Development of the
Sydney Harbour Catchment Model

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Synopsis: This report documents the construction of the Sydney Harbour Source catchments model. The model was constructed in the Source Catchments modelling framework 3.5 using locally derived land use and climate data. The model uses the inbuilt Simhyd rainfall runoff model for each land use in each subcatchment. The model operates on a 30 minute time step. Hydrographs represent flows on a 30 minute time step. The model incorporates point source flow and load time series representing sewer overflows.

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1 INTRODUCTION

This report documents the development and parameterisation of the Sydney Harbour Catchment Model. The model extends and supersedes the previously developed Sydney Harbour catchment and pollutant export models including:

- the Upper Parramatta River model;
- the Lower Parramatta River model; and
- the Lane Cove model.

The Sydney Harbour Catchment Model now simulates all Sydney Harbour Catchments in one model domain, including the Middle harbour and Port Jackson subcatchments. The model also simulates all model processes directly in the Source Catchments framework (version 3.5.0) and simulates on a 30 minute time step.

The key purposes of this model is to provide:

- Subdaily flow and pollutant load time series for all inflow locations to Sydney Harbour for use in receiving water modelling; and
- Subcatchment and land use based mean annual flow and pollutant load estimations for use in the Sydney Harbour Decision Support System and associated Water Quality improvement Plan.

The catchment area draining to the Sydney Harbour is approximately 484 km^2 which has been broken into 550 subcatchments, connected via a node link network. The model includes the facility to incorporate modelled sewer overflow time series for approximately 553 sewer overflow locations within the model domain. In addition to these features, the model simulates the rainfall runoff process using 30 minute rainfall data from 23 rain gauge locations and the Simhyd rainfall-runoff model for land use based subcatchment flows. The Event Mean Concentration/ Dry Weather Concentration model has been used for water quality constituent generation.

Section 2 of this report reviews the input data sets used to construct the Sydney Harbour Source Catchments Model.

Section 3 reports on analysis undertaken on the sewer overflow timeseries provided by Sydney Water for this model.

Section 4 summarises the water quantity and quality parameterisation process and associated results.

Section 5 provides the overall model results and Section 6 of this report provides a summary of the model development process, key results and recommendations for further investigation.

2 SYDNEY HARBOUR CATCHMENT MODEL INPUT DATA

The Sydney Harbour Source Catchments model (Figure 2-1) is represented by 550 subcatchments, 10 land use classes and runs over a 30 minute time step. Unlike previously developed HNCMA catchment models, locally derived rainfall data has been used directly in the model to facilitate rainfall-runoff modelling with the Source Catchments framework, rather than externally within the RAFTS modelling framework.

This section presents the underlying data sets used to construct the Sydney Harbour Catchment Model including summaries of the land use, climate, water quality, stream gauging and storage data featured in the model.

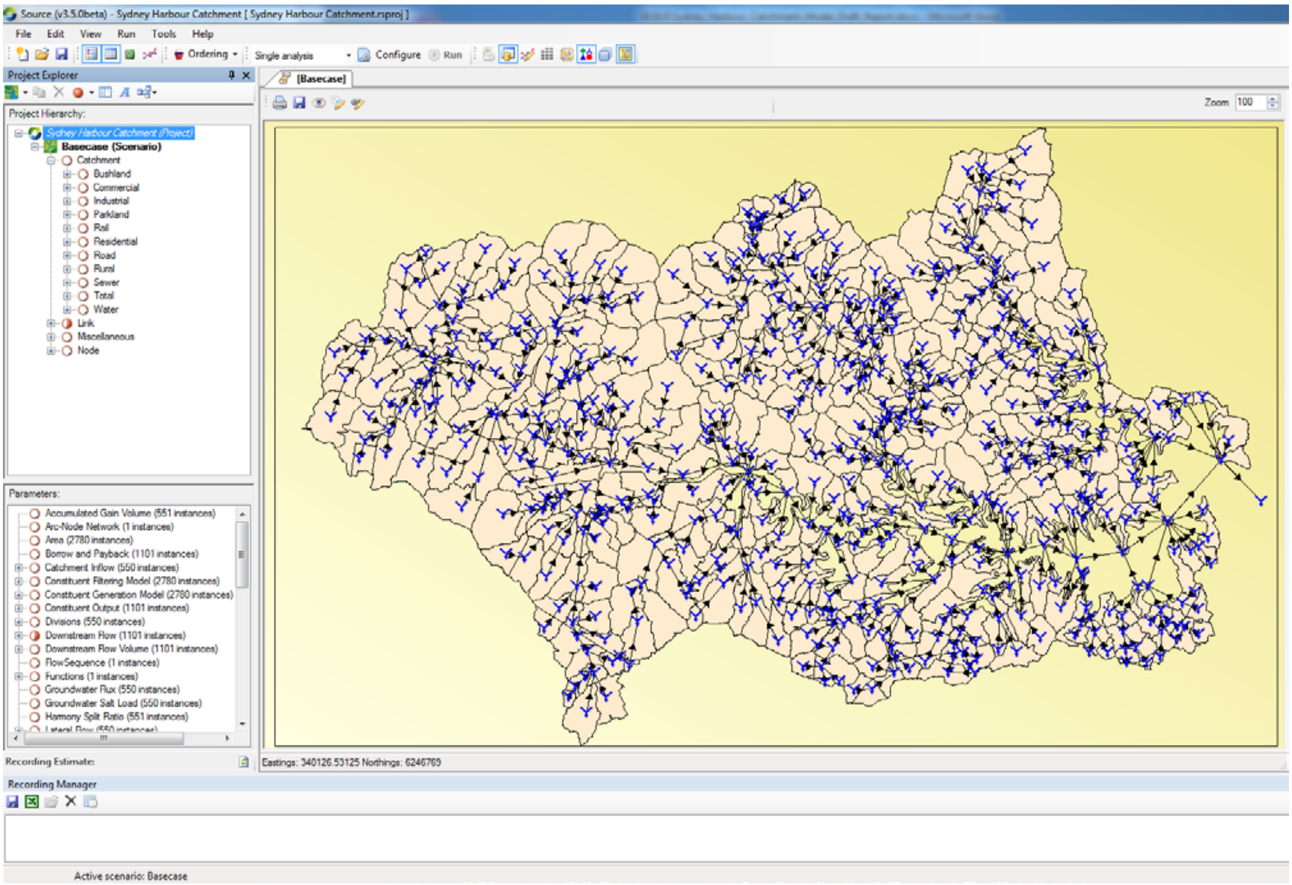

Figure 2-1. The Sydney Harbour Source Catchments Model

2.1 Subcatchment and Node-Link network

The subcatchment and associated node-link network was derived from data sets supplied by the HNCMA from previous work undertaken to construct the following models:

- Upper Parramatta River Model (CSS, 2011, HNCMA 2013);
- Lower Parramatta River model (CSS 2012);
- Lane Cove River Model (SMCMA 2012); and

- Middle Harbour and Port Jackson subcatchment delineation for RAFTS modelling (SMCMA unpublished)

The subcatchment and associated node-link maps obtained for the above projects were agglomerated to one map for the entire Sydney Harbour catchment, resulting in approximately 1900 subcatchments. These subcatchments were then accumulated to reduce the overall model size and enable the entire catchment to be constructed in 1 model domain with a model time period of > 10 years.

In addition to the existing subcatchment maps provided by the HNCMA, a local Government Area (LGA) map was obtained. This map was used in the subcatchment accumulation process to split subcatchments along LGA lines.

Subcatchments were accumulated based on the following general rules:

- At least one subcatchment draining to each major bay;
- All Subcatchments less than 5 ha were considered for amalgamation; and
- Subcatchments were amalgamated to align with gauging locations and water quality sampling points.

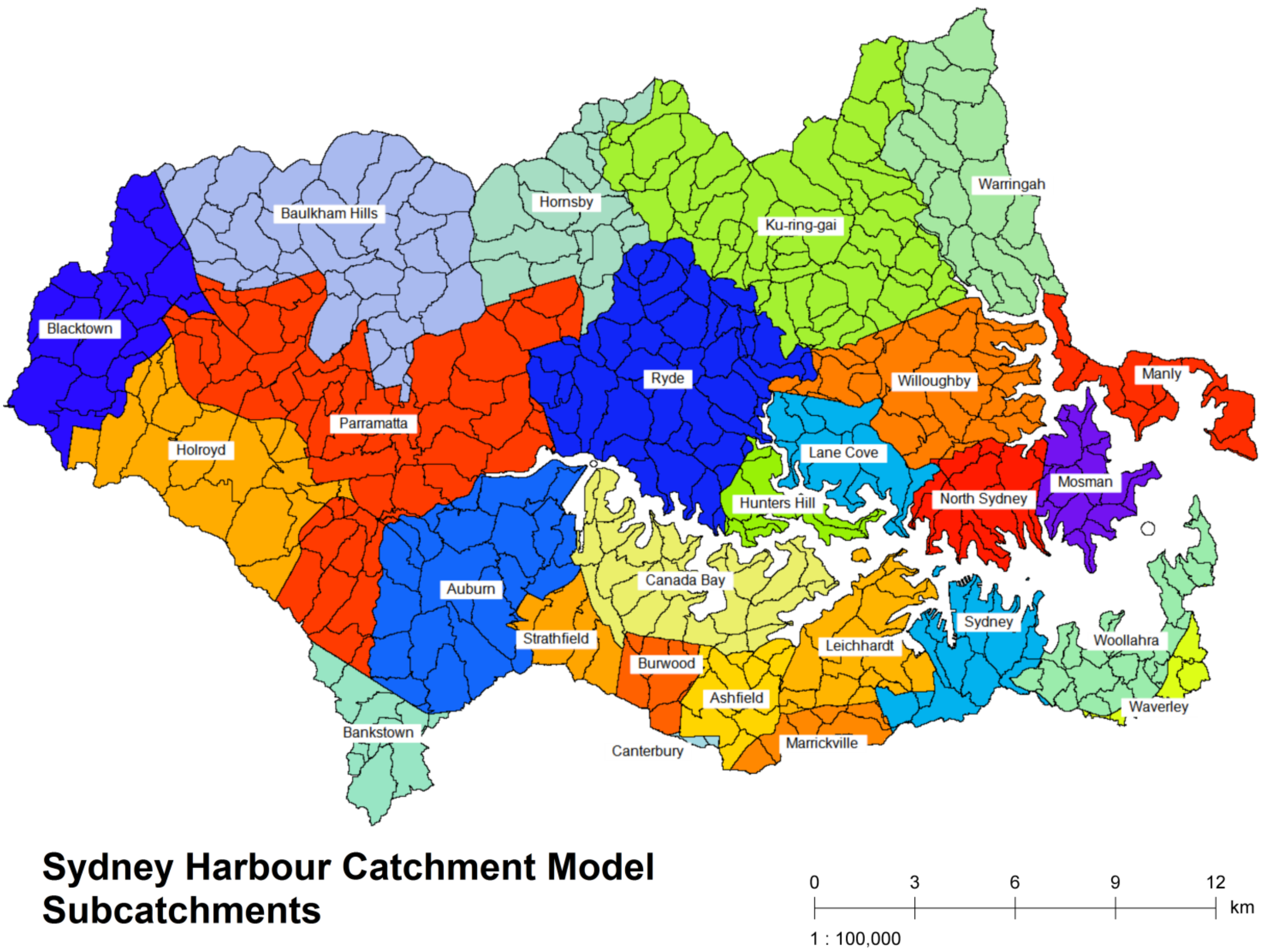

Figure 2-2. The Sydney Harbour Subcatchment Map

2.2 Land Use

Land use in the 484 km^2 Sydney Harbour Model is broken into 10 categories (Functional Units) as described in Table 2-1. The Land use map was supplied by the HNCMA as a 2m grid and was aggregated to a 5m grid for import to the Sydney Harbour catchment Model.

