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Jersey Avenue Wetland Investigation

WRL Technical Report 2015/06
June 2015

By W C Glamore, J E Ruprecht and P F Rahman

Water Research Laboratory
University of New South Wales
School of Civil and Environmental Engineering

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Water Research Laboratory
110 King Street, Manly Vale, NSW, 2093, Australia
Tel: +61 (2) 8071 9800 Fax: +61 (2) 9949 4188
ABN: 57 195 873 179
www.wrl.unsw.edu.au

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1. Introduction

The Jersey Avenue wetland (Figure 1-1) was constructed as a stormwater runoff management system between the Sandgate Industrial Estate and Market Swamp. Recent studies (SLR, 2013; BMT WBM, 2011) undertaken at the study site indicate that the wetting and drying regime of Market Swamp has been altered by drainage structures and the urban hydrology of the surrounding catchment. These studies recommend large-scale engineering works, including the implementation of water level controls and stormwater quality measures within the Sandgate Industrial Estate and Jersey Avenue wetland, to remediate the natural hydrology of Market Swamp. Since the completion of the studies, various stakeholders have raised concerns regarding the necessity and feasibility of the large-scale works and the potential impact these works will have on the downstream hydrology and ecology.

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Australia was commissioned by The City of Newcastle (Council) to undertake field investigations to quantify hydrologic and sediment dynamics within the existing Jersey Avenue wetland system and to develop feasible long-term site management plans/options. This project involved both field and desktop components.

This report is separated into 7 sections. Following this introduction,

- **Section 2** provides background information on previous work undertaken by SLR Consulting Australia (SLR) to establish a catchment management plan for the Sandgate Industrial Estate catchment, including improvement works for the Jersey Avenue wetland;
- **Section 3** provides details of the topography of the Sandgate Industrial Estate catchment;
- **Section 4** presents a water balance carried out to quantify and assess the hydrological response of the Sandgate Industrial Estate catchment for a large local catchment rainfall event in April 2015;
- **Section 5** describes the methodology undertaken to assess sediment input to the wetland by particle size analysis and provides an assessment of sediment retention times and predicted infilling rate of the Jersey Avenue wetland; and
- **Section 6** provides a summary of the study investigations and provides feasible recommendations to manage the Jersey Avenue wetland.

Additional information that supports the body of this report has been provided as Appendices.

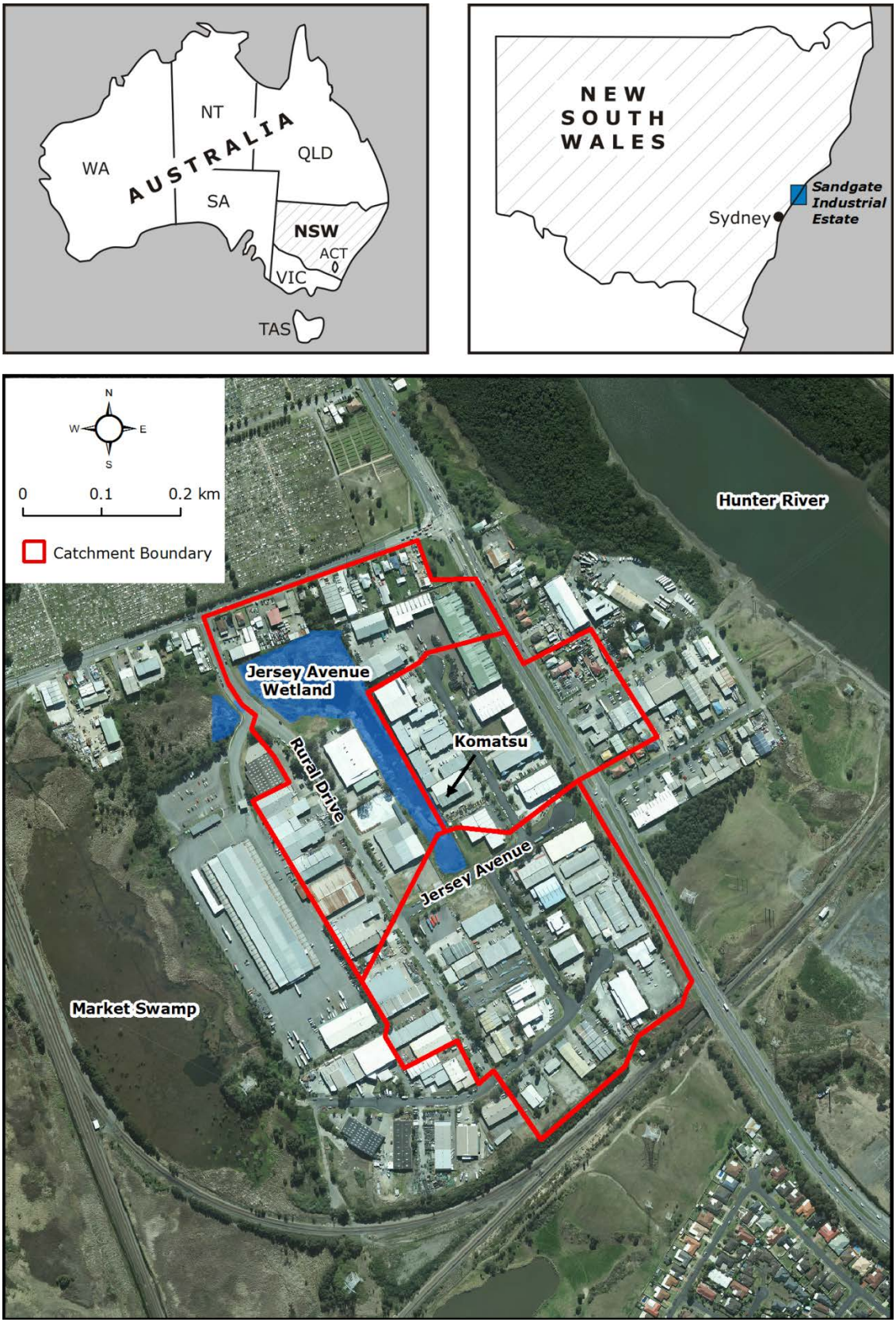

Figure 1-1: Study Site Location

2. Background Information

2.1 Preamble

This chapter provides background information on previous work undertaken by SLR Consulting Australia (SLR) to establish a management plan for the Sandgate Industrial Estate catchment, including improvement works for the Jersey Avenue wetland (SLR, 2013).

