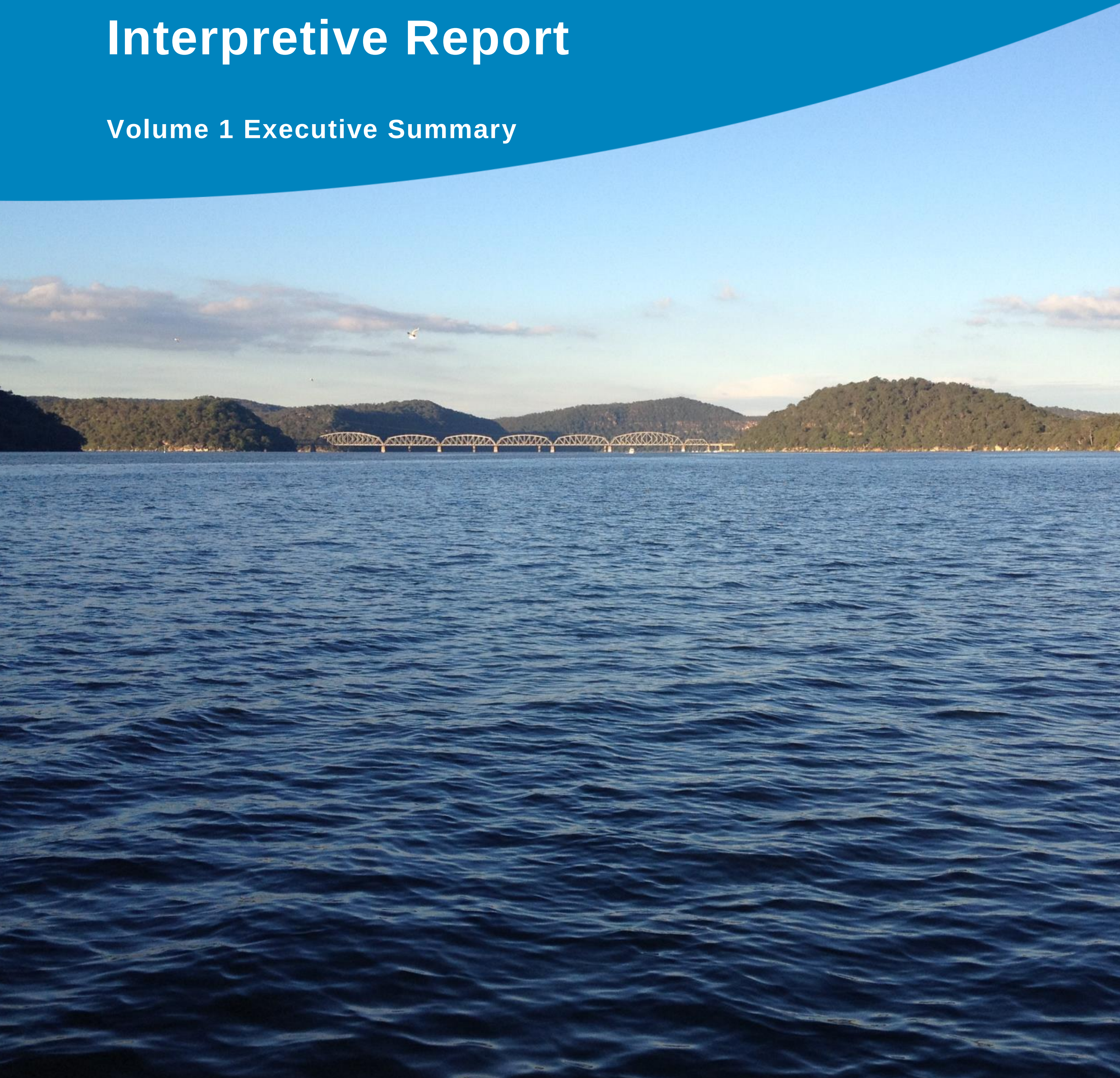
Sydney WATER

2014 Sewage Treatment System Impact Monitoring Program

Interpretive Report

Volume 1 Executive Summary



Foreword

This report forms Volume 1 (of four) for the 2014 Sewage Treatment System Impact Monitoring Program (STSIMP). It presents an integrated summary of the key findings from the:

- long term trend analysis (greater than ten years)
- six case studies
- 2013-14 annual data report
- Ocean Sediment Program

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Glossary/Acronyms (for Volumes 1, 2, 3 and 4)

ADCP	Acoustic Doppler Current Profile
AEAP	Aquatic Environmental Assessment Program
AED	Aquatic EcoDynamics
AFRI	Acute Febrile Respiratory Illness
Amm	Ammonia nitrogen
ANOSIM	Analysis of similarities
ANOVA	ANalysis Of VAriance
ANZECC	Australian and New Zealand Environment and Conservation Council.
AWTP	Advanced Water Treatment Plant
BACI	Before After Control Impact
BOD	Biochemical Oxygen Demand
BOM	Bureau of Meteorology
CAP	Canonical Analysis of Principal coordinates
CBtotbv	Cyanobacteria (blue-green) total biovolume
CBtoxcnt	Potentially toxigenic cyanobacteria count
CCTV	Closed-Circuit Television
Cells/mL	Algal cells per millilitre
cfu/100mL	Colony forming units per 100 millilitres
Chla	Chlorophyll *a*
Cond	Conductivity
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTD	Conductivity Temperature Depth profiler
DC	Decommissioned
DISTLM	Distance based linear model
DO	Dissolved oxygen (concentrations)
DOsat	Dissolved oxygen saturation (percent)
EBA	Effects Based Assessment
EC_{50}	Effect Concentration for immobilization of 50%of exposed target biota
EIMP	Environmental Indicators Monitoring Program
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EPL	Environment Protection Licence
FTP	Filterable total phosphorus
HRC	Healthy River Commission
KL/day	Kilolitre/day
Licence	Environment Protection Licence
LOEC	Lowest Observed Effect Concentration
Maximum	Maximum value of set of observations
MBACI	Multiple Before After Control Impact

MDS	Multidimensional Scaling
nMDS	Nonmetric Multidimensional Scaling
Mean	Mean value of a set of observation
Median	Median or 50th percentile value
mg/L	milligrams per litre
Minimum	Minimum value of a set of observations
mL	Millilitre
ML	Megalitre
mm3/L	Algal biovolume millimeter cube per litre
NA	Not applicable
NARCliM	NSW and ACT Regional Climate Modelling
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
No. or No. of Obs	Number of observations
NOEC	No Observed Effect Concentration
NOx	Oxidised Nitrogen
NTU	Nephelometric Turbidity Unit
OEH	Office of Environment and Heritage, New South Wales
ORS	Ocean Reference Station
OSP	Ocean Sediments Program
P	Permutational significance level
PCA	Principal Components Analysis
PERMANOVA	Permutational Analysis of Variance
PLOOM	Primary Lagrangian Ocean Outfall Model
POEO	Protection Of the Environment and Operations Act
R	Regression co-efficient
RMA	Resource Management Associates
SCAMP	Sewer Catchment Area Management Plan
SIGNAL-SG	Stream Invertebrate Grade Number Average Level - Genus taxonomic level for the greater Sydney region. Which is a biotic index based on freshwater macroinvertebrate diversity, abundance and tolerance to organic pollution
SIMPER	Similarity percentage
SMWRI	St Marys Water Recycling Initiative
SOI	Southern Oscillation Index
Stats	Statistics
Std dev	Standard deviation
STSIMP	Sewage Treatment System Impact Monitoring Program
Temp	Temperature
TUFLOW FV	Three dimensional Unsteady FLOW – Finite Volume
Turb	Turbidity
TN	Total nitrogen

TOC	Total organic carbon
TP	Total phosphorus
WBC	Western Boundary Current
WFP	Water Filtration Plant
WRP or plant	Water Recycling Plant
WSUD	Water Sensitive Urban Design
WWTP or plant	Wastewater Treatment Plant
μg/L	micrograms per litre
UPR	Upper Parramatta River
μS/cm	micro Siemens per centimetre (unit of conductivity)

1 Introduction

1.1 Background

One of Sydney Water's principal objectives is to minimise the impact of its activities on the environment. Sydney Water is supported in this capacity by a comprehensive regulatory framework. The New South Wales Environment Protection Authority (EPA) regulates Sydney Water's wastewater operational activities via Environment Protection Licences (EPLs). The EPLs specify the performance standards and monitoring that we need to satisfy these licence requirements. There is one licence for each of the 23 wastewater systems currently operating across the greater Sydney, Blue Mountains and Illawarra region (Figure 1-1).