The model area attributed to sewer overflows is an artefact of the Upper Parramatta River model where sewer overflows were modelled as small land parcels. In the current model, sewer overflows are modelled as input time series at nodes, however the sewer overflow land use artefact in the Upper Parramatta remains.

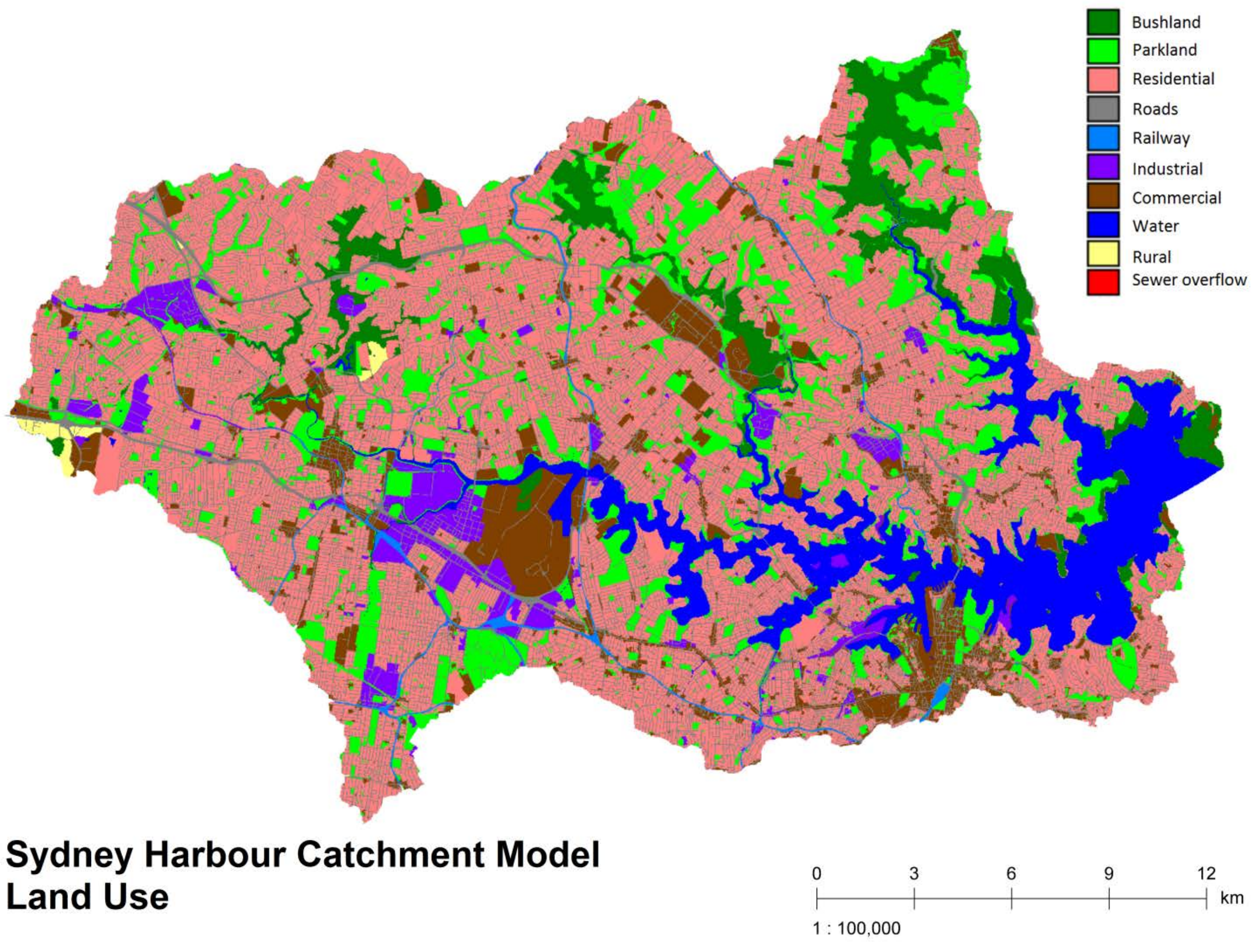

Figure 2-3. The Sydney Harbour Land Use Map

Table 2-1 Sydney Harbour Land Use

Land Use	Area (km2)	Area (%)
Bushland	30.25	6.25%
Parkland	67.91	14.04%
Residential	227.33	47.00%
Roads	89.47	18.50%
Railway	4.08	0.84%
Industrial	18.96	3.92%
Commercial	41.08	8.49%
Water	2.97	0.61%
Rural	1.60	0.33%
Sewer	0.04	0.01%
Total	483.7	100%

2.3 Climate

Rainfall and evaporation data used in the Sydney Harbour Catchment model has been sourced from the HNCMA and Bureau of Meteorology (BOM 2013). The raw data used includes 30 minute time step data and pluvio data from the Bureau of Meteorology in addition to 30 minute time step data and raw data (time and number of tips) from stations collated by the CMA.

There are more rainfall gauging stations in the Sydney Harbour catchment than are practical to incorporate in the catchment model and from these gauges, a subset of 22 gauge locations has been chosen for incorporation to the model. These gauge locations are:

- 7 hills radio
- Baukham hills pool
- Belrose
- Chatswood
- Concord
- Cumberland Golf
- Gladesville
- Lindfield
- Manly croquet
- Mossman
- Observatory Hill
- Parramatta (Masonic+ North)
- Rosney

- Sierra basin (baulkham hills west)
- SOP AWS
- St Ives
- Terry Hills
- Vacluse
- Waverly
- West Epping
- West pennant hills
- West Pymble

These gauges were chosen for their location within or nearby to the model domain, their length of record and completeness of record and their availability for future updating by the HNCMA. 30 minute time step data (mm/time step) has been derived from this data and gaps in data records have been filled by using records from the nearby gauges

The resultant time series from all 22 gauges covers the period from 1/1/2000 to 25/7/2013.

The location of rain gauges and subcatchments assigned to each gauge are shown in Figure 2-4. Key rainfall stations are Observatory Hill, Parramatta North, Sydney Olympic Park AWS and Terry Hills AWS. Gaps in the rainfall record in gauges other than the key gauges have been gapfilled with data from the nearest adjacent key gauge. Gaps in the key gauges have been filled with data from Observatory Hill.

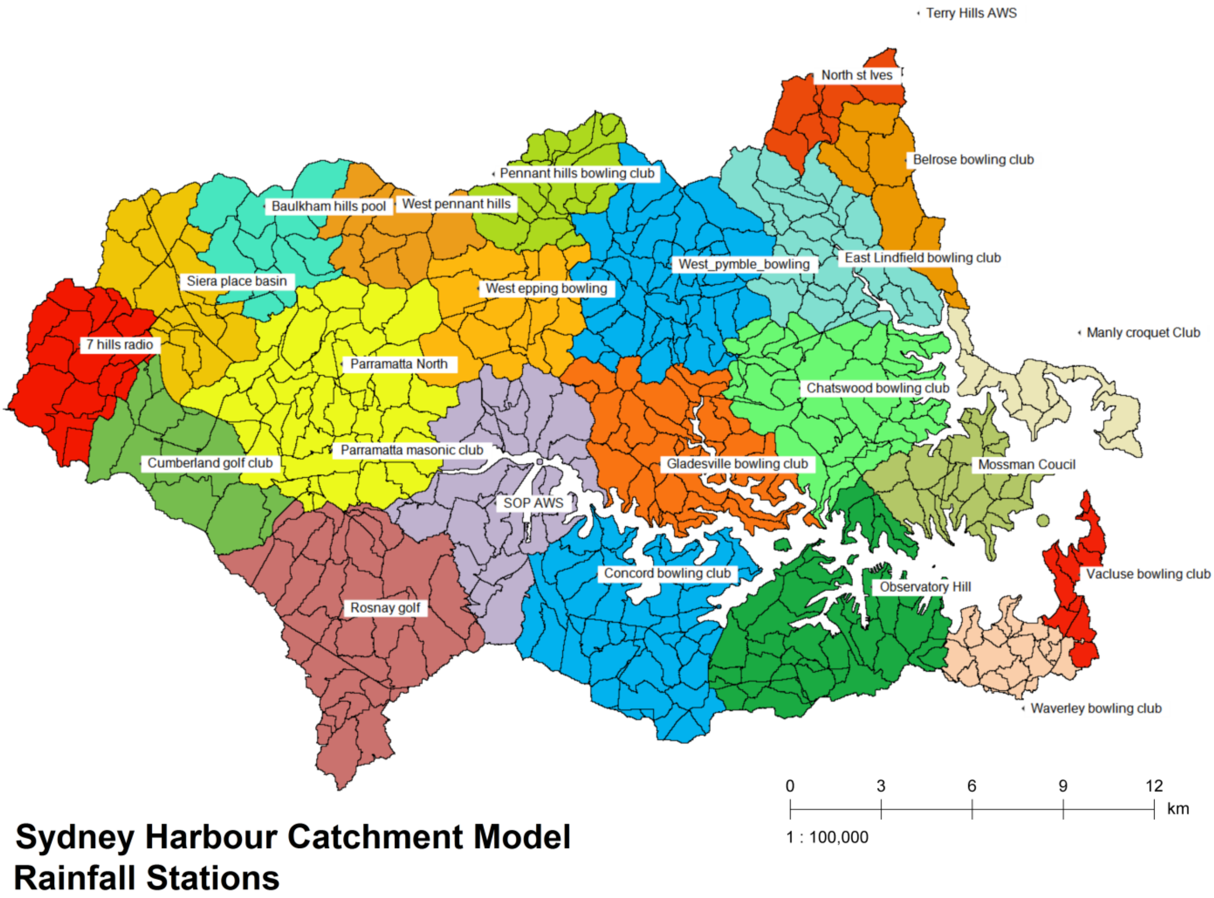

Figure 2-4. Rain Gauges and Subcatchment Rainfall Assignment.