2.2 Sandgate Industrial Estate Catchment Management Plan

SLR prepared a report in 2013 (SLR, 2013) for Council investigating options to address stormwater impacts from the Sandgate Industrial Estate on Market Swamp. The SLR report provided a general overview of the changes to the Market Swamp catchment and the present values and threats to its ecology, water quality and hydrology. The report focused on the management of the Jersey Avenue wetland, which was constructed as a stormwater runoff management system between the Sandgate Industrial Estate and Market Swamp. The report provided an assessment of the performance (in 2013) of the Jersey Avenue wetland in terms of hydrologic and water quality management using a simplified, un-calibrated catchment numerical model and theoretical stormwater pollutant loads.

Key outcomes from the study include:

1. SLR determined that the catchment area of the Sandgate Industrial Estate draining to the Jersey Avenue wetland is 17.5 ha and that the Jersey Avenue wetland has a 0.2 ha footprint (i.e. approximately 1% of the contributing catchment area).
2. The Jersey Avenue wetland drains via two 0.750 m pipe culverts beneath Rural Drive to Market Swamp.
3. The Jersey Avenue wetland was relatively ineffective at capturing nutrients and fine sediments from stormwater due to the small residence time provided by the wetland outlet.
4. Modelling predicted that the Jersey Avenue wetland was capable of trapping 50% of incoming sediment from stormwater.
5. The Jersey Avenue wetland was noted to be operating at a reduced capacity due to accumulated silts in the north-west corner of the wetland.
6. The vegetated borders of the Jersey Avenue wetland were noted to be dominated by noxious and common weeds.

The study recommends the implementation of water level controls and stormwater quality control measures within the Sandgate Industrial Estate. It recommends modifying the management and operation of the Jersey Avenue wetland and optimising its function through several large-scale engineering works. A range of other management recommendations for the Industrial Estate catchment were made to improve the hydrologic and water quality inflows to the Market Swamp.

2.3 Study Aims

Based on the findings of the SLR (2013) report and a review of the report's recommendations, this study aims to:

- Confirm the hydrologic water balance of the site;
- Assess the rate of sedimentation over the long-term;
- Determine whether a sediment extraction plan is required onsite; and

- Address concerns regarding proposed large-scale engineering works onsite.

This report reviews the SLR (2013) recommendations through the analysis of field data and by using direct measurements to calculate the hydrologic properties of the Jersey Avenue wetland.

3. Catchment Properties

3.1 Preamble

This chapter provides details of the topography and area of the Sandgate Industrial Estate catchment. Bathymetric survey data of the Jersey Avenue wetland was combined with LiDAR of the wider catchment to create a Digital Elevation Model (DEM) of the study region. This information was used to determine catchment boundaries, flow paths and to develop a stage-volume relationship of the Jersey Avenue wetland.

3.2 Survey Data

WRL received survey data from Council for the Jersey Avenue wetland and surrounding Sandgate Industrial Estate catchment in the following forms:

- Digital elevation contours at 0.2 m intervals to AHD;
- Spot height elevations of the Jersey Avenue wetland bathymetry to AHD; and
- LiDAR of the greater Newcastle area to AHD at a 1 m horizontal resolution.

All available survey data was combined using GIS techniques to produce a DEM of the study region at a 1 m horizontal resolution as shown in Figure 3-1. Note that in Figure 3-1 elevations for Market Swamp are based on LiDAR of the greater Newcastle area. No bathymetric data was provided by Council for Market Swamp as this was outside the scope of works for this study.

3.3 Catchment Area

In addition to the LiDAR provided for the wider catchment, Council also provided a map of the existing pipe drainage network for the Sandgate Industrial Estate. This information was used to determine the boundary lines of the catchment draining to the Jersey Avenue wetland, as shown in Figure 1-1. The area of the Sandgate Industrial Estate catchment (Figure 1-1) draining to the Jersey Avenue wetland was determined to be approximately 27 ha and the Jersey Avenue wetland was determined to have a plan area of approximately 1.7 ha (i.e. approximately 6% of the contributing catchment area). Therefore, the Jersey Avenue wetland is shown to be large relative to the catchment size. In fact, wetlands sized to achieve Council's Development Control Plan (DCP) pollution reduction targets are typically sized to be 4 to 6% of the catchment area (SLR, 2013).

Note that whilst a similar catchment boundary (as provided in Figure 1-1) was used in the SLR report (SLR, 2013), there is a difference in the catchment area calculated in this report (27 ha) and the catchment area adopted by SLR (17.5 ha). Calculations in this report using catchment area are based on the area presented in this Section.

