimize differences between total flow in the predicted and observed streamflow;
- NSE & Bias penalty – this method combines the NSE while it also tries to minimize the bias between the observed and modelled streamflows using log-transformed flows. As in the NSE option, it is possible to apply a function to monthly or daily flows; and
- NSE and Flow duration – it combines the NSE method while also trying to minimize differences along the flow duration curves (flow quartiles). The use of flow duration introduces focus not only on timing of flows (NSE), but also on the distribution of flow magnitudes. The option also allows using the log of flow duration to improve the fit for the low flow in the distribution. Finally, it is possible to use weights to distribute more importance to the NSE or flow duration.

While the model had several different functional units, for the purpose of the calibration and validation the functional units were grouped into Urban and Non-Urban hydrologic response units (HRU). As such, the calibration procedure generated two sets of parameters for each sub-catchment, one for each HRU. While other studies suggested that the use of more than one HRU per catchment improves calibration (Fleming *et al.*, 2012), this study assumed that the (relatively) low number of gauging stations was not sufficient to properly separate the signal from different functional units. In addition, it was considered that the variation in hydrological response within the non-urban land uses was not significant enough to warrant a further divide (i.e further splitting of non-urban into agriculture and forestry). Therefore, only two units that are likely to have very different hydrological responses were used.



Apx Figure 1-9: Gauging stations used for calibration and the node-link network of the catchment model

Instead of choosing one objective function for the model calibration, four different objective functions were used and the final choice of parameters was based on the daily NSE and total volumes for each parameter set obtained based on the following objective functions:

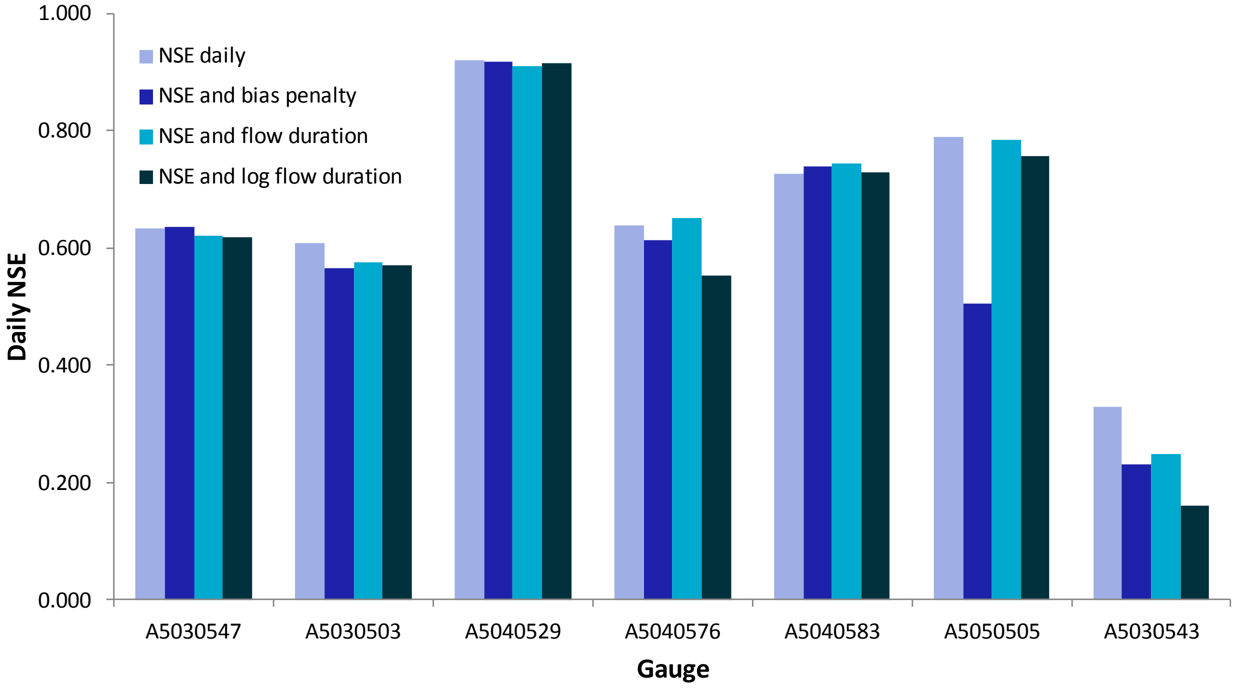
- NSE (daily)
- NSE (daily) and bias penalty
- NSE (daily) and flow duration (NSE weight = 0.7)
- NSE (daily) and log flow duration (NSE weight = 0.7).

The record length for the different gauges used in the calibration varied from catchment to catchment, and therefore the calibration and validation periods vary for different gauges. In all cases, the model has a 1 year warm period before calibration, and the calibration/validation periods are given in Apx Table 1-5.

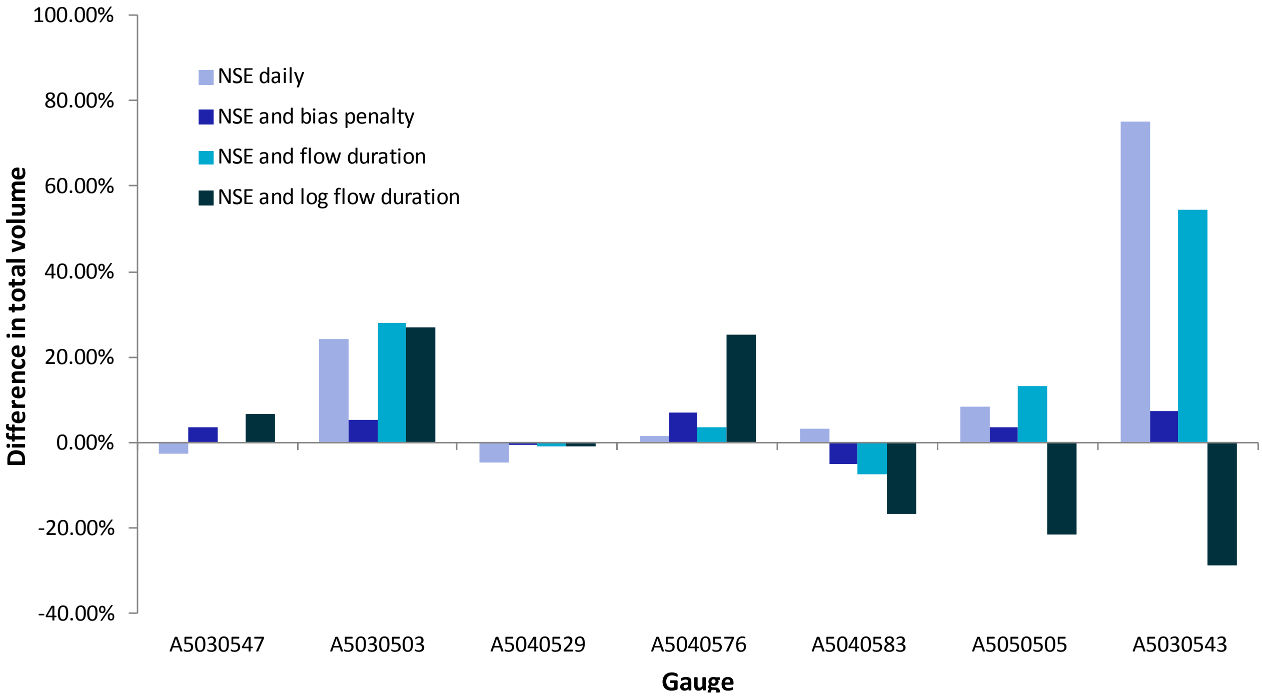
The daily NSE values for calibration of the different gauges and objective functions are shown in Apx Figure 1-12 while the differences in flow volumes are shown in Apx Figure 1-13. What is clear from these figures is that, while the differences in daily NSE are relatively small across the different gauges, the differences in total volumes can vary significantly for the different optimization functions. Overall, NSE values are higher than 0.6 for all but the gauge A5030543 located in Pedler Creek, while it is possible to choose an optimization function that keeps the total volume error below 10% for all gauges. The selected optimization function to obtain the SIMHYD parameter set for each gauge was based on trying to obtain a balance between high NSE and low volume difference values, and the chosen function for each catchment are shown in Apx Table 1-5.

For the gauge A5030543 located in Pedler Creek, the simulated NSE values are reasonably low, ranging between 0.16 and 0.33. The streamflow record for this gauge shows several zero value days with some fairly high values, and based on the streamflow metadata, the gauging quality is poor for most of the high peaks. Therefore, the poor NSE values are caused by the inability of the model to reproduce the very large peak that are in fact, poor data and probably represent gauging errors. In Apx Figure 1-11 however, the use of the bias penalty allows for the calibration to a parameter set that have a low (7.3 %) error in terms of total volume, despite the low NSE (likely) caused by the gauging errors.

The daily NSE values for validation of the different gauges and objective functions are shown in Apx Figure 1-12, while the differences in flow volumes are shown in Apx Figure 1-13. The performance for both the validation and calibration periods is similar for the gauges A5030547 (Christie Creek), A5030503 (Onka River), A5040529 (River Torrens) and A504583 (Brown Hill Creek), with NSE values higher than 0.6 and volumes differences < 10% for most optimization functions. The exceptions are for gauges A5040576 (Sturt River) and A5050505 (Gawler River), while for gauge A5030543 (Peder Creek) there was not enough data for validation due to the issues discussed above. Although for the gauge A504576 most optimization functions yielded a low NSE, the use of the NSE and flow duration function to calibrate the model yielded a NSE > 0.6 and a low total volume error (8.6%). Therefore, for 4 of the 7 gauges used, Apx Table 1-5 shows that it was possible to obtain a set of parameters that delivered a NSE > 0.6 and a total volume error < 10% for both calibration and validation periods, while for a fifth (A5030503, Onka River) only the calibration NSE did not meet this criteria with a value of 0.565.



Apx Figure 1-10: Daily Nash-Sutcliffe values for the hydrological calibration for different gauges



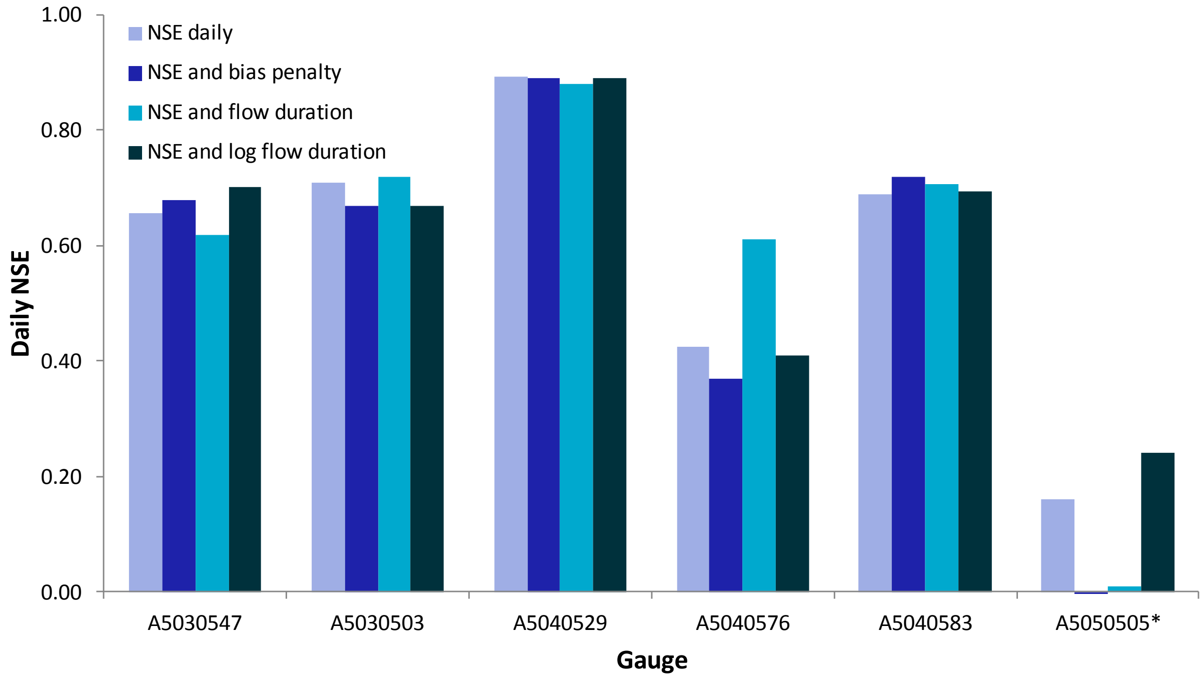
Apx Figure 1-11: Difference in simulated and observed total volumes in the hydrological calibration for different gauges

For the gauge A5050505, the validations results show a much poorer performance compared to the calibration period, with the model total streamflow over estimations ranging between

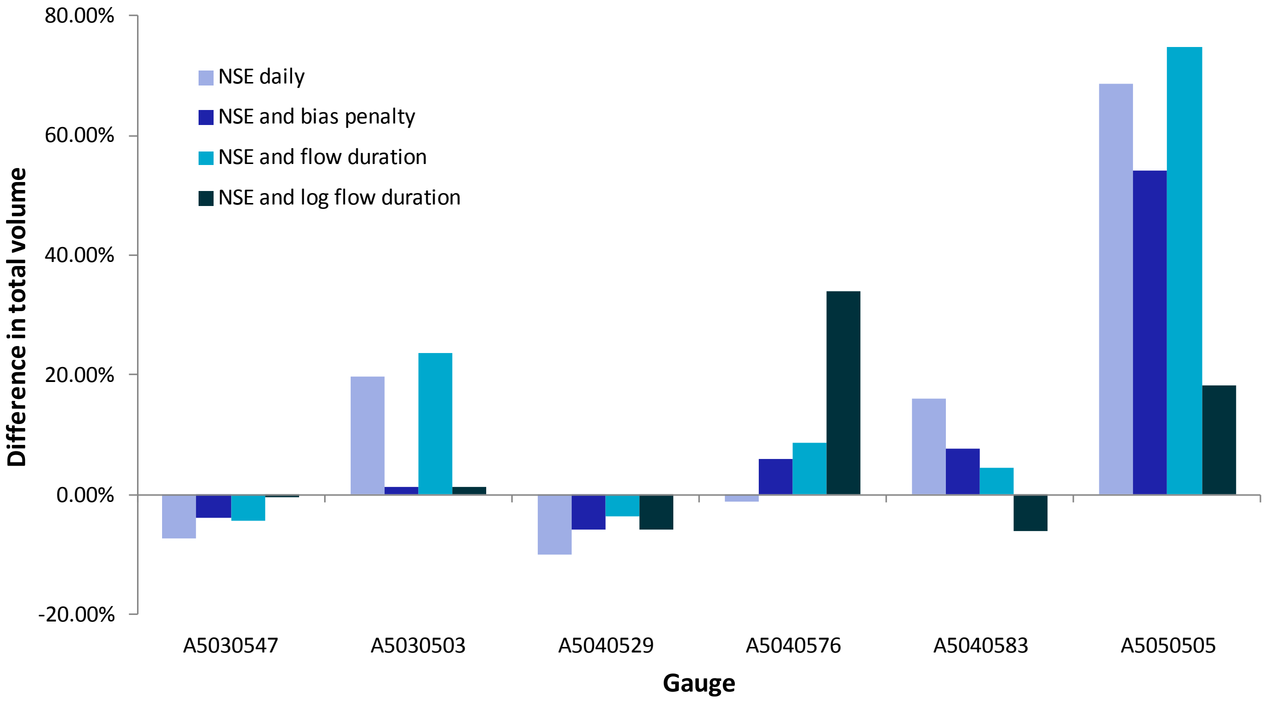
18.2 and 74.7 %, with low NSE values between -0.56 and 0.24. However, the average annual rainfall for the catchment area above the gauge shows a reduction of 3% from the calibration to validation period, but the reduction in mean average flow for the same period is around 50 %. Therefore, it seems likely that there is a significant reduction in gauged streamflow for a small reduction in rainfall, indicating gauging errors or water diversions.

Apx Table 1-5: Calibration and validation periods and selected optimization functions and respective daily NSE and total volume differences for calibration and validation periods

Gauge	Location	Optimisation	Calibration			Validation		
		function	Daily NSE	Total volume difference (%)	Period	Daily NSE	Total volume difference (%)	Period
A5030547	Christie Creek	NSE daily and bias penalty	0.637	3.60	30/11/2000-31/12/2007	0.68	-4	1/1/2008-31/12/2012
A5030503	Onka River	NSE daily and bias penalty	0.565	5.10	13/04/1967-23/02/1989	0.67	1.20	7/01/2000-1/02/2003
A5040529	River Torrens	NSE daily and flow duration	0.911	-1.10	1/01/1980-31/12/1999	0.88	-3.70	1/01/2000-31/12/2012
A5040576	Sturt River	NSE daily and flow duration	0.651	3.50	2/09/1994-31/12/2003	0.61 0	8.60	1/01/2004-1/06/2009
A5040583	Brown Hill Creek	NSE daily and bias penalty	0.740	-5.10	1/01/1994-31/12/2005	0.72	7.60	1/1/2006-31/12/2012
A5050505	Gawler River	NSE daily	0.789	8.30	1/01/1970 - 31/12/1994	0.16	68.60	1/1/1996-31/12/2003
A5030543	Peder Creek	NSE daily and bias penalty	0.230	7.30	4/07/2000 - 06/03/2013	Not enough data		



Apx Figure 1-12: Daily Nash-Sutcliffe values for the hydrological validation for different gauges



Apx Figure 1-13: Difference in simulated and observed total volumes in the hydrological validation for different gauges

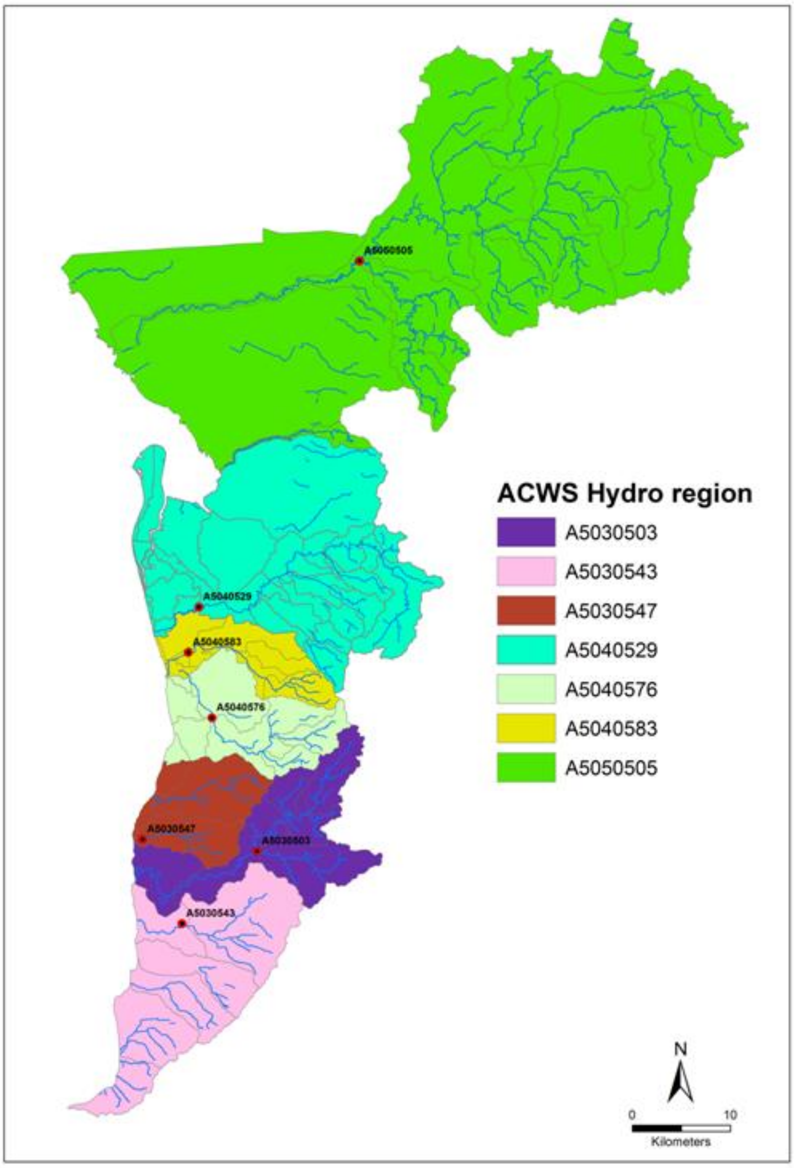
1.6 Regionalisation

The new model was carefully constructed to contain sub-catchment outlets at gauge stations used for model calibration. The model parameters for any sub-catchments located upstream of a gauge were obtained through calibration. Hydrological parameterisation of the remainder of the model involved the adoption of parameter sets from nearby calibrated catchments having simular land use and soil types. Therefore, the new catchment model includes 7 hydrological regions as shown in Apx Figure 1-14 and the adopted hydrological parameter sets for the two HRUs (urban and non-urban) are shown in Apx Table 1-6.

Apx Table 1-6: Adopted hydrological parameters

SimHyd Parameters*	Gauging Station						
	A5050505	A5050529	A5040583	A5040576	A5030547	A5030503	A5030543
bc_NonUrban	0.2	0.2	0.2	0.4	0.3	0.5	0.5
i_NonUrban	1.2	5.0	3.0	5.4	2.2	10.0	5.4
ic_NonUrban	306	298	241	531	585	486	323
is_NonUrban	3.8	3.2	0.0	0.0	2.5	5.0	4.6
itc_NonUrban	0.2	0.0	0.0	0.0	0.0	0.0	0.0
pf_NonUrban	1.0	1.0	1.0	1.0	0.9	1.0	1.0
RISC_NonUrban	3.5	2.4	6.5	8.1	3.0	9.0	5.0
rc_NonUrban	0.3	0.9	0.4	0.7	1.0	0.6	0.1
SMSC_NonUrban	302	408	699	596	350	463	535
bct_Urban	0.2	0.4	0.4	0.0	0.4	0.2	0.3
i_Urban	2.7	1.8	2.9	9.8	0.0	10.0	2.8
ic_Urban	272	373	323	343	294	119	600
is_Urban	10.0	0.0	1.3	7.1	6.7	2.7	11.2
itc_Urban	0.0	0.1	0.1	0.0	0.1	0.0	0.2
pf_Urban	1.0	0.9	0.9	1.0	1.0	1.0	1.0
RISC_Urban	3.0	1.7	1.2	5.4	0.8	9.1	0.6
rc_Urban	0.0	0.5	0.9	0.8	0.2	0.5	1.0
SMSC_Urban	359	500	700	489	700	118	287

Note: bc = baseflow coefficient, i = impervious threshold, ic = infiltration coefficient, is = infiltration shape, itc = interflow coefficient, pf = pervious fraction, RISC = rainfall interception storage capacity, rc = recharge coefficient, SMSC = soil moisture store capacity*



Apx Figure 1-14: Hydrological parameterisation of ACWS model

Appendix 2 Reduction in water demand due to demand management

The study used demand management (DM) as an option to reduce the amount of water required from other sources, which included River Murray, surface water from Mount Lofty Ranges, desalinated water, stormwater, rainwater, groundwater and wastewater. This Appendix describes the assumptions made with regard to the estimation of the reduction in water demand due to DM options. The DM options considered were:

- dual 6/3 litre toilets
- 3-star showerheads
- front loading washing machines (or clothes washers).

The Behavioural End-use Stochastic simulator (BESS) (Thyer et al., 2009) was used to determine the effect of different demand management scenarios. To capture the differences between households in BESS, for each of the 400 household that was simulated the household size and appliance type for each end use category was randomly sampled based on the proportion of household sizes/appliance types. Data on appliances were incorporated from the preliminary survey completed by 1654 participants from the Adelaide metropolitan area. A year of indoor usage was simulated with the occurrence, flow rate/volume for each event sampled from within probability distributions for the event type. The underlying probability distribution for individual water use events, such as occurrence rate, were not available for the Adelaide study households and are based on the previous studies (Roberts, 2005; Roberts et al., 2011) from Yarra Valley Water (YVW).

Four demand management scenarios were modelled:

- Scenario 1: 2013 No demand management (current stock)
- Scenario 2: 2013 Demand management (100% efficient toilets, 84% efficient showers and front loader washing machines)
- Scenario 3: 2025/2050 No demand management (current proportion of front loaders, 100% efficient toilets and 84% efficient showers)
- Scenario 4: 2025/2050 Demand management (100% efficient toilets, 84% efficient showers and front loader washing machines).