Evaporation data for the Sydney Harbour model has been disaggregated from mean monthly values for the Observatory Hill weather station. These values have been applied to the entire model domain.

2.4 Stream flow data

The Toongabbie Creek stream gauge (Briens Road) in the Upper Parramatta River catchment was the only stream gauge reporting stream discharge identified in the Sydney Harbour Catchment (Office of Water 2013). The Toongabbie Creek gauge data has been obtained from 1/1/2000 to 20/8/2013 at 15 minute time step.

Several other flood warning gauges were identified for this project, particularly in the Upper Parramatta River catchment, however these gauges report stream height, not discharge and are therefore unsuitable for stream flow calibration.

The location of the Toongabbie stream flow gauge in relation to the catchment is shown in Figure 2-5. This gauge drains 62 km2, or approximately 13% of the Sydney Harbour model domain.

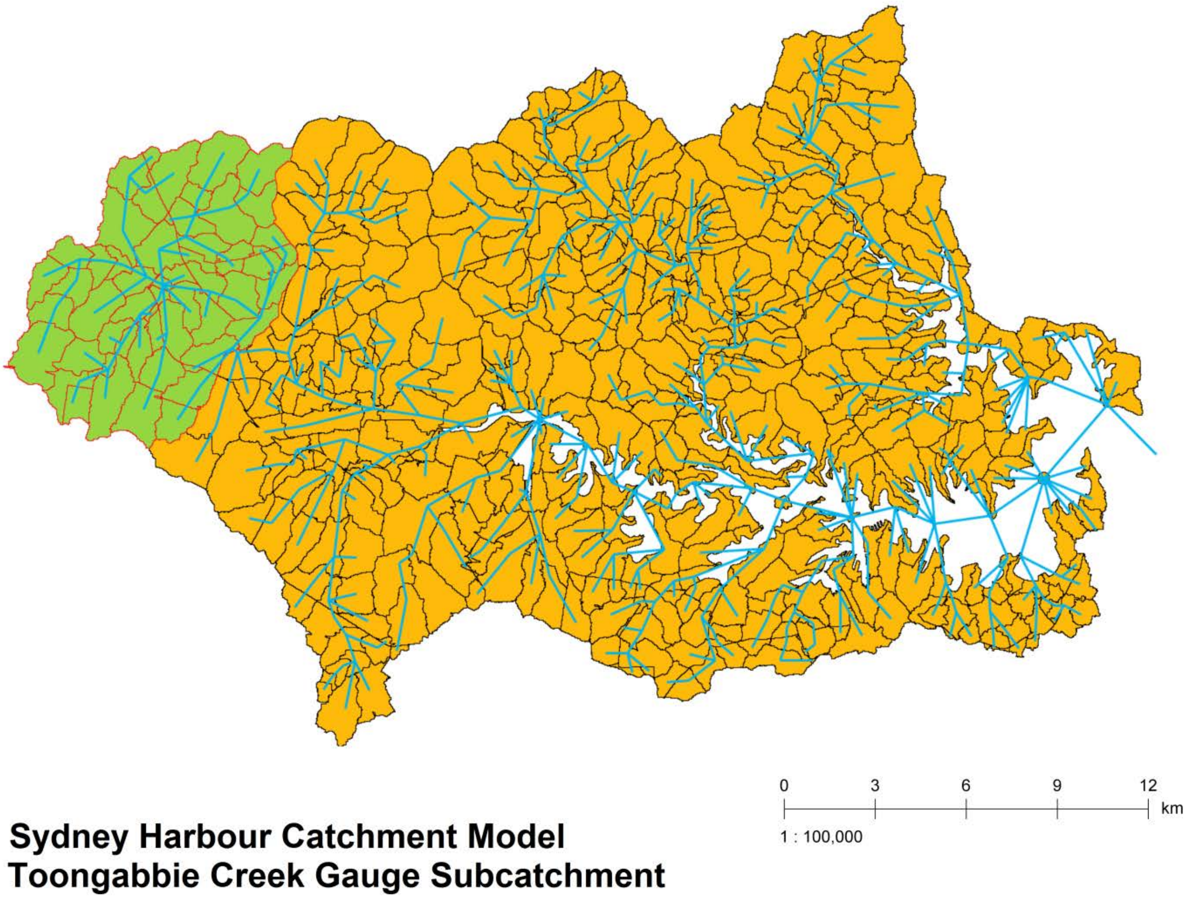

Figure 2-5. Toongabbie Creek and Subcatchment

Key flow statistics from this gauge are:

- Mean annual discharge (2000-2013) of 21,700 ML/yr;
- Mean annual runoff of 345 mm/yr (2000-2013)
- Peak daily discharge of 6400 ML/d; and
- Median daily discharge of 5.8 ML/d

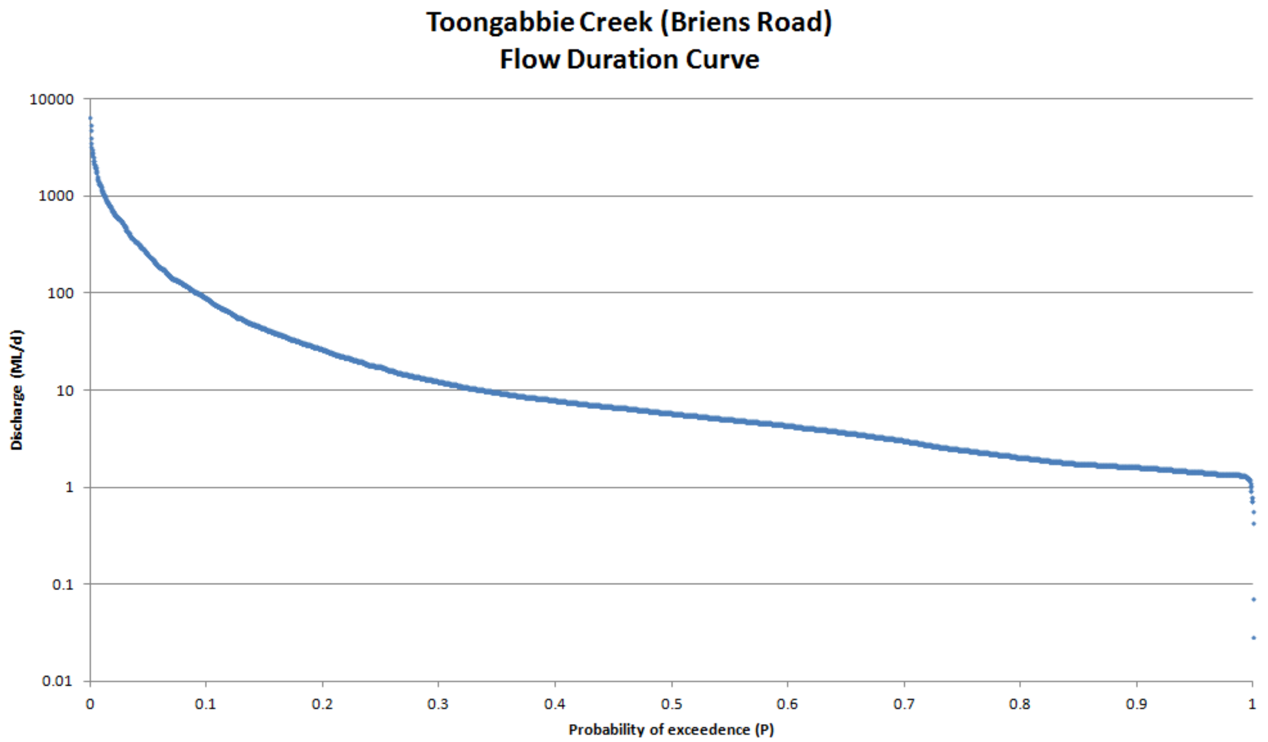

Figure 2-6. Toongabbie Creek Flow Duration Curve

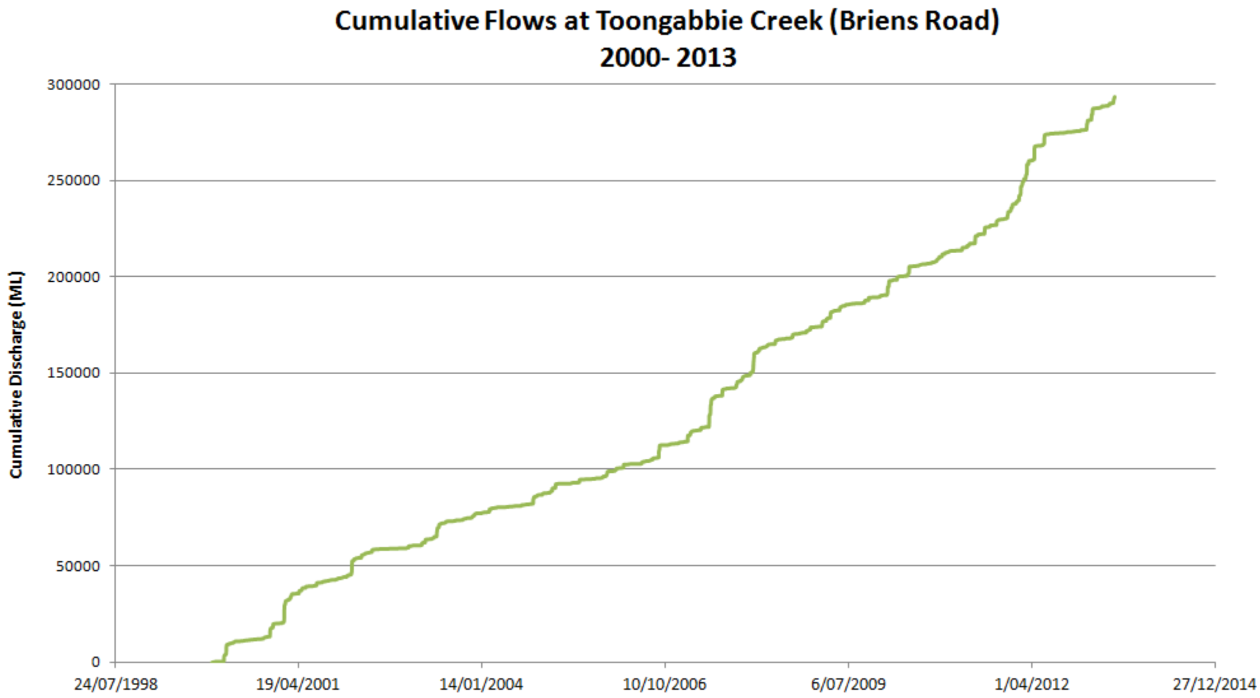

Figure 2-7. Toongabbie Creek Cumulative Discharge (2000-2013)

The cumulative discharge time series and flow duration curve for this gauge are presented below. The plots show:

- large, episodic events punctuate the cumulative discharge plot, demonstrating the importance of these large events in contributing flows and pollutant loads to Sydney Harbour;

- The influence of upstream storages on the Toongabbie Creek gauge is evident in the flow duration curve, where flows generally remain above 1ML/d for the entire record analysed. This magnitude of baseflow in an urban context generally indicates storages upstream of the gauge that may be balancing out the flows to create the long baseflow recession seen on the flow duration curve.