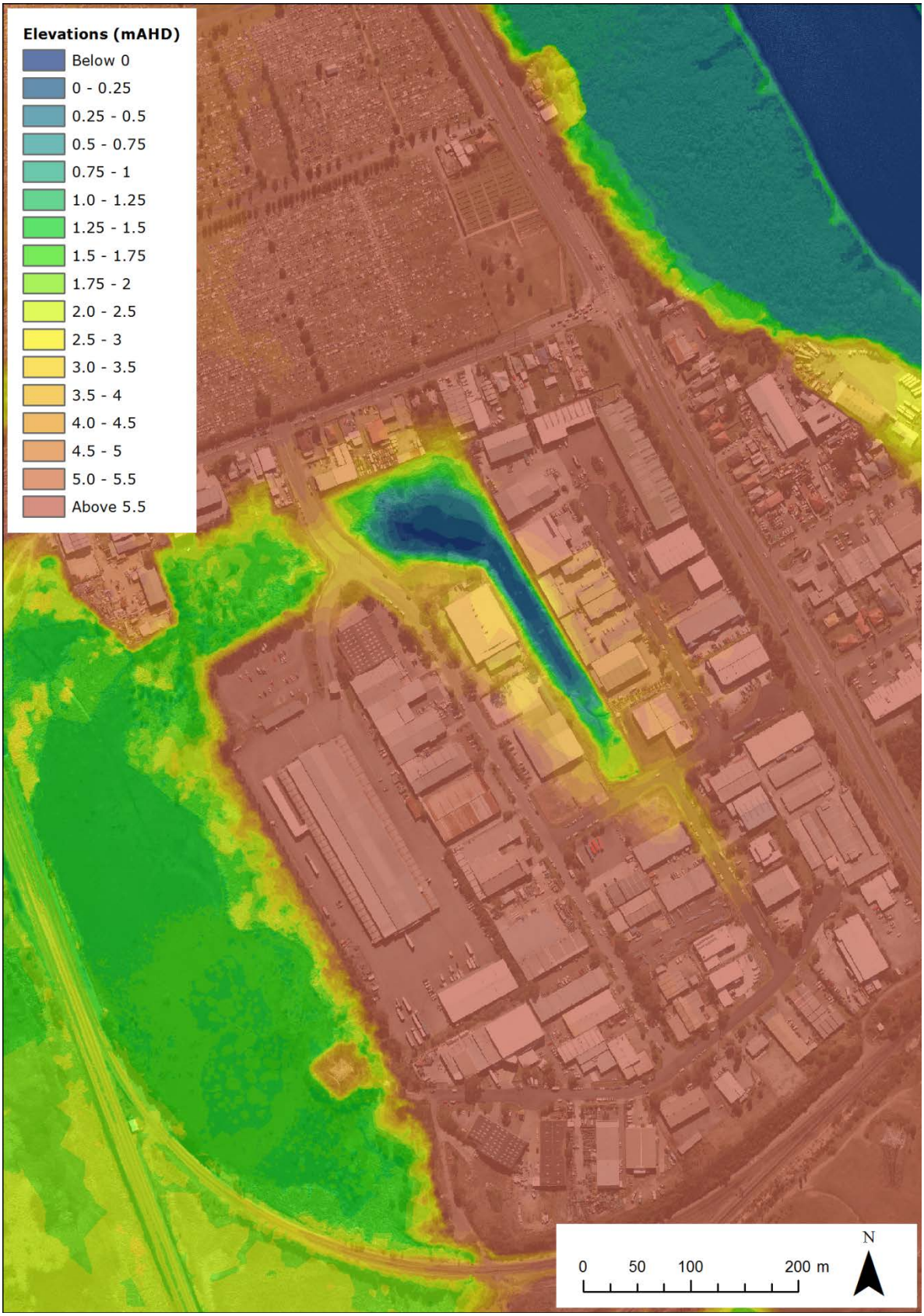

Figure 3-1: Jersey Avenue Wetland Digital Elevation Model

3.4 Stage-Volume Relationship

A key step in assessing the flooding response of the site was to develop a stage-volume relationship from the site topography. The stage-volume relationship indicates the volume of water below a certain elevation in the DEM. The analysis was constrained to the Jersey Avenue wetland (i.e. wetted area only) and volume data was extracted for the site using the DEM at a range of water levels as provided in Figure 3-2.

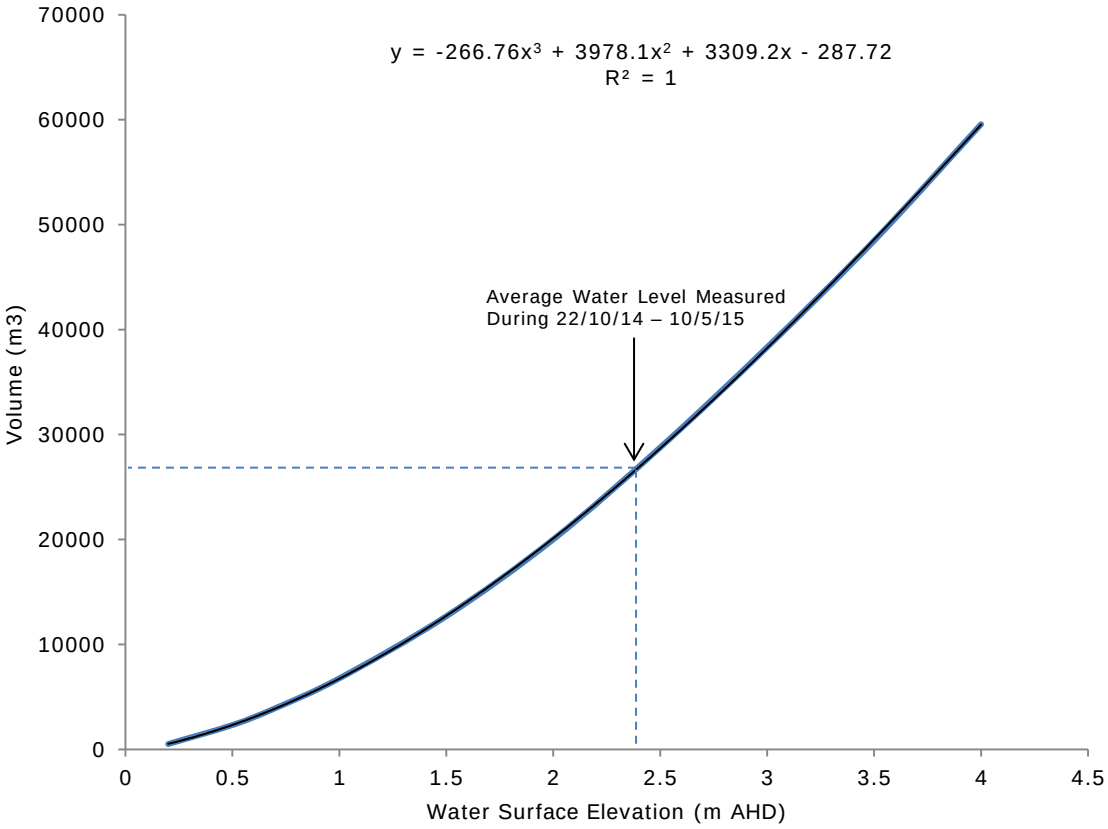

Figure 3-2: Stage Volume Relationship Jersey Avenue Wetland

The stage-volume relationship for Jersey Avenue wetland indicates that for the average water level measurements during the field study, approximately 27,000 m^3 of water was stored in the wetland. When combined with meteorological and runoff data, this information can be used to calculate storage retention times, sedimentation rates and response to rainfall events.