Each wastewater system generally consists of a water recycling or wastewater treatment plant (called 'plant' hereafter), and its reticulation (transport) system. The Malabar wastewater system includes three additional Georges River plants (Fairfield, Glenfield and Liverpool) and the Wollongong wastewater system includes the Bellambi and Port Kembla plants.

The Sydney, Blue Mountains and Illawarra regions are a major centre of economic, industrial and agricultural activity. These diverse activities all contribute to the environmental health of the region. Sydney Water's activities represent just one input to the complex system of local riverine, estuarine and ocean environments. The challenge for Sydney Water is to identify the effects of our operations against the background of diverse human activities which reside outside the organisations mandate.

This has been addressed by implementing well designed monitoring programs. Some of these programs are targeted studies with sensitive indicators to measure the direct impact from our operations. Others are state of environment type monitoring which capture the combined impacts from all catchment sources.

1.2 The Sewage Treatment System Impact Monitoring Program (STSIMP)

The STSIMP was developed in consultation with the Office of Environment and Heritage (OEH) and implemented from July 2008, to monitor Sydney's waterways (Sydney Water 2008). The program was endorsed by the NSW EPA in 2008 and slightly amended in 2010 (Sydney Water 2010). The STSIMP succeeded an earlier monitoring program, the Environmental Indicators Monitoring Program, which had similar broad objectives (Sydney Water 1995). This program ran consistently for a period of 14 years from 1994.

The STSIMP aims to monitor the environment within Sydney Water's area of operations to determine general trends in water quality over time, monitor Sydney Water's performance and to determine where Sydney Water's contribution to water quality may pose a risk to environmental ecosystems and human health. The indicators selected are based on current knowledge of the relationship between pollutants and ecological or human health impacts. Monitoring sites downstream of wastewater discharges enables sites to be 'flagged' for more intense investigation to determine if Sydney Water's operations may be impacting receiving waters. The program is consistent with National Water Quality Guidelines (ANZECC 2000) and NSW State of the Environment reporting, as well as the objectives of previous monitoring programs undertaken by Sydney Water, NSW OEH and other agencies.

The STSIMP is referenced in Section 5 M5.1 of each EPL which specifies the environmental monitoring and reporting requirements for Sydney Water's wastewater operations. The EPLs also specify other types of monitoring requirements such as wastewater discharge quantity and quality, as well as performance standards (Section 3 L2-4). Sydney Water is required to report on monitoring from all of these programs to assess our environmental performance in relation to the EPLs issued by the EPA. As per Section M5.1, a data report is produced annually and an interpretive report every four years. This years report forms the interpretive report.

1.2.1 2014 Interpretive Report

The 2014 interpretive report uses long term trend analysis, (greater than ten years), to identify significant changes in the environmental performance of the wastewater system and receiving waters. It also incorporates individual case studies, the annual data report and detailed assessment of marine benthic and sediment quality (Ocean Sediment Program).

The case studies for the 2014 interpretive report were based on existing programs where Sydney Water had data available. The subjects for the papers were discussed between Sydney Water and the Environment Protection Authority (EPA) at the February 2014 Joint Officers Group. Future case studies will be jointly selected by the EPA and Sydney Water where adverse trends are flagged from the STSIMP or on matters of mutual interest.

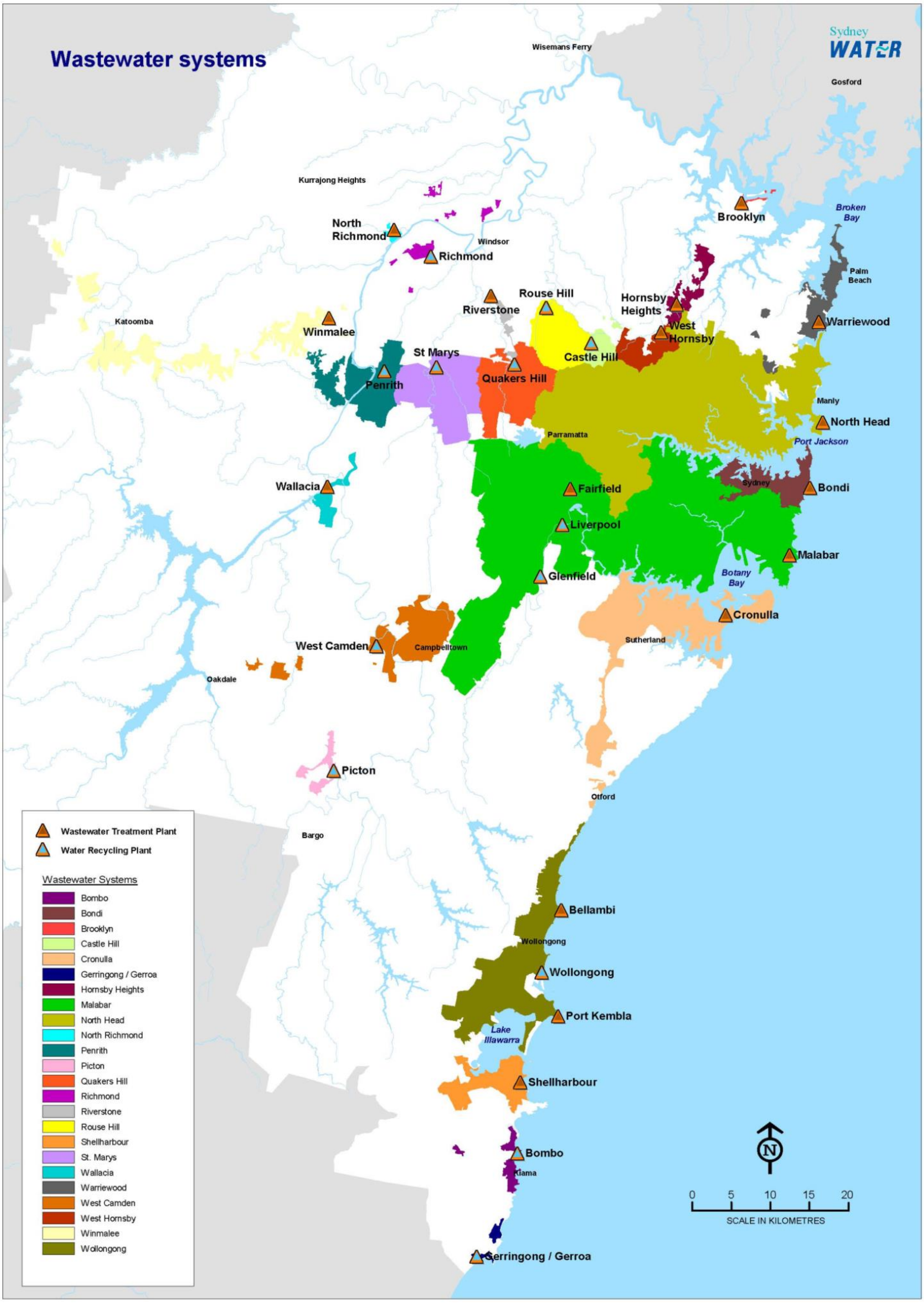
The case studies have been aligned to three themes with the aim to better differentiate wastewater and recycled water discharge inputs from diffuse source inputs to receiving waters:

- treated wastewater discharges
- sewage overflows
- sensitivity of receiving environments.