These scenarios assumed that by 2025 all homes will move to efficient toilets, as these are the only options available for purchase and have been mandated as the only option that can be installed. For 3 star showerheads and front loaders, an 84% maximum uptake rate was assumed, which was based on the diffusion of innovation theory (Rogers, 2003) that assumed approximately 16% of people were ‘laggards’ who only adopt innovation when forced. These accounted for those people who would choose to use a less efficient product.

The scenarios also assumed that no behavioural changes, such as shorter showers, would occur over time as these changes were difficult to model and the research into the impact of behaviour was ongoing. Leaks were neglected as they were highly variable.

Outdoor water use was not within the scope of Task 4 of the OWRM project, and thus the assumptions of 62 L/per capita annum as provided by SA Water based on Water for Good with a reduction factor was used. The following assumptions were also made for determining the reduction factor for each demand management scenario:

- non potable refers to garden, laundry (Washing Machine) and toilet uses
- potable refers to bathroom (bath and shower), kitchen (tap and dishwasher) and other indoor uses
- an average occupancy rate of 2.4 person per household (ABS, 2011a)
- the mains water usage of 77.8% for residential and 22.2% for non-residential for all demand zones (North, Central, South), which implied 58.0 L/capita/day non-residential based on the 204 L/capita/day modified water for good residential use
- non-residential use was further split to: 20% non-potable and 80% potable, which indicated 46.4 L/capita/day potable non-residential use, 11.6 L/capita/day non-potable non-residential use.

The assumptions for each event type are described below and the proportions used summarised in Apx Table 2-1.

Apx Table 2-1: Proportions of appliances used for each scenario

	Task 3 (Marchi et al., 2014)	Scenario 1: 2013 No DM	Scenario 2: 2013 with DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 with DM
Shower 0 star	0.35	0.15	0.053	0.053	0.053
Shower 1 star		0.15	0.053	0.053	0.053
Shower 2 star		0.15	0.053	0.053	0.053
Shower 3 star	0.65	0.55	0.84	0.84	0.84
Front Loaders	0.75	0.54	0.84	0.54	0.84
Top Loaders	0.25	0.46	0.16	0.46	0.16
Dishwashers	-	0.72	0.72	0.72	0.72
Bath	-	0.05	0.05	0.05	0.05
Toilets					
Single Flush (10 L)	0.11	0.07	0	0	0
Dual 11/6L	0.89	0.15	0	0	0
Dual 9/4.5L		0.32	0	0	0
Dual 6/3L		0.46	1	1	1

2.1 Household occupancy

The household occupancy distribution assumed was based on ABS (2011a) for Adelaide. The following values were assumed:

- occupancy rate 1, for 25% of the population;
- occupancy rate 2, for 35% of the population
- occupancy rate 3, for 16% of the population
- occupancy rate 4, for 16% of the population
- occupancy rate 5, for 5% of the population
- occupancy rate 6, for 1% of the population
- occupancy rate 7+, for 1% of the population.

2.2 Showers

The following assumptions were made:

- based on the Preliminary survey 37% of houses identified as having non efficient showers, 48% as having efficient showers and 15% as mixed or unsure
- efficient was assumed to refer to 3 star efficiency (max flow rate <9 L/min)
- non efficient was split evenly between 0 star (>16 L/min), 1 star (12 – 16 L/min)and 2 star (9 – 12 L/min) efficiency
- mixed/unsure was split evenly between efficient and non-efficient
- for demand management and future scenarios, a 84% uptake rate was used based on the diffusion of innovation theory (Rogers, 2003) and the remaining split evenly between the 0 to 2 star efficiencies
- proportions used:
    - Scenario 1: 0 star 15%, 1 star 15%, 2 star 15%, 3 star 55%
    - Scenario 2,3,4: : 0 star 5.3%, 1 star 5.3%, 2 star 5.3%, 3 star84%

2.3 Washing machines

The following assumptions were made:

- based on the Preliminary survey 54% of houses identified as having front loaders, 46% as having top loaders
- for demand management a 84% uptake rate is used based on the diffusion of innovation theory (Rogers, 2003)
- proportions used:
    - Scenario 1 and 3: Front Loaders 54%, Top Loaders 46%
    - Scenario 2 and 4: Front Loaders 84% , Top Loaders 16%.

2.4 Dishwashers

The following assumptions were made:

- Preliminary survey did not include a question on dishwasher ownership
- 72% ownership used for all scenarios based on the YVW study (Roberts, 2005).

2.5 Baths

The following assumptions were made:

- Preliminary survey did not include a question on bath frequency
- 5% chance of the household having a bath event was used based on the YVW study (Roberts, 2005).

2.6 Toilet

The following assumptions were made:

- based on the Preliminary survey 7% of houses identified as having single flush toilets, 85% as having dual flush and 8% as mixed or unsure
- single flush was assumed to refer to a standard efficiency single flush toilet (flush volume 10 L)
- dual and mixed responses were split between the three modelled dual flush options, based on the proportional split of the 2010 YWV study (Roberts et al., 2011) as this was assumed to most accurately reflect the current stock in Adelaide
- for demand management a 100% uptake rate is used as the installation of this option is mandated
- proportions used:
    - Scenario 1: Single 7%, Dual 11/6L 14.5%, Dual 9/4.5L 32.3%, Dual 6/3L 46.2%
    - Scenario 2,3 and 4: Dual 6/3L 100%.

2.7 Garden use

The following assumptions were made:

- average use of 62 L/person/day as provided SA Water based on Water for Good with a reduction factor
- garden use is assumed to be constant over time, i.e. garden size and water habits will not change
- monthly usage factors, and consequently non drinking usage factors have been taken from Barton and Argue (2005) which was generated from the outputs from the six water treatment plants
- it was assumed that the usage pattern remains the same, but the average usage has been reduced from the average of 136kL/dwelling

- Apx Table 2-2 shows the assumed season proportions and factors for garden use for each month. A 2.4 person per household average in Adelaide (ABS, 2011a) has been used to convert from per dwelling for comparison.

Apx Table 2-2: Assumed Seasonal proportions and factors for garden use

	Usage (kL) per dwelling from Barton and Argue (2005)	Usage (L) per /person/day adapted from Barton and Argue (2005)	Outdoor seasonal proportion	Outdoor seasonal factor (mean = 1)	Assumed outdoor usage (L/person/day)
January	31130	418	0.229	2.75	169
February	25610	318	0.188	2.26	139
March	19240	259	0.141	1.70	105
April	8720	121	0.064	0.77	47
May	4040	54	0.030	0.36	22
June	0	0	0.000	0.00	0
July	130	2	0.001	0.01	1
August	890	12	0.007	0.08	5
Sept	1900	26	0.014	0.17	10
October	6710	90	0.049	0.59	36
November	14520	202	0.107	1.28	79
December	23110	311	0.170	2.04	126

Apx Table 2-3 summarises the usage per person per day for each of the end uses for the four scenarios and the reduction factor from the 2013 current modelled usage (Scenario 1) for the residential drinking usage and the total drinking usage including the non-residential usage. Marchi et al. (2014) estimated water savings per household, for front loading washing machines as 20.2 kL/year/household, efficient shower heads as 13.8 kL/year/household and dual flush toilets as 8.4 kL/year/household. These savings were estimates to be applied to 25%, 35% and 11% of the homes respectively. Assuming a 2.4 person per household average in Adelaide (ABS, 2011a) these results are compared to the output of demand management for 2013 scenario (Scenario 2) in Apx Table 2-6. The discrepancies results from the assumed current stock namely:

- washing machines: a higher proportion of current front loaders was assumed in Marchi et al. (2014) (Apx Table 2-1)
- Toilets: Marchi et al. (2014) did not take into account moving from a dual 11/6L to an efficient Dual 6/3L.

Apx Table 2-4 and Apx Table 2-5 present the monthly reduction factors for the non-drinking usage for residential and total usage respectively.

Analysis of the Adelaide sample houses was not completed while undertaking this study. However an estimate of the per capita usage per day was available for comparison to the simulations above. The water usage in June was assumed to represent indoor only water usage. The quarterly billing data were then used for the 2011/12 period, with the assumption that indoor use remained constant, to estimate the outdoor usage. The results for the 139 homes included in this analysis had the following attributes:

- average total usage 226 L/per person/day
- estimate Indoor usage 143 L/per person/day (note this may include leakage and some outdoor use)
- estimated Outdoor usage 83 L/per person/day.

Apx Table 2-3: Litres per capita per day for each end use and scenario

	Modified Water for Good	Scenario 1: 2013 No DM	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
Bathroom	56	40.7	37.8	37.8	37.8
Toilet	26	28.3	24.0	24.0	24.0
Laundry	32	34.1	27.2	34.1	27.2
Kitchen	27	29.4	29.4	29.4	29.4
Indoor	141	132.5	118.4	125.3	118.4
Outdoor	62	61.6	61.6	61.6	61.6
Total	**203**	**194.1**	**180.0**	**186.9**	**180.0**
Drinking - Residential	83	70.1	67.2	67.2	67.2
Non Drinking - Residential	120	124.0	112.8	119.7	112.8
Reduction from Drinking -Residential			4%	4%	4%
Reduction from Drinking -Total			2%	2%	2%
Reduction from Non potable -Residential			See Apx Table 2-4		
Reduction from Non potable Total			See Apx Table 2-5		

Marchi et al. (2014) estimated water savings per household, for front loading washing machines as 20.2 kL/year/household, efficient shower heads as 13.8 kL/year/household and dual flush toilets as 8.4 kL/year/household. These savings were estimates to be applied to 25%, 35% and 11% of the homes respectively. Assuming a 2.4 person per household average in Adelaide (ABS, 2011a) these results are compared to the output of demand management for 2013 scenario (Scenario 2) in Apx Table 2-6. The discrepancies results from the assumed current stock namely:

- washing machines: a higher proportion of current front loaders was assumed in Marchi et al. (2014) (Apx Table 2-1)

- Toilets: Marchi et al. (2014) did not take into account moving from a dual 11/6L to an efficient Dual 6/3L.

Apx Table 2-4: Reduction from Scenario 1 of non drinking residential usage per month

	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
January	5%	2%	5%
February	6%	2%	6%
March	7%	3%	7%
April	10%	4%	10%
May	13%	5%	13%
June	18%	7%	18%
July	18%	7%	18%
August	17%	6%	17%
Sept	15%	6%	15%
October	11%	4%	11%
November	8%	3%	8%
December	6%	2%	6%

Apx Table 2-5: Reduction from Scenario 1 of total non drinking usage per month

	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
January	5%	2%	5%
February	5%	2%	5%
March	6%	2%	6%
April	9%	4%	9%
May	12%	4%	12%
June	15%	6%	15%
July	15%	6%	15%
August	14%	5%	14%
Sept	13%	5%	13%
October	10%	4%	10%
November	7%	3%	7%
December	6%	2%	6%

Apx Table 2-6: Comparison of water saving results from current stock to efficient stock between Task 3 and Task 2 (L/per person/day)

	Scenario 2: 2013 DM	Task 3
Washing machines	6.9	5.8
Efficient shower heads	2.9	5.5
Dual flush toilets	4.3	1.1

The reduction in potable and non-potable residential demand computed by using the above mentioned approach is given in Percent reduction in residential demands due to demand management, compared to the demand without demand management.

Apx Table 2-7: Percent reduction in residential demands due to demand management, compared to the demand without demand management

Month	Percent reduction in residential potable demand	Percent reduction in residential non-potable demand
January	4	5
February	4	6
March	4	7
April	4	10
May	4	13
June	4	18
July	4	18
August	4	17
September	4	15
October	4	11
November	4	8
December	4	6

Appendix 3 Non-dominated solutions for 2013 scenario (Priority Sets #1 and #2)

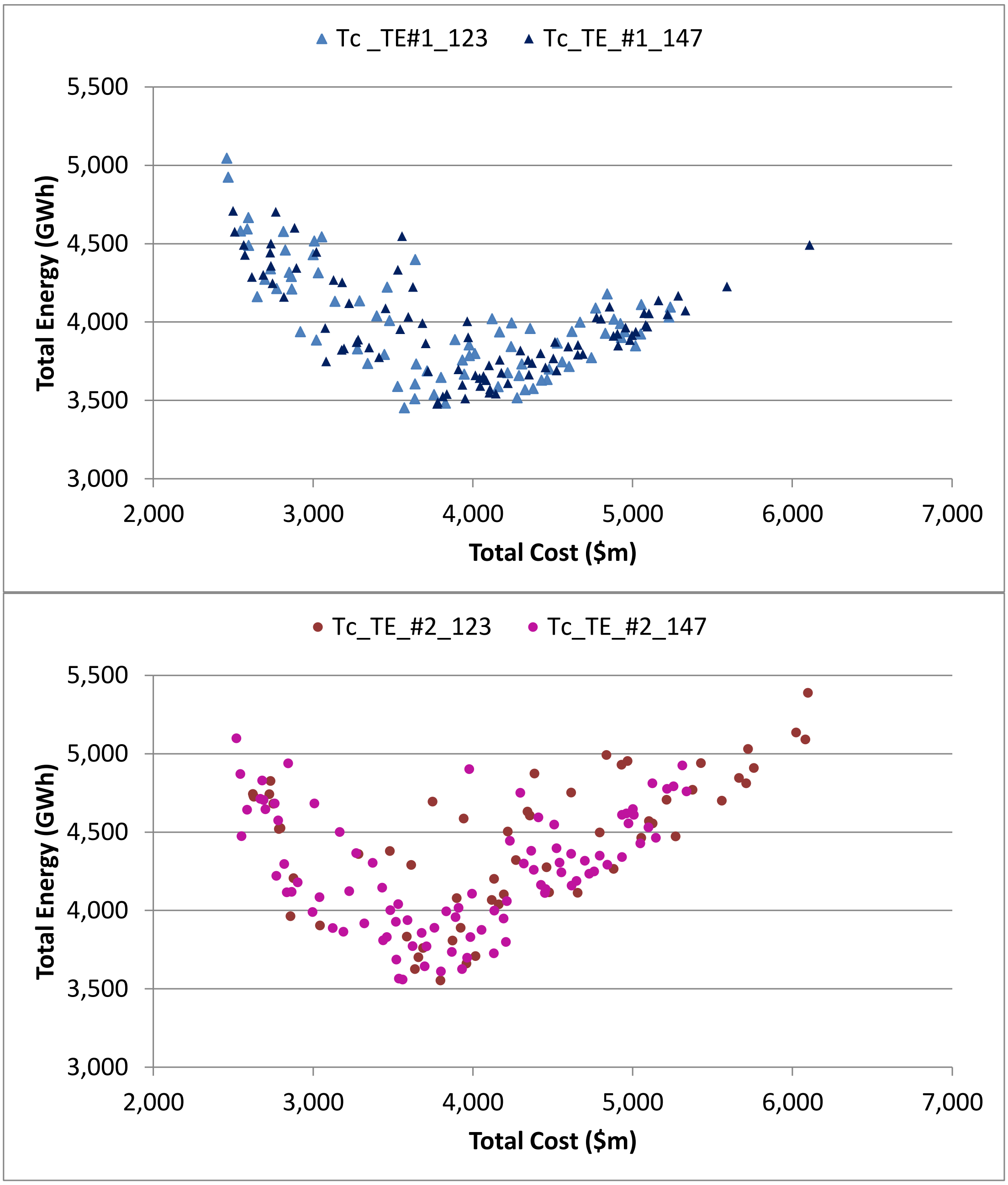
This Appendix shows the results of 2013 scenario when the solutions found using Priority Sets #1 and #2 are kept separate. In this case there are 167 non-dominated solutions (out of 200) for the model with Priority Set #1 (See Table 36 of the report repeated here as Apx Table 3-1). For model with Priority Set #2, the number of non-dominated solutions is 151. Note that the total number of non-dominated solutions when all of the 400 solutions is merged is 233 as some of the solutions of one model dominated some solutions of the other.

Apx Table 3-1: Priorities of water sources

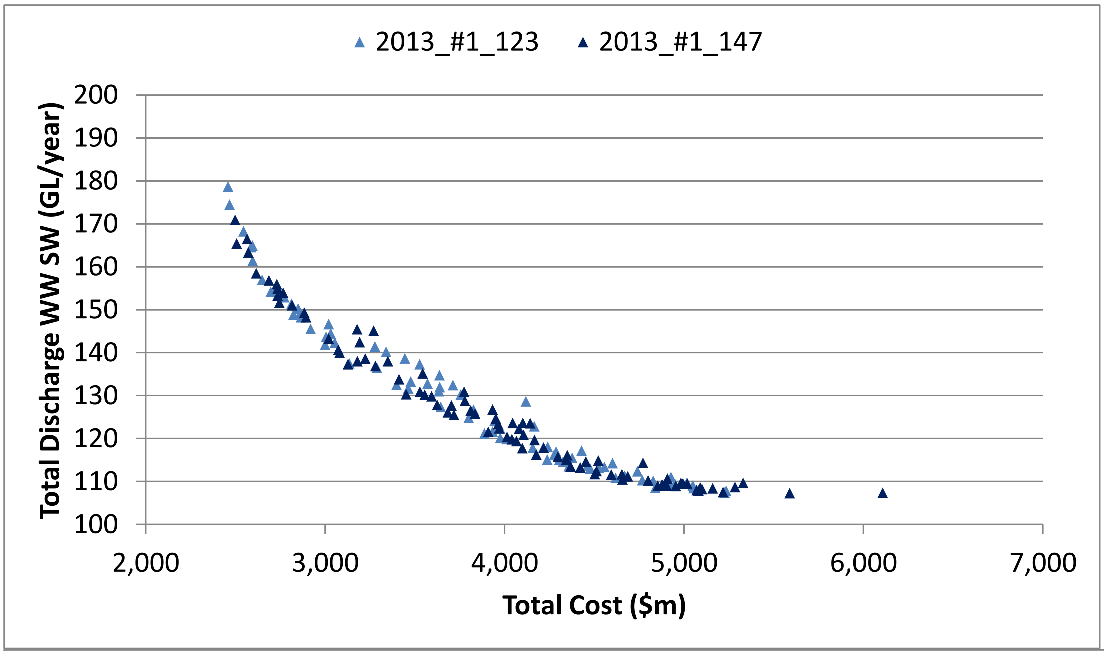
Priority Set	Priority order for Potable Use[1]	Priority order for Non-Potable Use[1]
#1	1. Mt Lofty Ranges 2. River Murray 3. Desalinated Water	1. Harvested Stormwater 2. Reclaimed Wastewater 3. Mt Lofty Ranges 4. River Murray 5. Desalinated Water
#2	1. Mt Lofty Ranges 2. River Murray 3. Desalinated Water	1. Mt Lofty Ranges 2. River Murray 3. Harvested Stormwater 4. Reclaimed Wastewater 5. Desalinated Water
#3	1. Mt Lofty Ranges 2. Desalinated Water Plant 3. River Murray	1. Harvested Stormwater 2. Reclaimed Wastewater 3. Mt Lofty Ranges 4. Desalinated Water 5. River Murray

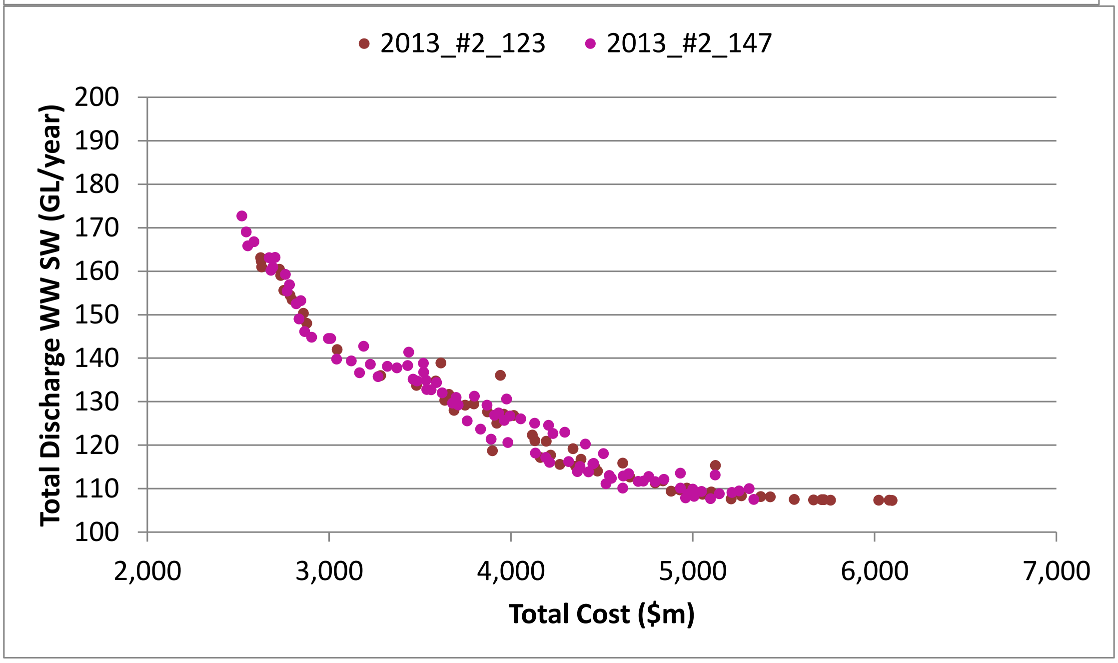
Note 1: The lowest number has the highest priority

As can be seen in the comparative Apx Figure 3-1 to Apx Figure 3-8, the results from the two models are similar, meaning that the optimisation algorithm had sufficient time to explore a wide range of the optimal front of solutions and that the final results are not strongly influenced by the NetLP decisions.