4. Jersey Avenue Wetland Water Balance

4.1 Preamble

A water balance was carried out to quantify and assess the hydrological response of the Sandgate Industrial Estate catchment for a large local catchment rainfall event in April 2015. Note that monitoring of water levels in the Jersey Avenue wetland was undertaken between October 2014 and May 2015. The following section describes the methodology and provides an assessment of the capacity of the Jersey Avenue wetland to manage stormwater runoff from the highly urbanised Sandgate Industrial Estate catchment.

4.2 Environmental Conditions

4.2.1 Meteorological Conditions

Meteorological conditions were sourced from the Bureau of Meteorology (BOM). BOM stations in close proximity to the study site are provided in Table 4.1. Daily rainfall totals recorded at Newcastle University and Nobbys Head were found to be statistically similar during the monitoring period.

Table 4.1: Summary of Rainfall and Evaporation Data (01/01/2015 – 01/05/2015)

BOM Station ID	Station Location	Distance to Study Site (km)	Rainfall Data	Evaporation Data
061390	Newcastle University	4.5	9am/3pm	Not Available
061055	Newcastle Nobbys Signal Station AWS	11.9	3-hourly	Not Available
061078	Williamtown RAAF	14.1	3-hourly	Daily Data

The nearest evaporation data was available from the Williamtown RAAF station. However, this was not available as a continuous time-series of daily values, as such monthly averaged values were used for the analysis as provided in Table 4.2.

Table 4.2: Monthly Averaged Evaporation Data from Williamtown RAAF during the Field Study

Month	Evaporation (mm/day)
January	12.0
February	9.6
March	9.0
April	5.7

4.2.2 Rainfall Events

Three (3) discrete rainfall events were sampled during the monitoring period of the field study at the Jersey Avenue wetland. The selected rainfall events occurred between March and April 2015. On the basis of meteorological conditions presented in Section 4.2.1, it is possible to

estimate the equivalent design rainfall average recurrence interval (ARI), using the design rainfall curves provided in Appendix A, for each rainfall event. Note that this method assumes that the recorded 3-hourly rainfall at Nobbys Signal Station is continuous over that period (i.e. the recorded rainfall was the same rate (mm/hour) in the 1st-hour, 2nd-hour and 3rd-hour). A summary of the events is provided in Table 4.3.

Table 4.3: Summary of the Rainfall Events Sampled during the Field Study

Rainfall Event (#)	Sampling Period	Rainfall Station	Rainfall Total (mm)	Estimated Equivalent ARI (Years)
1	12/3/2015 - 14/3/2015	Newcastle University	11	<1
2	30/3/2015 - 2/04/2015	Nobbys Head	23.2	<1
3	1/4/2015 - 6/04/2015	Nobbys Head	61.6	<1

4.2.3 Water Levels

The field program involved the installation of two (2) short-term deployable water level devices to measure the site's response to rainfall. Odyssey water level capacitance loggers were installed at Sites 2 and 3 (Figure 4-1) on 22/10/2014. The loggers were securely contained within slotted 50 mm PVC pipe. Site 3 was decommissioned on 12/02/2015 following a rainfall event on 15/12/2014 which caused the logger to malfunction. A Solinst water level probe replaced the Odyssey logger at Site 3 but the station was displaced by floating debris and has not been retrieved.

Figure 4-1: Monitoring Locations in Jersey Avenue Wetland

A continuous time-series of water level data was collected at Site 2 (Figure 4-1) between October 2014 and May 2015. Water level data was related to the Australian Height Datum (AHD) using a Trimble 5800 RTK-GPS (Real-Time Kinematic Global Positioning System) with an accuracy of ±20 mm vertically and horizontally. Water levels in the Jersey Avenue wetland were compared with recorded (3-hourly) rainfall data at Nobbys Signal Station as provided in Figure 4-2. The data provided in Figure 4-2 shows that water levels in the Jersey Avenue wetland are relatively sensitive in response to rainfall, particularly for large local catchment rainfall events.

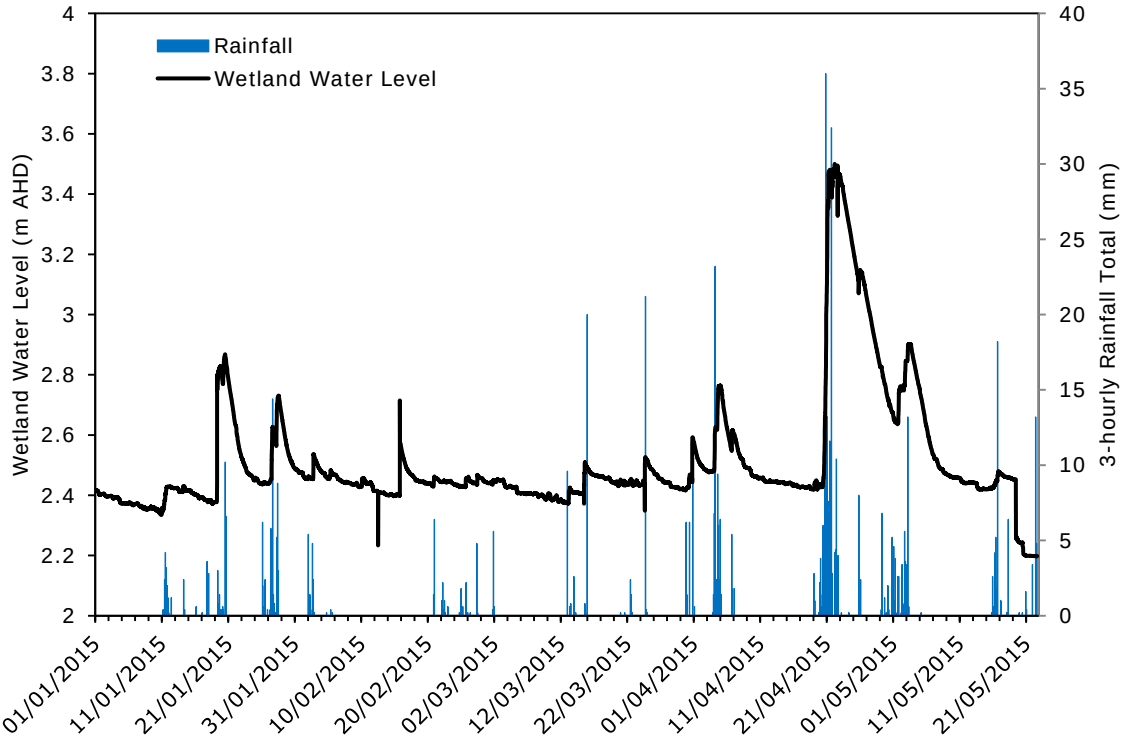

Figure 4-2: Rainfall Data as Recorded at Nobbys Signal Station and Water Levels Measured in Jersey Avenue Wetland

4.3 Water Balance Calculations

On the basis of water level observations in the Jersey Avenue wetland, the Newcastle University and Nobbys Head rainfall records generally did not appear to be representative of the rainfall generated runoff at the Sandgate Industrial Estate for the selected rainfall events presented in Section 4.2.2. However, Event #3 in April 2015 is one occasion where the timing of the runoff from the rainfall event, as recorded at Nobbys Head, is consistent with the stage-volume response in the Jersey Avenue wetland, as provided in Figure 4-3. As such, Event #3 was used to confirm the water balance of the Jersey Avenue wetland.