The findings from the trend analysis and case studies will inform future case studies and monitoring. This in turn will feed into business planning aimed at more efficiently meeting the environmental performance expectations of the community, as well as Sydney Water's regulatory compliance obligations.

A range of outcomes have emerged from this report which will inform future monitoring, develop new improved science based tools and potential management actions to improve environmental performance.

It is important to note that this is the second STSIMP interpretive report, with the first being produced in 2011. The format of the report has been changed to improve rigour, useability and reader friendliness. It is anticipated that the next interpretive report may vary slightly again. This is part of Sydney Water's strive for continual improvement.



Note: Gerringong/Gerroa system is included for completeness. The licence is held by Veolia Water

Figure 1-1 Wastewater systems showing location of plants

Environment Protection Licence

The requirements for the STSIMP reporting are specified in each Environment Protection Licence for each wastewater treatment plant under section M5 (presented below).

M5 Environmental monitoring

M5.1 Sewage Treatment System Impact Monitoring Program

a) The licensee must undertake the monitoring programs detailed in the Sydney Water publication "Sewage Treatment System Impact Monitoring Program, December 2010", or in any replacement document approved in writing by the EPA.

b) The licensee must maintain a database of the results obtained in undertaking monitoring programs specified in the document cited above. Information from the database must be made available to any authorised officer of the EPA on request.

c) The licensee must provide to the EPA the reports specified in the document cited above.

d) The "Sewage Treatment System Impact Monitoring Program (STSIMP): Annual Data Report" specified in the document cited above must be submitted not later than 31 October in each year where the "STSIMP: Interpretive Report" is not required.

e) The "STSIMP: Interpretive Report" specified in the document cited above must be submitted not later than 31 December every fourth year.

f) For the purposes of conditions e) above, the next "STSIMP: Interpretative Report" following the 31 December 2014 report must be submitted not later than 31 December 2016 and thereafter every fourth year.

Note: Copies of reports relating to the Sewage Treatment System Impact Monitoring Program can be found at http://www.sydneywater.com.au/SW/water-the-environment/how-we-manage-sydney-s-water/waterquality/stsimp-reports/index.htm

2 Structure of this report

The 2014 STSIMP interpretive report is produced in four volumes (Figure 2-1):

Volume 1: '**Executive Summary**', presents an integrated summary of the key findings from the STSIMP monitoring program.

Volume 2: '**Trend analysis and case studies**', reports on the significant changes in the environmental performance of the wastewater system and receiving waters through trend analysis (greater than ten years). It also includes targeted case studies designed to investigate change associated with treated wastewater discharges; sewage overflows; and sensitivity of receiving environments.

Volume 3: '**Data Report**', provides an annual data summary from 2013-14, summary statistics, a brief commentary commensurate with the results and a ten yearly trend plot on each site if available. This includes data from the Shellharbour rocky intertidal assemblage study, the ecosystem health intertidal community study and the freshwater macroinvertebrate study.

Volume 4: '**Ocean Sediment Program**', presents the analysis and findings from the Ocean Sediment Program. This year forms the 'assessment' year which includes the identification and counting of benthic macrofauna and the analysis of sediment quality at all sites.

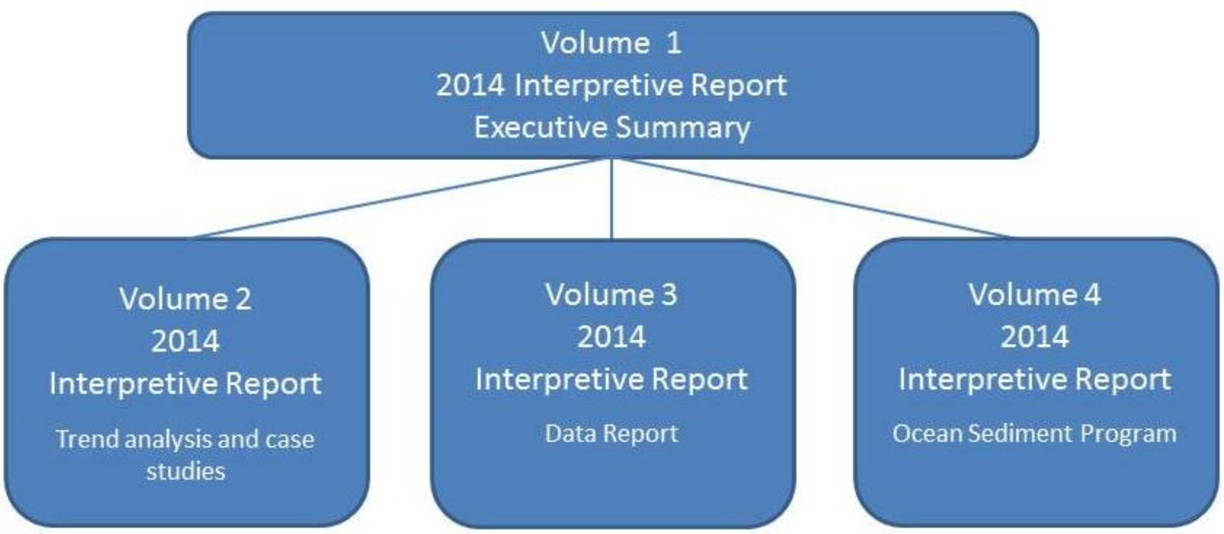


Figure 2-1 STSIMP interpretive report structure

3 Trend analysis

Key findings:

- Decreasing long term trends in total nitrogen were identified along the length of the Hawkesbury Nepean River and in the majority of plants discharging to the Hawkesbury Nepean River catchment.
- There is evidence of gradually increasing total phosphorus concentrations in discharges from Winmalee and Hornsby Heights plants. A watching brief has been applied to monitor these trends closely in future.
- The discharge of suspended solids from the North Head plant is near to licence limits and will be monitored closely in the future.
- Oil and grease concentrations from ocean plant discharges gradually increased until 2007 before steadying in response to plant upgrades.

The trend analysis has been designed to provide a screening level assessment of long term changes in treated wastewater discharges and their respective receiving waters. Outcomes from this analysis will provide the basis for identifying when further detailed assessment may be required, particularly if the long term changes have the potential to impact on the health of the waterways. This is one of the primary mechanisms for generating discussion and identifying case studies for future STSIMP interpretive reports.

As this is a screening level assessment, the approach was to provide a relatively simple analysis of longer term, (greater than ten years), datasets to detect broad changes in the quality of wastewater or in waterway health. Waterway sites were chosen to be representative of areas that may be affected by wastewater discharges and of areas primarily affected by other influences (ie urban, agricultural and natural). The parameters chosen for analysis represent the major waterway health management issues with possible links to wastewater discharges. Three focus areas were targeted:

1) **Eutrophication –** the enrichment of a waterbody with nutrients, resulting in excessive growth of photosynthetic organisms and depletion of dissolved oxygen.
2) **Recreational amenity** –suitability for swimming in estuary and beach sites monitored under the Beachwatch Program.
3) **Treated wastewater discharge quality –** to indicate if changes in wastewater discharge may be linked to changes in waterways or if treatment efficacy has changed over time.