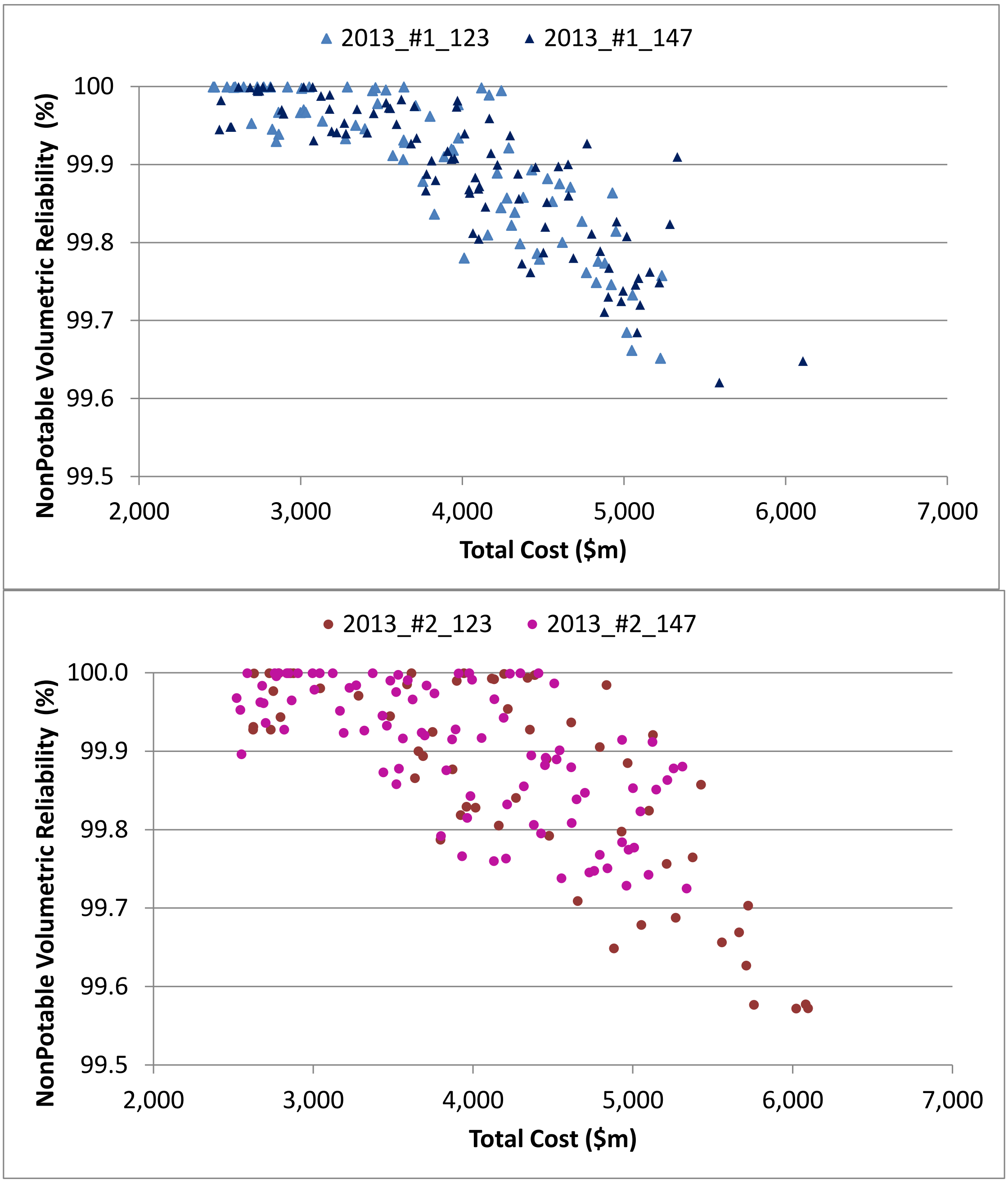
Apx Figure 3-1: Costs and energies (of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart) (solutions kept separate)



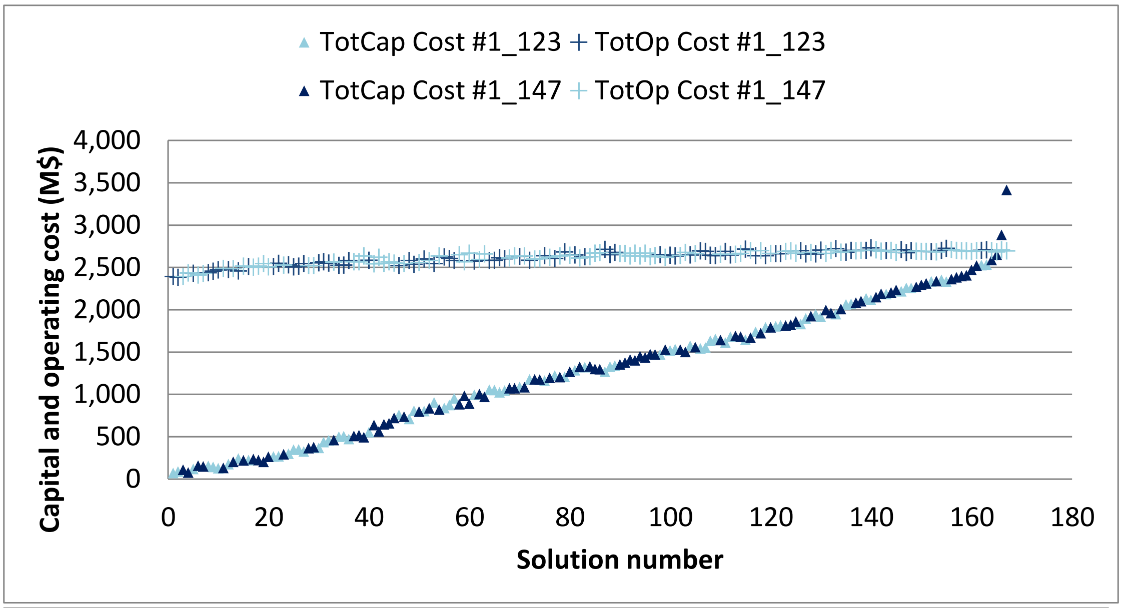


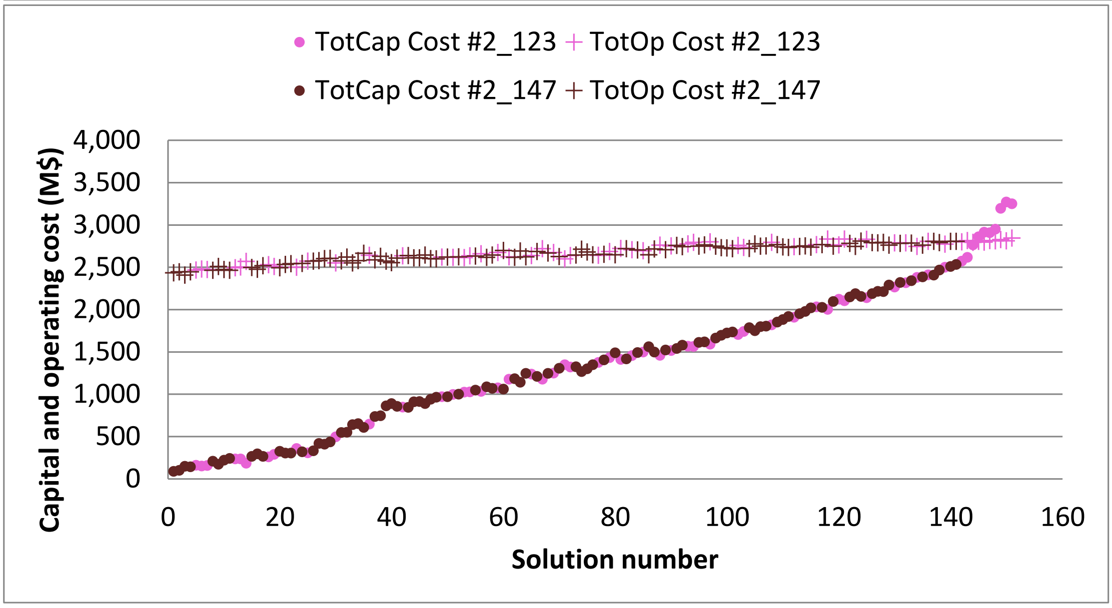
Apx Figure 3-2: Costs and discharges of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart) (solutions kept separate)

The non-potable volumetric reliability of the solutions is usually high (Apx Figure 3-3).

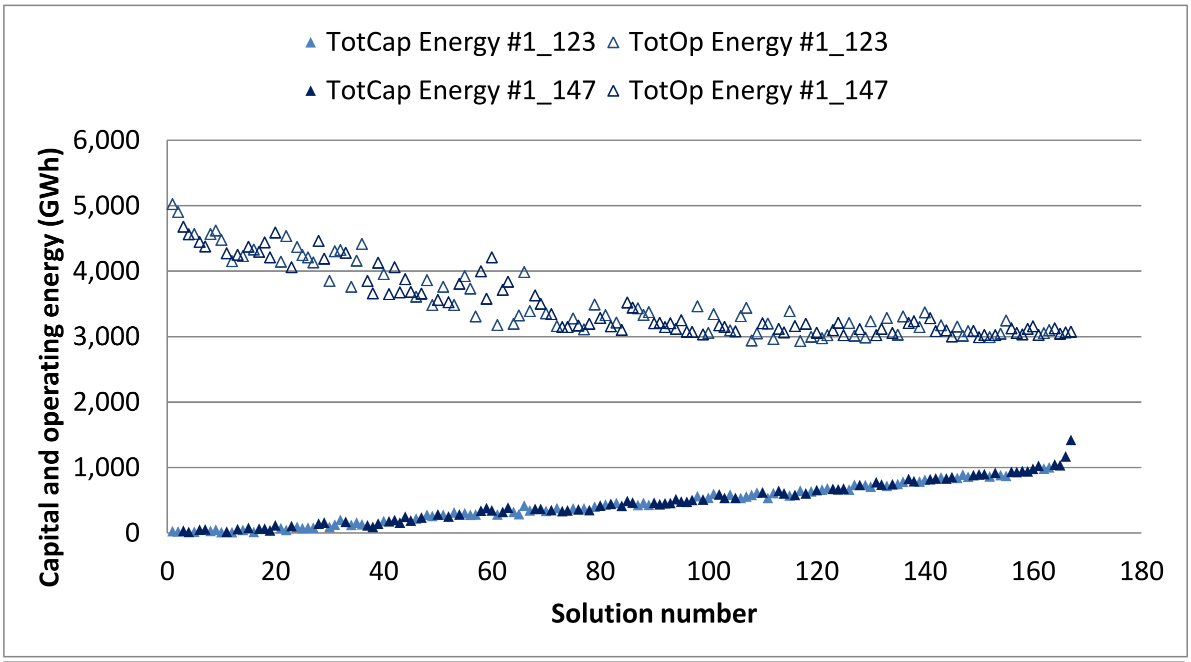


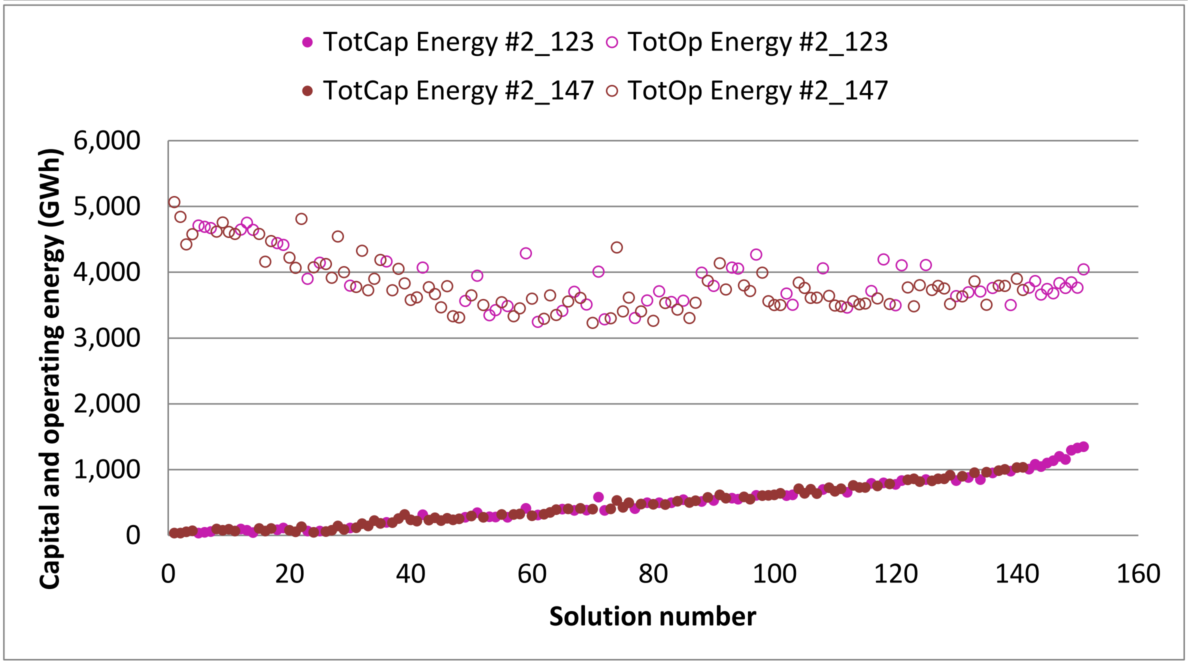
Apx Figure 3-3: Costs and non-potable volumetric reliability of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart) (solutions kept separate)





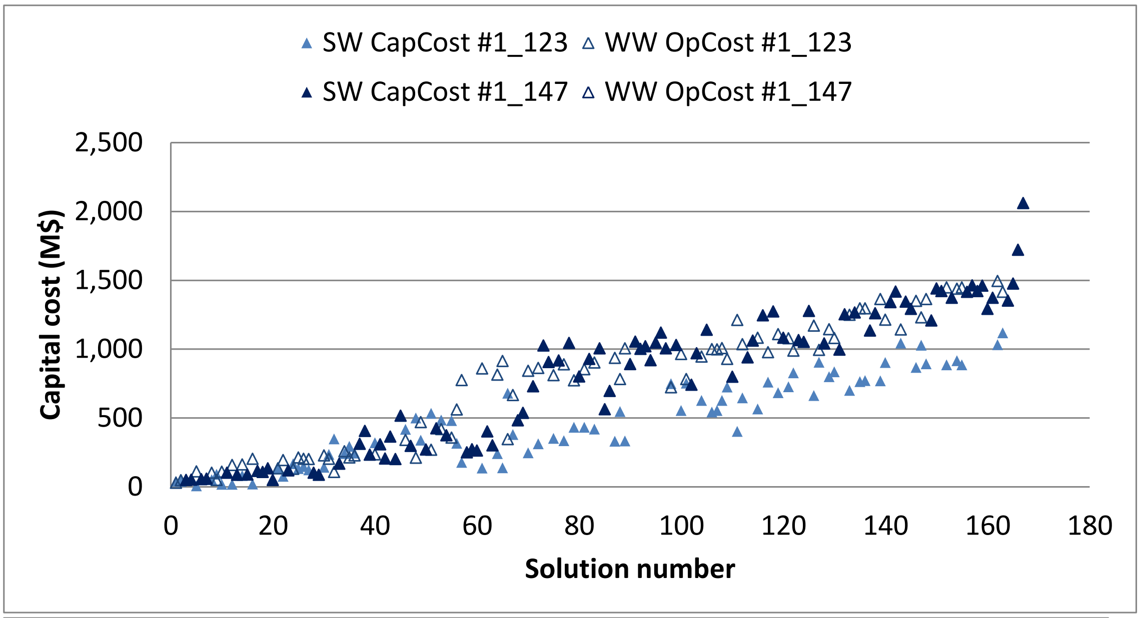
Apx Figure 3-4: Capital and operational costs of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart) (solutions kept separate)

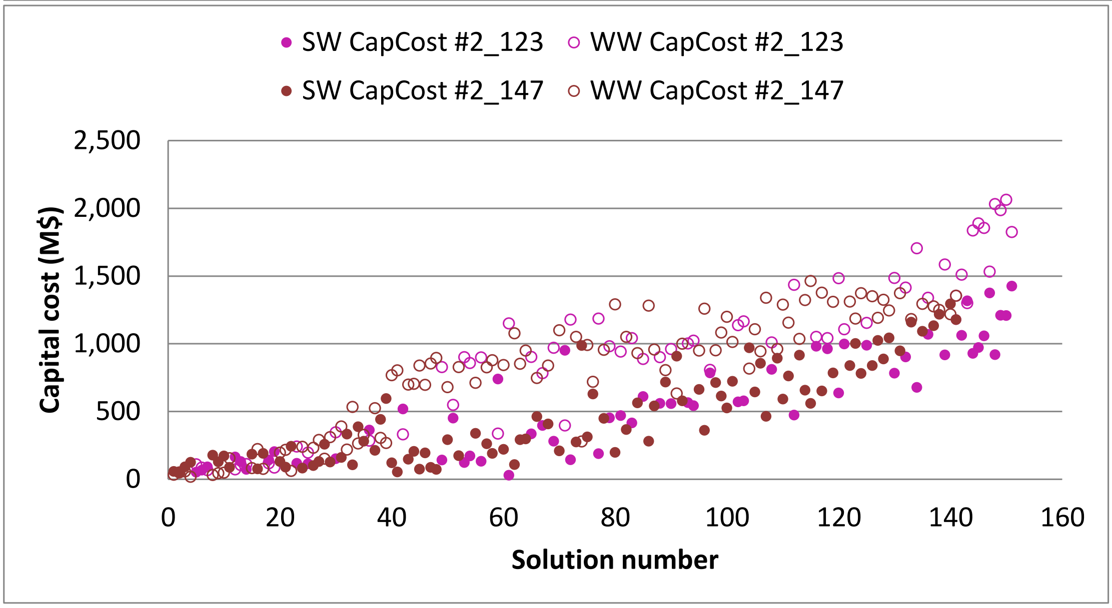




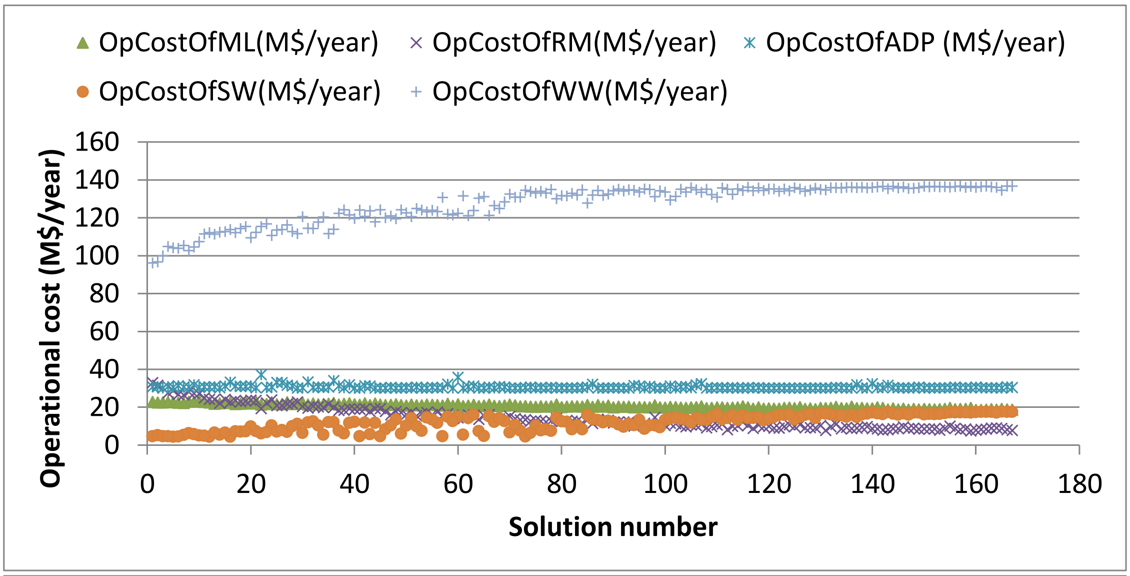
Apx Figure 3-5: Capital and operational energy of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart) (solutions kept separate)

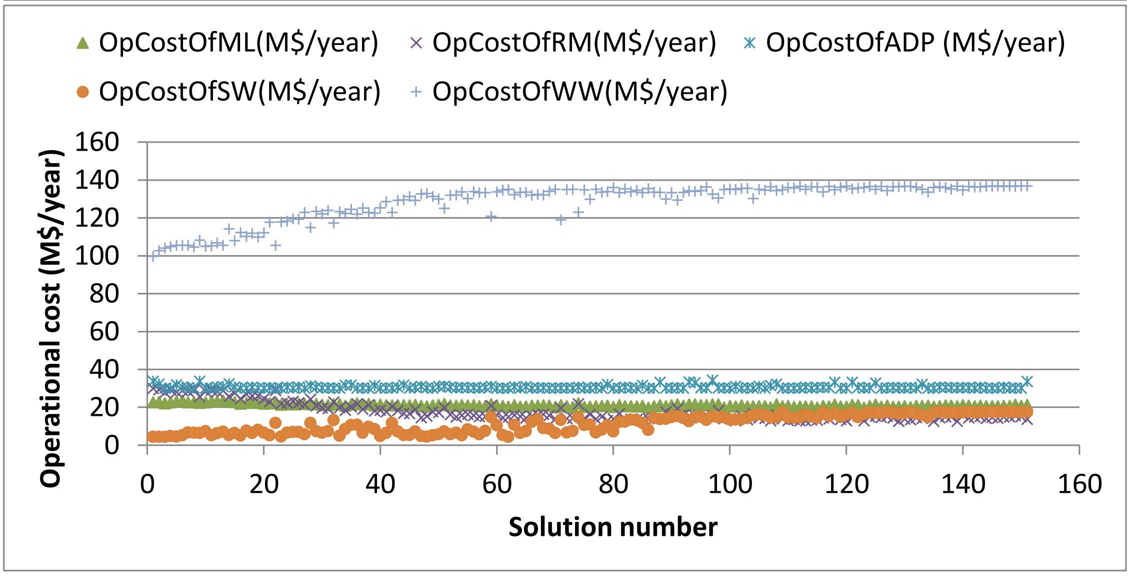
The capital cost of wastewater (WW) and stormwater (SW) are comparable, with the costs associated to the wastewater recycling plants being slightly larger than the capital costs of stormwater for the model with Priority Set #2 (Apx Figure 3-6).





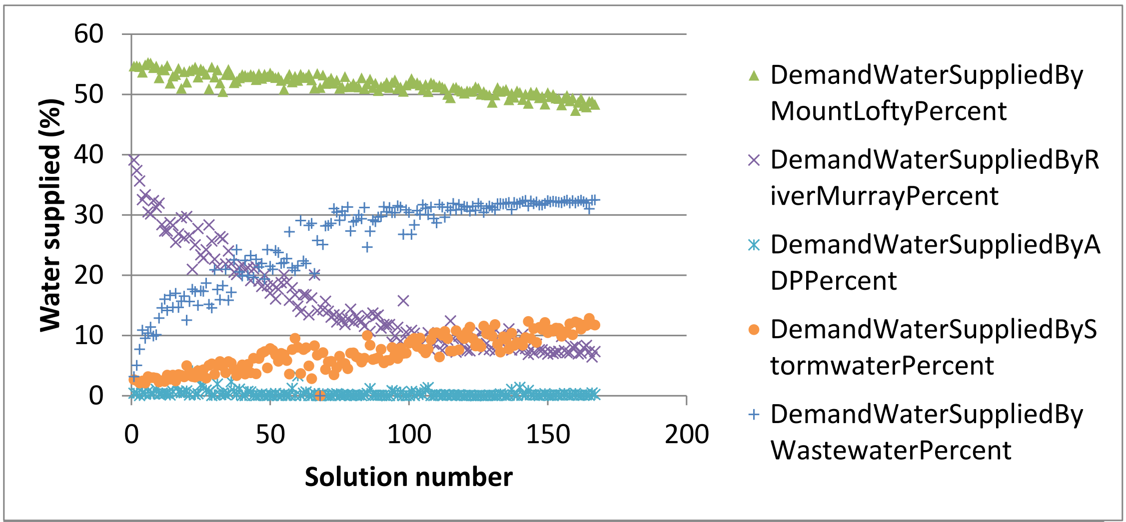
Apx Figure 3-6: Capital cost of stormwater (SW) and wastewater (WW) for non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart) (solutions kept separate)

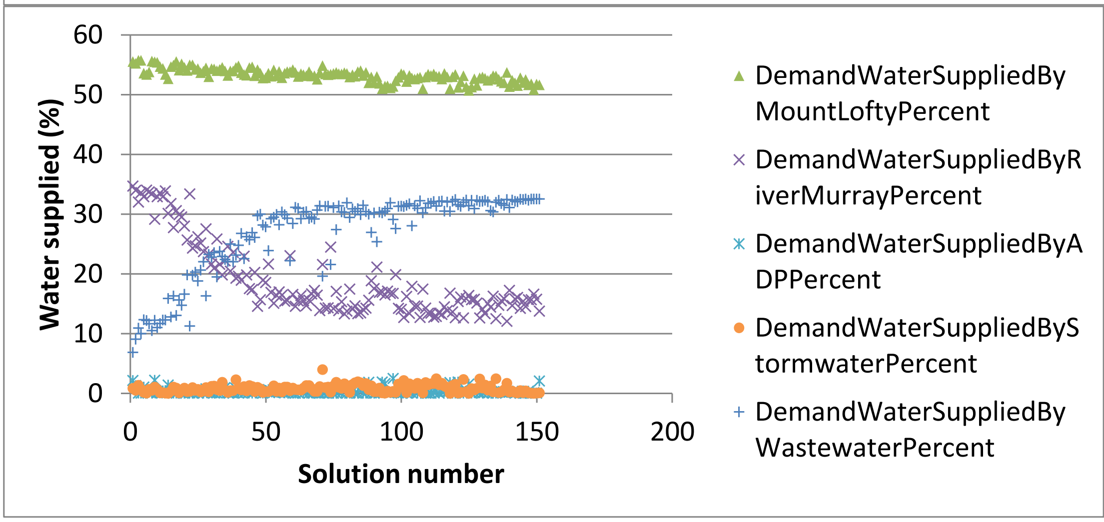




Apx Figure 3-7: Operational costs of the various sources: Mount Lofty (ML), Murray River (MR), Adelaide Desalination plant (ADP), stormwater (SW) and wastewater (WW) of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart)

As can be seen in Apx Figure 3-8, the percentage supply for each source is similar, with the exception of the most expensive solutions favour stormwater for the model with Priority Set #1 instead of the River Murray water, which is favoured by the Priority Set #2.





Apx Figure 3-8: Water supplied by the various sources: Mount Lofty (ML), Murray River (MR), Adelaide Desalination plant (ADP), stormwater (SW) and wastewater (WW) of non-dominated solutions using 2 different seeds (0.123 and 0.147) for the 2013 scenario with Priority Sets #1 (top chart) and #2 (bottom chart)

Apx Table 3-2 to Apx Table 3-9 show the results for the selected solutions in case the solutions from the models with different priorities are kept separate.