2.5 Water Quality

Water quality data from within the model domain was obtained by contacting each LGA and requesting data for water quality constituents Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorous (TP), Faecal Coliforms, Enterococci, E.Coli, Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC). In addition to LGA data, water quality data from the HNCMA and Sydney Water was also obtained for incorporation to this study.

In summary, water quality data was collated from:

- Parramatta City Council Data as recorded in a series of reports by Laxton et al (2008);

- Sydney Water data at Charles Street Weir and event based sampling data undertaken by Sydney Water at the Cumberland Hospital Site (Sydney Water, 2005)

- LGAs including Baulkham Hills, Blacktown, Holroyd, Hornsby, Manly, Canada Bay, Ryde, Woollahra, Ku-Ring-gai and Mossman Councils.

Water quality data collected included a limited amount of event based data used previously to parameterise the Upper Parramatta River model (HNCMA 2013).

2.5.1 Grab sample Data

All grab sample based water quality data had been incorporated into a database for statistical analysis and is summaried below:

- 108 + potential WQ locations with some data (mostly grab sampling)

- 2397 individual sampling occasions

- Only 18% of all data had a time stamp as well as a date stamp

- 1370 TSS samples, median 8.2 mg/L

- 1810 TN samples, median 1.04 mg/L

- 1776 TP samples, median 0.073 mg/L

- 1741 Faecal Coliform samples, median 300 cfu/100ml

- 269 Enterococci samples, median 260 cfu/100ml

2.5.2 Event Based Data

Event based data used previously to parameterise the Upper Parramatta River models has also been made available for this study and is summarised in Table 2-2.

Table 2-2 Event based Water Quality Data: Upper Parramatta River, Cumberland Hospital (Sydney Water 2005)

SW Event ref	Dates	Duration	SS conc. (mg/L)	TN conc. (mg/L)	TP conc. (mg/L)
4	25-26/2/2004	34 hours	180	1.24	0.275
5	5-6/4/2004	8.5 hours	60	1.16	0.178
1	18/08/2004	13 hours	97	2.42	0.339
2	1-2/10/04	21 Hours	317	2.04	0.449
3	18-20/10/04	45 Hours	156	4.13	0.355
4	21-25/10/04	72 Hours	164	2.77	0.279
5	10-11/12/04	18 hours	168	1.61	0.312
6	2-3/2/05	40 hours	181	1.48	0.242
7	22-23/3/05	8 hours	180	1.8	0.26
8	27-30/6/05	100 hours	142	2.15	0.292
	value				

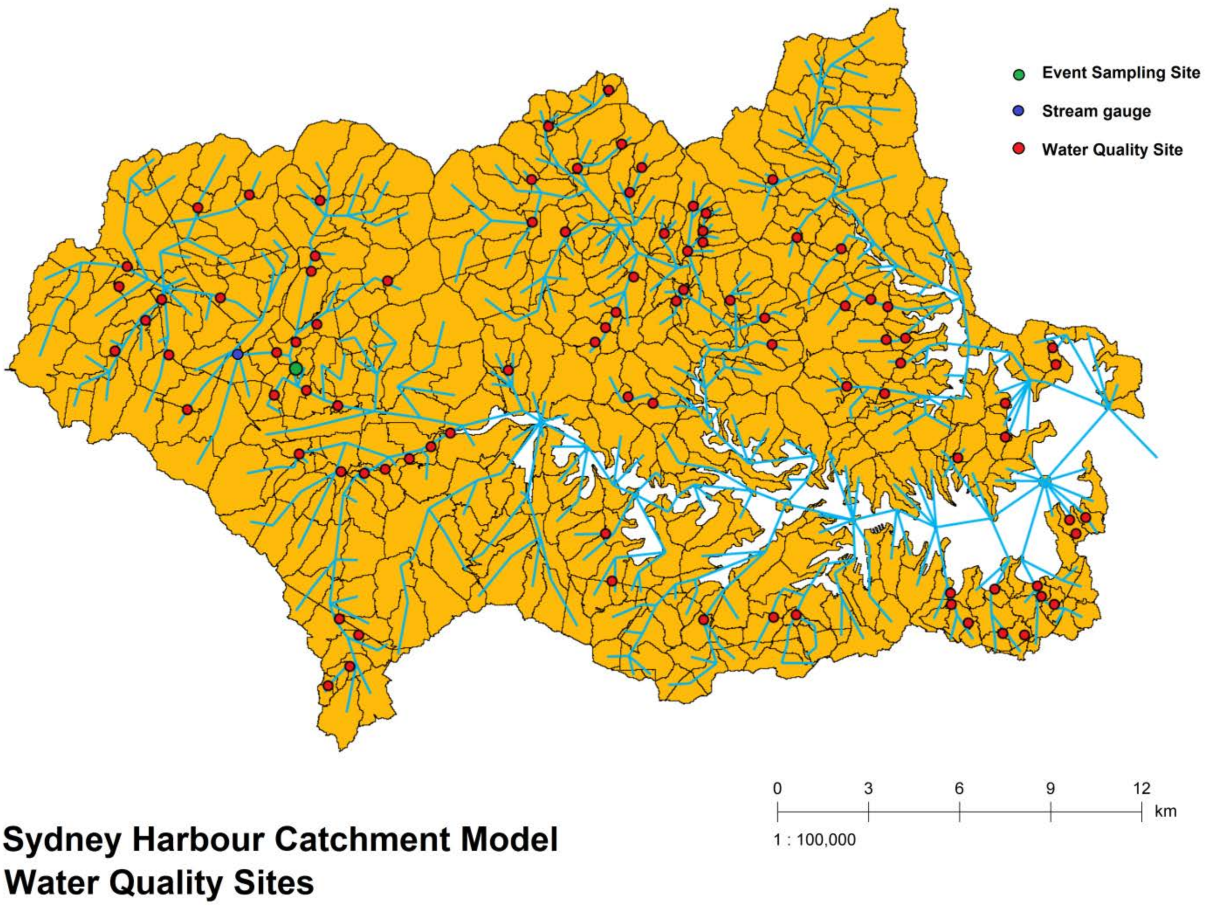

Figure 2-8. Sydney harbour Water Quality Sites

2.5.3 Literature Water Quality Parameters

Water quality parameters from other Sydney Harbour catchment models (Original Upper Parramatta River model and Lower Parramatta River model) were assigned from literature values and were also partially based on those used in the Botany Bay catchment model (Stewart et al 2010). These water quality parameters are provided in Table 2-3 and are used as a starting point for the current model study. Units for microorganism parameters are included in the model as mg/L, but are actually representative of cfu/100 ml. Appropriate conversions are undertaken during post processing to obtain results in the correct units.

Table 2-3 Literature water quality parameters

	Biochemical Oxygen Demand		Faecal Coliforms		Total Nitrogen		Total Organic Carbon		Total Phosphorous		Total Suspended Solids		Enterococci		Ecoli	
	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC
Bushland	6.2	0	600	100	1.3	0.4	8	8	0.1	0.04	58	9	120	20	120	20
Commercial	20	0	4000	350	2.8	1.8	33	8	0.33	0.18	204	23	800	70	800	70
Industrial	20	0	4000	350	2.8	1.8	33	8	0.33	0.18	204	23	800	70	800	70
Parkland	6.2	0	600	100	1.3	0.4	8	8	0.1	0.04	58	9	120	20	120	20
Railway	20	0	4000	100	2.8	1.8	33	8	0.33	0.18	204	23	800	20	800	20
Residential	18	0	20000	2500	2.8	1.8	19	8	0.33	0.18	204	23	4000	500	4000	500
Roadway	20	0	4000	350	2.8	1.8	33	8	0.33	0.18	204	23	800	70	800	70
Rural	6.2	0	600	100	2.8	1.3	8	8	0.1	0.04	131	20	120	20	120	20
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2.6 Water Storages

Of the three Sydney Harbour catchment model developed previously, only the Upper Parramatta River (HNCMA 2013) model included water storages. The UPR model contained 24 storages shown in the locations of Figure 2-9.