4.3.1 Incident Rainfall

The runoff volume from the incident rainfall event recorded at Nobbys Head in April 2015 (Event #3) was calculated using the principles of the rational method as described in Book 8 of Australian Rainfall and Runoff (ARR, 2001). The runoff volume (m^3) was calculated using the following formula:

$$V_c = CiA$$

where

C = runoff coefficient (dimensionless)
i = rainfall depth (mm) equal to rainfall intensity (mm/hr) x storm duration (hrs)
A = area of catchment (m^2)

Runoff coefficients provide for the relationship between rainfall-runoff volumes and allow for varying amounts of pervious and impervious surfaces across a catchment. The Sandgate Industrial Estate comprises a mix of medium to large industrial lots that are dominated by impervious or 'hard' surfaces. On the basis of this information it is appropriate to use a runoff coefficient of 0.9 to account for the land-use at the Sandgate Industrial Estate being dominated by impervious surfaces.

During the April 2015 event, approximately 61 mm fell in 33 hours, which is equivalent to a rainfall depth of 1.8 mm/hr. Assuming that the rainfall fell evenly over the Sandgate Industrial Estate catchment during the storm event, the runoff volume from the incident rainfall was estimated to be 14,823 m^3.

4.3.2 Volume Change in the Jersey Avenue Wetland

The runoff volume routed through the Jersey Avenue wetland can be approximated using the stage-volume relationship of the wetland. The runoff volume for the April 2015 event is equivalent to the shaded area under the curve as shown in Figure 4-3. Using area calculation methods, the volume change (i.e. captured) in the wetland was calculated to be approximately 12,836 m^3 (i.e. 87% of the runoff volume calculated from the incident rainfall (Section 4.3.1)). Note that this estimate could be improved by installing a rainfall gauge in the local catchment.

4.3.3 Discussion

When it rains across the Sandgate Industrial Estate, the Jersey Avenue wetland fills up and a large volume of the stormwater runoff is captured, which slowly drains from the system over several days following the runoff event. SLR Consulting noted in (SLR, 2013) that the Jersey Avenue wetland drains via two 0.750 m pipe culverts beneath Rural Drive to Market Swamp. However, following several investigations by Council, the pipe culverts have not been located and the downstream control of the Jersey Avenue wetland still remains a major unknown in the project.

On the basis of the field observations and the water balance calculations presented above, it is reasonable to assume that the Jersey Avenue wetland has some form of downstream drainage structure which regulates water levels in the wetland. For the purpose of completing the water balance, it was assumed that that the Jersey Avenue wetland drains via two 0.750 m pipe culverts beneath Rural Drive to Market Swamp. Assuming that the pipe culverts are 100% efficient and that continuing losses due to evaporation and infiltration across the wetland were small during the April 2015 event, the estimated discharge from the system was calculated to be 59 m^3/hr (or, 16.5 L/s), which is equivalent to a pipe flow velocity of approximately 0.01 m/s. Note that a minimum velocity of 0.6 m/s is typically required to scour and remove sediment in pipes.

For the calculated discharge rate of 59 m^3/hr from the Jersey Avenue wetland and a duration of approximately 63.5 hours (Figure 4-3) before the next runoff event, the volume of water assumed to have drained from the system over that time was calculated to be 2,018 m^3. Adding the volume of water 'lost' from the system to the volume 'captured' by the system, the total volume routed through the Jersey Avenue wetland for the April 2015 event was calculated to be 14,853 m^3 (i.e. the same runoff volume generated from the incident rainfall during the April 2015 event). This confirms the presence of a downstream control equivalent to the capacity of two 0.750 m pipe culverts beneath Rural Drive.

The **key outcomes** of the water balance assessment are:

1. On the basis of water level observations in the Jersey Avenue wetland, the Newcastle University and Nobbys Head rainfall records generally did not appear to be representative of the rainfall generated runoff at the Sandgate Industrial Estate.
2. The Jersey Avenue wetland is hydrologically connected to the downstream Market Swamp system. This assessment has assumed the site drains via two 0.750 m pipe culverts beneath Rural Drive to Market Swamp.
3. The hydrological connection (i.e. pipe culverts) appears to be effective in routing stormwater runoff from the Sandgate Industrial Estate to Market Swamp for minor ARI rainfall events (i.e. <1 year), without flooding the surrounding Sandgate Industrial Estate.