Apx Table 3-2: Objective function value for the selected non-dominated solutions of 2013 scenario with Priority Set #1

No	Total Cost (M$)	Cost/kL ($/kL)	Total Energy (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
1	2459	0.57	5045	1.17	100.00%	179	Min Tc, Max TE, Max Discharge, CP13
30	2920	0.68	3938	0.91	100.00%	145	Max NP Vol Rel
54	3453	0.80	4088	0.95	99.97%	130	CP134, CP14
61	3570	0.83	3453	0.80	99.91%	133	Min TE
75	3798	0.88	3646	0.85	99.96%	125	CP1234
166	5589	1.30	4226	0.98	99.62%	107	Min NP Vol Rel, Min Discharge

No	Total Cost (M$)	Cost/kL ($/kL)	Total Energy (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
167	6111	1.42	4492	1.04	99.65%	107	Max Tc

Apx Table 3-3: Supply from each source for the selected non-dominated solutions of 2013 scenario with Priority Set #1

No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Water Supplied By Mount Lofty Percent	Water Supplied By River Murray Percent	Water Supplied By ADP Percent	Water Supplied By SW Percent	Water Supplied By WW Percent
1	94.1	67.3	0.7	4.6	5.5	54.7%	39.1%	0.4%	2.7%	3.2%
30	91.1	39.0	0.2	6.1	35.9	52.9%	22.6%	0.1%	3.5%	20.8%
54	90.1	32.3	0.0	12.1	37.7	52.3%	18.8%	0.0%	7.0%	21.9%
61	91.8	24.0	0.0	6.3	50.0	53.3%	13.9%	0.0%	3.7%	29.0%
75	87.8	23.0	0.0	11.3	50.1	51.0%	13.4%	0.0%	6.5%	29.1%
166	83.9	11.0	0.7	20.4	55.8	48.8%	6.4%	0.4%	11.9%	32.5%
167	83.1	12.5	0.3	20.1	55.8	48.3%	7.3%	0.2%	11.7%	32.5%

Apx Table 3-4: Decision variables values and final aquifer storage for the selected non-dominated solutions of 2013 scenario with Priority Set #1

No	MN ADP to Onka Conf (ML/month)	MNMA to Torrens (ML/month)	MN MBO to Onka (ML/month)	MNSRS to Gawler (ML/month)	WW DistCap SimLimit Bolivar (ML/year)	WW DistCap SimLimit Christies (ML/year)	WW DistCap SimLimit Glenelg (ML/year)	WWDist Cap Sim Limit Bolivar Fraction RND	WW Dist Cap Sim Limit Christies Fraction RND	WW Dist Cap Sim Limit Glenelg Fraction RND	No. of new SW schemes	Average annual SW aquifer storage (GL/year)	Notes
1	2709	2170	13300	593	1050	4200	328	0.60	0.49	0.51	3	1.56	Min Tc, Max TE, Max Discharge, CP13
30	778	4780	13500	113	37000	8560	4190	0.39	0.44	0.70	4	2.28	Max NP Vol Rel
54	12	2780	11789	331	41292	15158	2304	0.53	0.09	0.73	9	6.96	CP134, CP14
61	17	1080	6410	26	32200	14000	15000	0.60	0.60	0.84	7	0.91	Min TE
75	17	1190	13900	509	39900	9970	13600	0.61	0.38	0.49	5	2.21	CP1234
166	1128	3566	5259	13	47244	15536	21478	0.66	0.83	0.94	18	2.61	Min NP Vol Rel, Min Discharge
167	1934	550	11572	179	58478	15655	16978	0.74	0.88	0.78	18	2.80	Max Tc

Apx Table 3-5: Capital and operational costs for each source for the selected non-dominated solutions of 2013 scenario with Priority Set #1

No	PV ofCapital Cost (M$)	PV of Op. Cost (M$)	Capital Cost Of SW (M$)	Capital Cost Of WW (M$)	Op Cost Of ML (M$/year)	Op Cost Of RM (M$/year)	Op Cost Of ADP (M$/year)	Op Cost Of SW (M$/year)	Op Cost Of WW (M$/year)
1	68	2391	40	29	23	33	31	5	96
30	367	2553	141	227	22	20	30	6	121
54	818	2635	445	373	21	17	30	15	123
61	995	2575	135	859	21	14	30	5	131
75	1160	2638	350	810	20	13	30	10	133
166	2883	2706	1161	1722	19	8	31	18	137
167	3416	2695	1354	2062	19	8	30	18	137

Apx Table 3-6: Objective function value for the selected non-dominated solutions of 2013 scenario with Priority Set #2

No	Total Cost (M$)	Cost/kL ($/kL)	Total Energy (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
1	2521	0.59	5098	1.18	99.97%	173	Min Tc, Max Discharge, CP13
31	3123	0.73	3887	0.90	100.00%	139	Max NP Vol Rel
60	3757	0.87	3889	0.90	99.97%	126	CP1234
61	3799	0.88	3553	0.83	99.79%	129	Min TE
67	3897	0.91	4078	0.95	99.99%	119	CP134, CP14
133	5123	1.19	4811	1.12	99.91%	113	Max TE
139	5272	1.22	4474	1.04	99.69%	108	Max Tc, Min NP Vol Rel, Min Discharge

Apx Table 3-7: Supply from each source for the selected non-dominated solutions of 2013 scenario with Priority Set #2

No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Water Supplied By Mount Lofty Percent	Water Supplied By River Murray Percent	Water Supplied By ADP Percent	Water Supplied By SW Percent	Water Supplied By WW Percent
1	95.6	59.7	3.7	1.4	11.8	55.5%	34.7%	2.2%	0.8%	6.8%
31	93.5	36.0	0.1	2.1	40.5	54.3%	20.9%	0.1%	1.2%	23.5%
60	93.2	28.5	0.0	1.5	48.9	54.2%	16.6%	0.0%	0.9%	28.4%
61	92.4	25.0	0.1	1.1	53.5	53.7%	14.5%	0.0%	0.6%	31.1%
67	91.4	28.5	0.2	1.3	50.7	53.1%	16.6%	0.1%	0.8%	29.4%
133	90.6	24.8	2.1	2.1	52.6	52.6%	14.4%	1.2%	1.2%	30.6%
139	92.3	20.7	0.2	2.9	55.7	53.7%	12.1%	0.1%	1.7%	32.4%

Apx Table 3-8: Decision variables values and final aquifer storage for the selected non-dominated solutions of 2013 scenario with Priority Set #2

No	MN ADP to Onka Conf (ML/month)	MNMA to Torrens (ML/month)	MN MBO to Onka (ML/month)	MNSRS to Gawler (ML/month)	WW Dist Cap Sim Limit Bolivar (ML/year)	WW DistCap SimLimit Christies (ML/year)	WW DistCap SimLimit Glenelg (ML/year)	WWDist Cap Sim Limit Bolivar Fraction RND	WW DistCap Sim Limit Christies Fraction RNP	WW Dist Cap Sim Limit Glenelg Fraction RNP	No. of new SW schemes	Average annual SW aquifer storage (GL/year)	Notes
1	2457	3603	7185	177	2034	12066	3366	0.06	0.11	0.50	3	4.46	Min Tc, Max Discharge, CP13
31	41	1564	5716	263	33200	8460	5378	0.73	0.79	0.24	3	7.46	Max NP Vol Rel
60	11	1612	5710	35	40216	14066	15132	0.56	0.04	0.49	6	12.37	CP1234
61	9	1138	6058	7	41306	16220	17654	0.52	0.84	0.64	4	5.97	Min TE
67	63	3930	4910	112	37306	9546	14041	0.58	0.79	0.53	10	16.56	CP134, CP14
133	1234	2886	4346	267	46020	8663	13795	0.69	0.61	0.66	16	22.91	Max TE
139	114	1103	4741	2	49464	10369	18175	0.58	0.93	0.88	13	22.88	Max Tc, Min NP Vol Rel, Min Discharge

Apx Table 3-9: Capital and operational costs divided by source for the selected non-dominated solutions of 2013 scenario with Priority Set #2

No	Total Capital Cost (M$)	Total Op. Cost (M$)	Capital Cost Of SW (M$)	Capital Cost Of WW (M$)	Op Cost Of ML (M$/year)	Op Cost Of RM (M$/year)	Op Cost Of ADP (M$/year)	Op Cost Of SW (M$/year)	Op Cost Of WW (M$/year)
1	88	2433	57	32	23	30	34	4	100
31	547	2576	159	388	21	19	30	7	124
60	1060	2697	219	842	21	16	30	10	134
61	1178	2621	27	1150	21	14	30	5	135
67	1177	2720	395	782	21	16	30	14	132
133	2339	2783	1159	1181	21	14	32	16	135
139	2501	2772	916	1584	20	13	30	17	137

Appendix 4 Optimal solutions for 2013 scenario (Priority Set #3)

The results of the selected solutions for the 2013 scenario with Priority Set #3 are given in Apx Table 4-1. The comparison of the selected solutions shows that solutions obtained using the Priority Set #3 are slightly more expensive than the ones obtained with Priority Sets #1 and 2 and that this difference is in the order of 1-3%. The increased total cost is caused by the reduced use of River Murray water.

Note that the maximum demand supplied by wastewater plants is about 33% in all cases, while the minimum amount of recycled wastewater supplied changes depending on the scenarios and the priority sets used. For example, solutions found with the Priority Set #3 use a larger volume of recycled stormwater (in the order of 3-5% for Priority Sets #1 and 2 compared to about 10% for priority set #3).

Apx Table 4-1: Objective function value for the selected non-dominated solutions of 2013 scenario with Priority Set #3

No	TC (M$)	Cost/kL ($/kL)	TE (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
1	2513	0.58	4537	1.05	100.00%	166	Min Tc, Max Discharge, CP13
29	3355	0.78	5306	1.23	100.00%	138	Max TE
33	3482	0.81	4234	0.98	100.00%	133	CP134
34	3527	0.82	4129	0.96	99.90%	129	CP14
40	3664	0.85	3380	0.79	99.87%	131	Min TE
52	3971	0.92	3459	0.80	99.93%	119	CP1234
54	4035	0.94	3947	0.92	100.00%	120	Max NP Vol Rel
90	5184	1.20	4432	1.03	99.71%	107	Min Discharge
95	5400	1.25	4419	1.03	99.64%	108	Min NP Vol Rel
100	5607	1.30	4212	0.98	99.67%	108	Max Tc

Apx Table 4-2: Supply from each source for the selected non-dominated solutions of 2013 scenario with Priority Set #3

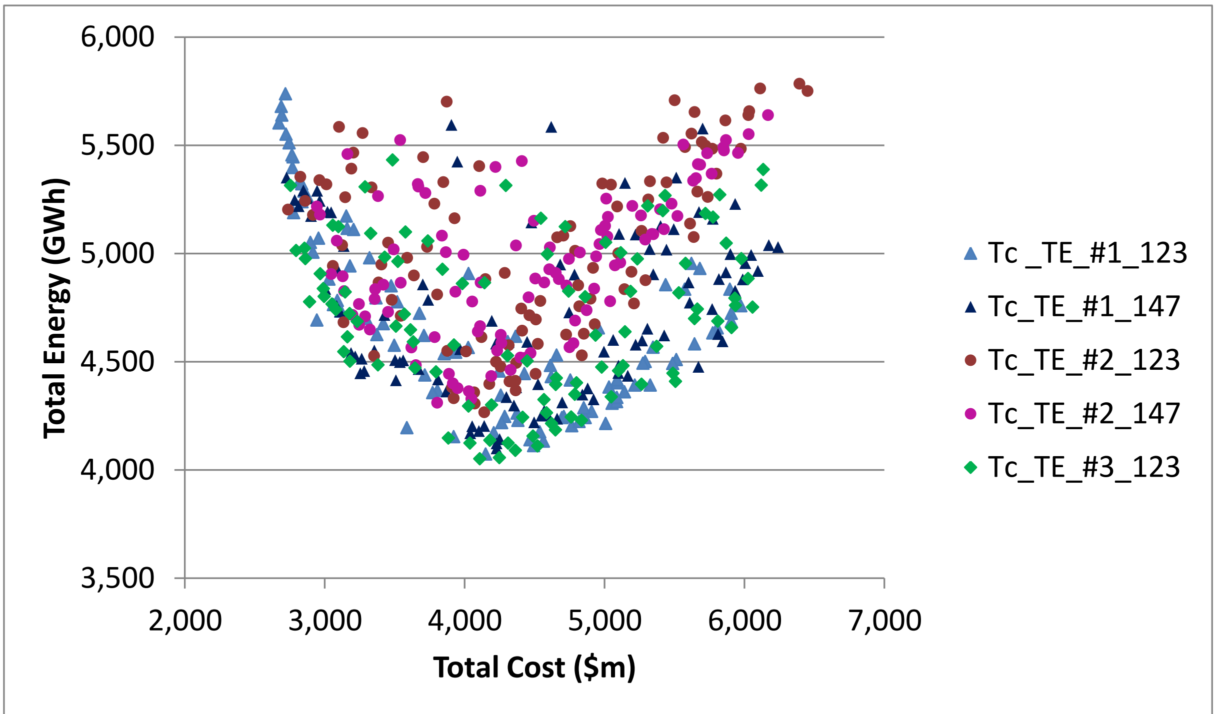
No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Water Supplied By Mount Lofty Percent	Water Supplied By River Murray Percent	Water Supplied By ADP Percent	Water Supplied By SW Percent	Water Supplied By WW Percent
1	93.2	55.8	0.6	3.7	18.9	54.1%	32.4%	0.3%	2.1%	11.0%
29	90.6	20.8	15.6	10.5	34.8	52.6%	12.1%	9.0%	6.1%	20.2%
33	92.2	29.3	1.9	13.3	35.5	53.5%	17.0%	1.1%	7.7%	20.6%
34	88.1	28.0	2.6	11.5	41.8	51.2%	16.3%	1.5%	6.7%	24.3%
40	91.5	21.3	0.0	7.3	51.9	53.2%	12.4%	0.0%	4.2%	30.2%
52	89.4	15.3	0.0	15.5	52.0	51.9%	8.9%	0.0%	9.0%	30.2%
54	88.7	13.3	4.4	14.9	50.9	51.5%	7.7%	2.6%	8.6%	29.6%
90	82.9	13.0	3.3	17.1	55.7	48.2%	7.5%	1.9%	10.0%	32.4%
95	83.0	10.7	3.4	18.9	55.8	48.3%	6.2%	2.0%	11.0%	32.5%
100	83.0	12.6	0.2	20.4	55.7	48.3%	7.3%	0.1%	11.9%	32.4%

Apx Table 4-3: Decision variables values and final aquifer storage for the selected non-dominated solutions of 2013 scenario with Priority Set #3

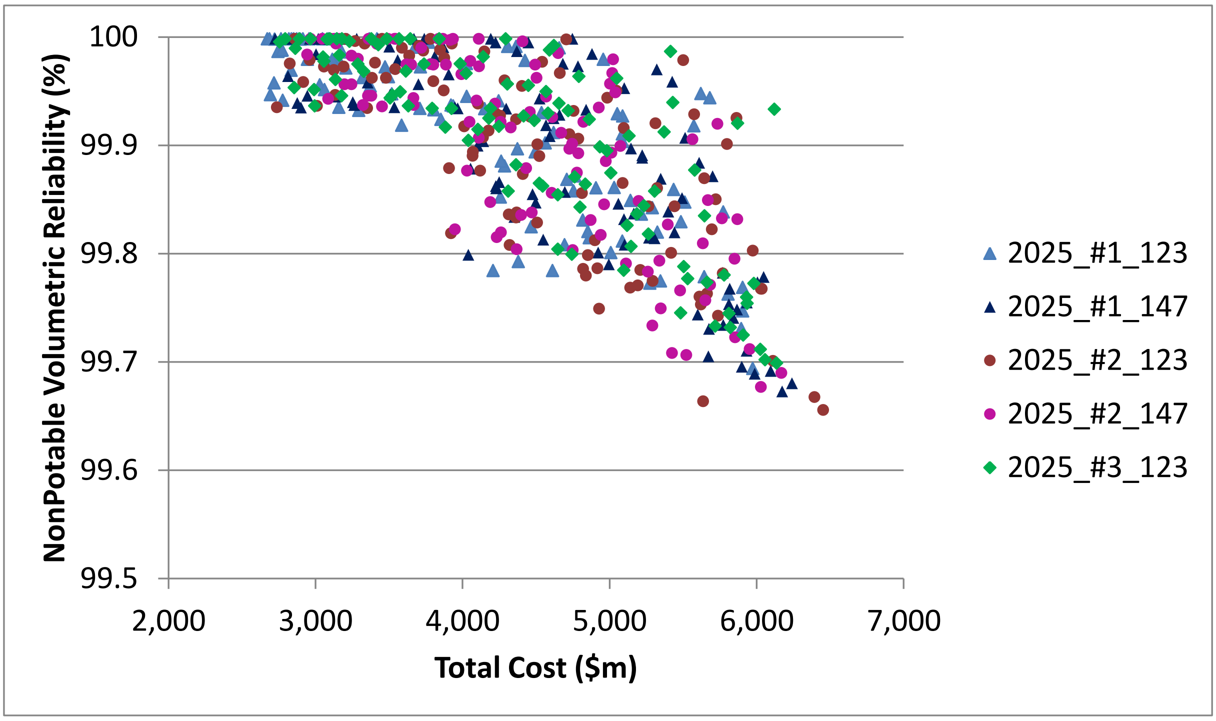
No	MN ADP to Onka Conf (ML/month)	MNMA to Torrens (ML/month)	MN MBO to Onka (ML/month)	MNSRS to Gawler (ML/month)	WW DistCap SimLimit Bolivar (ML/year)	WW DistCap SimLimit Christies (ML/year)	WW DistCap SimLimit Glenelg (ML/year)	WW Dist Cap Sim Limit Bolivar Fraction RND	WW Dist Cap Sim Limit Christies Fraction RND	WW Dist Cap Sim Limit Glenelg Fraction RND	No. of new SW schemes	Average annual SW aquifer storage (GL/year)	Notes
1	74	8941	6989	437	14527	9637	3465	0.08	0.01	0.93	2	2.21	Min Tc, Max Discharge, CP13
29	3267	10187	9880	3	28776	8686	3706	0.50	0.57	0.78	8	4.84	Max TE
33	336	1663	9895	4	28776	8686	3706	0.51	0.76	0.84	11	5.51	CP134
34	438	163	7678	300	37476	14888	3816	0.74	0.85	0.65	9	4.96	CP14
40	3	1101	5210	130	37682	12399	13967	0.64	0.74	0.65	6	0.19	Min TE
52	0	1540	5454	49	37682	12399	13967	0.66	0.74	0.65	6	1.31	CP1234
54	1286	846	7757	164	38542	8998	13424	0.65	0.68	0.67	8	1.77	Max NP Vol Rel
90	1543	3397	2628	1088	46638	11324	16921	0.66	0.79	0.81	18	5.98	Min Discharge
95	1546	1312	4236	949	50663	14509	16916	0.69	0.79	0.73	15	3.88	Min NP Vol Rel
100	70	2366	5607	330	51401	15634	18198	0.56	0.94	0.89	16	2.27	Max Tc

Appendix 5 Optimal solutions for 2025 scenario (Priority Sets #1, #2 and #3)

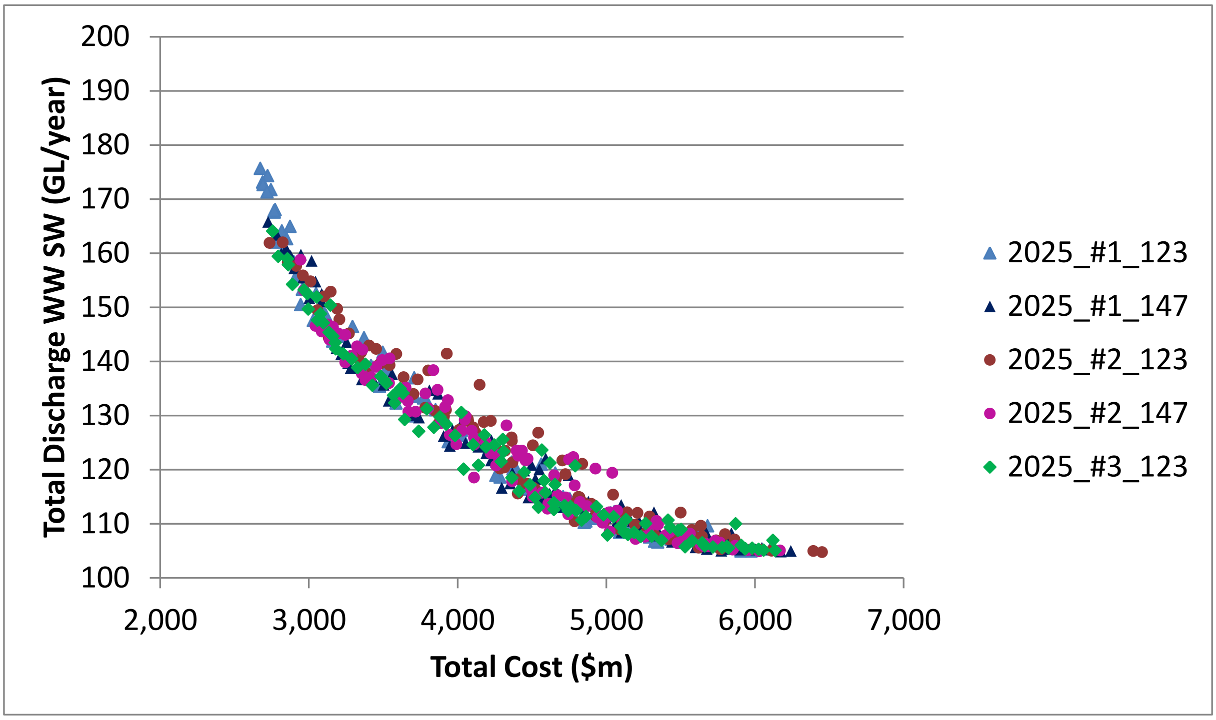
Apx Figure 5-1 to Apx Figure 5-3 show the total cost, total energy, non-potable volumetric reliability and discharges to the Gulf of the solutions obtained using Priority Sets #1, #2 and #3 for the 2025 scenario. As the solutions obtained using Priority Sets #3 have values of the objective functions similar to solutions obtained using Priority Sets #1 and #2, in the following the non-dominated solutions obtained using Priority Sets #1 and #2 will be presented.