The analytes included in the analysis, depending on availability, were:

- total nitrogen, dissolved inorganic nitrogen, total phosphorus, filtered total phosphorus and chlorophyll *a* (eutrophication indicators in Hawkesbury Nepean River, estuaries and urban rivers and treatment plants that discharge to the Hawkesbury Nepean River catchment)
- faecal coliforms and/or Enterococci (recreational amenity in estuaries and beaches and treated wastewater discharge quality for shoreline ocean outfall treatment plants)

- suspended solids and oil and grease (treated wastewater quality for ocean discharge plants)
- toxicity (discharge quality including all plants - inland and ocean discharges)

These are the key analytes related to environmental pollution and EPL conditions. A combination of temporal plots, and regression analysis where appropriate, provided the foundation for analysis of trends.

Table 3-1 presents a comparison of longitudinal trends down the Hawkesbury Nepean River. Table 3-2 presents a summary of results for estuaries (including coastal lagoons) and urban rivers. Results are colour coded according to the significance of each sites and parameters trend, with dark green representing a significant decreasing trend through to red representing a significant increasing trend.

A gradual increasing trend in total phosphorus was observed in the treated wastewater discharged from Winmalee and Hornsby Heights plants. Winmalee underwent a major upgrade between 2007 and 2009 meaning the wastewater monitoring data available after this was too short for a meaningful regression analysis of total phosphorus in the current operational setup. Regression analysis of total phosphorus concentrations in Hornsby Heights wastewater indicated the trend was significantly different from zero trend. The trends in total phosphorus wastewater concentrations were not reflected in the Hawkesbury Nepean River with declining total phosphorus concentrations evident at all river sites downstream of Penrith, except for Berowra Creek (downstream of the Hornsby Heights plant) where no trend was identified.

All Hawkesbury Nepean River sites, except for Penrith Weir, had declining total nitrogen concentrations. This is consistent with declining total nitrogen concentrations being discharged from most inland plants in response to upgrades carried out over the previous 15 years.

Penrith Weir showed an increasing trend in chlorophyll *a* concentrations. This site is not directly affected by discharges of treated wastewater, indicating Penrith Weir water quality is also influenced by factors other than treated wastewater discharges. An increasing chlorophyll *a* trend was also identified at North Richmond. This trend may have been influenced by the macrophyte washout caused by flooding in 2012, with elevated chlorophyll *a* levels observed since then. Routine samples, (monthly average), were used in the long term trend analysis to limit the effects of season and one off events. A weak increasing trend in chlorophyll *a* levels was also observed in the Georges River at Liverpool Weir. Further detail on chlorophyll *a* levels in the Georges River is provided in Section 4.3.2 and Volume 2 Chapter 8, which analyses the data associated with a large sewage overflow event at Glenfield.

Although no significant trend was observed in suspended solids concentrations from the North Head plant, current concentrations are close to licence limits. As such suspended solids concentrations in the discharge from North Head will be closely monitored in future. The ocean plants showed a gradual increase in the discharge of oil and grease concentrations up until 2007, when the trends steadied following plant upgrades.

The following action is proposed in response to increasing long term trends:

- Winmalee plant – currently developing a Pollution Reduction Program to inform future upgrade planning.
- Hornsby Heights plant - Sydney Water plans to build a new clarifier within the next 3 years to address the operational issues associated with the secondary clarifiers and tertiary filters

that were not typical of the norm. The water quality will continue to be monitored to determine impacts.

- North Head plant – further action will be considered if the long term trend in suspended solids concentrations continue to increase.

Table 3-1 Regression results presented longitudinally for Hawkesbury Nepean River monitoring sites (where >10 years of data available)

Site code	Site description	Plant location and discharge waterway	Hawkesbury Nepean River and tributaries trends		
			Total nitrogen	Total phosphorus	Chlorophyll *a*
N92	Hawkesbury Nepean River at Maldon Weir				
		West Camden WRP via Matahil Creek			
N75	Hawkesbury Nepean River at Sharpes Weir, d/s West Camden WRP				
N67	Hawkesbury Nepean River at Wallacia Bridge, u/s Warragamba River				
N57	Hawkesbury Nepean River at Penrith Weir				
		Penrith WRP via Boundary Creek			
N53	Hawkesbury Nepean River at BMG Causeway, d/s Penrith WRP				
N48	Hawkesbury Nepean River at Smith St, upstream of Winmalee plant				
		Winmalee WWTP via Winmalee Lagoon			
N42	Hawkesbury Nepean River at North Richmond, d/s of Winmalee				
		North Richmond WWTP via Redbank Ck			
		St Marys WRP via South Creek			
		Quakers Hill WRP via South Creek			
		Riverstone WWTP via South Creek			
NS04	Lower South Creek, at Fitzroy Bridge		a		
N35	Hawkesbury Nepean River at Wilberforce, d/s of South Creek				
		Rouse Hill WRP via Cattai Creek			
		Castle Hill WRP via Cattai Creek			
N3001	Hawkesbury Nepean River off Cattai SRA, d/s of Cattai Creek		a		
N26	Hawkesbury Nepean River at Sackville Ferry				
		West Hornsby WWTP via Berowra Ck			
		Hornsby Heights WWTP via Berowra Ck			
NB13	Berowra Creek at Cunio Point				

[a] trends were analysed using a parametric t-test as available data was split into two periods; 1996 to 2001 and 2008 and 2014.

	no trend		down p<0.01		down p<0.05		up p<0.05		up p<0.01

Table 3-2 Regression results presented for estuaries and urban rivers

Site code	Site description	Estuaries and urban rivers	
		Chlorophyll *a*	Enterococci
NL01	Narrabeen Lagoon, canal entrance upstream of Ocean Bridge		
NL06	Narrabeen Lagoon, 150m north of confluence with South Creek		
DW01	Dee Why Lagoon, entrance at North Curl Curl		
CC01	Curl Curl Lagoon, entrance at North Curl Curl		
ML01	Manly Lagoon, upstream of Queenscliff Beach Bridge		
ML03	Manly Lagoon, at footbridge in Nolan Reserve		
WL83	Wattamolla Lagoon		
PJLC	Lane Cove Weir		
PJPR	Parramatta River Weir		
GR01	Cooks River, downstream of Muddy Creek		
GR22	Liverpool Weir		

	no trend		down $p<0.05$		up $p<0.05$		not monitored

Refer to Volume 2 for full report.

4 Case studies

4.1 Theme One: Treated wastewater discharges

Key findings:

- The aquatic environmental assessment of the St Marys Recycled Water Initiative (SMWRI) found that water quality and stream health improved significantly in Boundary Creek in response to the discharge of the high quality recycled water.
- The Hawkesbury Nepean River had low sensitivity to changes from the SMWRI with a spatially limited reduction in nitrogen and phosphorus concentrations and no measurable effect on stream health.
- Initial analysis of the Hawkesbury Nepean River and South Creek model indicates that the Hawkesbury Nepean River has a low sensitivity to change in nutrients and algae in the lower estuarine reach. The most sensitive reach is within the South Creek catchment and downstream Hawkesbury River. The upper Nepean River also responded to the majority of the management options tested for nutrients.

The purpose of the 'treated wastewater discharges' theme is to better understand the effects of Sydney Water's discharges on receiving water quality and the contribution of such effects to changes in waterway health. Where a deleterious impact is detected and a contribution to this impact from wastewater discharges can be inferred, further assessment or management action may be triggered.

Key to this theme is differentiating sources of pollutants in a waterway. This will allow a better understanding of the contributors to the condition of a waterway, and in turn allow for more targeted management action.

The case studies representing this theme are an assessment of the effects of the St Marys Water Recycling Initiative (SMWRI) on the aquatic environment of the Hawkesbury Nepean River and an overview of the Hawkesbury Nepean River and South Creek water quality and hydrodynamic model.