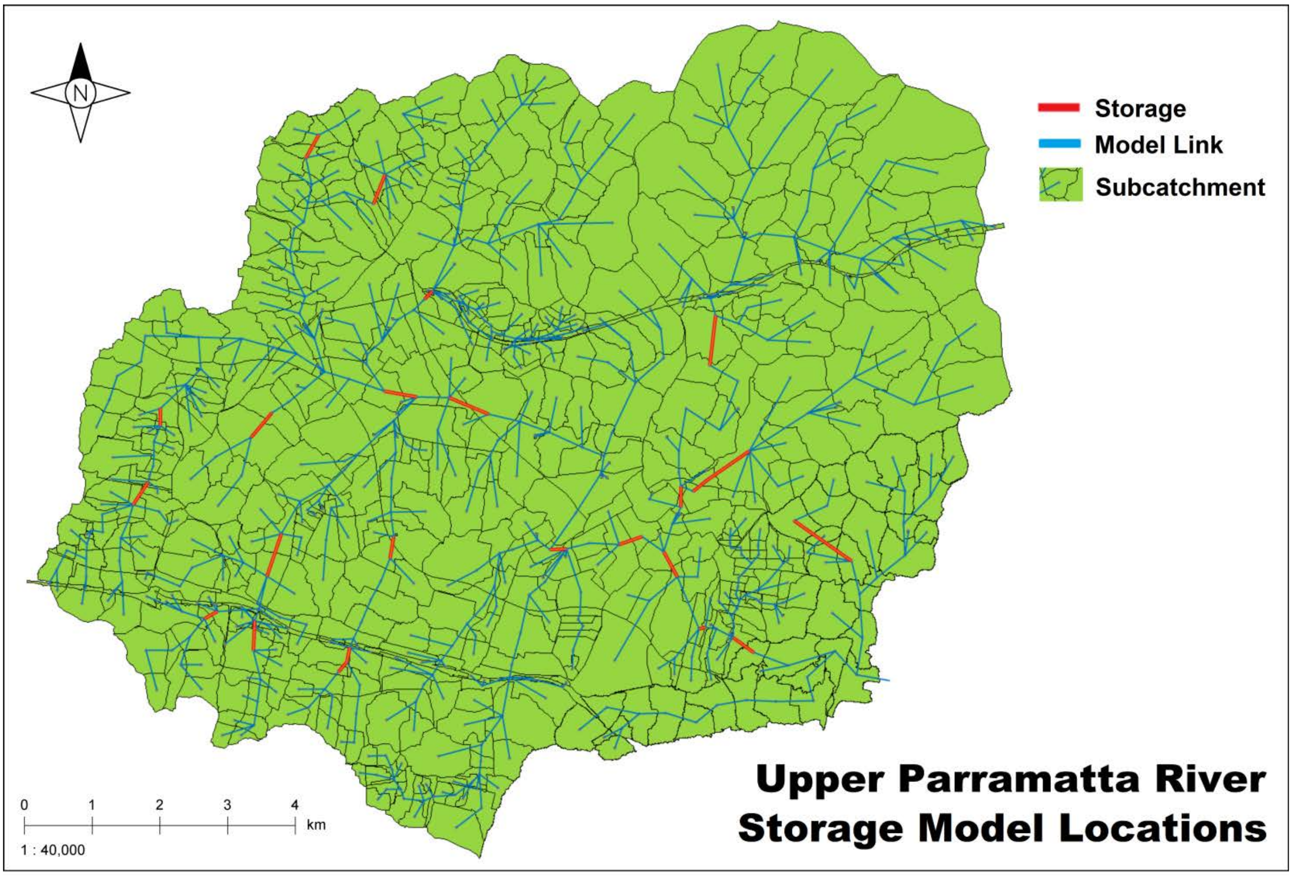

Figure 2-9. UPR 'storage' model locations

The majority of these storages included in the UPR model were intended for flood detention in the RAFTS flood models and have initial storage conditions of no volume. During large events, culverts or spillways from these storages may retard water for short periods as flood prevention, however from a long term water balance and water quality perspective most of these storages do not retard small to medium flows.

Of the 24 storages in the UPR model, 8 have been included in the Sydney Harbour model including:

- lake Parramatta, approximately 370 ML;
- Lower Parramatta River below Toongabbie Creek (3 storages to Charles Street Weir), approximately 20, 100, 36 ML;
- 3 storages along Toongabbie Creek, including the gauging weir; and
- Upper Greystanes creek, approximately 58 ML

Storages in the remainder of the model domain were identified through contacting Councils and inspection of aerial photography. Councils were asked or storage dimensions where available. In the absence of dimensions for input the model, the area of the storage and weir overflow was estimated from aerial photography and side slope batters of 1:10 were assumed to estimate volume and storage. Only online storages were incorporated and included:

- Impoundments behind weirs on the lower Duck River;

- 1 storage on the upper Duck River;
- Avondale Dam; and
- Stringy Bark weir in the Lane Cove catchment

The lane Cove weir was to be incorporated in the recieving water model for the Harbour, and was therefore not incorporated in the model.

The model locations of storages are shown in Figure 2-10 and the stage discharge curves, stage volume curves and spillway characteristics are tabulated in the associated data files.

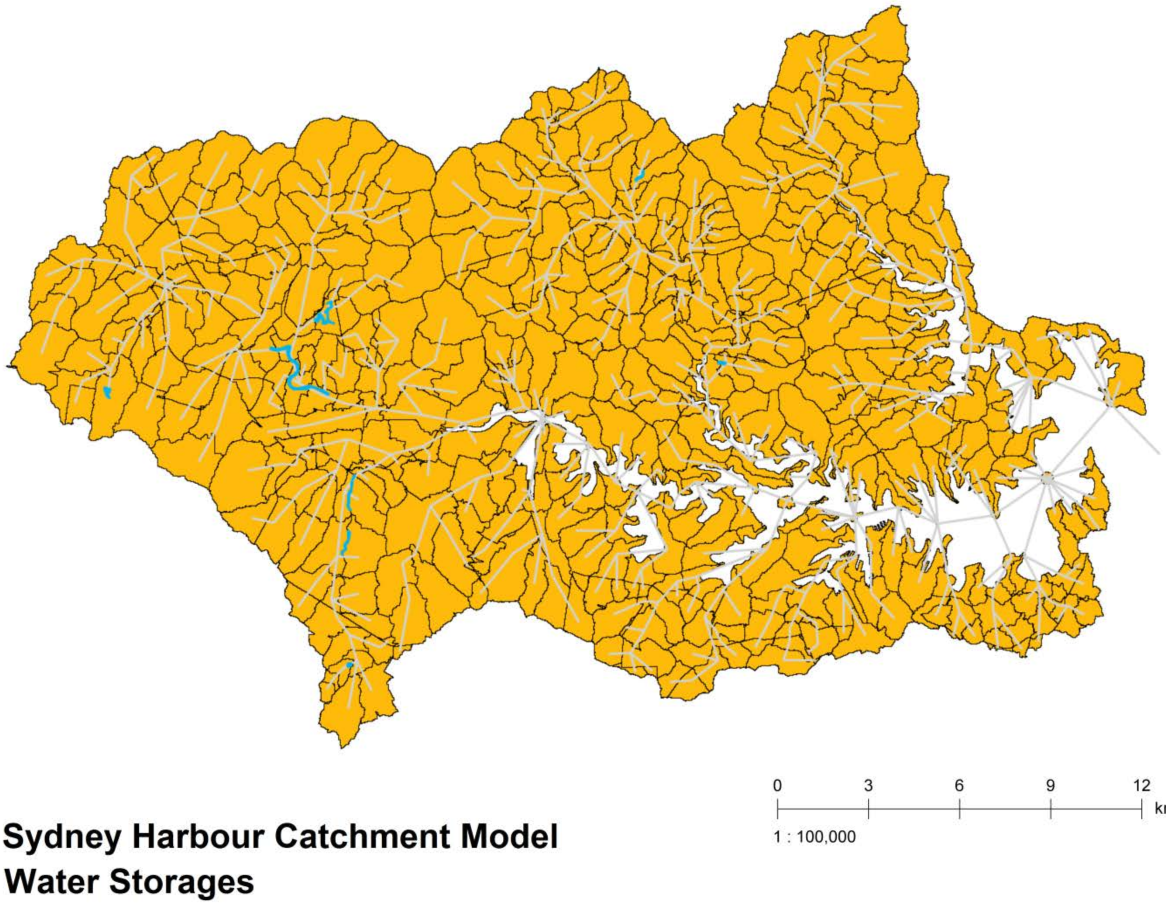

Figure 2-10. Sydney Harbour Catchment Model Storage Locations

3 SEWER OVERFLOWS

553 sewer overflow locations and associated 30 minute modelled time series of these overflows for the period 1/7/2010-1/7/2013 were provided by Sydney Water for this study. This number of time series is a 10 fold increase over the 48 time series included in the Upper Parramatta River model (HNCMA 2013) and therefore requires a different approach to incorporation into the model domain to keep model structure and size to a manageable level.

The locations of the overflows are shown in Figure 3-1.

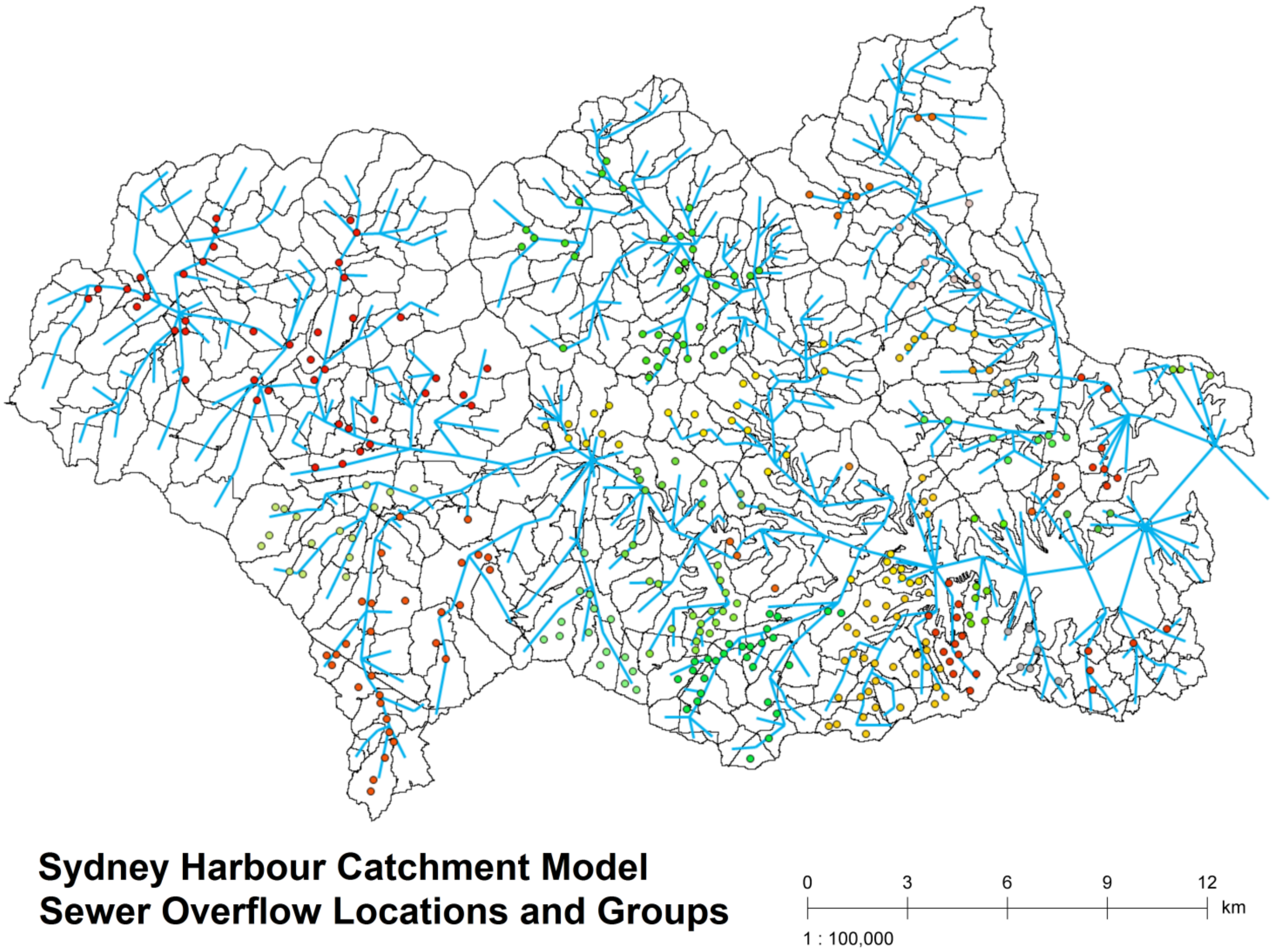

Figure 3-1. The Sydney Harbour Sewer Overflow Locations

Like the Upper Parramatta River Model, the method used for incorporating the sewer overflow into the Source Catchments structure was via node models, however the 553 time series were grouped to 32 time series representing major bays and inflows to the harbour. These groupings are shown in Figure 3-1.