Apx Figure 5-1: Total costs and total energy of the solutions found for the 2025 scenario with Priority Sets #1, #2 and #3

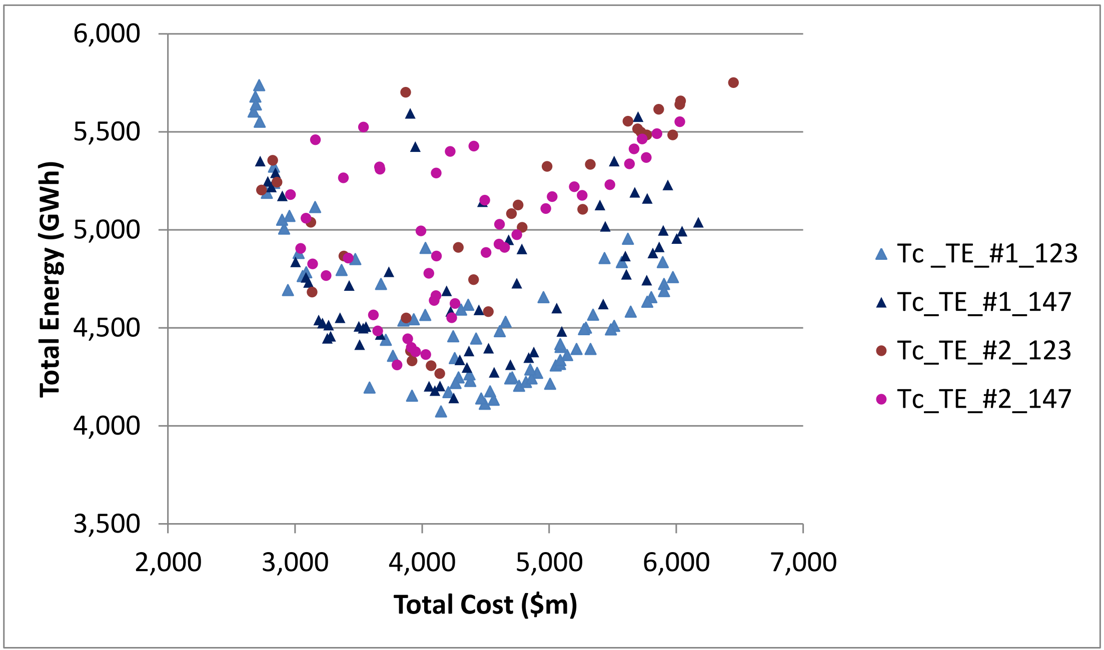


Apx Figure 5-2: Total costs and volumetric reliability of the solutions found for the 2025 scenario with Priority Sets #1, #2 and #3

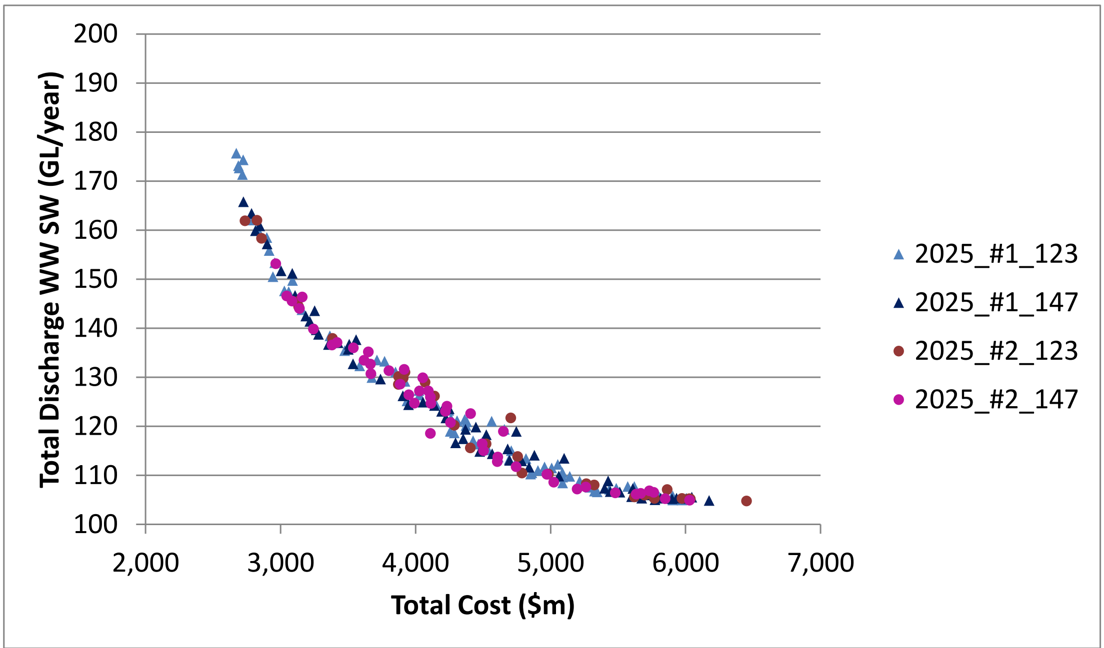


Apx Figure 5-3: Total costs and total discharges of the solutions found for the 2025 scenario with Priority Sets #1, #2 and #3

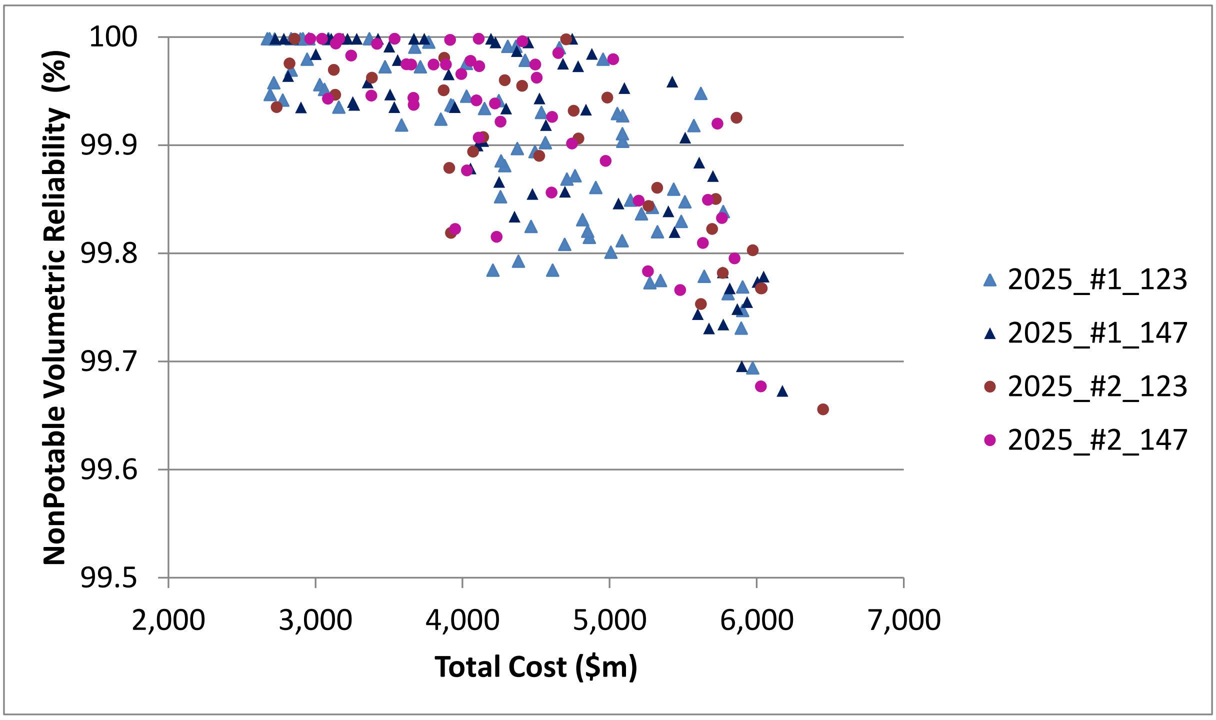
Non-dominated solutions for the 2025 scenario using Priority Sets #1 and #2 are shown in Apx Figure 5-4 to Apx Figure 5-13, while the characteristics of the selected solutions are given in Apx Table 5-1 to Apx Table 5-4. As for the other scenarios, there are trade-offs between the costs of the solutions, their energy consumptions and the volume of stormwater and wastewater discharged in to the Gulf. As for the other scenarios, the non-potable reliability is close to 100% (Apx Figure 5-6) and the largest part of the operational costs comes from the treatment of wastewater (Apx Figure 5-12). For this scenario, the percentage of stormwater reuse reaches values close to 10% as in the 2050 scenario (Apx Figure 5-13).



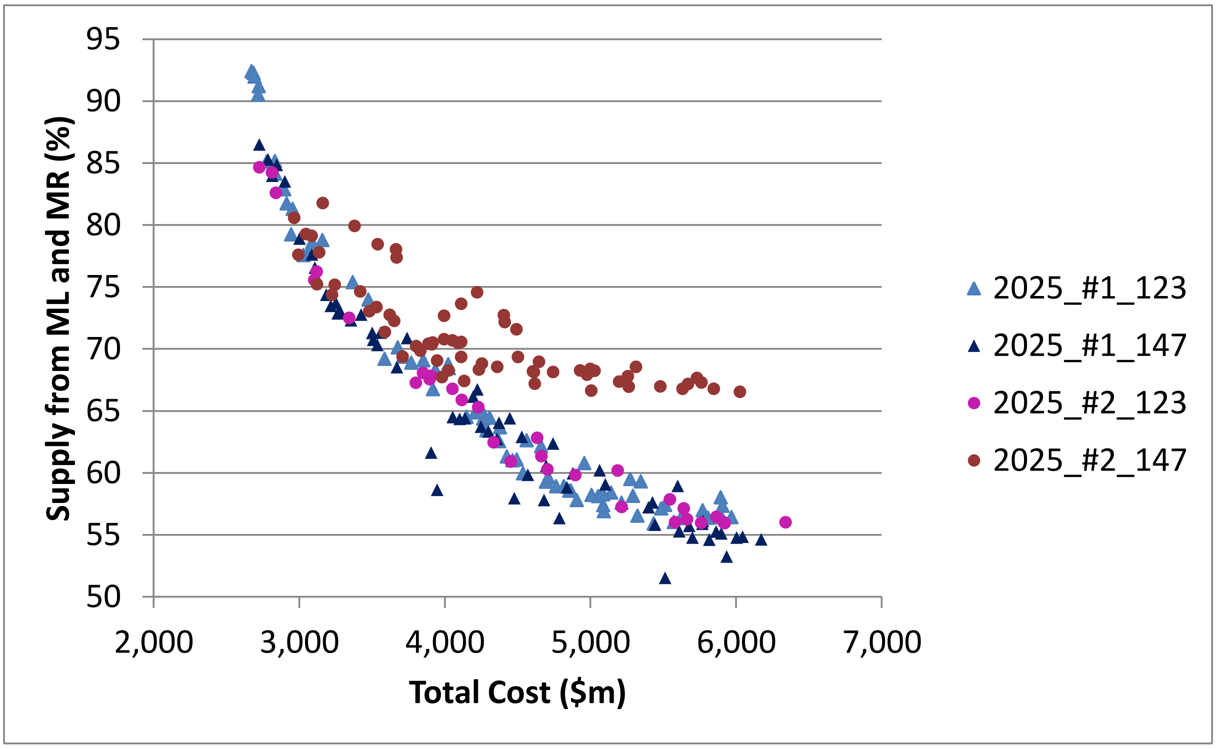
Apx Figure 5-4: Cost and energy of non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



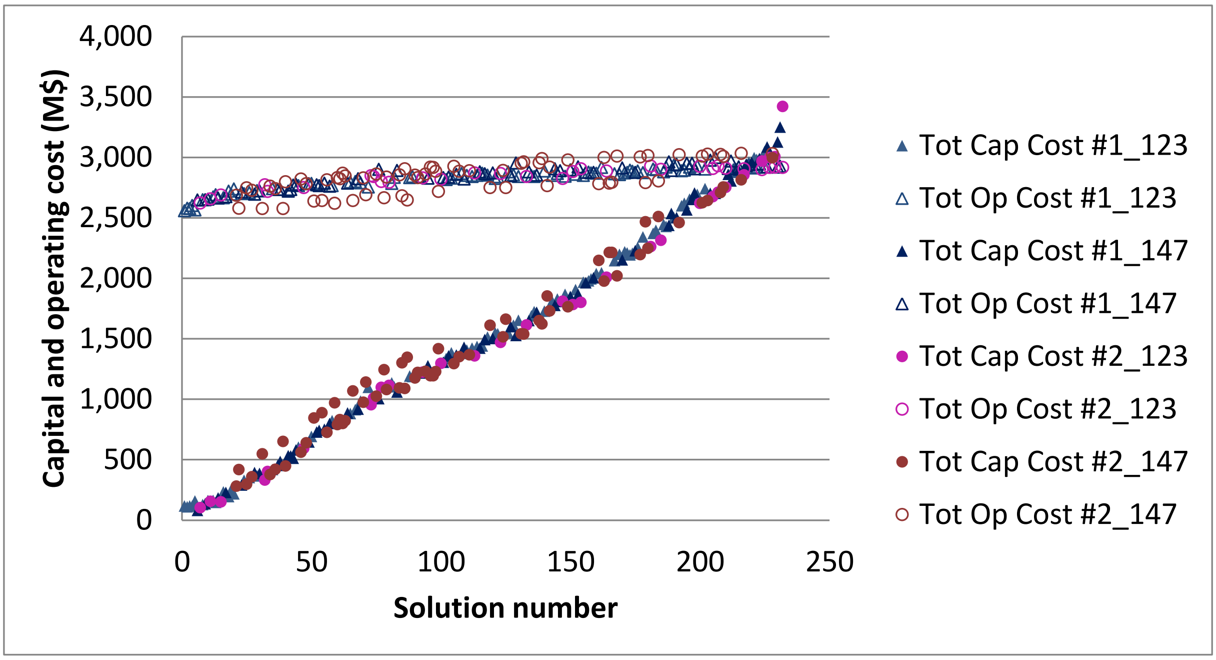
Apx Figure 5-5: Costs and total discharges from stormwater and wastewater of non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



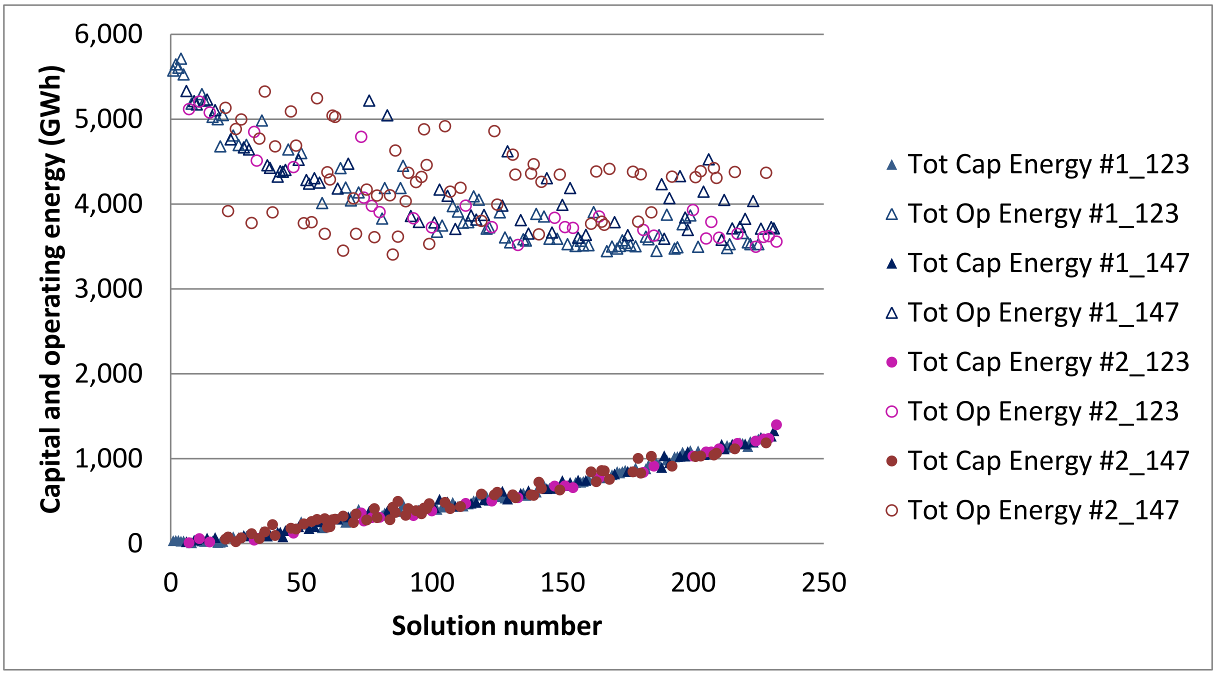
Apx Figure 5-6: Costs and non-potable volumetric reliability of non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



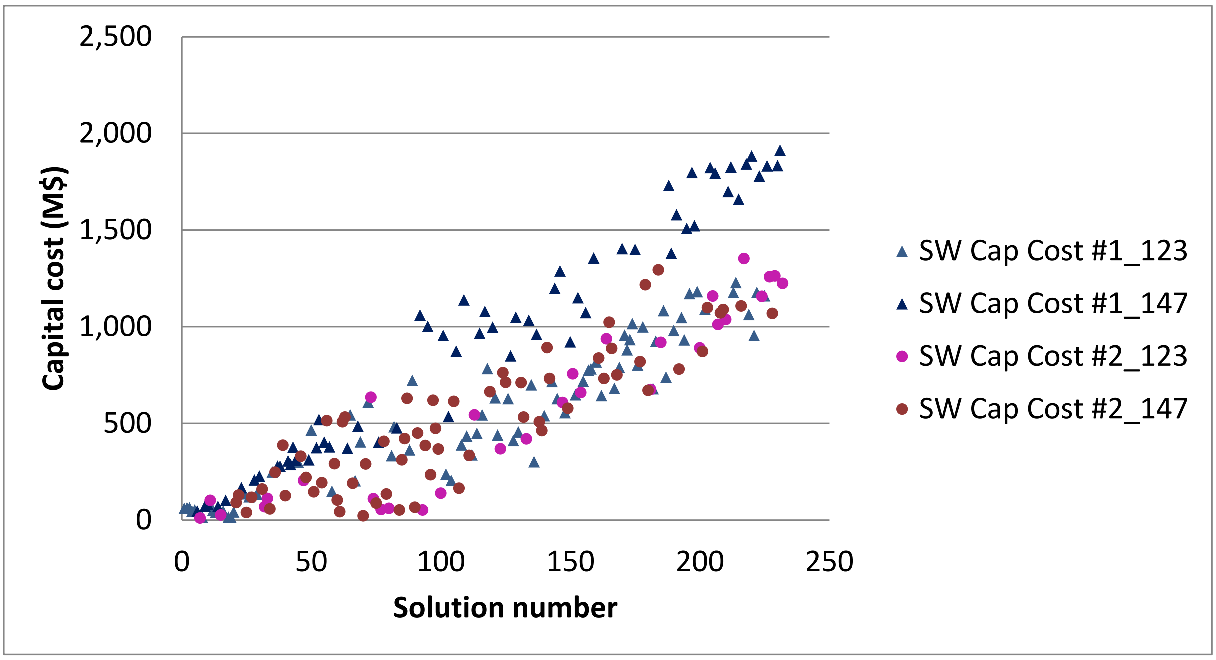
Apx Figure 5-7: Cost and percentage of water supplied by Mount Lofty (ML) and Murray River (MR) sources of non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



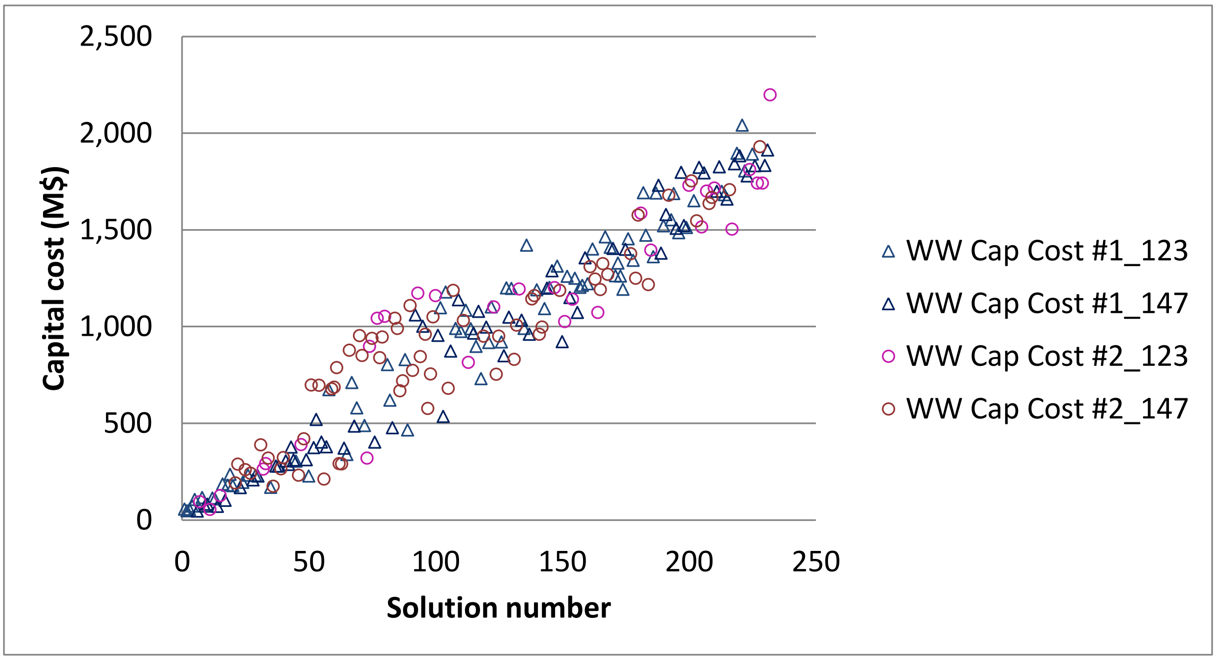
Apx Figure 5-8: Operational and capital cost of the non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



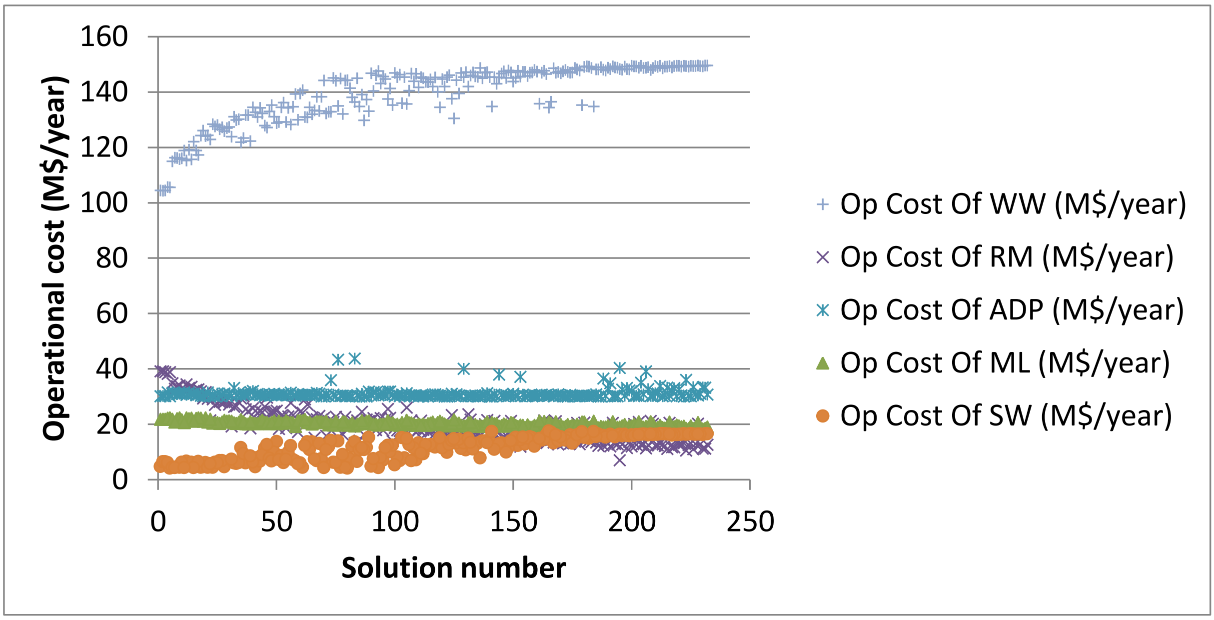
Apx Figure 5-9: Operational and capital energy non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



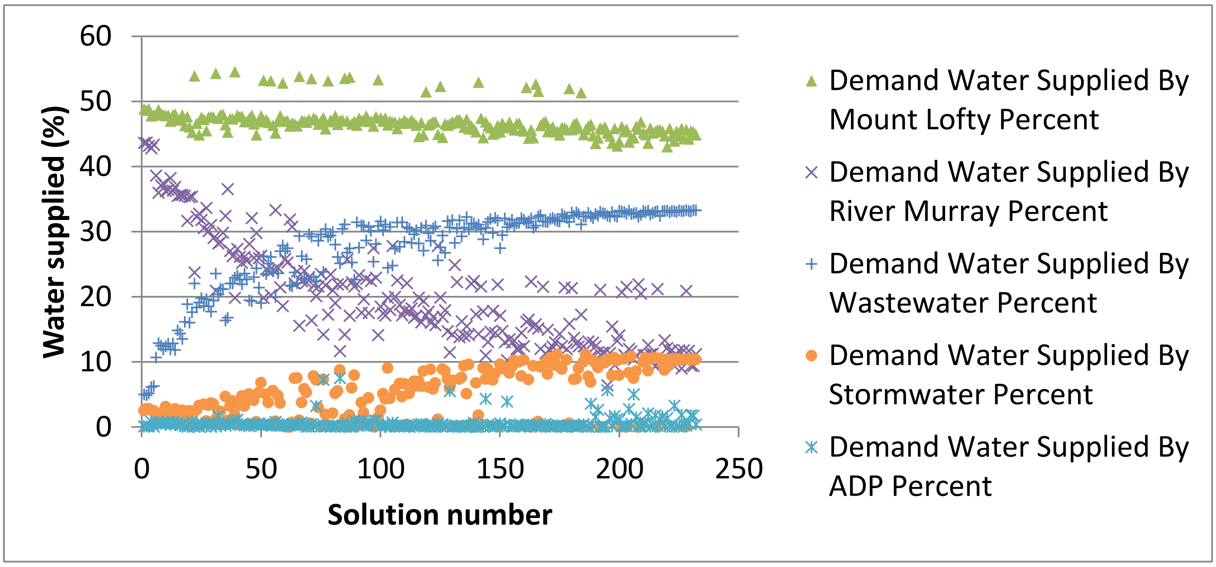
Apx Figure 5-10: Capital cost of the new infrastructure associated with stormwater (SW) of non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



Apx Figure 5-11: Capital cost of the new infrastructure associated with wastewater (WW) of non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



Apx Figure 5-12: Operational costs of non-dominated solutions divided by source for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147



Apx Figure 5-13: Percentage of supply for each source for the non-dominated solutions for the 2025 scenario with Priority Sets #1 and #2 and seeds 0.123 and 0.147

The value of the objective functions of the selected solutions is given in Apx Table 5-1, while Apx Table 5-4 shows the capital and operational costs. It can be seen that solutions with the lowest discharges to the Gulf usually have larger total cost, resulting from the operational and capital costs of stormwater schemes and wastewater plant upgrades. It can also be seen that, for the most expensive solutions, the operational costs of Mount Lofty and River Murray sources decrease as they supply a smaller volume of water (Apx Table 5-4).