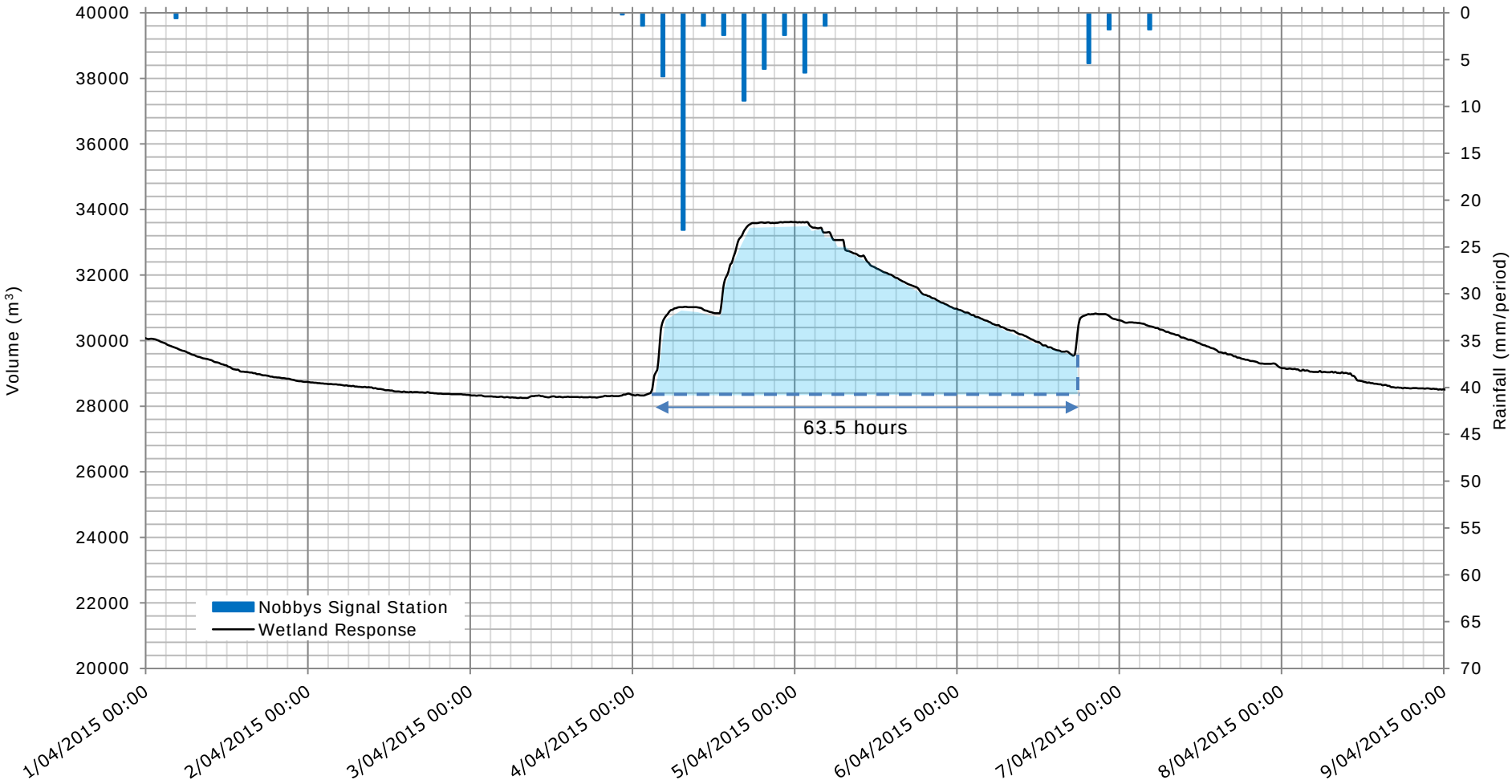

Figure 4-3: Jersey Avenue Wetland Volume Response to April 2015 Rainfall-Runoff Event

5. Sediment Dynamics

5.1 Preamble

Stormwater runoff from the Sandgate Industrial Estate to the Jersey Avenue wetland has been shown to contain varying amounts of industrial pollutant loads (SLR, 2013). Pollutant loads may also be derived from other sources such as the organic decomposition of vegetation in and around the wetland. As such, water samples containing suspended sediment were collected for pre-selected rainfall events (Section 4.3.2) using two (2) ISCO auto-samplers. A series of sediment investigations were undertaken on the water samples for particle size distribution and suspended sediment concentrations to assist with the development of long-term management plans for the Jersey Avenue wetland.

The following section describes the methodology and provides an assessment of sediment retention times and predicted infilling rates of the Jersey Avenue wetland. Time-series plots of particle size and suspended sediment concentrations for each sampling event are provided in Appendix C. An example of the result analysis report from the MasterSizer 2000 is provided in Appendix D.

5.2 Methodology

5.2.1 Field Data Collection

The auto-samplers use a peristaltic pump to draw water samples at a user-specified time interval and quantity and then store these samples in up to 24 bottles contained within the unit. Note for this experiment the samplers were configured to collect one sample of approximately 800 mL per time interval. The time interval was based on the expected runoff event duration and the samplers were typically set to sample every 1-2 hours.

The samplers were installed on 22/10/2014 at two (2) inflow points to the Jersey Avenue wetland, including Sites 1 and 2 as provided in Figure 4-1. These locations are the main discharge points from the pipe drainage network for the Sandgate Industrial Estate. Further details on the field monitoring program are provided in Appendix B.

5.2.2 Particle Size Distribution

Particle size distributions were tested for particles less than 5 mm using a MasterSizer 2000 particle analyser (owned by UNSW Australia) as provided in Figure 5-2. The particle size distribution is derived by a volume-based technique (i.e. the MasterSizer 2000 uses the volume of the particle to measure its size). The analysed distribution is expressed as a set of size classes that are optimised to match the detector geometry and optical configuration. Distribution parameters and derived particle sizes are calculated using the summation of the contributions from each size band. Further information on the particle analyser can be found in Malvern (1997).

A total of 120 samples from three (3) discrete runoff events (Section 4.2.2) were analysed using the MasterSizer 2000. Samples were well-mixed before undertaking the particle size analysis to ensure a representative distribution was obtained. Approximately 20 mL from each sample was extracted and injected into the MasterSizer 2000 for analysis. Five (5) independent measurements were taken by the MasterSizer 2000 on each sample and averaged to compute a distribution of particle size within the sample. The definition of a particle size distribution is provided in Figure 5-1.