Grouped overflow time series were assigned water quality constituents according to Table 3-1.

Table 3-1 Sewer overflow water quality parameters

Water Quality parameter	mg/L, cfu/100ml
Biochemical Oxygen Demand	20
Faecal Coliforms	1,250,000
Total Nitrogen	10.1
Total Organic Carbon	17.2
Total Phosphorous	1.2
Total Suspended Solids	200
Enterococci	250,000
Ecoli	1,000,000

3.1 Sewer Overflow Data Summary

Results of data analysis on the sewer overflow time series are provided in Table 3-2. One batch of data was provided for analysis and incorporation to the model one series covering the period July 2010-July 2013, however a second series covering the period 1985-1995 may be available in the future for more long term analysis. The 1985-1995 series can not currently be incorporated into the model without substantial work on rainfall data analysis and historic land use data compilation and resultant rebuild of the catchment model to reflect the conditions of 1985-1995.

Analysis of the sewer overflow data has been conducted as part of this investigation by looking at the number and magnitudes of overflow events. An event is a series of overflow time steps with zero flow on time steps either side of the event. events have been calculated based on data groupings as described above.

- In the 3 year period provided (2010-2013), 1422 events occurred across the 32 groups totalling 165 ML of sewer overflow for the entire harbour.
- Previous Upper Parramatta sewer overflow volume for the period 2004-2008 was 2762 ML[1] (HNCMA 2013)

[1] Notably, the units of the data series provided for this investigation are in ML/d, as opposed to that provided previously for the Upper Parramatta model and Hunts Creek models of m3/s. Direct comparisons between the data sets used on both models are not possible due to differences in the model time periods, however analysis of some overflow locations common to both models suggests that either the units applied in the Upper Parramatta River model were incorrect or the units applied in the current study are incorrect. Further investigations will be required in the future to clear up this discrepancy. In the present study, data has been obtained directly from Sydney Water and is assumed to be correct until instructed otherwise: Sewer overflow time series are provided in flow rate units of ML/d. Calculating total overflow volume is undertaken by summing all time series and dividing by 48 to account for the 30 minute time step.

Table 3-2 Sewer Overflow time series analysis (07/2010-07/2013)

Site	Group Description	events	events/year	Total (ML) (3 years)	% of total flow
Group 1	Upper Parramatta	52	17.3	43.67	26.5%
Group 2	Duck Creek	67	22.3	6.11	3.7%
Group 3	Duck River	69	23.0	12.90	7.8%
Group 4	Haslams Creek	70	23.3	5.62	3.4%
Group 5	Powells Creek	111	37.0	4.63	2.8%
Group 6		37	12.3	2.15	1.3%
Group 7		120	40.0	11.93	7.2%
Group 8		78	26.0	7.25	4.4%
Group 9		101	33.7	3.13	1.9%
Group 10	Darling Harbour	32	10.7	0.15	0.1%
Group 11		11	3.7	0.02	0.0%
Group 12		49	16.3	2.73	1.7%
Group 13		23	7.7	0.15	0.1%
Group 14	Manly	0	0.0	0.00	0.0%
Group 15	Balmoral	98	32.7	1.43	0.9%
Group 16		56	18.7	26.23	15.9%
Group 17		68	22.7	0.35	0.2%
Group 18		17	5.7	0.25	0.2%
Group 19		37	12.3	1.08	0.7%
Group 20	Mid Middle Harbour	31	10.3	2.16	1.3%
Group 21	Upper Middle Harbour	31	10.3	1.11	0.7%
Group 22		13	4.3	0.01	0.0%
Group 23		16	5.3	0.11	0.1%
Group 24		9	3.0	0.06	0.0%
Group 25		0	0.0	0.00	0.0%
Group 26		6	2.0	0.06	0.0%
Group 27		67	22.3	12.69	7.7%
Group 28	Lane Cove River	66	22.0	16.00	9.7%
Group 29	Archers Creek	36	12.0	1.90	1.2%
Group 30		15	5.0	0.67	0.4%
Group 31		16	5.3	0.27	0.2%
Group 32		20	6.7	0.10	0.1%
Total		1422.0	474.0	165.0	100.0%

4 MODEL PARAMETERISATION

This Chapter presents the methodology and results of the Hydrological and water quality parameterisation for the Sydney Harbour model. All hydrologic modelling undertaken in recent HNCMA models of harbour catchments has been undertaken in the RAFTS modelling package and limited information is available regarding the suitability of this calibration or correlation with field data. This study presents the process of hydrologic parameterisation used in the Source catchments framework and applied to the entire model domain

4.1 Hydrology

The Toongabbie Creek stream gauge was the only stream flow data identified for this investigation. Hydrologic parameterisation for this gauge was undertaken with the Source Catchments modelling framework by undertaking the following steps:

- A Toongabbie Creek sub-model was created using a cut down version of the land use map, subcatchment map and node link network used in the Sydney harbour model;
- The Toongabbie model operated on a 30 minute time step;
- The storages upstream of the Toongabbie gauge were not used in the model at this stage due to apparent software issue that is yet to be resolved.
- The 30 minute time step stream gauging data was input to Source Catchments and the internal calibration tool was used to obtain a suitable fit between modelled and measured data using the daily Nash-Sutcliffe coefficient of efficiency as a model performance criteria (Nash, Sutcliffe, 1970).

Land use based hydrology models were parameterised in an attempt to differentiate hydrologic responses between urban and non urban land surfaces, however the relatively small portion of non-urban land surfaces meant that independent and reliable parameters associated with this land use could not be obtained.

The results of this model parameterisation are provided below and include:

- The Nash-Sutcliffe coefficient of efficiency for daily and monthly flow volumes;
- Comparisons between the measured and modelled flow duration curves;
- Cumulative volumes and
- hydrograph shape

4.1.1 Model performance statistics

Table 4-1 Nash-Sutcliffe and volumetric model performance

	Old Rafts+Source model	Current Model
Daily Nash Sutcliffe Coefficient	0.19	0.82
Monthly Nash Sutcliffe Coefficient	0.45	0.83

The daily and monthly Nash Sutcliffe (NS) coefficient of efficiency for the Source Catchments derived model parameters show considerable improvement over past Upper Parramatta River model performance. A NS of 1 is representative of a perfect model fit and a value of 0.8 is considered well calibrated and a value of 0 is considered no better model fit than using the mean of the recorded data as the model prediction.

4.1.2 Cumulative Flows

The cumulative flows plot in Figure 4-1 shows the predicted modelled flows are slightly over predicted and the trend is relatively consistent from 2003-2010. This indicates that there is still improvement that can be made in model predictions to reduce the level of long term overprediction which is currently 24% compare to gauge data. We note that no assessment has been undertaken as part of this study regarding the accuracy of the stream gauge.

Further reduction in the percentage impervious parameters or introduction of instream losses may address the over prediction issues in the future.

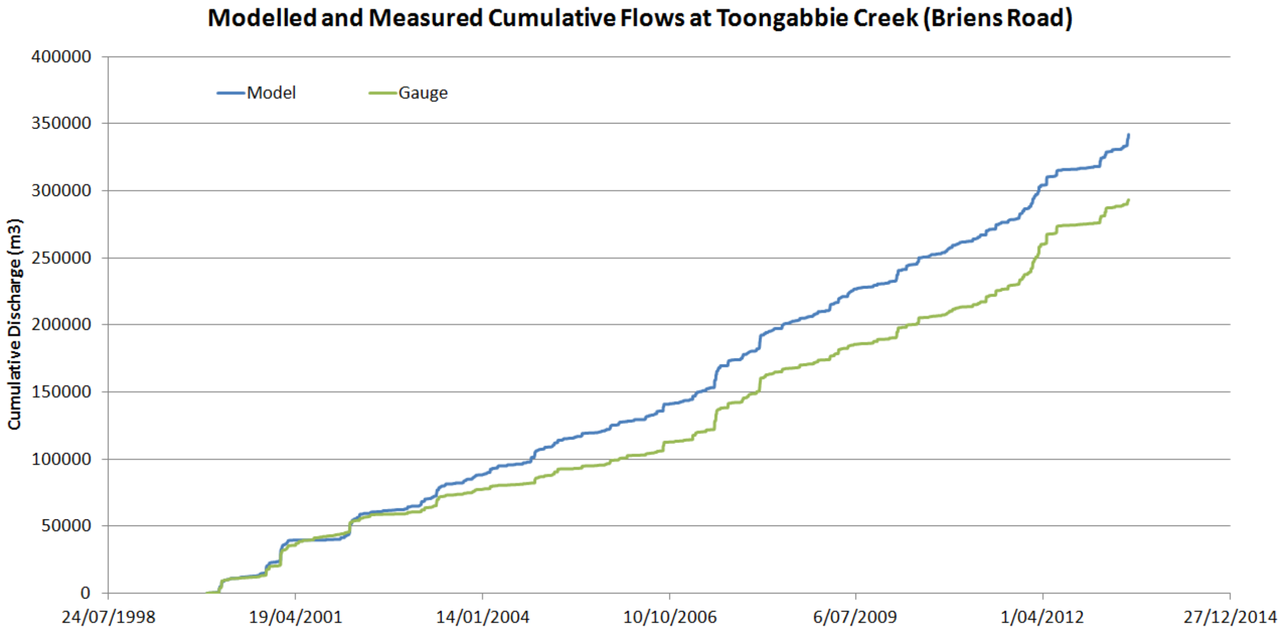

Figure 4-1. Cumulative Flows - Measured and Modelled

4.1.3 Flow Duration Curve

The modelled flow duration curve deviates significantly from the measured flow duration curve in a number of ways including:

- The frequency of medium flow rates between 10 and 500 ML/d is overpredicted; and
- The long tail of low flows above 1ML/d is not replicated.