As can be seen in Apx Table 5-3, the number of stormwater schemes implemented ranges from 2 for the minimum cost solution to 19 for the minimum discharge solution. Also in this case, some stormwater is stored in the aquifer: for example, solution 232 (the minimum discharge solution) only 2.77 GL/year are stored in the aquifer, while 18.9 GL/year are on average supplied to the users. In contrast, some solutions (e.g. 96) supplied only 0.6 GL/year to the users and stored 14.96 GL/year in the aquifer. Storing stormwater in the aquifer reduces the discharges to the Gulf, although some of the volume stored in the aquifer could be due to the difficulty of the model of matching injection and extraction.

Apx Table 5-1: Objective function values for the selected non-dominated solutions of 2025 scenario

No	Total Cost (M$)	Cost/kL ($/kL)	Total Energy (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
1	2674	0.59	5603	1.23	100.00%	176	Min Tc, Max Discharge, CP13
31	3123	0.68	3887	0.85	100.00%	139	Max NP Vol Rel
65	3677	0.80	4723	1.03	99.99%	130	CP134
66	3711	0.81	3770	0.83	99.98%	129	Min TE, CP1234
96	4113	0.90	4664	1.02	99.90%	119	CP14
232	6340	1.39	4952	1.08	99.66%	105	Max Tc, Max TE, Min Discharge, Min NP Vol Rel

Apx Table 5-2: Supply from each source for the selected non-dominated solutions of 2025 scenario

No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Water Supplied By Mount Lofty Percent	Water Supplied By River Murray Percent	Water Supplied By ADP Percent	Water Supplied By SW Percent	Water Supplied By WW Percent
1	89.3	79.7	0.1	4.6	9.1	48.8%	43.6%	0.0%	2.5%	5.0%
31	93.5	36.0	0.1	2.1	40.5	54.3%	20.9%	0.1%	1.2%	23.5%
65	84.5	43.7	0.5	13.8	40.3	46.3%	23.9%	0.3%	7.5%	22.0%
66	92.7	26.7	0.4	1.8	50.5	53.8%	15.5%	0.3%	1.1%	29.3%
96	85.8	40.9	0.5	0.6	55.0	47.0%	22.4%	0.2%	0.3%	30.1%
232	81.8	20.3	0.7	18.9	60.7	44.9%	11.2%	0.4%	10.4%	33.3%

Apx Table 5-3: Decision variable values and final aquifer storage for the selected non-dominated solutions of 2025 scenario

No	MN ADP to Onka Conf (ML/month)	MNMA to Torrens (ML/month)	MN MBO to Onka (ML/month)	MNSRS to Gawler (ML/month)	WW DistCap SimLimit Bolivar (ML/year)	WW DistCap SimLimit Christies (ML/year)	WW DistCap SimLimit Glenelg (ML/year)	WWDist Cap Sim Limit Bolivar Fraction RND	WW DistCap Sim Limit Christies Fraction RND	WW Dist Cap SimLimit Glenelg Fraction RND	No. of new SW scheme s	Average annual SW aquifer storage (GL/year)	Notes
1	87	3790	11700	17	7	9660	223	0.78	0.56	0.87	2	1.59	Min Tc, Max Discharge, CP13
31	41	1564	5716	263	33200	8460	5378	0.73	0.79	0.24	3	7.46	Max NP Vol Rel
65	1406	1310	13300	731	39600	10600	1510	0.54	0.58	0.71	10	4.17	CP134
66	154	2419	4051	126	35358	8513	15297	0.71	0.55	0.71	6	7.85	Min TE, CP1234
96	4616	1530	13235	259	36911	15965	17650	0.63	0.48	0.48	7	14.68	CP14
232	7421	3085	11536	148	58489	14809	20945	0.69	0.94	0.66	19	2.77	Max Tc, Max TE, Min Discharge, Min NP Vol Rel

Apx Table 5-4: Capital and operational costs for each source for the selected non-dominated solutions of 2025 scenario

No	PV of Capital Cost (M$)	PV of Op. Cost (M$)	Capital Cost Of SW (M$)	Capital Cost Of WW (M$)	Op Cost Of ML (M$/year)	Op Cost Of RM (M$/year)	Op Cost Of ADP (M$/year)	Op Cost Of SW (M$/year)	Op Cost Of WW (M$/year)
1	116	2558	60	56	22	39	30	5	104
31	547	2576	159	388	21	19	30	7	124
65	882	2795	544	338	20	22	31	14	132
66	1067	2644	190	877	21	15	30	7	133
96	1195	2919	234	960	20	22	30	12	145
232	3422	2918	1224	2199	19	13	31	17	150

Apx Table 5-5 to Apx Table 5-7 give objective function values, decision variable values and supply from each source for selected solutions obtained using the Priority Set #3. Results are similar to the ones shown for Priority Sets #1 and #2.

Apx Table 5-5: Objective function value for the selected non-dominated solutions of 2025 scenario with Priority Set #3

No	Total Cost (M$)	Cost ($/kL)	Total Energy (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
1	2756	0.60	5314	1.16	100.00	164	Min TC, Max Discharge, CP13
23	3486	0.76	5432	1.19	100.00	137	Max TE
30	3646	0.80	4471	0.98	100.00	129	Max NP Vol Rel
31	3738	0.82	5058	1.11	99.98	127	CP134
38	4038	0.88	4125	0.90	99.90	120	CP1234, CP14
39	4108	0.90	4052	0.89	99.91	125	Min TE
100	6134	1.34	5388	1.18	99.70	105	Max Tc, Min Discharge, Min NP Vol Rel

Apx Table 5-6: Supply from each source for the selected non-dominated solutions of 2025 scenario with Priority Set #3

No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Water Supplied By Mount Lofty Percent	Water Supplied By River Murray Percent	Water Supplied By ADP Percent	Water Supplied By SW Percent	Water Supplied By WW Percent
1	85.0	72.5	0.1	3.8	21.3	46.5%	39.7%	0.1%	2.1%	11.7%
23	86.4	43.1	7.4	10.7	35.1	47.3%	23.6%	4.1%	5.9%	19.2%
30	86.7	39.8	0.0	13.4	42.8	47.4%	21.8%	0.0%	7.3%	23.4%
31	83.5	38.4	5.2	13.2	42.4	45.7%	21.0%	2.9%	7.2%	23.2%
38	86.7	31.4	0.1	8.3	56.1	47.5%	17.2%	0.0%	4.5%	30.7%

No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Water Supplied By Mount Lofty Percent	Water Supplied By River Murray Percent	Water Supplied By ADP Percent	Water Supplied By SW Percent	Water Supplied By WW Percent
39	86.4	31.0	0.1	9.0	56.3	47.3%	17.0%	0.0%	4.9%	30.8%
100	79.4	20.4	5.3	16.8	60.6	43.5%	11.2%	2.9%	9.2%	33.2%

Apx Table 5-7: Decision variables values and final aquifer storage for the selected non-dominated solutions of 2025 scenario with Priority Set #3.

No	MN ADP to Onka Conf (ML/month)	MNMA to Torrens (ML/month)	MN MBO to Onka (ML/month)	MNSRS to Gawler (ML/month)	WW DistCap SimLimit Bolivar (ML/year)	WW DistCap SimLimit Christies (ML/year)	WW DistCap SimLimit Glenelg (ML/year)	WWDist Cap Sim Limit Bolivar Fraction RND	WW DistCap Sim Limit Christies Fraction RND	WW Dist Cap SimLimit Glenelg Fraction RND	No. of new SW schemes	Average annual SW aquifer storage (GL/year)	Notes
1	14	7792	11754	1141	30122	13711	250	0.15	0.00	0.08	2	1.94	Min TC, Max Discharge, CP13
23	1002	5463	7914	178	32272	9950	2184	0.43	0.49	0.63	8	5.46	Max TE
30	7	2788	6803	268	38142	9610	6501	0.47	0.64	0.59	9	2.99	Max NP Vol Rel
31	727	4921	6442	1048	37214	10797	3165	0.71	0.67	0.84	10	5.17	CP134
38	9	1209	7061	113	38426	12686	17132	0.61	0.68	0.64	6	4.75	CP1234, CP14
39	8	2519	5618	113	38984	12528	17255	0.61	0.83	0.56	8	0.43	Min TE
100	1904	3345	13964	1059	58895	13717	18949	0.69	0.94	0.79	15	4.76	Max Tc, Min Discharge, Min NP Vol Rel

Appendix 6 Optimal solutions for 2050 scenario (Priority Set #3)

The results of the selected solutions for the 2050 scenario with Priority Set #3 are given in Apx Table 6-1 to Apx Table 6-3.

Apx Table 6-1: Objective function value for the selected non-dominated solutions of 2050 scenario with Priority Set #3

No	Total Cost (M$)	Cost/kL ($/kL)	Total Energy (GWh)	Energy/kL (kWh/kL)	System Demand NP Volumetric Rel (%)	Total System Discharges SW and WW (GL/year)	Notes
1	3202	0.60	7332	1.38	99.99%	167	Min Tc, Max Discharge
2	3221	0.61	7360	1.39	100.00%	165	CP13
28	4013	0.76	6360	1.20	100.00%	132	Max NP Vol Rel
33	4215	0.79	6693	1.26	100.00%	128	CP134
36	4376	0.82	6302	1.19	99.94%	125	CP14
42	4613	0.87	6230	1.17	99.98%	121	CP1234
55	5067	0.95	5902	1.11	99.91%	115	Min TE
63	5337	1.00	7668	1.44	99.95%	111	Max TE
99	6838	1.29	7082	1.33	99.81%	99	Min NP Vol Rel, Min discharge
100	6914	1.30	6671	1.26	99.85%	99	Max TC

Apx Table 6-2: Supply from each source for the selected non-dominated solutions of 2050 scenario with Priority Set #3

No	Total Supply ML (GL/yr)	Total Supply RM (GL/yr)	Total Supply ADP (GL/yr)	Total Supply SW (GL/yr)	Total Supply WW (GL/yr)	Demand Water Supplied By Mount Lofty Percent	Demand Water Supplied By River Murray Percent	Demand Water Supplied By ADP Percent	Demand Water Supplied By SW Percent	Demand Water Supplied By WW Percent
1	74.1	114.2	0.0	3.8	20.3	34.9%	53.8%	0.0%	1.8%	9.6%
2	74.2	113.6	0.3	4.6	19.9	34.9%	53.4%	0.1%	2.1%	9.4%
28	73.5	81.4	0.0	12.1	45.6	34.6%	38.3%	0.0%	5.7%	21.4%
33	71.6	81.3	1.6	11.6	46.4	33.7%	38.2%	0.8%	5.5%	21.9%
36	74.2	75.8	0.0	13.2	49.2	34.9%	35.7%	0.0%	6.2%	23.2%
42	72.6	73.4	0.1	10.2	56.2	34.2%	34.6%	0.0%	4.8%	26.4%
55	74.0	62.5	0.1	11.1	64.7	34.8%	29.4%	0.0%	5.2%	30.5%
63	73.0	45.5	19.3	12.2	62.4	34.4%	21.4%	9.1%	5.8%	29.4%
99	72.0	44.0	8.3	17.1	70.9	33.9%	20.7%	3.9%	8.0%	33.4%
100	72.0	50.3	2.1	17.2	70.6	33.9%	23.7%	1.0%	8.1%	33.3%

Apx Table 6-3: Decision variables values and final aquifer storage for the selected non-dominated solutions of 2050 scenario with Priority Set #3

No	MN ADP to Onka Conf (ML/month)	MNMA to Torrens (ML/month)	MN MBO to Onka (ML/month)	MNSRS to Gawler (ML/month)	WW DistCap SimLimit Bolivar (ML/year)	WW DistCap SimLimit Christies (ML/year)	WW DistCap SimLimit Glenelg (ML/year)	WWDist Cap Sim Limit Bolivar Fraction RND	WW DistCap Sim Limit Christies Fraction RND	WW Dist Cap SimLimit Glenelg Fraction RND	No. of new SW schemes	Average annual SW aquifer storage (GL/year)	Notes
1	1	8225	11284	39	10895	14511	2018	0.53	0.10	0.05	4	1.35	Min Tc, Max Discharge
2	25	6983	11770	72	10494	10108	519	0.54	0.48	0.25	3	2.24	CP13
28	2	7809	7489	81	39059	11471	3228	0.54	0.91	0.16	6	0.34	Max NP Vol Rel
33	161	9570	7875	705	41317	11468	3487	0.55	0.60	0.23	9	3.65	CP134
36	0	2269	9900	110	43984	15866	2648	0.63	0.81	0.61	9	2.36	CP14
42	8	2506	12420	610	35902	13692	19047	0.52	0.17	0.91	4	2.54	CP1234
55	11	1635	10335	144	43642	12100	21898	0.60	0.58	0.64	6	0.02	Min TE
63	2341	2921	12598	201	41672	15580	19805	0.81	0.56	0.38	8	3.73	Max TE
99	1118	1606	11867	652	60100	14932	21873	0.71	0.71	0.90	15	1.85	Min NP Vol Rel, Min Discharge
100	280	1606	11885	652	60071	14969	20905	0.70	0.81	0.66	18	1.88	Max TC

Appendix 7 Command line instructions for the Insight module

An Insight optimisation run can be carried out through a graphic user interface (GUI) or using Command Line (i.e. scripts). As the command line option is more flexible and faster, it is used in this project. A brief guideline on how to use Insight on Command Line is provided here. A detailed description of how to use Insight through the GUI can be found on the eWater website[5].

In order to run Insight using Command Line, four files are required: a configuration text file specifying optimisation configurations (i.e. InsightConfig.txt), a WCF test file indicating the server(s) to be used by the Source model (i.e. WcfFile.txt), a batch file to start the server(s) (I.e. StartServer.bat) and a batch file to start the insight run (i.e. InsightRun.bat). When running Insight, start the server(s) using the startserver.bat batch file first. Once the servers are ready, the optimisation run can be started simply by double-clicking the InsightRun.bat batch file. An example of these files are summarised in Apx Figure 7-1 to Apx Figure 7-4. A summary of the Insight help file is provided in Apx Figure 7-5.

```
Project D:\Data\Documents\OPTIMALmix2013\TestRun\AdelaideBase1.00.rsproj
Output ObjectiveVariable1
Output ObjectiveVariable2
Output ObjectiveVariable3
Real RealNumberDV1 lowerBoundOfDV1 UpperBoundOfDV1
Real RealNumberDV2 lowerBoundOfDV2 UpperBoundOfDV2
Discrete DiscreteDV1 Option1 Option2 Option3
Discrete DiscreteDV2 Option1 Option2 Option3 Option4
```

Apx Figure 7-1: Example of Insight configuration file – InsightConfig.txt

```
net.tcp://localhost:8523/eWater/Services/RiverSystemService
net.tcp://localhost:8524/eWater/Services/RiverSystemService
net.tcp://localhost:8525/eWater/Services/RiverSystemService
net.tcp://localhost:8526/eWater/Services/RiverSystemService
```

Apx Figure 7-2: Example of WCF file – WcfFile.txt

5 <https://ewater.atlassian.net/wiki/display/SD35/Insight%3A+Objective+optimisation>

```
@echo off
Set SourceExe="C:\Program Files\eWater\Source 3.3.0.236\RiverSystem.CommandLine.exe"
REM Start Source in server mode
start cmd /c "%SourceExe% -m Server -a net.tcp://localhost:8523/eWater/Services/RiverSystemService"
start cmd /c "%SourceExe% -m Server -a net.tcp://localhost:8524/eWater/Services/RiverSystemService"
start cmd /c "%SourceExe% -m Server -a net.tcp://localhost:8525/eWater/Services/RiverSystemService"
start cmd /c "%SourceExe% -m Server -a net.tcp://localhost:8526/eWater/Services/RiverSystemService"
echo PLEASE WAIT FOR THE SERVERS TO LOAD
REM The line below just waits 15 seconds for the server to load
ping 1.1.1.1 -n 1 -w 15000 > nul
REM @set /p getch="Press any key to continue..."
```

Apx Figure 7-3: Example of the batch file to start the server(s) - StartServer.bat

```
@echo off
set InsightExe="C:\Program Files\eWater\Source 3.3.0.236\Insight.Optimiser.Console.exe"
%InsightExe% --generations=500 --population=100 --configurationOption=InsightConfig.txt --output=InsightOut.txt
--seed=0.123 --sourcewcf=WcfFile.txt > ModelResults.log
@set /p getch="Press any key to continue..."
```

Apx Figure 7-4: Example of the batch file to run Insight - InsightRun.bat

Flag	Option	Notes
-g*	--generations=VALUE	Set number of generations to run. Default value is 1.
-p*	--population=VALUE	Set number of population. Default value is 4.
-c	--configurationOption=ConfigFile	Specifies the configuration file. Example ConfigFile in Appendix.
-o	--output=OutFile	Outputs the optimisation results in OutFile in csv format. Example OutFile in Appendix.
-r	--seed=SEED	Set random seed. SEED needs to be a value between 0 and 1. Default is CPU time.
-s	--spawnprocess	Spawn a new process for every model run.
-e	--source=ServerCount	Runs each model the source external interface locally, using a most Server/count number of servers. ServerCount should not exceed the number of CPUs in a computer.
-v	--viewGlobalExpressions	View global expressions defined in the project.
-w	--sourcewcf=WcfFile	Runs each model on multiple servers using the source external interface. Specify the list of WCF endpoints in WcfFile. Example WcfFile in Appendix. The servers specified in WcfFile need to be started manually in advance.
-k	--knapsack	Runs a test problem (a version of the knapsack problem). The decision and model configuration do not need to be specified.
-h, -?	--help	Show the help message.
-a	--about –licence	About the program.
*** Either flag or option can be used.**		

Apx Figure 7-5: Insight.Optimiser.Console.exe options

Most of the options shown in Apx Figure 7-5 can be used on Command Line. However, the following options can only be specified in a configuration file:

- Output objective1
- real RealDV1 LowerBound UpperBound
- discrete DiscreteDV1 Option1 Option2 Option3 (if NumberOfOption=3)

In addition, the following options can be used on both Command Line and in a configuration file. However, if they are specified at both places, the values specified on Command Line dominate the values specified in configuration file:

- --generations
- --population.

Appendix 8 Key global variables included in the Source simulation modules

Variable Name	Description
$g_TurnSubSystemOnOff_DM	Simulation level On/Off for Demand Management
$g_TurnSubSystemOnOff_RWT	Simulation level On/Off for Rainwater Tanks
$g_TurnSubSystemOnOff_SW	Simulation level On/Off for Stormwater
$g_TurnSubSystemOnOff_WW	Simulation level On/Off for Wastewater
$gCostOfAllSourcesCum	Cumulative cost of running the simulation
$gDemandWaterSuppliedByADPPercent	Percentage of supply sourced from ADP
$gDemandWaterSuppliedByMountLoftyPercent	Percentage of supply sourced from Mount Lofty dams
$gDemandWaterSuppliedByRiverMurrayPercent	Percentage of supply sourced from River Murray
$gDemandWaterSuppliedByStormwaterPercent	Percentage of supply sourced from Stormwater
$gDemandWaterSuppliedByWastewaterPercent	Percentage of supply sourced from Wastewater
$gPVOC	Cost discounted at 6% over 25 years
$gPVOE	Energy over 25 years
$gSWDischargeAllCum	Cumulative Stormwater discharges
$gSystemDemandDOrderedCum	Cumulative volume of demands over the simulation
$gSystemDemandDSuppliedCum	Cumulative volume of demands supplied over the simulation
$gSystemDemandDTimeRel	Potable supply time reliability
$gSystemDemandDVolumetricRel	Potable supply volumetric reliability
$gSystemDemandNDTimeRel	Non-Potable supply time reliability
$gSystemDemandNDVolumetricRel	Non-Potable supply volumetric reliability
$gSystemDemandTimeRel	System supply time reliability
$gSystemDemandVolumetricRel	System supply volumetric reliability
$gTC	Total Cost
$gTE	Total Energy
$gTotalSupplyADP	Total supply from the ADP
$gTotalSupplyAllSources	Total supply from the ADP
$gTotalSupplyMountLofty	Total supply from the Mount Lofty Ranges
$gTotalSupplyRiverMurray	Total supply from River Murray
$gTotalSupplyStormwater	Total supply from Stormwater
$gTotalSupplyWastewater	Total supply from Wastewater

Appendix 9 Estimating stormwater related constituent loads discharging to the Gulf

Quantifying constituent loads discharging to the Gulf St Vincent was not part of the current study. However, an attempt was taken to estimate the annual N (nitrogen), P (phosphorous) and SS (suspended solids) loads discharging to the Gulf because these were the key water quality parameters considered in the coastal water quality improvement plan of Metropolitan Adelaide (McDowell and Pfennig, 2013).

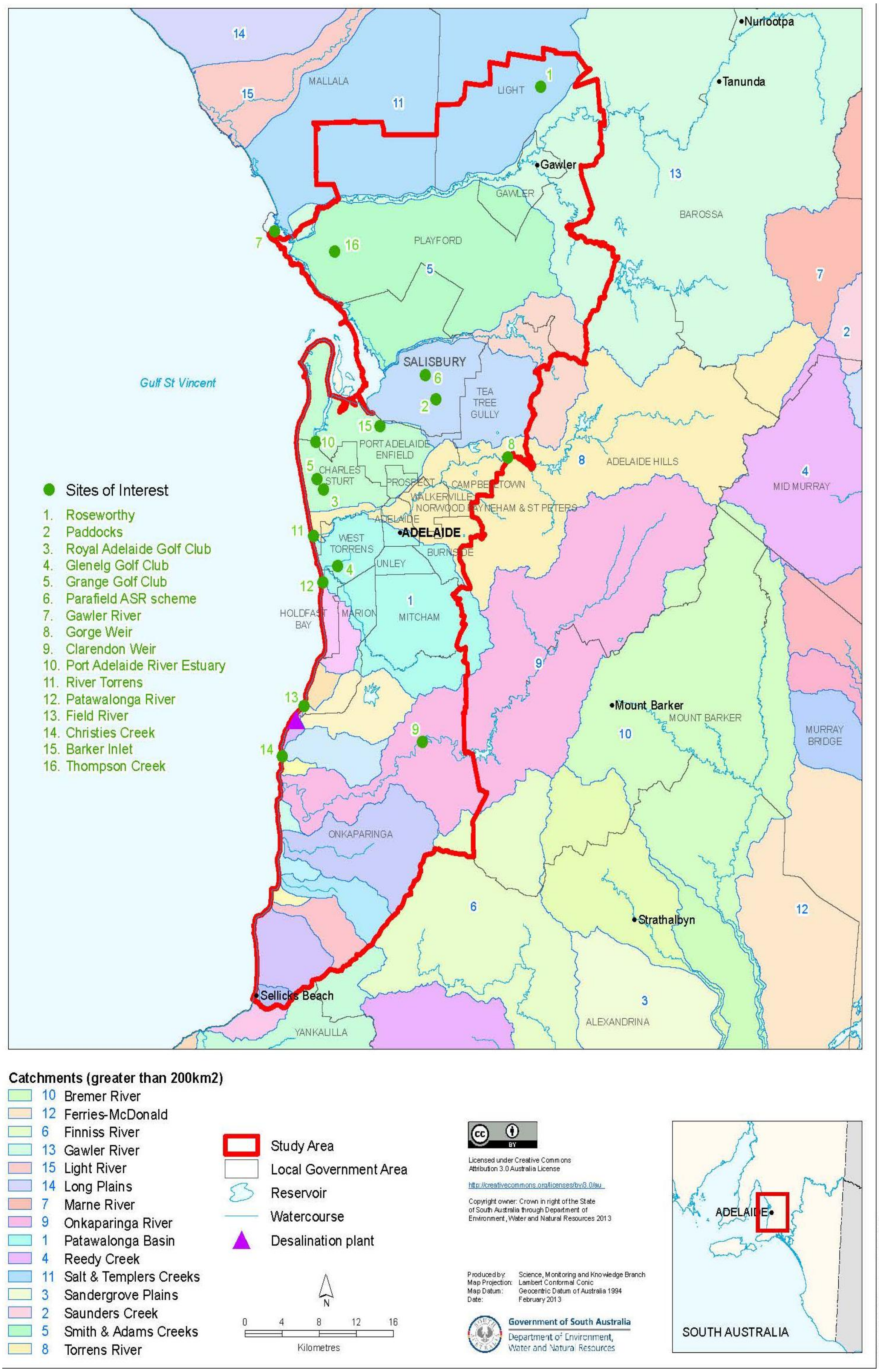
The aim of this work was to provide a better interpretation to the multi-objective optimisation related objective aimed at minimising wastewater and stormwater discharges to the Gulf St Vincent, in terms of constituent loads. Due to the limited time and funding availability, however, the focus of this work was on estimating N, P and SS associated with stormwater discharges to the Gulf only. This Appendix describes the work carried out to provide relationships to estimate the amount of P, N and SS loads associated with stormwater at some selected locations along the coast of Metropolitan Adelaide.