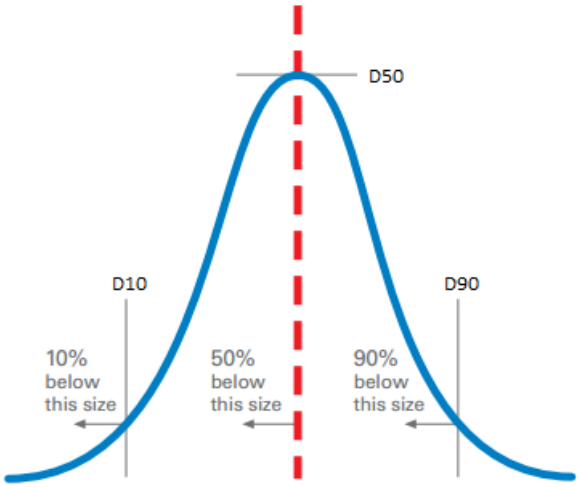

Figure 5-1: Definition of a Particle Size Distribution

A summary of the average particle size distribution and suspended sediment concentrations for water samples collected during the field monitoring program at the Jersey Avenue wetland are provided in Table 5.1 and Table 5.2. The results showed that particle size (Table 5.1) generally increased with event magnitude, however, there appeared to be no direct correlation between the event magnitude and suspended sediment concentrations (Table 5.2). It is worth noting that the data collected for the analysis was from two (2) independent point sources and only provided a snapshot in time without accounting for antecedent conditions, land-use changes and other inflow source points. Nonetheless, for the selected runoff events the field data showed that particle (diameter) sizes range from 0.01 mm (D10) to 0.34 mm (D90), with an average of 0.08 mm (D50). The average suspended sediment concentration from the runoff events was approximately 400 mg/L, with a range from 118 mg/L to 896 mg/L.

SLR Consulting undertook a pollutant capture efficiency assessment of the Jersey Avenue wetland in 2013 (SLR, 2013) using a catchment area of 17.5 ha, theoretical pollutant load values from literature, rainfall data from Williamtown RAAF (14.1 km from study site) and a runoff coefficient of 0.9 for the Sandgate Industrial Estate. SLR estimated the mean annual runoff volume from the Jersey Avenue catchment as 151 ML/year and the total suspended sediment pollutant load as 21,300 kg/year. This is equivalent to a total suspended sediment concentration of approximately 141 mg/L, which is in the lower range of values measured during the 2015 field study.

However, on the basis of the assumptions made by SLR in (SLR, 2013) and the recent field data collection, the mean annual runoff volume from the Jersey Avenue catchment and the total suspended sediment pollutant load used by SLR were considered to be underestimated. As such, mean annual rainfall for Nobbys Head over 150 years as reported by BOM was used to determine a mean annual runoff volume for the Jersey Avenue catchment. Assuming a catchment area of 27 ha and a runoff coefficient of 0.9, the mean annual runoff volume for the Jersey Avenue catchment was calculated to be approximately 275 ML/year.

Table 5.1: Summary of Average Particle Size Distribution for Water Quality Samples Collected during the Field Monitoring Program at the Jersey Avenue Wetland

Location	Event #1			Event #2			Event #3		
	D10 (mm)	D50 (mm)	D90 (mm)	D10 (mm)	D50 (mm)	D90 (mm)	D10 (mm)	D50 (mm)	D90 (mm)
Site 1	0.001	0.025	0.250	0.004	0.044	0.198	0.012	0.172	0.513
Site 2	NS[1]	NS[1]	NS[1]	0.007	0.087	0.485	0.010	0.070	0.271

[1]NS = No Samples taken.

Table 5.2: Summary of Average Suspended Sediment Concentrations for Water Quality Samples Collected during the Field Monitoring Program at the Jersey Avenue Wetland

Location	Concentration (mg/L)		
	Event #1	Event #2	Event #3
Site 1	268	896	213
Site 2	NS[1]	553	118

[1]NS = No Samples taken.

Figure 5-2: MasterSizer 2000 Particle Sampling Instrumentation Setup

5.2.3 Hydraulic Residence Time

The design of urban stormwater wetlands is informed by the Constructed Wetlands Manual (DLWC, 1998). The manual provides pollutant removal curves which have been published for a number of stormwater wetlands in Sydney, Canberra and Adelaide. These curves relate detention time (in days) to pollutant removal (%) for total phosphorus, total nitrogen and suspended solids. The configuration of these wetlands is similar, being large deep open water bodies with fringing macrophytes. The generic curve for suspended sediment retention (%) is provided in Figure 5-3.

Water level observations from a capacitance probe installed in the Jersey Avenue wetland for the period between October 2014 and May 2015 indicate that the average water level (d_{av}) during this time was approximately 2.4 m AHD. Using the stage-volume relationship for the Jersey Avenue wetland, a water level of 2.4 m AHD corresponds to an approximate volume of 27,000 m^3. For an estimated mean annual runoff volume from the Jersey Avenue catchment of 275 ML/year, the average hydraulic residence time (HRT) can be determined by:

$$HRT = \frac{Wetland\ System\ Volume}{Runoff}$$

$$\therefore HRT = \frac{27{,}000(m^3)}{275\left(\frac{ML}{year}\right) * 1000\left(\frac{m^3}{ML}\right)} = 0.098\ years \approx 36\ days$$

Using Figure 5-3, and plotting a HRT of 36 days, indicates that the Jersey Avenue wetland is likely capturing between 70% (lower bound) to 100% (upper bound) of the suspended sediment load entering the system from stormwater runoff. This is consistent with theoretical sedimentation efficiencies (Table 5.3) for particle sizes greater than the D50 (i.e. 0.08 mm) as determined during the particle size analysis. It is possible, however, that fine particles equivalent to the D10 (i.e. 0.01 mm) may short-circuit the system and be discharged to Market Swamp. Fine particles require flocculation to settle and this process is dependent on sufficient suspended sediment concentrations. Field data collection of flocculation rates was outside the scope of this study.