4.1.1 Assessing the Impact of the St Marys Water Recycling Initiative on the Hawkesbury Nepean River

The St Marys Water Recycling Initiative (SMWRI) was designed to save drinking water released from Warragamba Dam. It provides recycled water by taking tertiary treated wastewater from Penrith, St Marys and Quakers Hill Water Recycling Plants (WRPs) for reverse osmosis treatment at the St Marys Advanced Water Treatment Plant (AWTP). The high quality recycled water is then piped to Penrith WRP for discharge to the Hawkesbury Nepean River via Boundary Creek.

A summary of results is presented in Table 4-1. The key finding was that the Hawkesbury Nepean River downstream of the recycled water inflow had low sensitivity to the changed discharge quality and quantity, with the exception of a significant reduction in concentrations of nitrogen and phosphorus within a limited spatial extent (~1 km). There were no detectable impacts (positive or negative) on the aquatic ecology of the river.

At the much smaller scale of Boundary Creek, which has minimal natural flow, a significant improvement was detected in water quality and aquatic ecology after the SMWRI began operation. Prior to the SMWRI the condition of Boundary Creek was generally poor.

The very low conductivity water observed in Boundary Creek post commissioning (median 32 µs/cm) did not have a significant impact on aquatic biota. This was evidenced by improved macroinvertebrate stream health in Boundary Creek. In the Hawkesbury Nepean River, post commissioning conductivity levels downstream from the Boundary Creek inflow were within the recommended ANZECC (2000) guideline for the protection of aquatic ecosystems.

Table 4-1 Summary of results from the SMWRI Aquatic Environmental Assessment Program (AEAP) in the Hawkesbury Nepean River

Key indicators	Boundary Creek		Hawkesbury Nepean River		
	AWTP discharge (pure recycled water)	Impact site: Lower Boundary Creek (N5401)	Impact site: Hawkesbury Nepean River 1.2 km downstream (N53)	Downstream site: Hawkesbury Nepean River ~10 km downstream (N48)	Downstream site: Hawkesbury Nepean River ~20 km downstream (N42)
Nutrients					
Chlorophyll *a*					
Bacterial					
Conductivity					
Macroinvertebrates					

Legend *

Clear positive impact[1]	Positive impact likely[2]	No impact detected[3]	Negative impact likely[4]	Clear negative impact[5]	No study required [6]

1 Clear positive Impact – positive statistically significant change in water quality or ecological parameter that is attributable to the Project

2 Likely positive impact – a positive change in water quality or ecological parameters is detected after commissioning but is statistically too small to be clearly attributable to the Project

3 Minimal change – no change evident (positive or negative)

4 Likely negative impact – a negative change in water quality or ecological parameters is detected after commissioning but is statistically too small to be clearly attributable to the Project

5 Clear negative impact – negative statistically significant change in water quality or ecological variable that is attributable to the project

6 No study possible or required by the AEAP

4.1.2 Hawkesbury Nepean River and South Creek model: a powerful tool to inform management decisions in the Hawkesbury Nepean catchment

Considerable urban growth is planned for the Hawkesbury Nepean catchment over the next 30 years to accommodate Sydney's increasing population. New wastewater services will be required, in addition to the already extensive wastewater system operating in Western Sydney. To plan for the most efficient and effective service for customers while protecting the environment requires a holistic understanding of the various impacts on the waterway and the interrelationships between them. This will allow for an improved understanding of how the Hawkesbury Nepean receiving waters will respond to changes in inputs of treated wastewater and recycled water.

A water quality and hydrodynamic model of the Hawkesbury Nepean catchment has been developed to meet this need. The model provides guidance on the relative changes in water quality and quantity when testing different catchment, environmental flow, wastewater and landuse options over time. It provides the ability to differentiate between diffuse and point sources of pollution, and better understand the impact of plant discharge in wet compared to dry weather conditions, and the complex interactions within such a large river system.

Initial analysis of the model output indicates that the Hawkesbury Nepean River is relatively resilient to change in nutrients and algae in the lower estuarine reach. The reach of the river most sensitive to change is downstream of the South Creek inflow near Windsor, as well as within South Creek itself. The upper Nepean River also responded to the majority of the management options tested for nutrients. Continued use of the model and scenario analysis will further refine these preliminary findings to provide scientific evidence to support infrastructure decisions. This will ensure future expenditure is targeted to provide the maximum benefits to both the community and the environment.

Refer to Volume 2 for full report.

4.2 Theme Two: Sewage overflows

Key findings:

- The pilot water quality and hydrodynamic model developed for the upper Parramatta River as part of the wet weather overflow abatement program indicated that sewage overflow discharges only contribute to the condition of Parramatta River via a temporary deterioration of water quality during rainfall events, with stormwater the largest contributor to poor water quality.
- The new wet weather overflow abatement models will be extended to other areas of Sydney Harbour and Botany Bay. This will assist Sydney Water's prioritisation of work to provide maximum environmental gain from future investment in wastewater systems.
- The expected benefits of the Malabar Stormwater Diversion Project were realised through a marked improvement in recreational amenity and ecological health at Malabar Beach, confirming stormwater rather than sewage overflows were the predominant contributor to poor water quality at Malabar Beach.
- Assessing the benefits of the Malabar Stormwater Diversion Project demonstrated the value of the salinity and Enterococci monitoring and modelling tools used in differentiating stormwater and sewage overflow sources of pollution in coastal waters.

This theme assesses the potential for untreated discharges to impact on receiving water environments. The wastewater system contains a large network across Sydney Water's operational area for transporting sewage from private premises to plants for treatment. During periods of high rainfall, runoff can infiltrate into the network leading to sewer mains exceeding their hydraulic capacity. Sewage overflow points have been designed as part of this system to alleviate pressure during high flow events which ensure sewage flows in the network do not back up into private premises. During high flow events sewage may discharge from overflows to waterways. These discharges are episodic, typically of short duration and often diluted by large volumes of stormwater.

A key aspect of this theme is to differentiate sources of pollutants in a waterway. Differentiating sewage from stormwater will allow a better understanding of sewage overflow contributions to the condition of a waterway and ultimately inform more effective long term capital investment. Two case studies were developed for this theme: modelling wet weather sewage overflows in the upper Parramatta River; and a validation of the expected benefits of the Malabar Beach stormwater diversion. Central to both case studies are recently developed techniques to improve our ability to differentiate stormwater inputs from sewage overflow inputs.

4.2.1 Modelling wet weather overflows in the upper Parramatta River

Environment Protection Licences limit the number of overflows per wastewater system to minimise potential impacts to receiving waters. Currently a program of works is in place to improve the performance of the network over time, known as the Wet Weather Overflow Abatement program (WWOA). To inform this program of works an 'effects based assessment' approach complemented by new models has been developed to better understand the impact of overflows on the waterways and communities of Sydney. This will allow more targeted and effective investments in wastewater infrastructure.

A hydrodynamic and water quality pilot model was developed to improve understanding and prediction of water quality in the upper Parramatta catchment. The upper Parramatta River has been noted as having generally poor water quality in a community with an aspiration to develop a stronger connection with the river, making this a highly relevant pilot for the new model. Further models are in development for other Sydney Harbour and Botany Bay waterways. Findings from this pilot model provided the focus for a case study aimed at differentiating pollution sources in the Parramatta River.

The pilot models were calibrated and validated against field data collected specifically for that purpose. The main finding from the model showed that water quality is poor in the Parramatta River with the most effective approach for improvement being through water sensitive urban design, which would reduce stormwater entering the river. Sewer overflow abatement is unlikely to achieve significant benefits in the upper Parramatta River. The models indicate that the only notable contribution from sewage overflow discharges to the condition of Parramatta River is a temporary deterioration of water quality during rainfall events.