These differences can possibly be attributed to modelling of storages within the model domain. Four storages have been incorporated in the model above the gauge, however incorporation of many more temporary storages as was included in the Upper Parramatta River model may be necessary to improve the model for model fit for flow duration curve. Encouragingly, the model replicated the high flows days (flows > 500 ML/d) very closely.

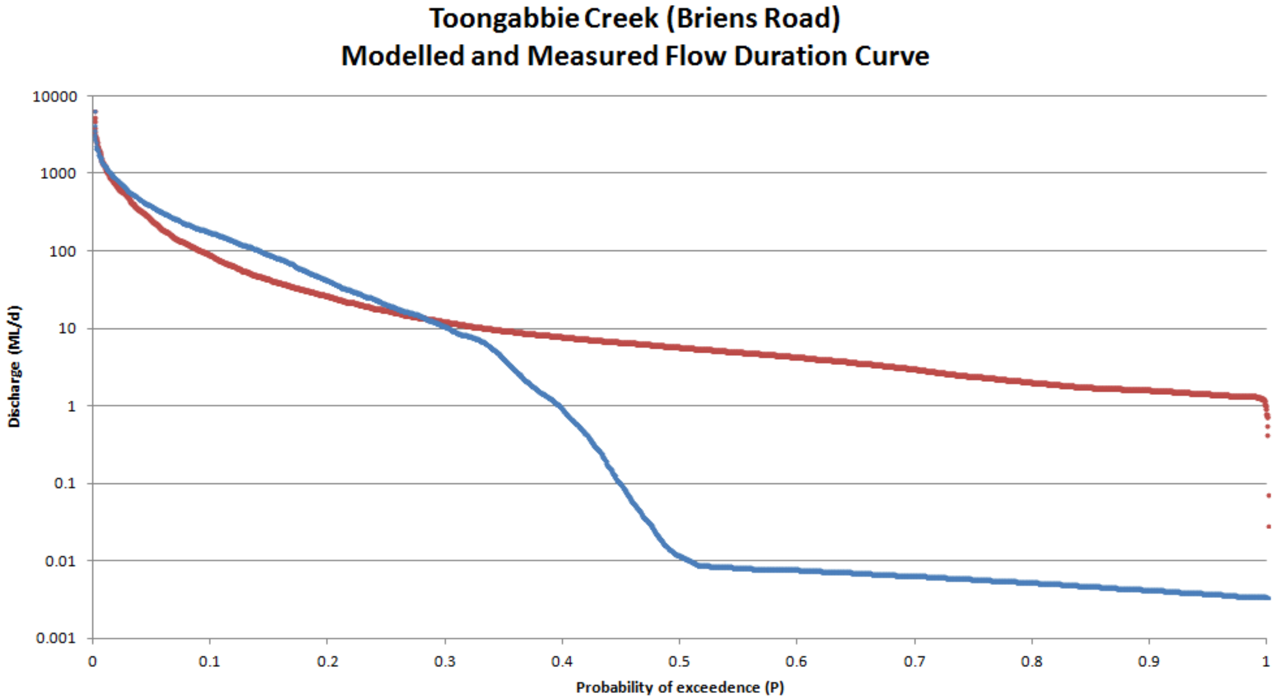

Figure 4-2. Cumulative Flows - Measured and Modelled

4.1.4 Typical Hydrographs

A typical modelled hydrograph time series is presented in Figure 4-3 and shows the agreement in the timing and magnitude of modelled flows compared to gauged flows

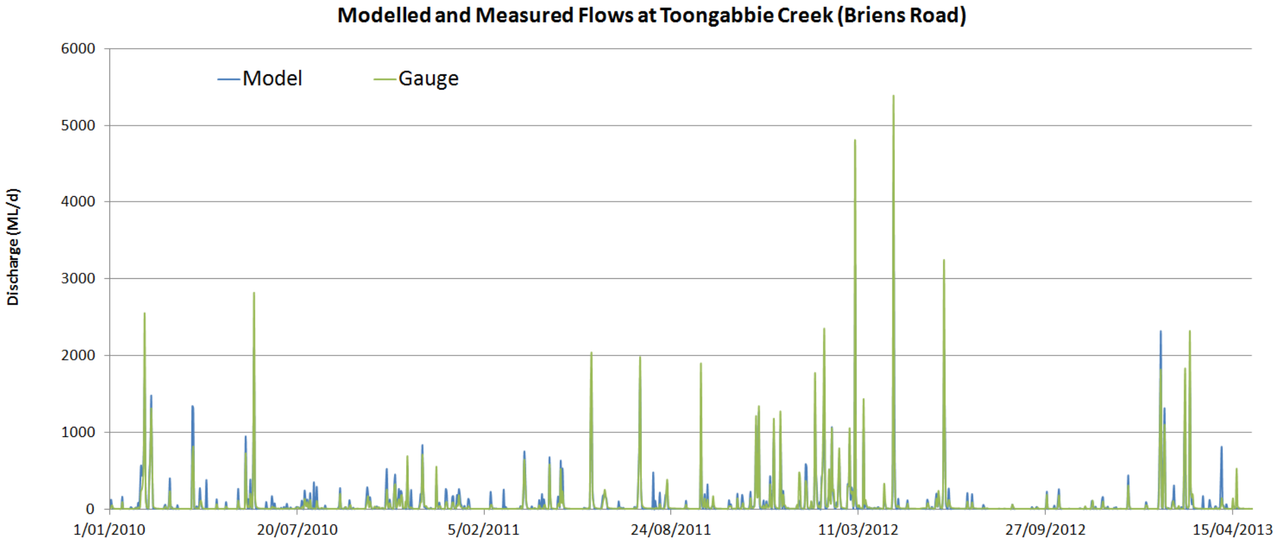

Figure 4-3. Daily Flows - Measured and Modelled

4.1.5 Hydrologic parameters

The overall model performance is summarised as:

- Acceptable statistical model fit;
- Some issues with overprediction of runoff in the long term;
- Difficulties with the model reproducing the baseflow, possibly due to the modelling of storages and associated overflow structures; and
- General agreement in the timing and magnitude of event flows.

The hydrologic parameters adopted for this model are provided in Table 4-2

Table 4-2 Hydrologic model parameters

Parameter	Bushland/Parkland	Residential	Commercial	Industrial
Baseflow coeff.	0.25	0.25	0.25	0.25
Impervious Threshold	0	0	0	0
Infiltration Coeff.	400	400	400	400
Infiltration shape	0.05	0.05	0.05	0.05
Interflow Coeff.	1	1	1	1
K	200	200	200	200
Perv. Fraction	0	0.7	0.6	0.5
RISC	2	0	0	0
Recharge coefficient	1	1	1	1
SMSC	120	120	120	120
X	0	0	0	0

4.2 Water Quality

The literature based water quality parameters used in previous Sydney Harbour models such as the Upper Parramatta, Lower Parramatta and Lane Cove models were presented in Table 2-3 and was used as a starting point for parameterisation of the present model. These land use based parameters were updated using the collated grab sample data from the entire model domain.

Direct correlation and optimisation between modelled water quality values and recorded values is not applicable with the current 30 minute time step model. Only a small fraction (18%) of all the water quality data collated had a time stamp at which the sample was taken. Therefore there is no direct correlation between most of the water quality data and corresponding output value from the model unless the model was reverted to a daily time step.

despite this limitation, the collated water quality data has been used to generate mean and percentile values which have then been used to adjust the literature water quality values. For example:

- The literature based Dry Weather Concentration (DWC) parameter for Total Nitrogen was 1.8 mg/L for residential land use:
- The 50th percentile from all 1811 water quality data points was 1.03 mg/L
- The 1.8 mg/L corresponded roughly to the 80th percentile of all monitoring data suggesting that using this value as the DWC for the main land use in the model would result in overprediction of baseflow water quality levels.
- Therefore the 50th percentile value for TN was adopted for the DWC as the model parameter.

The above example methodology was used on a case by case basis to adjust many of the DWC water quality parameters used in the model. Most event mean Concentration (EMC) parameters were not adjusted and remained as per literature values with the exception of BOD parameters which were identified and adjusted in a systematic parameterisation exercise undertaken on the Upper Parramatta River (REF) using grab and event based data .

The final water quality parameters used in the model are presented in Table 4-3. Units for microorganism parameters are included in the model as mg/L, but are actually representative of cfu/100 ml. Appropriate conversions are undertaken during post processing to obtain results in the correct units

Table 4-3 Model Water Quality Parameters

	Biochemical Oxygen Demand		Faecal Coliforms		Total Nitrogen		Total Organic Carbon		Total Phosphorous		Total Suspended Solids		Enterococci		Ecoli	
	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC
Bushland	6.2	0.1	600	100	1.3	1.03	8	8	0.1	0.07	60	8	120	20	120	20
Commercial	5.5	0.1	10000	300	2.8	1.03	33	8	0.33	0.07	204	8	1000	260	1000	260
Industrial	5.5	0.1	10000	300	2.8	1.03	33	8	0.33	0.07	204	8	1000	260	1000	260
Parkland	6.2	0.1	600	100	1.3	1.03	8	8	0.1	0.07	60	8	120	260	120	260
Railway	5.5	0.1	10000	100	2.8	1.03	33	8	0.33	0.07	204	8	1000	260	1000	260
Residential	10.1	0.1	10000	300	2.8	1.03	19	8	0.33	0.07	204	8	4000	260	4000	260
Roadway	5.5	0.1	10000	300	2.8	1.03	33	8	0.33	0.07	204	8	1000	70	1000	70
Rural	6.2	0.1	600	100	2.8	1.03	8	8	0.1	0.07	204	8	120	20	120	20

4.2.1 Storage models and parameters

Past modelling efforts on the Upper Parramatta River highlighted the importance of storages and their impact on simulated water quality (HNCMA 2013). This study found that water quality behaviour in the lower part of the model is dominated by storage behaviour and that without an in-stream model acting on water quality, the storages act like completely mixed reactors and consequently, modelled water quality concentrations within these storages reflect the high flow event based concentrations rather than the actual baseflow type concentrations that are typically present in the recorded data.