9.1 Purpose

The specific purpose was to provide a relationship (or relationships) between the constituents associated with stormwater, in particular N, P and SS and the stormwater flow and, to use these relationships to estimate the amount of constituents discharging to the Gulf. It was not expected that these relationships be used as part of the optimisation described in Volume 1 (Maheepala et al., 2014), rather the expectation was, if required, these relationships be used in the optimal solutions being identified through multi-objective optimisation, to obtain an indication on the amount of N, P and SS loads discharging to the Gulf. However, since the focus was only on stormwater, these relationships would be of limited use for interpreting total N, P and SS loads to the Gulf because discharges included both stormwater and wastewater. The methodology followed and the relationships derived are described below.

9.2 Methodology

The method involved selecting sites with sufficient data on stormwater flow and the constituents mentioned above, processing and cleaning the data as required, double-mass analysis to investigate homogeneity of the constituent data in a full range of flow regime expected at the selected sites, flow duration analysis to understand probability of occurrence of specific flow values, as well as constituent values, and develop relationships to quantify loading of SS, N and P in the stormwater for the selected sites.



Apx Figure 9-1: Sites (or locations) of environmental significance

In discussion with EPA, SA Water and DEWNR, 16 environmentally sensitive sites were identified (Apx Figure 9-1) of which only 5 were considered by considering availability of the water quality data. Basic information of the five selected sites along with reference to the geographical location in Apx Figure 9-1 is given in Apx Table 9-1.

Apx Table 9-1: Sites used to examine relationship between stormwater flows and TP, TN and TSS

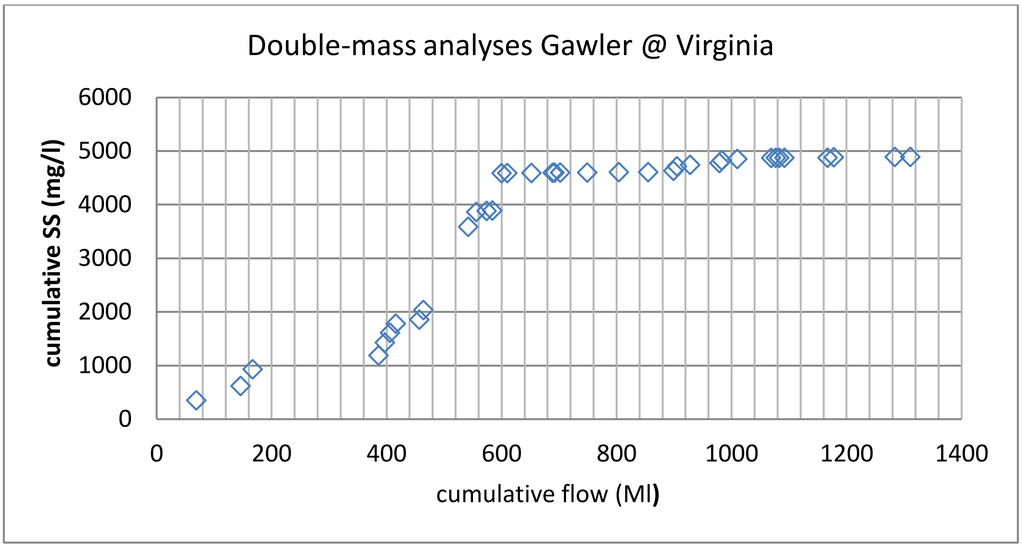
Station Number	Site Name	River	Location	Catchment area (km^2)	Flow data used	Reference to Apx Figure 9-1
A5050510	Virginia	Gawler	34:38:22.6 S, 138:32:27.6 E	1170	1972 – 2013	7
A5041014	Seaview road Bridge	Torrens	34:56:05.8 S, 138:29:58.9 E		2010-2013	11
A5031010	South Road (u/s)	Field River	35:05:16.4S, 138:29:43.1 E	26.16	2000-2009	13
A5030547	Galloway road (d/s)	Christies Creek	35:07:33.3S, 138:28:50.1E	35.9	2000-2013	14
A5041009	Barker wetland outlet	Port River	34:49:45.8S, 138:34:14.9 E	N/A	2004-2013	15

Apx Table 9-2 shows the format of the available data. Column 1 indicates the date when the collected sample was taken to the laboratory for testing. The water quality values shown against each date indicate the water quality in the sampling container. Hence, the water quality value shown against any day is considered as an average over the period from the previous sampling date. Daily flow data are available at each site for the period shown in Apx Table 9-2 although there have been gaps in data.

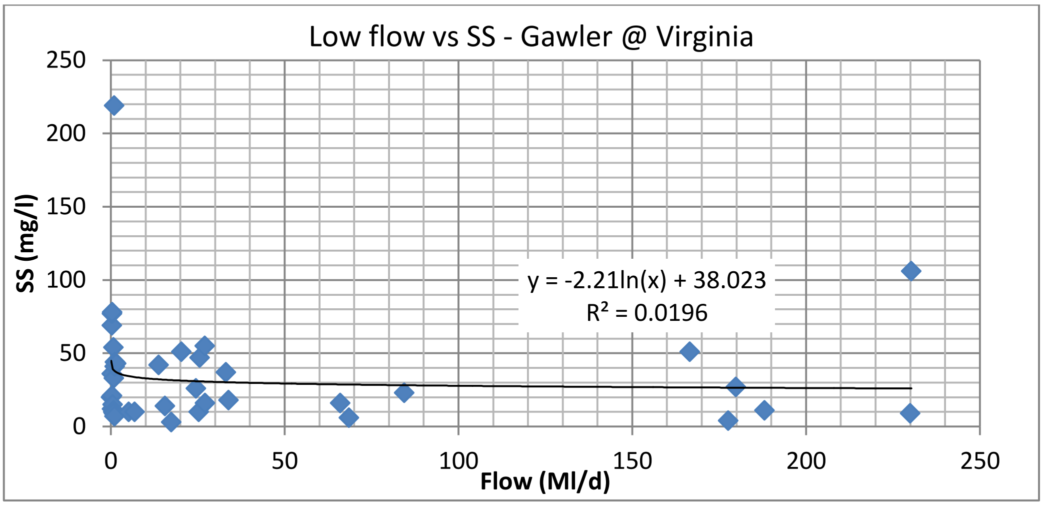
Apx Table 9-2: Sample of recorded water quality data (Gawler River at Virginia)

Date	SS (mg/L)	Turbidity (NTU)	Total P (mg/L)	TKN (mg/L)
7/07/2009 13:00	11	20.52	0.174	1.22
22/07/2009 15:20	6	16.44	0.125	1.29
4/08/2009 13:22	75	27.4	0.159	1.37
20/08/2009 14:45	8	28.2	0.133	1.82
2/09/2009 11:00	59	48.1	0.284	2.07
17/09/2009 14:45	27	35.5	0.161	1.75

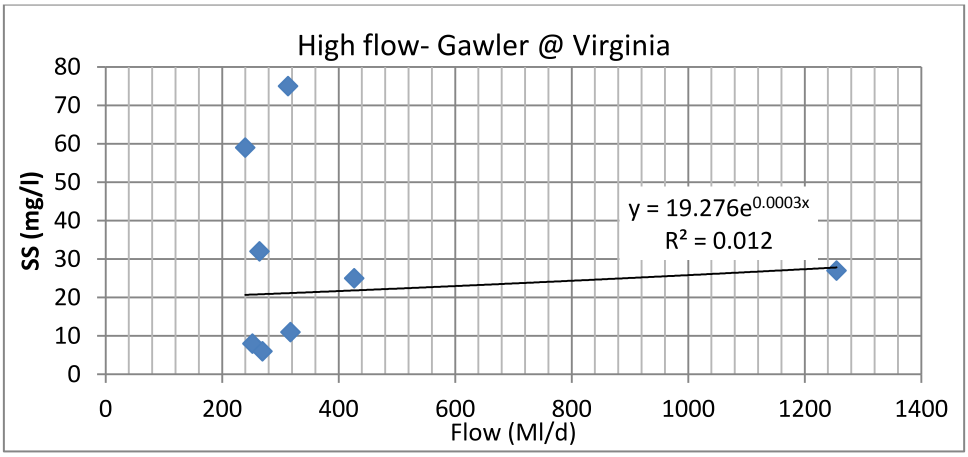
The recorded data for each constituent represented average concentration since the last sampling date. Hence, the average flow between sampling dates were computed. Time interval between water quality sampling dates varied from one week to few months. Hence, the appropriate time period within which mean flow was estimated, was decided subjectively, by considering the magnitude and the sequence of the flow data within the two sampling dates. The derived average flow data and the measured water data of N, P and SS were then analysed by using double-mass and flow duration methods to identify meaningful relationships. For an example, the analysis conducted for Gawler River at Virginia for SS is described below. The same analysis was followed for N and P for Gawler River at Virginia, as well as for other sites shown in Apx Table 9-1.



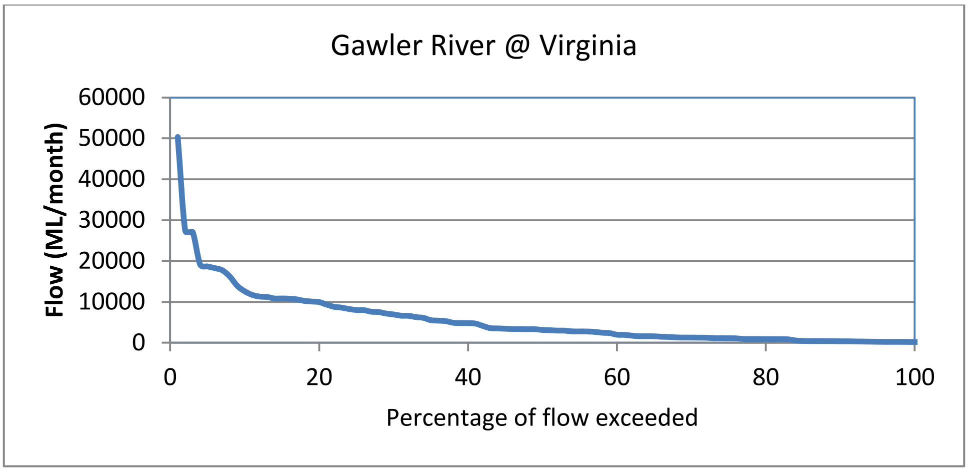
Apx Figure 9-2: Double-mass analysis for Gawler River at Virginia



Apx Figure 9-3: Variation of SS versus mean flow at low flow regime



Apx Figure 9-4: Variation of SS versus mean flow at high flow regime



Apx Figure 9-5: Monthly flow duration curves for Gawler River at Virginia

The double-mass analysis (Apx Figure 9-2) for SS and mean flow at Gawler River at Virginia indicated two possible trends, one for low flows and another for high flows. These trends were examined in detail(Apx Figure 9-3and Apx Figure 9-4). However, no clear relationship between TSS and flow was evident for both high flow and low flow regimes. Consequently, it was decided to express mean values of SS for different flow bands (or regimes).

9.3 Flow, TSS, TN and TP relationships

The flow bands were identified by using flow duration analysis. Since the optimisation was supported by monthly simulation of flows, monthly flow duration analysis was performed (Apx Figure 9-5). It was evident from the monthly flow duration curve (Apx Figure 9-5) that the flow could be divided into two groups: 0-880 ML/month occurring at least 80% of the time (i.e. the percentage of time exceeded was greater than 20%) and a flow greater than 880 ML/month occurring at least 20% of the time (i.e. the percentage of time exceeded was less than 20%). Hence the monthly flow corresponding to 20% time exceeded was chosen as a threshold to develop a relationship between SS and the flow. Following the same process for N and P, as well for N, P and SS for other stations, the relationship shown in Apx Table 9-3 was developed.

Apx Table 9-3: Relationships developed for estimating SS, P and N loads discharging to the Gulf at selected locations, based on the monthly flow

Station	% of time flow exceeded in monthly FDC	Mean flow (ML/month)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
Gawler River	< 20	>880	36	1.72	0.19
	>20	< 880	30	2.83	0.18
Torrens River	<20	> 4650	76	1.49	0.1
	>20	<4650	25	1.2	0.07
Field River	<20	>385	25	1.26	0.07
	>20	<385	17	1.45	0.07
Christies Creek	< 20	>300	142	1.81	0.19
	20–40	300-170	105	1.29	0.10

Station	% of time flow exceeded in monthly FDC	Mean flow (ML/month)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
	>40	<170	81	1.57	0.10
Barker inlet	<20	>180	55	1.0	0.16
	>20	<180	30	0.97	0.13

For example, if the flow in the Gawler River was 700 ML in a particular month, the estimated amount of SS discharging to the Gulf, corresponding to that month would be = 36 Kg. It should be noted that this method requires a calibration, for which better quality data on water quality parameters are essential. At present such data do not exist. Hence the above method should be used cautiously, noting that the values given in Apx Table 9-3 provide indicative estimates only.

9.4 Application of the methodology

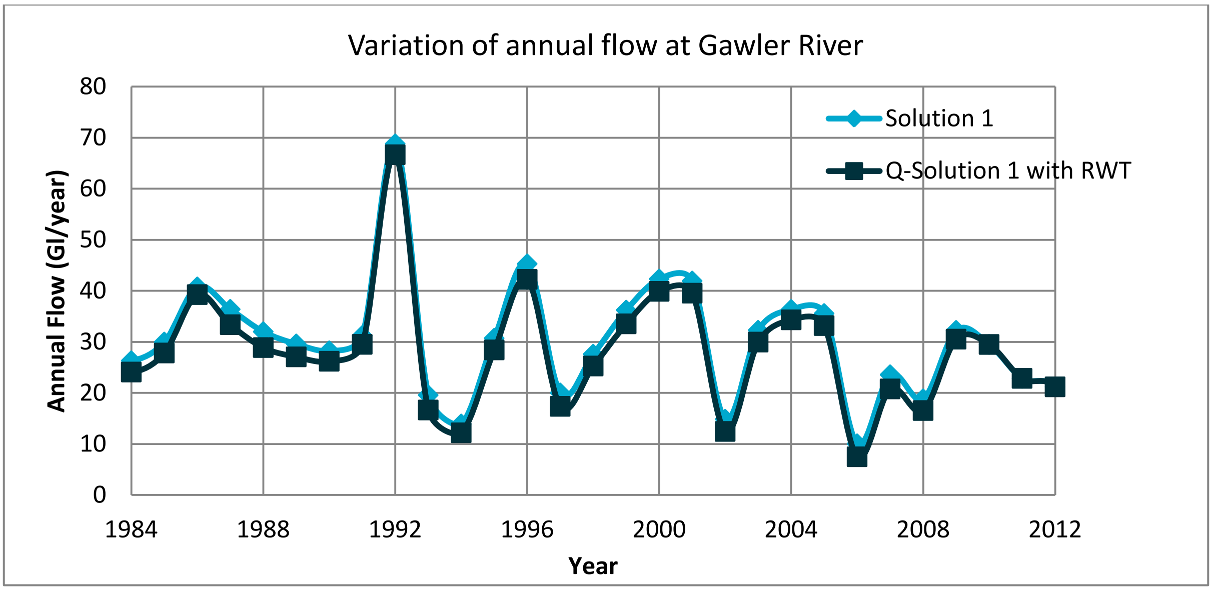
The developed methodology was applied to three rivers within the study area and assessed how far the TSS, TP and TN contribution into Gulf can be controlled by the use of rainwater tanks. For this assessment, flow data at Gawler River, Christies Creek and Field River were obtained from the simulation model corresponding to the optimal solution with minimum cost and maximum discharge (i.e. solution ID #1 for 2013 scenario given in Maheepala et al. (2014) Section 5.2.2), with and without rainwater tanks. The relationships given in Apx Table 9-3 were used to computer TSS, TP and TN at monthly scale.

Apx Table 9-4 summarizes how the RWT option can help in reducing average annual contribution of TSS, TP and TN to the Gulf via these three rivers. Apx Figure 9-6 to Apx Figure 9-17 show annual flow, monthly flow, % reduction in annual loads of TSS, TP and TN in the presence of rainwater tanks, discharging to coastal waters from the Gawler River, Christies Creek and Field River.

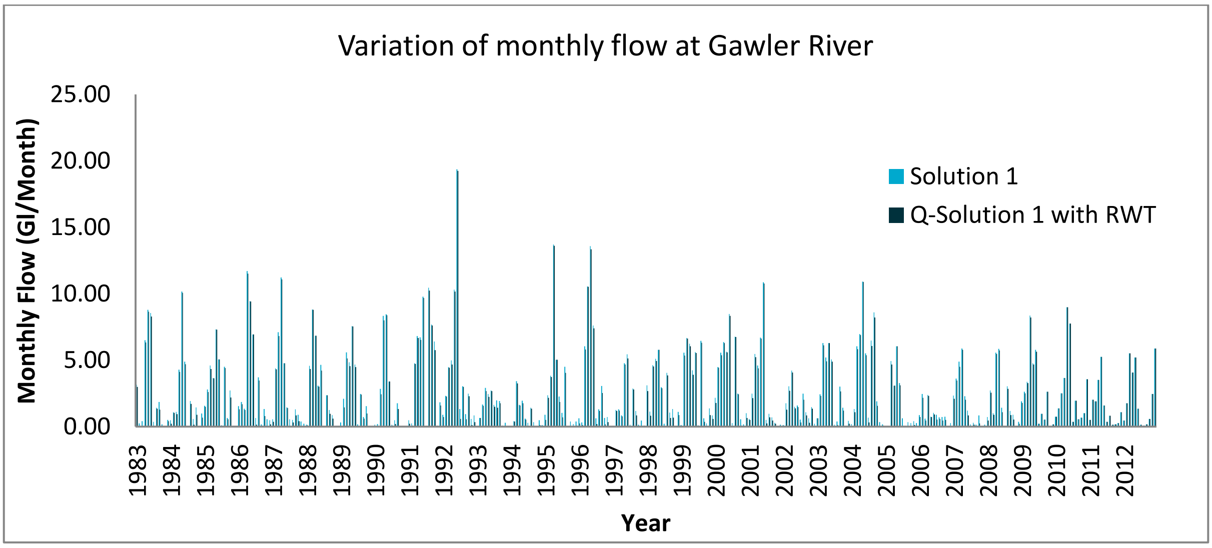
In summary, these results indicate that although the option of rainwater tanks is not financially attractive, for a scenario of 100% rainwater tank uptake, under 2013 climatic conditions, rainwater tanks have the potential to reduce 6% -30% annual TSS load reduction to the Gulf, from the flows discharging through at the Gawler River, compared to a scenario with 0% uptake of rainwater tanks. For TP, the reduction range is 5%-25% and for TN, the reduction rate is 6%-34% (see Apx Figure 9-8). Similar reductions can be observed for Christies Creek and Field River (see Apx Figure 9-12 and Apx Figure 9-16).

Apx Table 9-4: Mean annual % reduction due to rainwater tanks (RWT)

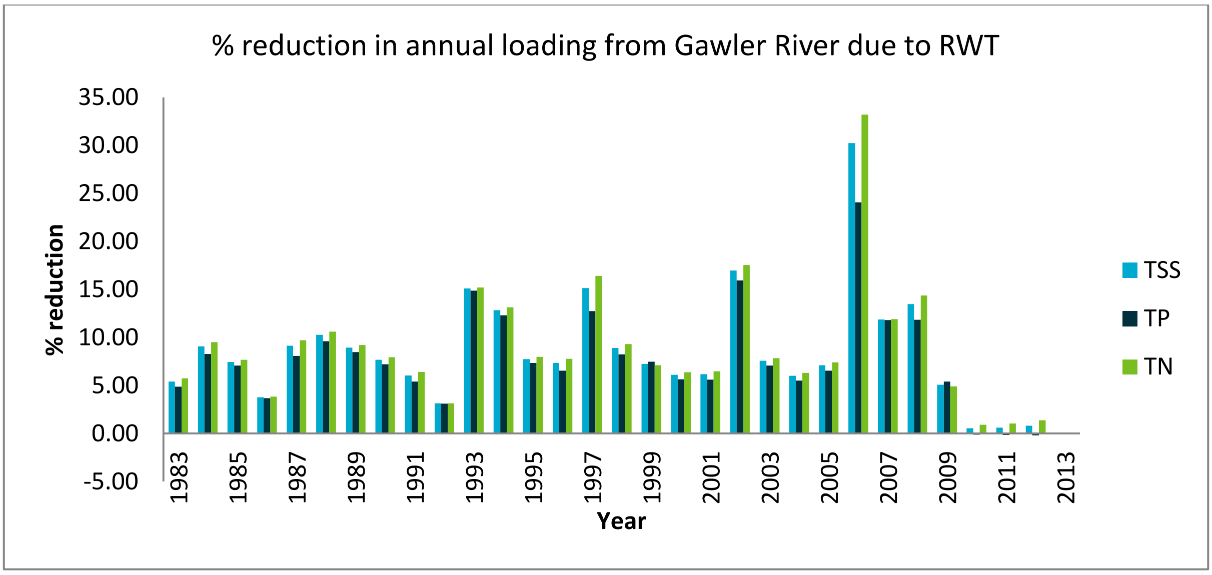
	Flow	TSS	TP	TN
Gawler River	6.85	7.35	6.73	7.70
Christies Creek	15.77	13.75	12.92	14.71
Field River	12.42	11.70	12.40	11.93



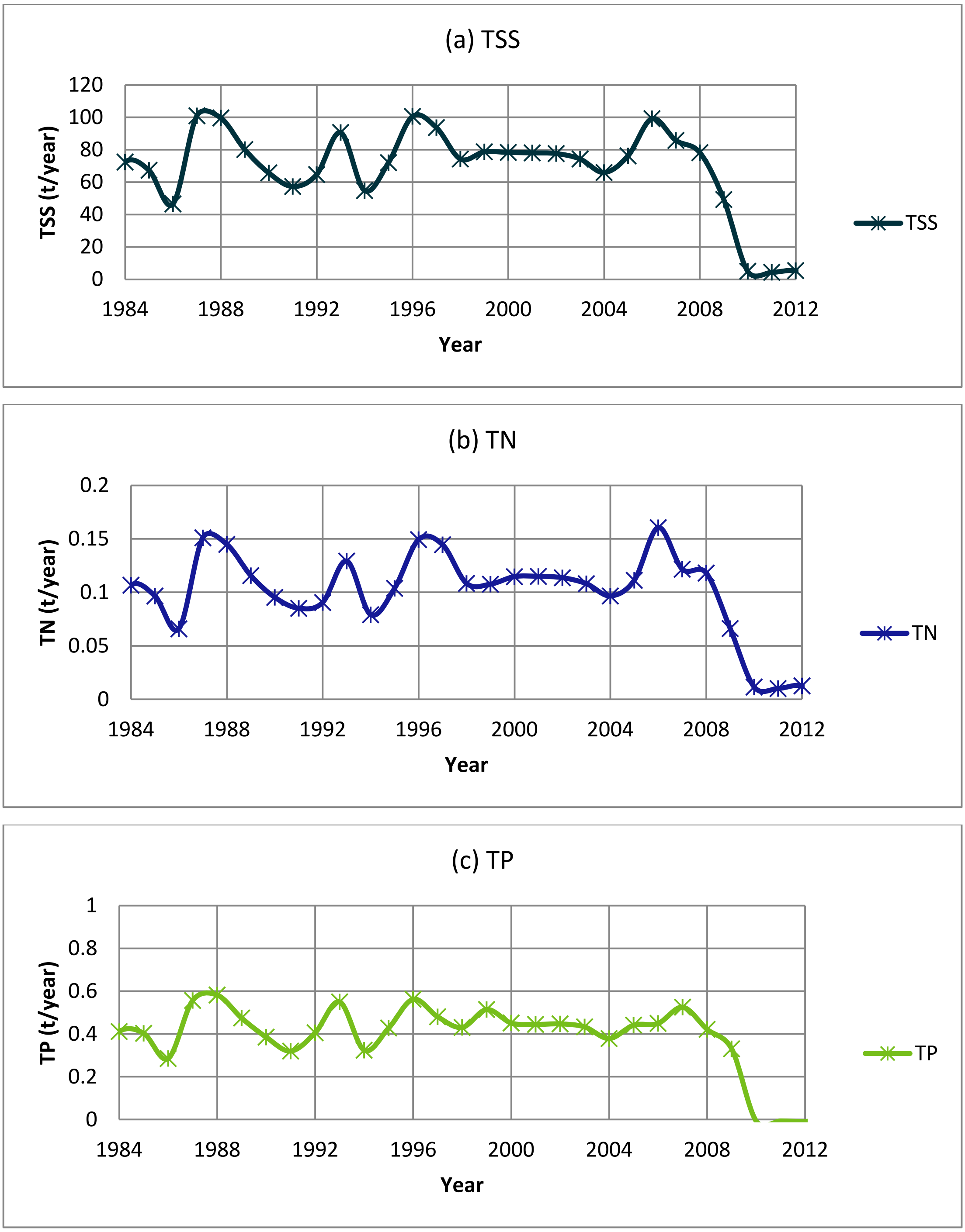
Apx Figure 9-6: Total annual flow variation in Gawler River at Virginia