4.2.2 Validating the expected benefits of the Malabar Beach stormwater diversion

Malabar Beach has previously been identified as a coastal swimming location with poor beach bathing water quality by the Beachwatch Program administered by the Office of Environment and Heritage. Sydney Water conducted an investigation to determine the source of this poor water quality, with both a major council stormwater drain and Malabar WWTP stormwater drain discharging to the beach at similar locations. The subsequent source detection study, which used high spatial resolution conductivity monitoring to represent salinity, modelled Enterococci concentrations in the Malabar Beach embayment. Results of this modelling indicated that the main council stormwater drain was the likely source of the majority of contaminants contributing to poor beach bathing water quality.

In response to this investigation, a joint project between Sydney Water and Randwick Council was instigated to divert the Council stormwater drain from Malabar Beach to the Malabar plant cliff-face outfall via the Long Bay outfall tunnel. Monitoring programs of beach water quality (through the existing Beachwatch Program) and intertidal zone ecological health were set up to assess whether the expected benefits of the diversion were realised. These programs involved monitoring microbial water quality and ecological health before and after the diversion to identify changes that occurred in response to the diversion.

Beach water quality was assessed using the NHMRC (2008) guidelines designed to assign a Beach Suitability Grade for swimming. These grades are based on a matrix of microbial assessment categories (Enterococci levels being categories A through D) and Sanitary Inspection categories (based on local site characteristics and varying from very low risk to very high risk). This assessment found that the Beach Suitability Grade improved from Poor to Good due to the stormwater diversion in November 2012 (Table 4-2). This validates the outcomes of the source detection study and indicates the methods in that study can be confidently applied in future similar scenarios.

Table 4-2 Beach Suitability Grades before and after implementation of the stormwater diversion at Malabar Beach

Year	Enterococci 95%ile (cfu/100mL)	Microbial Assessment Category	Sanitary Inspection Category	Beach Suitability Grade
2011-2012	580	D	Moderate	Poor
2012-2013	155	B	Moderate	Good
2013-2014	195	B	Moderate	Good

The assessment of ecological health identified a distinct change in intertidal zone ecology at the discharge point for the stormwater drains. This change altered the ecological communities to a structure similar to those observed at nearby intertidal zones not significantly affected by stormwater. The most notable change was the almost complete removal of a dense mat of green algae that dominated the stormwater drains discharge zone before the diversion.

The findings of the beach water quality and ecological health studies clearly indicate the expected improvements from the Malabar stormwater diversion were realised.

Refer to Volume 2 for full report.

4.3 Theme Three: Sensitivity of the receiving environment

Key findings:

- The deepwater ocean outfalls continue to operate better than the design criteria and there is expected to be no change in performance of the outfalls in the foreseeable future.
- The water quality, recreational amenity and stream health of the Georges River between Bunbury Curran Creek and Liverpool Weir was effected for up to two weeks following a large sewage overflow at the Glenfield plant on 22 to 24 November 2013.

The purpose of the 'sensitivity of the receiving environment' theme is to improve understanding of the current condition and resilience of the receiving waters. A water quality disturbance resulting from the input of wastewater discharges or stormwater does not necessarily reflect a deleterious impact in a waterway. Improved knowledge of the natural variations in a waterway and how they respond to inputs of treated and untreated wastewater or stormwater improves the ability to detect or predict an impact in that waterway. A highly sensitive receiving environment will be more susceptible to water quality and ecological conditions being pushed beyond the bounds of existing variability when a discharge containing pollutants occurs. This is when the potential is highest for a deleterious impact on the receiving environment.

Two case studies are presented in this theme. The first case study presents an analysis of the effect of longer term fluctuations in climate on the oceanography of Sydney's coastal waters and of the performance of the deepwater ocean outfalls with respect to design criteria. The second is an assessment of the effects the sewage overflow at Glenfield on the Georges River, including recovery rates for the river, in November 2013.

4.3.1 Assessing long term oceanographic fluctuations using deep water ocean outfall plume models

The Ocean Reference Station (ORS) enables us to understand the oceanography of receiving waters for ocean outfall discharge, particularly the deepwater ocean outfalls. The movement of plumes through high energy ocean waters including currents, waves and tides provides the means for high levels of plume dilution. The predominant ocean conditions also limit the frequency with which plumes surface and reach the coastline. In turn this substantially reduces the environmental risk of wastewater plumes to ocean waters and adjacent coastlines. Generally, ocean waters provide a low sensitivity receiving environment. However changes in the oceanography of receiving waters, for example due to climate fluctuations, have the potential to change the ability of ocean waters to mitigate the environmental risks of wastewater plumes.

Data from the ORS which characterises many of these oceanographic processes drives the deepwater ocean outfall plume models. These models allow an assessment of the continuing performance of the deepwater ocean outfalls to be assessed against design criteria for plume behaviour and for long term oceanographic fluctuations to be identified.

The key finding from this case study is that the plumes from the deepwater ocean outfalls continue to operate better than anticipated in terms of dilutions achieved and frequency of surfacing plumes. Monitoring will continue into the future to ensure that this is maintained.

The southern oscillation index (SOI) allowed ocean conditions to be placed into a long-term context in an attempt to assess potential conditions into the future and possible effects on the movement of wastewater from the deepwater ocean outfalls. These analyses suggest that (a) there is a coupling of the SOI and the surface currents off Sydney during non-drought years and a decoupling during drought years, and (b) the lead up to an El Nino event is characterised by a changing phase difference between the SOI and the surface currents. Attempts to use the SOI to predict future conditions were however unsuccessful. Trials using other variables continue to be examined. Such predictions will allow Sydney Water to plan for likely changes in plume dilution and movement.

4.3.2 Assessing the ecological and recreational amenity impacts on the Georges River of a large sewage overflow event at Glenfield in November 2013

A sewage overflow incident at Glenfield on November 2013 resulted in the Georges River receiving environment being exposed to a large unexpected discharge of untreated wastewater. Existing routine and event water quality and aquatic ecology monitoring programs provided the basis for assessing impacts from this discharge.

Water quality samples from the Georges River upstream of the Bunbury Curran inflow down to the estuary, were analysed at varying frequencies, primarily for total nutrients, chlorophyll *a* and microbial indicators. Stream health was also monitored in the river through macroinvertebrate sampling programs. These indicators were assessed to allow for a determination of impact on three aspects of waterway health: eutrophication (potential for algal blooms); ecological health; and recreational amenity.

The key findings were that changes in water quality were largely limited to the freshwater reaches of the Georges River from the sewage overflow point into Bunbury Curran Creek to Liverpool Weir, and that this impact was brief, with conditions returning to 'pre overflow' levels within two weeks. The changes that did occur were driven by elevated levels of microbial indicators, low dissolved oxygen which led to a localised fish kill in Bunbury Curran Creek and elevated nutrients. Algal levels, as indicated by elevated chlorophyll *a,* remained high well into autumn, but this trend extended beyond the waters affected by the overflow, including other rivers in the Sydney basin. The relatively high algal levels recorded in autumn were also not associated with problematic cyanobacteria levels, which were lower in most reaches of the river for the entire monitoring period after the overflow, compared to before the overflow. There was no measurable impact from this incident on stream health with SIGNAL-SG scores remaining within natural variations observed before the sewage overflow incident.

These results suggest that the sensitivity of these receiving waters is generally low in response to a significant episodic event. Other local factors such as tidal movements, land use and river morphology were likely play significant roles in waterway health over the longer term.

Refer to Volume 2 for full report.