In attempting to overcome this model structure and strengthen the simulation capability of the model, instream decay models were installed on all storages within the model domain. A half like decay model was initially chosen as per the Upper Parramatta River model. Only 1 parameter is required for the decay model for each water quality constituent and the parameters found previously for the Upper Parramatta River were adopted:

- Total Suspended Solids – 3 days;
- Total Nitrogen – 7 days;
- Total Phosphorus – 4 days;
- Biological parameters – 1 day.

5 MODEL RESULTS

Model mass balance results for the current conditions scenario are presented in Table 5-1.

Table 5-1 Total flow and pollutant export mass balance current conditions, 7/2010- 7/2013

mass Balance	Diffuse Catchment loads	Sewer overflow load	Total Load	Sewer overflow contribution (%)
ML	902163.2	165.0	902328.2	0.02%
BOD (t)	6137	3.30	6140.4	0.05%
TSS (t)	107466	32.99	107499.2	0.03%
TN (t)	1723.9	1.67	1725.6	0.10%
TP (t)	181.4	0.20	181.6	0.11%
TOC (t)	15941	2.84	15943.8	0.02%
Enterococci (cfu)	1.68E+16	4.12E+14	1.72E+16	2.39%
Ecoli (cfu)	1.68E+16	1.65E+15	1.85E+16	8.94%
Faecal Coliforms (cfu)	4.95E+16	2.06E+15	5.16E+16	4.00%
BOD (mg/L)	6.80	20.0	6.8	
TSS (mg/L)	119.12	200.0	119.1	
TN (mg/L)	1.91	10.1	1.9	
TP(mg/L)	0.20	1.2	0.2	
TOC (mg/L)	17.67	17.2	17.7	
Enterococci (cfu/100ml)	1864	250000	1909	
EColi(cfu/100ml)	1864	1000000	2046	
Faecal Coliforms (cfu/100ml)	5489	1250000	5717	

The results of the mass balance show that over the 3 year model period (2010-2013) approximately 0.02% of the flow in Sydney Harbour may have been attributed to sewer overflows.

- Approximately 0.1% of total catchment nutrient load may be a result of sewer overflows; and
- Approximately 9% of Ecoli and 4% of faecal coliform loads and 2% of Enterococci may be a result of sewer overflows.

These results differ remarkably from those obtained from previous modelling of the Upper Parramatta River catchment and these differences are possibly due to an error in the units presented in the provided input files. Consequently, the comparison between total catchment diffuse loads and the sewer overflow loads should be interpreted with caution until the units can be clarified with Sydney Water.

Model results for diffuse loads from the entire 13.5 year model time series are presented in Table 5-2 and monthly totals for the entire period are shown in Figure 5-1.

Table 5-2 Total flow and pollutant export mass balance current conditions, 2000- 2013

mass Balance	Total Diffuse Catchment loads	Mean Annual Load	Mean concentration
ML	3287870	243546	
TSS (t)	394219	29201	119.9
TN (t)	6286	466	1.91
TP (t)	664	49	0.20
Faecal Coliforms (cfu)	1.8E+17	1.3484E+16	5536
Ecoli (cfu)	6.2E+16	4.5705E+15	1877
Enterococci (cfu)	6.2E+16	4.5705E+15	1877
TOC (t)	58752	4352	17.87
BOD (t)	23120	1713	7.03

The model results show mean concentrations of key water quality constituents are generally within the range reported by literature.

The monthly load plots show the large variability in flows and loads delivered to Sydney Harbour through time. Large episodic events and higher loads and flows during summer drive the overall loads to the harbour. Monthly loads closely resemble monthly flows due to modelled water quality concentrations typically being the same for storm events of all magnitude. this is typical of the EMC/DWC model

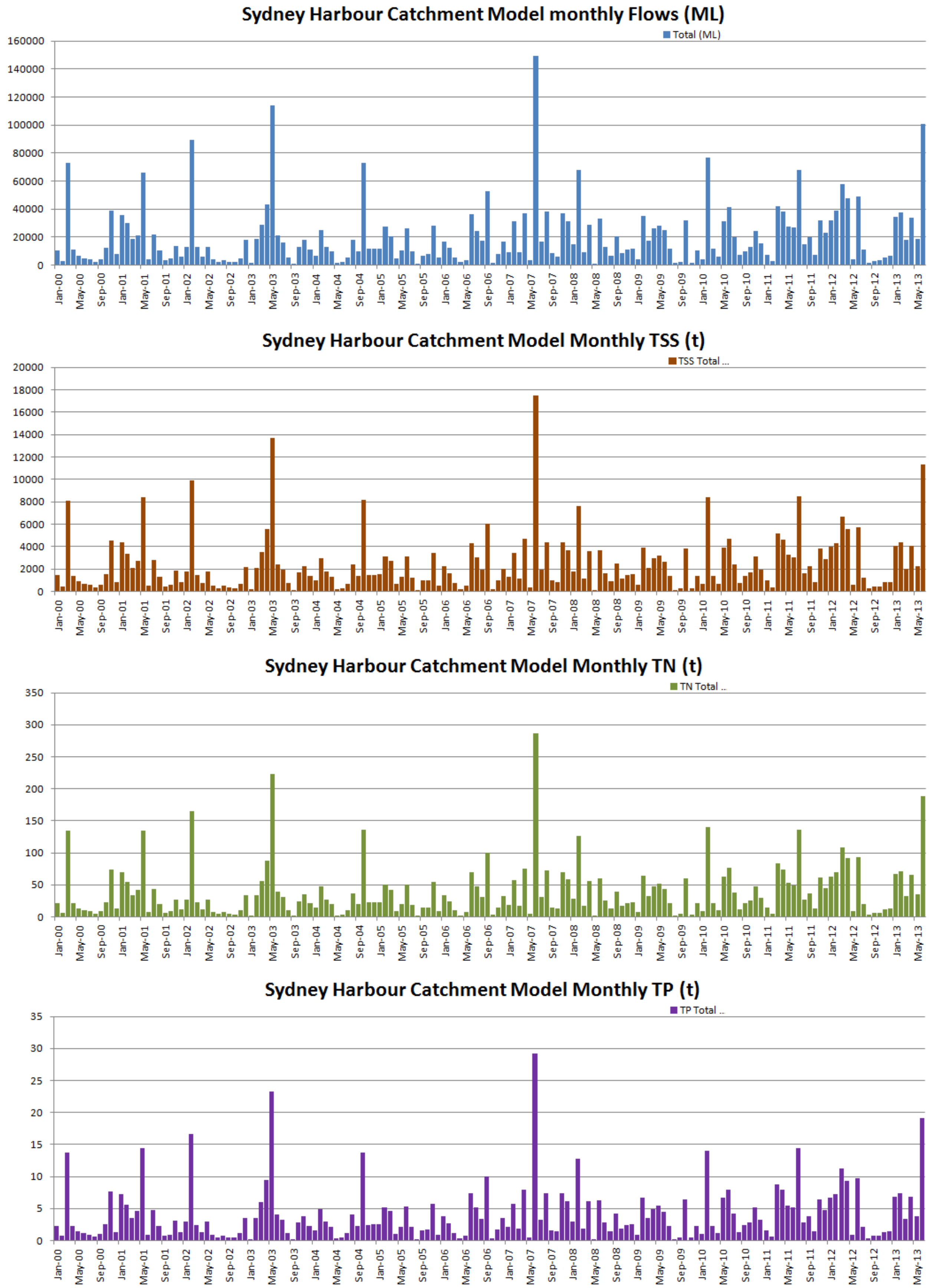

Figure 5-1. Sydney Harbour Monthly Flows and Loads

6 SUMMARY AND FURTHER INVESTIGATIONS

This report presents the data, methodology and results of the parameterisation of the Sydney Harbour Catchment Model. The model was established by the Hawkesbury Nepean CMA to provide water quality time series to receiving water quality models and summary data to be used in future Decision Support Systems.

The key features of this model are:

- A model has been created that can simulate on a 30 minute time step, flows and associated pollutant loads from all Sydney Harbour catchments from the period 1/1/2000 to 30/6/2013
- The model hydrology is based on calibrations at the Toongabbie Creek gauge in the Parramatta river catchment;
- The model simulates up to 10 land use classes and incorporates 8 water quality constituents
- The model incorporates 14 storages, many of which are in the Parramatta River catchment
- The model can incorporate sewer inflows for the period 1/7/2010 to 1/7/2013 and these time series have been grouped to 32 locations around the harbour.

The key findings of this model are:

- The model estimates a mean annual flow to the harbour of approximately 24 GL/yr
- The estimated annual sediment and nutrient load to the harbour is 29,000t TSS, 466t TN and 49t TP;
- The contribution of sewer overflows to the overall flow and loads to the Harbour was found to be very small, however this finding is subject to review; and
- the long term annual flow and loads quantities are dominated by large episodic events

6.1 Recommended further investigations

The following recommendations and opportunities for enhancement in the Source Catchments model are outlined below:

1. Instream decay in storage models should be investigated further as this appear to have a significant impact on overall load delivery to the Harbour, and particularly the Upper Parramatta River. In particular, the instream decay functions currently have no lower limit, pushing water quality concentrations to very low levels in low flow conditions. Options for in-stream processing within Source catchments include:
    1. Exponential decay (half life – currently used)
    2. Storage Nutrient deposition; and

3. Storage Sediment deposition

An investigation should be undertaken on these methods to overcome some of the limitations of the current approach.

2. The Toongabbie Creek gauge is the only gauge identified to assist with parameterising the Sydney Harbour model. Model results for the entire harbour depend on these calibrations. We recommend that uncertainty analysis be undertaken on the model calibration to determine the sensitivity of the current model results to the calibration at this one gauge

3. Uncertainty estimation of the overall flows and loads should be undertaken. The results of the current model present one possible estimate of flow and load, however the reliability of this estimate is unknown at this stage. The significant effort underway to model the impacts of these flows and loads on the Harbour will depend on the reliability of the current estimates and an indication of the accuracy of the current estimate will assist in the effort to understand harbour processes in more detail;

4. Similarly, an estimate of uncertainly in the model results, based on the currently available data used to calibrate the model will provide guidance on the usefulness or otherwise of installing more gauging equipment and or water monitoring equipment which may be required to reduce the model uncertainty.

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