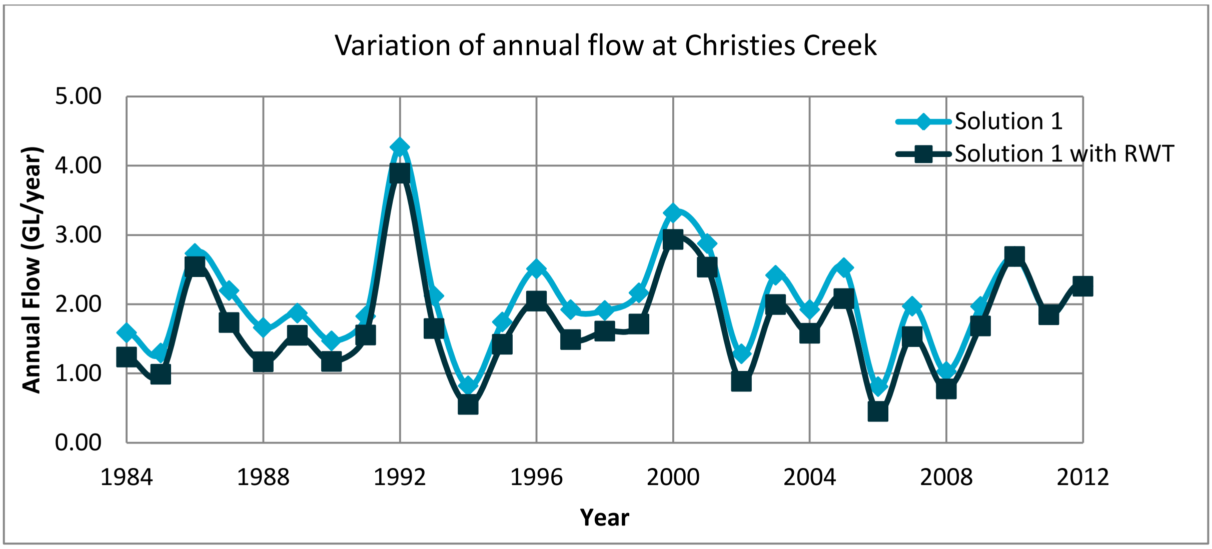
Apx Figure 9-7: Total monthly flow variation in Gawler River at Virginia due to use of RWT



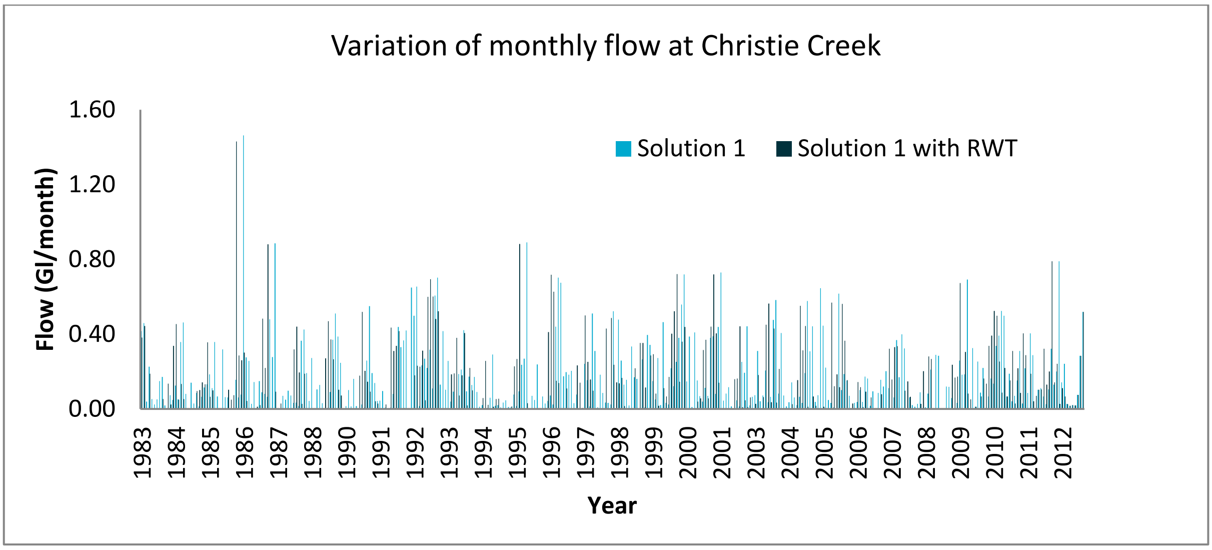
Apx Figure 9-8: Percentage reduction in annual TSS, TP and TN loads from Gawler River due to use of RWT



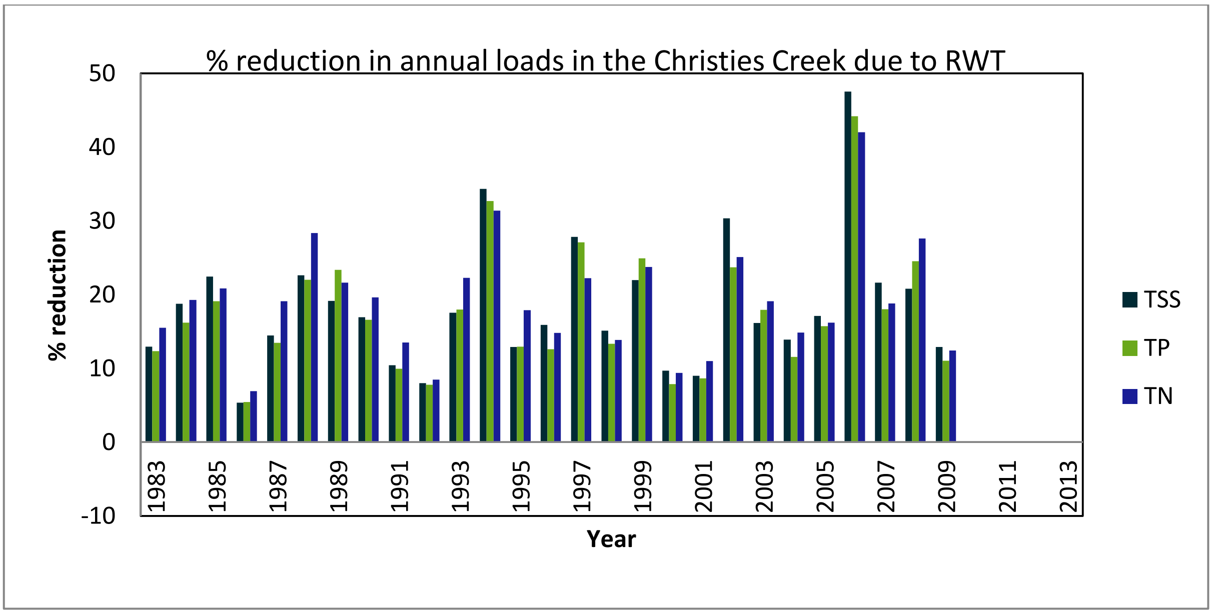
Apx Figure 9-9: Reduction in annual (a) TSS, (b) TN and (c) TP loads from Gawler River due to use of RWT



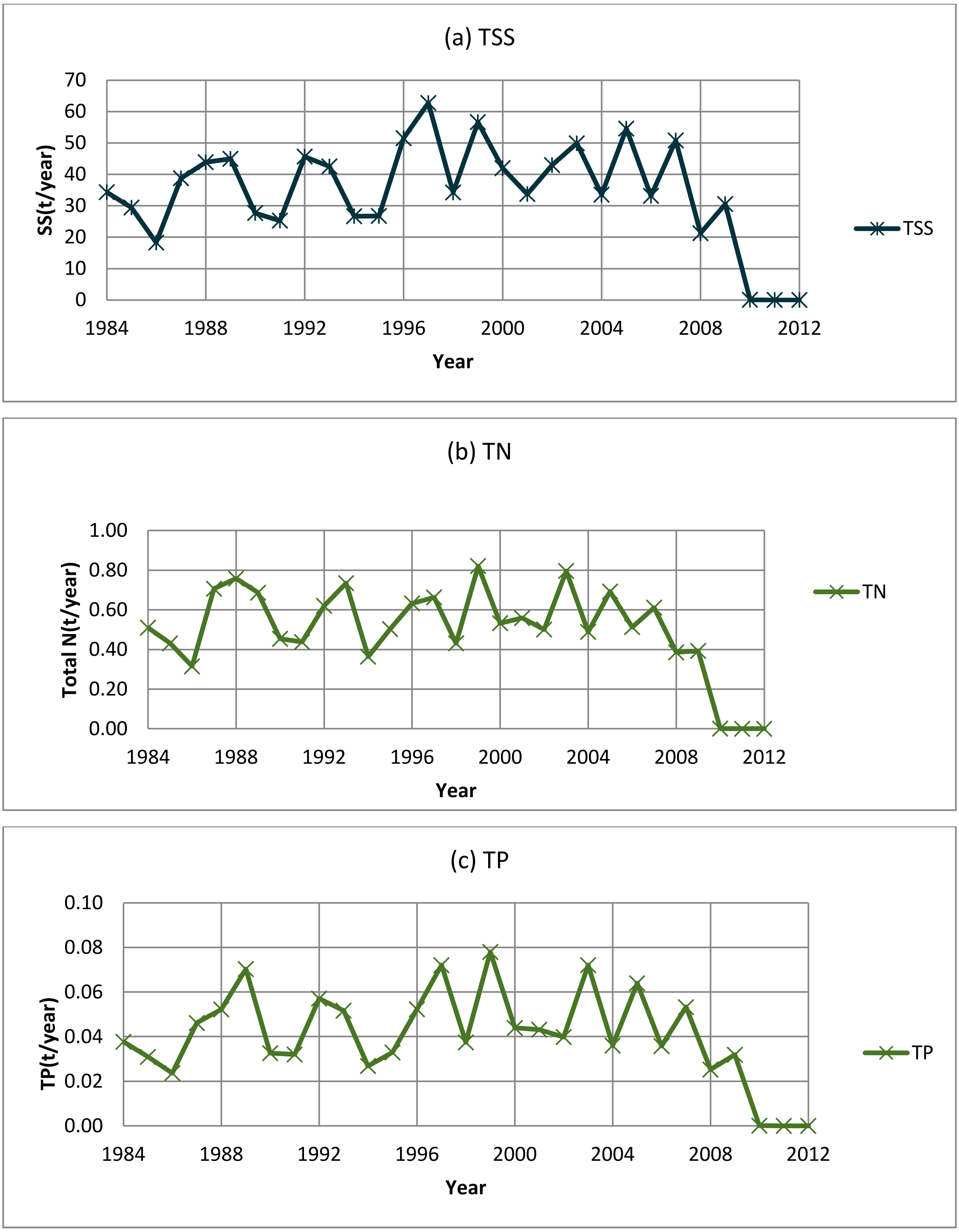
Apx Figure 9-10: Total annual flow variation in Christies Creek



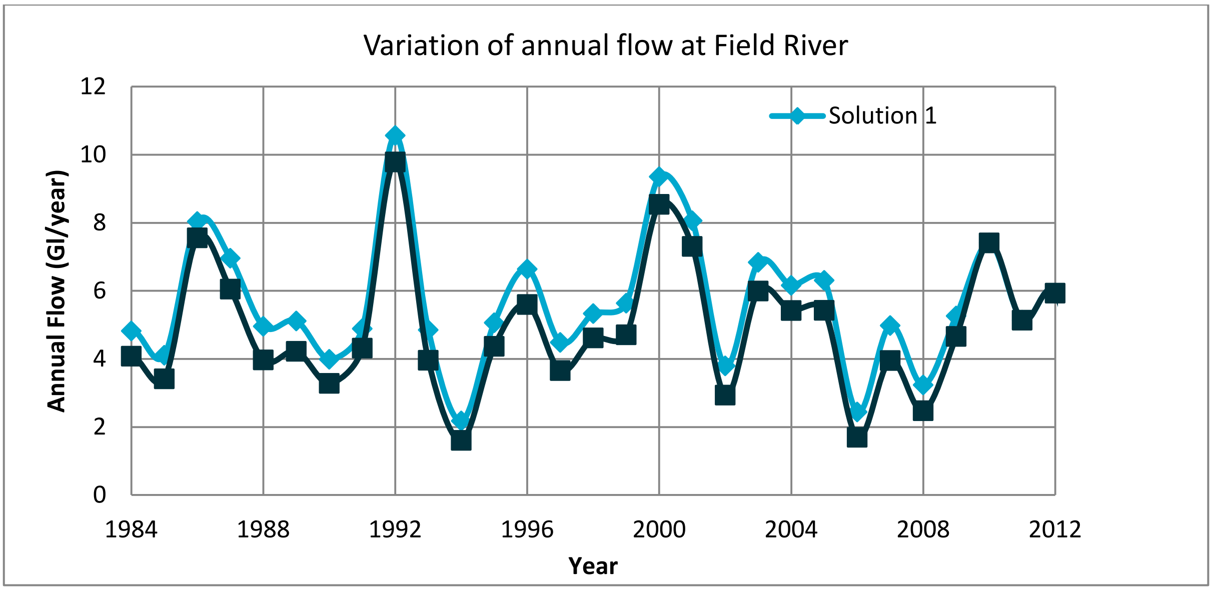
Apx Figure 9-11: Total monthly flow variation in Christies Creek



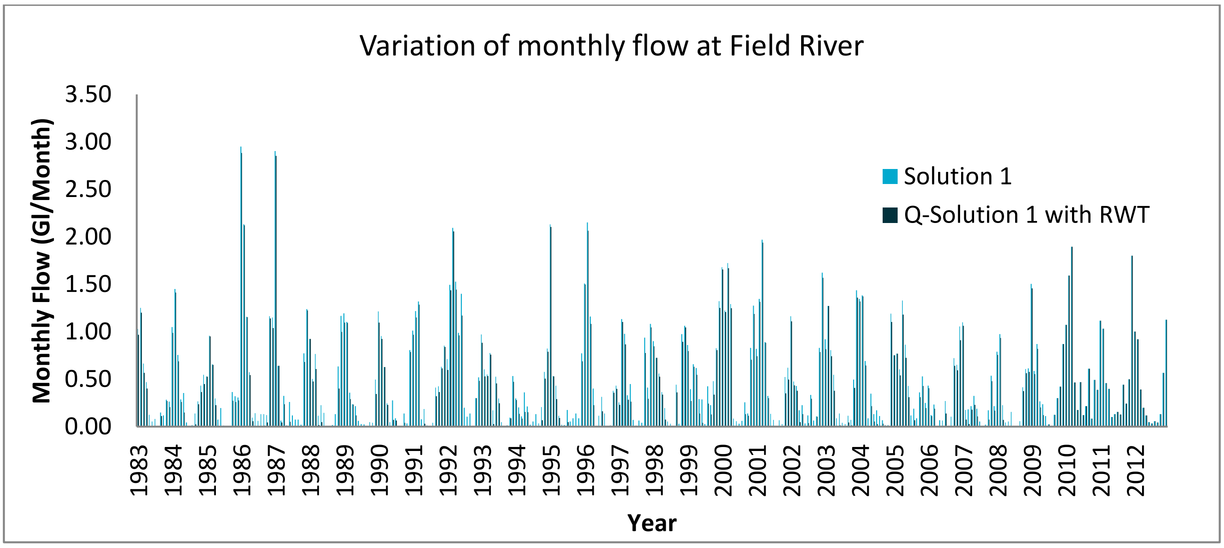
Apx Figure 9-12: Annual percentage reduction in TSS, TP and TN Christies Creek



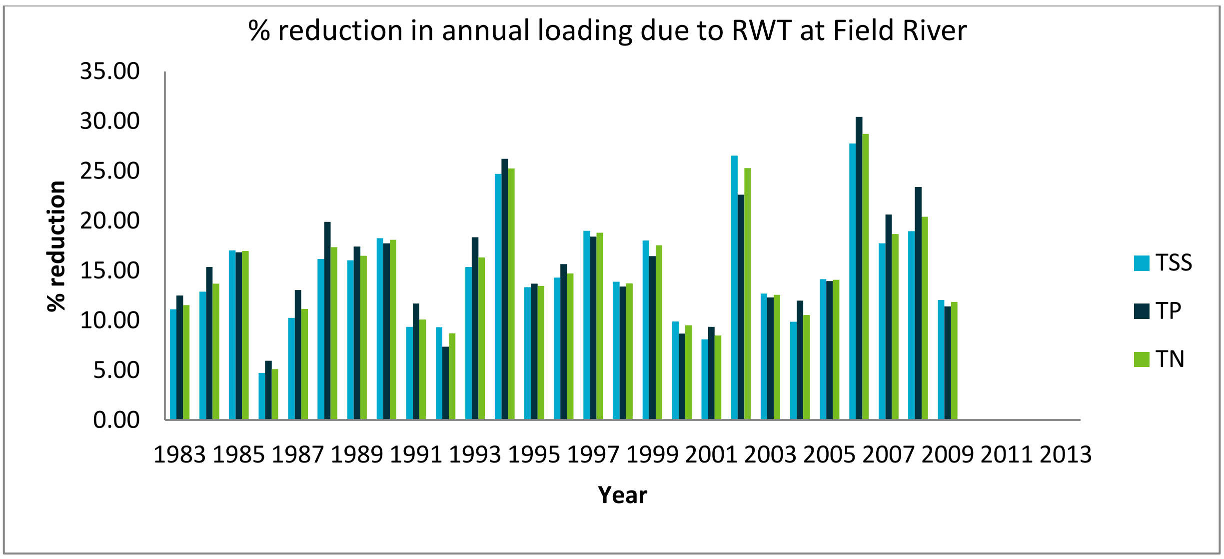
Apx Figure 9-13: Reduction in annual (a) TSS, (b) TN and (c) TP loadings from Christies Creek due to use of RWT



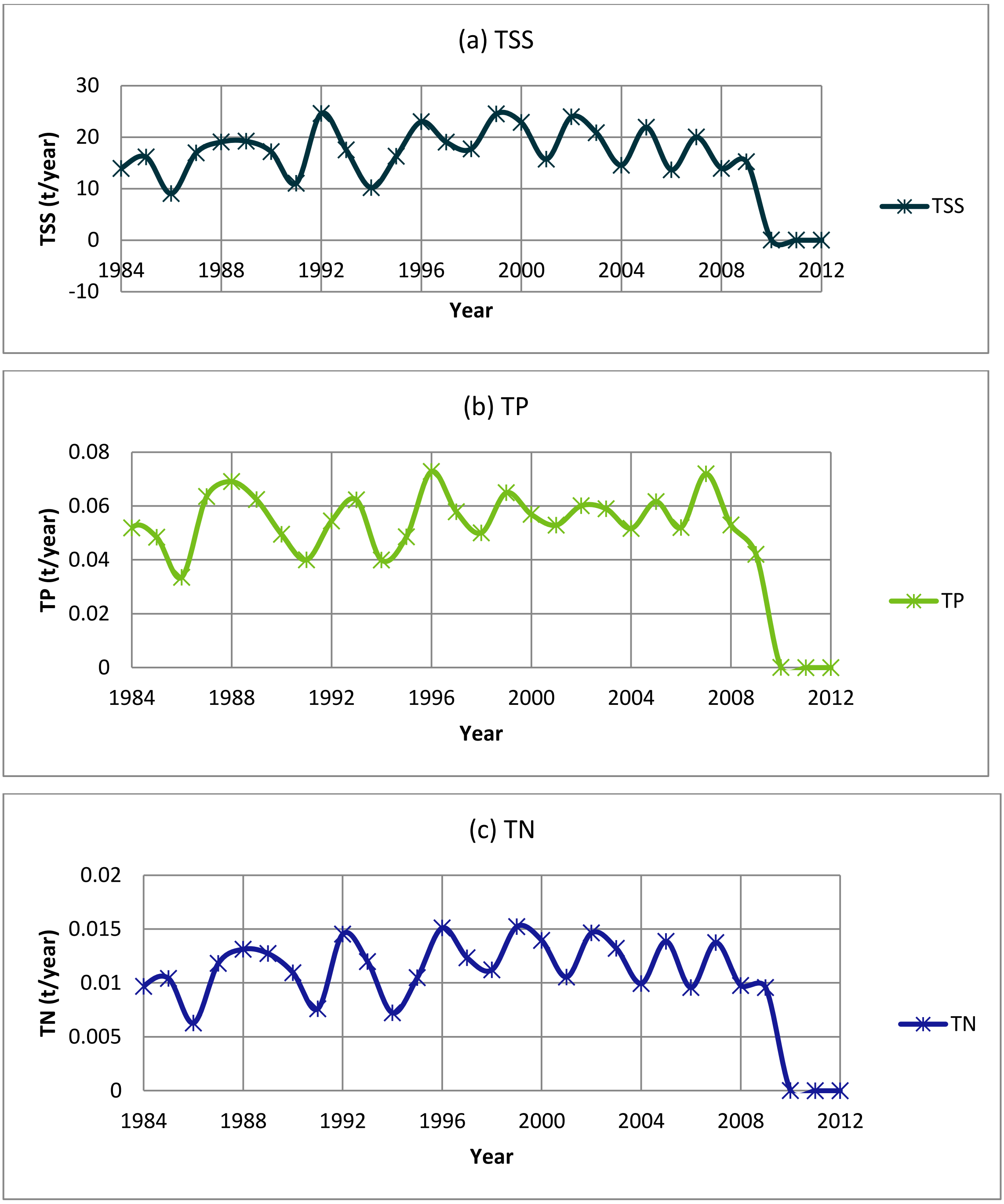
Apx Figure 9-14: Total annual flow variation at Field River



Apx Figure 9-15:Total monthly flow variation in Field River



Apx Figure 9-16: Percentage reduction in annual loading of TSS, TP and TN at Field River



Apx Figure 9-17: Reduction in annual (a) TSS, (b) TP and (c) TN loading from Field River due to RWT

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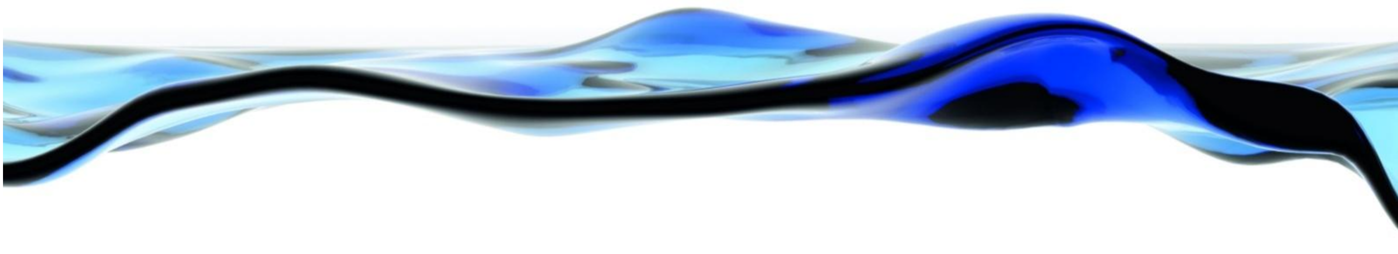

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