5 2013-14 Data report

Key findings –wastewater discharges:

- The volume of wastewater for treatment and discharge was lower in 2013-14 compared to the previous year.
- Pollutant loads and concentrations discharged to the environment were within the licence limits for all plants in 2013-14.
- Discharges from all ocean and inland plants complied with the effluent toxicity limits.
- Ecosystem health, using the macroinvertebrate indicator, was maintained downstream of nine of the 12 inland plants. Localised impacts downstream of three plants did not extend to the Hawkesbury Nepean River.
- There was a slight increase in the frequency and volume of dry weather wastewater overflows in 2013-14, but a decrease in wet weather overflows.
- Approximately 28 billion litres of water was recycled or reused from all Sydney Water plants in 2013-14. This was slightly less than the previous year.
- There was no measureable impact on benthic invertebrate communities associated with the deepwater outfalls.
- The deepwater ocean outfalls have proven successful in dispersing and mixing the wastewater to concentrations non-toxic to the benthic communities of the ocean off Sydney.

Key findings – environmental waters:

- Ninety percent of the 114 beaches and nearshore swimming sites reported on were graded as ‘Very good’ or ‘Good’, with eight classed as ‘Poor’, two rated as 'Fair' and one ‘Very poor’.
- Chlorophyll *a* (an indicator of algal abundance) in urban rivers and estuaries was ‘Good’ at one third of the monitoring sites, being ‘Fair’ or ‘Poor’ at the remaining fifteen sites.
- Chlorophyll *a* in the Hawkesbury Nepean River and tributaries was rated ‘Fair’ or ‘Poor’ at more than half of the 18 monitored sites.

Unless indicated below please refer to Volume 3 for full data report.

The weather conditions of 2013-14 were typically dry with the least rainfall recorded in ocean and inland wastewater catchments since 2005-06. Rainfall generates stormwater runoff and intense rain events can trigger discharges from wastewater transport and treatment systems when capacities of pipes and some treatment processes are exceeded. These all contribute to pollution of waterways.

5.1 Wastewater discharges

5.1.1 Wastewater quantity

The volume of wastewater available for treatment and discharge decreased in 2013-14. Altogether, 469 billion litres of wastewater was received for treatment during 2013-14. Approximately 436 billion litres (93% of total wastewater) was discharged to the environment after treatment mostly via deepwater ocean outfalls (79% of total discharges). The remaining 7% was reused or recycled elsewhere. Overall, the volumes of wastewater available for treatment and treated discharge volumes were less than the past few years' volumes due to dry weather conditions.

The volume of wastewater that was partially treated in wet weather (did not receive full treatment for all flows) in 2013-14 was also less than the previous wetter years.

5.1.2 Pollutant loads

During 2013-14, key pollutant loads such as oil and grease and total suspended solids discharged to the ocean were within the limit of the EPLs in all eight wastewater systems. On a year to year comparison, the oil and grease load was higher than last year's load (2012-13) but the suspended solids load was lower in 2013-14.

Key nutrient loads (total nitrogen and total phosphorus) from the 15 inland plants complied with the plant specific EPL limits, as did other pollutant loads such as biochemical oxygen demand and suspended solids. The shared EPL limits on nitrogen and phosphorus loads to South Creek from Quakers Hill, Riverstone and St Marys plants were also met.

5.1.3 Pollutant concentrations

There were no exceptions or exceedances for any pollutant concentrations at all 23 wastewater systems during 2013-14. The level of oil and grease or suspended solids, nutrients (nitrogen, phosphorus or ammonia nitrogen), metals (aluminium, zinc etc.) and other chemicals (cyanide, diazinon etc.) were within the licence specification for all ocean and inland plants.

5.1.4 Toxicity

All ocean and inland plant discharges complied with the effluent toxicity limits as specified in the EPLs.

5.1.5 Wastewater overflows

Wastewater overflows can occur in dry weather due to blockages in the transport system or infrastructure faults, and in wet weather when the hydraulic capacity of the pipes or treatment capacity of plants are exceeded.

The volume of dry weather overflows increased from a total volume of 16.3 ML in 2012-2013 to 24.5 ML in 2013-14 along with an increase in frequency from 602 overflows in 2012-2013 to 808 in 2013-14.

Last year (2013-14) was predominantly dry with the least rainfall recorded in ocean and inland catchments in the last seven years. As a result, the wet weather overflow volumes and frequencies were much less in 2013-14 in comparison to earlier years. The total volume of wet weather wastewater overflows was 2,746 ML in 2013-14 in comparison to 13,858 ML a year ago (2012-13).

In 2013-14, eighteen wastewater systems complied with wet weather overflow licence conditions. Two wastewater systems (Wallacia and Rouse Hill) did not comply with wet weather overflow licence limits (L7.2). The Malabar system (which includes Glenfield and Fairfield) did not comply with the licence for partial treatment discharges (O4.9).

5.1.6 Dry weather leakage detection program

This surveillance program monitors a major stormwater drainage line from each sewer catchment area in Sydney Water's area of operation to detect and fix any wastewater leaks that are not evident by other means.

In 2013-14, as in other years, most samples did not indicate sewage pollution with 82% of samples below 5,000 cfu/100 mL for faecal coliforms. Several sources of sewage pollution were found including from both private and public wastewater networks. Leaks were typically identified in the inner city, or inner west catchments, with older pipe age and typically hard to access underground networks. Where Sydney Water identified their own assets as a source of dry weather leakage, repairs were undertaken to fix the problem. Where private assets were identified as the source, the owner was notified and Sydney Water undertakes verification sampling upon notice of repair.

5.1.7 Recycled water

Altogether, about 28 billion litres of water was recycled or reused from all Sydney Water plants. The volume of recycled water produced from three plants (Wollongong, Liverpool and Bombo) decreased in 2013-14 compared to the previous year (2012-13).

The volume of recycled water produced from inland plants was mostly contributed (over 80%) by St Marys Advanced Water Treatment Plant with highly treated recycled water discharged into Boundary Creek.

The overall volume of recycled water produced decreased slightly in 2013-14.

5.2 Environmental waters

5.2.1 Beach Suitability Grades

Beach Suitability Grades provide a long-term assessment of how suitable a beach is for swimming. Swimming sites in NSW are graded as Very good, Good, Fair, Poor or Very poor in accordance with the National Health and Medical Research Council's 2008 Guidelines for Managing Risks in Recreational Waters (NHMRC 2008).

The NSW Office of Environment and Heritage (OEH) monitor swimming sites in NSW under the Beachwatch program and publish the 'State of the Beaches' report annually that contains comprehensive information. Sydney Water assists OEH by monitoring 18 Illawarra beaches as part of this program. Refer to the State of the Beaches report for detailed performance information (http://www.environment.nsw.gov.au/beach/ar1314/index.htm).

In 2013-14, ninety percent of the beaches and other near shore swimming sites monitored in the Sydney and Illawarra region were rated as 'Very good' or 'Good'. Of the 114 sites monitored, only two were categorised as 'Fair', eight as 'Poor' and one as 'Very poor'. The majority of these sites are located in Sydney Harbour, with two in Botany Bay, and one in each Pittwater, Sydney beaches and the Illawarra beaches. The cause is typically associated with stormwater, wet weather overflows, onsite sewage and birds.

Last year (2013-14) was characteristically a dry year with the lowest total rainfall recorded in Sydney's catchment in the last seven years. This might have contributed to better Beach Suitability

Grades during 2013-14 in comparison to the previous year (2012-13). The Beach Suitability Grades improved at 22 out of 114 monitoring sites (19%) during 2013-14. It remained stable at 88 monitoring sites and deteriorated at four sites.

The Narrabeen Lagoon at Birdwood Park was graded as 'Good' compared to a 'Poor' grade for the last few years. This improvement may be in response to initiatives taken by Warringah Council.

Malabar Beach maintained its 'Good' status as it benefited from a stormwater diversion project in November 2012. The project was jointly funded by Sydney Water, Randwick City Council and NSW Government Environmental Trust to divert the Council stormwater drain from Malabar Beach to Malabar plant cliff-face outfall.

5.2.2 Urban rivers, estuaries and lagoons: chlorophyll *a*

Chlorophyll *a*, an indicator of phytoplankton (algal) abundance, is measured at 16 estuarine sites and seven lagoon sites. Only about one third (eight out of 23) of monitoring sites were rated as 'Good', the remaining as 'Fair' or 'Poor'. On a year to year comparison, the ratings deteriorated from 'Good' to 'Fair' at two Botany Bay sites and one site in the Lane Cove River. The water quality ratings improved at one uppermost Georges River site and at Dee Why Lagoon from 'Poor' to 'Good' and 'Poor' to 'Fair', respectively.

Chlorophyll *a* tends to be highest in the upper freshwater sections of rivers. The upstream reaches of the Cooks, Parramatta, Georges and Lane Cove rivers had the highest chlorophyll *a* levels. Lower reaches of the rivers and the harbour areas had much lower levels of chlorophyll *a* due to tidal flushing by low nutrient marine water.

The chlorophyll *a* levels in coastal lagoons varied widely depending on whether the lagoon was open or closed to marine water flushing. Four sites, the Narrabeen Lagoon, Curl Curl Lagoon, mouth of the Manly Lagoon and upper Manly Lagoon were rated 'Poor'. There was an algal bloom incident at Curl Curl Lagoon at the beginning of 2014 with chlorophyll *a* reaching 192 μg/L. The lagoon was closed to marine waters during the majority of sampling occasions and prior to the algal bloom incident. This prevented flushing and enabled water velocity to decrease. Given the warm conditions and sufficient nutrients from catchment sources, ideal conditions were present for rapid phytoplankton growth.

5.2.3 Urban rivers and estuaries: freshwater macroinvertebrates and intertidal communities

Macroinvertebrate species and abundance was measured in freshwater environments and scores were used to indicate the ecosystem health. Four freshwater urban river sites located in the Parramatta, Lane Cove and Georges (two sites) rivers in 2013-14 showed impaired ecosystem health. This is consistent with monitoring since 1995. These sites are located in the lower freshwater reaches of the respective catchments and therefore assimilate the upstream catchment inputs.

In general, the community structure of outer estuarine sites, (both test and urban control), were similar to reference sites situated near national parks. Inner estuaries generally had differing community structures to those at reference sites.

5.2.4 Hawkesbury Nepean River and tributaries: nutrients, chlorophyll *a* and algae

The receiving water quality of the Hawkesbury Nepean River and its tributaries was monitored at 18 sites for nutrients, chlorophyll *a*, algae and other physico-chemical parameters. The water quality rating for each site was determined based on four key variables (total nitrogen, total phosphorus, chlorophyll *a* and cyanobacteria) and the percentage of samples within the guideline values or cyanobacteria alert levels.

The nutrients water quality rating at the majority of the monitoring sites was ‘Good’. The remaining sites were either ‘Fair’ or ‘Poor’ showing some levels of nutrient enrichment. For chlorophyll *a* and cyanobacteria, a higher proportion of sites were rated as ‘Fair’ or ‘Poor’ during 2013-14 compared to nutrients.

The water quality ratings at most sites along the river in 2013-14 remained similar to 2012-13 with slightly improved conditions at some sites especially in terms of chlorophyll *a.* Typically, the water quality was poor at a couple of sites downstream of the South Creek inflow, and at two major tributaries, South and Cattai creeks.

5.3 Testing of Shellharbour rocky intertidal communities

Rocky-intertidal communities are comprised of macro algae and macro invertebrates (macro is defined as visible to the naked eye). The abundance and diversity of littoral flora (macro algae) and fauna (macro invertebrates) that occur on suitable intertidal rocky reef substrates were used to assess rocky-intertidal community health.

Testing of Shellharbour wave exposed rocky intertidal communities recorded variability in taxonomic composition of photo quadrat samples taken at the outfall site that was comparable with photo quadrat samples taken from at least one control site through the study 2008 to 2013. No fundamental shift in community structure was detected at the outfall site. In fact, samples taken at the outfall site were similar to those taken at the control site. Statistical analysis indicated there was no measurable impact from wastewater discharges at the Shellharbour outfall at Barrack Point based on morphological taxonomic characters of rocky intertidal macro-organisms.

5.4 Ecosystem health: Intertidal communities

5.4.1 Wave sheltered rocky intertidal communities

The objective of this indicator was to measure the general ambient condition of Sydney estuaries that may be impacted by Sydney Water activities. Monitoring of rocky-intertidal communities occurred at relatively wave-sheltered sites in Sydney’s estuaries. Wave-sheltered areas have infrequent wave activity.

In general, the community structure in the outer estuary was similar to the control sites, while the inner estuary had a differing community structure to the controls. The 2011-13 results suggest sewer remediation works from the mid 2000’s have remained effective at both Rushcutters Bay and in the Iron Cove Creek arm of Iron Cove.

5.4.2 Settlement panels in wave sheltered areas

Settlement panels were used to supplement intertidal rock platform measurements and provide a focus on colonisation of intertidal larvae at the swimming juvenile life stage. Settlement panels were deployed at a number of sites that each included a large, muddy intertidal area with mangroves. In wave sheltered areas the presence of barnacles has been found to indicate sewage presence from time to time.

The 2011-13 period measurements of barnacle cover were similar to those recorded in the 2006 to 2010 period with the same pattern of similar and dissimilar sites shown. In both of these periods, higher levels of barnacle cover occurred in the Hawthorne Canal arm of Iron Cove and in the mouth of the Cooks River. These results suggest the presence of sewage from time to time.

5.5 Freshwater macroinvertebrates

Freshwater macroinvertebrate communities based on morphological taxonomic characters were used to indicate if ecosystem health differences occurred between sites upstream and downstream of Sydney Water plant discharges in the Hawkesbury Nepean River, South Creek, Cattai Creek and Berowra Creek. In 2013-14, ecosystem health was maintained downstream of nine of the 12 inland plants. While three localised impacts, as determined by the signal SG biotic index, were recorded in creeks downstream of Hornsby Heights, West Camden and Winmalee plants. Sydney Water is working to understand, and/or address potential issues with these plants. For example Sydney Water plans to build a new clarifier at the Hornsby Heights plant within the next three years, and is currently in the process of developing a Pollution Reduction Program (PRP) for Winmalee to inform future upgrade planning.

There was no evidence of measurable impacts further downstream in the Hawkesbury Nepean River system to which these creeks flow.

Refer to Volume 3 for full report.

6 Ocean Sediment Program

Monitoring of the off-shore ocean sediments provides an additional check to plume modelling of the deepwater ocean outfalls of Malabar, Bondi and North Head plants. This monitoring is conducted on a three-year cycle; the first year is an assessment year, and the second and third years are surveillance years. Under the current cycle 2013-14 was an assessment year. Monitoring in an assessment year involves collecting sediment samples from nine locations where benthic macrofauna (small animals that live on the ocean floor) are identified and counted. Sediment samples are also tested to determine concentrations of metals, organic compounds, nutrients and sediment grain size.

In 2013-14, and in all years since 1999, no accumulation of fine sediments was identified near the deepwater ocean outfall locations. The lack of a build-up of fine sediment suggested it is unlikely that metal concentrations had accumulated to levels that may harm the benthic community. This was confirmed following subsequent testing of metal concentrations in the ocean sediments. Anoxic conditions can occur from a build-up of organic material which is known to harm benthic communities. To check this aspect, total organic carbon was measured, (at the Malabar deepwater ocean outfall location only), and compared to a set trigger level. Concentrations were below the trigger level. A weight of evidence approach to analysis of data determined there was no measureable impact on the benthic invertebrate communities. What was highlighted by this analysis was a temporal change in the structure of the benthic communities at all locations including control and outfall locations.

Refer to Volume 4 for full report.

7 References

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