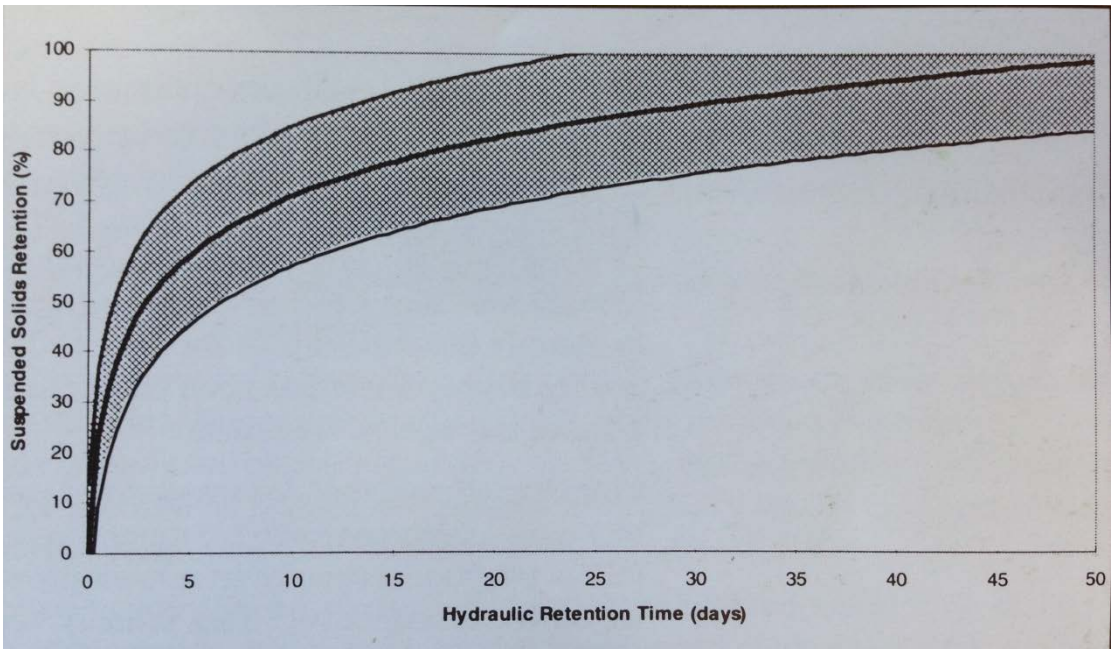

Figure 5-3: Generic Curve for Sediment Removal in Urban Stormwater Wetlands (DLWC, 1998)

Table 5.3: Particle Size Definition (DLWC, 1998)

Particle Name	Particle Size (mm)	Settling Velocity (m/s)	Sedimentation Efficiency (%)	Settleability
Clay (colloidal)	< 0.002	-	-	Very difficult
Silt	0.002 – 0.02	< 0.00029	< 60	Difficult
Fine Sand	0.02 – 0.2	0.0003 – 0.020	60 – 95	Moderate
Coarse Sand	0.2 – 2.0	> 0.020	> 95	Easy

5.2.4 Wetland Infilling Rate

Using the mean annual runoff volume from the Jersey Avenue catchment and the average suspended sediment concentration from stormwater runoff during the recent field investigations, it is possible to estimate an infilling rate of the Jersey Avenue wetland. A suspended sediment concentration of 400 mg/L is equivalent to a suspended sediment load of 110,000 kg/year. The Jersey Avenue wetland is considered near capacity when water levels in the wetland reach 3.5 m AHD, using the stage-volume relationship provided in Section 3.3 this equates to a storage volume of approximately 48,500 m^3. Assuming an average bulk (dry) density of 1.98 g/cm^3 for silty sand (Holtz and Kovacs, 1981), the predicted infilling time of the Jersey Avenue wetland is approximately 900 years. This estimated infilling time is based on suspended sediment loads from stormwater runoff only and does not account for additional input from gross pollutant loads or organic decomposition of vegetation in the wetland, which would ultimately reduce the infilling time of the wetland.

The **key outcomes** of the sediment dynamics analysis are:

1. For the selected runoff events the field data shows that the average particle (diameter) sizes range between 0.01 to 0.34 mm and the average suspended sediment concentration from stormwater runoff is approximately 400 mg/L, with an range between 118 to 896 mg/L.
2. Analysis shows that the Jersey Avenue wetland has a HRT of 36 days and is likely capturing greater than 70% of the suspended sediment load entering the system from stormwater runoff. This is consistent with theoretical sedimentation efficiencies for particle sizes of greater than 0.02 mm, being greater than 60%.
3. It is predicted that the infilling time of the Jersey Avenue wetland is approximately 900 years. This estimated infilling time is based on suspended sediment loads from stormwater runoff only and does not account for additional input from gross pollutant loads or organic decomposition of vegetation in the wetland, which would ultimately reduce the infilling time of the wetland.

6. Summary and Recommendations

Field monitoring of the Jersey Avenue wetland was undertaken between October 2014 and April 2015 and was successfully completed with the assistance of Council staff. The field program involved the installation of short-term deployable water level and water quality measurement devices to measure the site's response to rainfall and to measure sediment inputs following three (3) discrete rainfall-runoff events. The runoff events selected for the study were captured during March and April 2015 and included two short duration events and one larger catchment wide event. The key outcomes of the field assessment are:

- On the basis of water level observations in the Jersey Avenue wetland, the Newcastle University and Nobbys Head rainfall records generally did not appear to be representative of the rainfall generated runoff at the Sandgate Industrial Estate.
- The Jersey Avenue wetland is effective in routing stormwater runoff from the Sandgate Industrial Estate to Market Swamp for minor ARI rainfall events (i.e. <1 year), without flooding the surrounding Sandgate Industrial Estate.

At the completion of the field program, the desktop component of the study involved laboratory analysis of the water samples for particle size distribution and suspended sediment concentrations. Using the results of the laboratory analysis, an assessment was undertaken to quantify sediment retention times and predicted infilling rate of the Jersey Avenue wetland. The key outcomes of the desktop assessment are:

- The Jersey Avenue wetland is likely capturing greater than 70% of the suspended sediment load entering the system from stormwater runoff.
- Measured suspended sediment loads indicate that the Jersey Avenue wetland is unlikely to infill from the deposition of suspended sediment. However, this estimated infilling time is based on suspended sediment loads from stormwater runoff only and does not account for additional input from gross pollutant loads or organic decomposition of vegetation in the wetland, which would ultimately reduce the infilling time of the wetland.

In summary, the field study and desktop assessment of the Jersey Avenue wetland indicate that the system, in its existing state, meets the original design requirement, in accordance with the guidelines set out in the Constructed Wetlands Manual, being to manage stormwater runoff to Market Swamp and to capture industrial suspended sediment pollutant loads.

6.1 Recommendations

This assessment has found that:

- The highest priority recommendation for Council in the short-to-medium term (i.e. up to 5 years) is to manage the existing vegetation and noxious weeds onsite, while minimising the sediment disturbance in the wetland.
- It recommended that Council undertake another bathymetry survey of the wetland in approximately 5 years to confirm sedimentation rates and infilling. This will allow a direct comparison with the baseline bathymetry survey undertaken during the course of this study and can be used to estimate the infill rate of the system over that period. Further assessment of the system and appropriate management actions could then be carried out as required.

7. References

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Appendix A – Design Rainfall Events

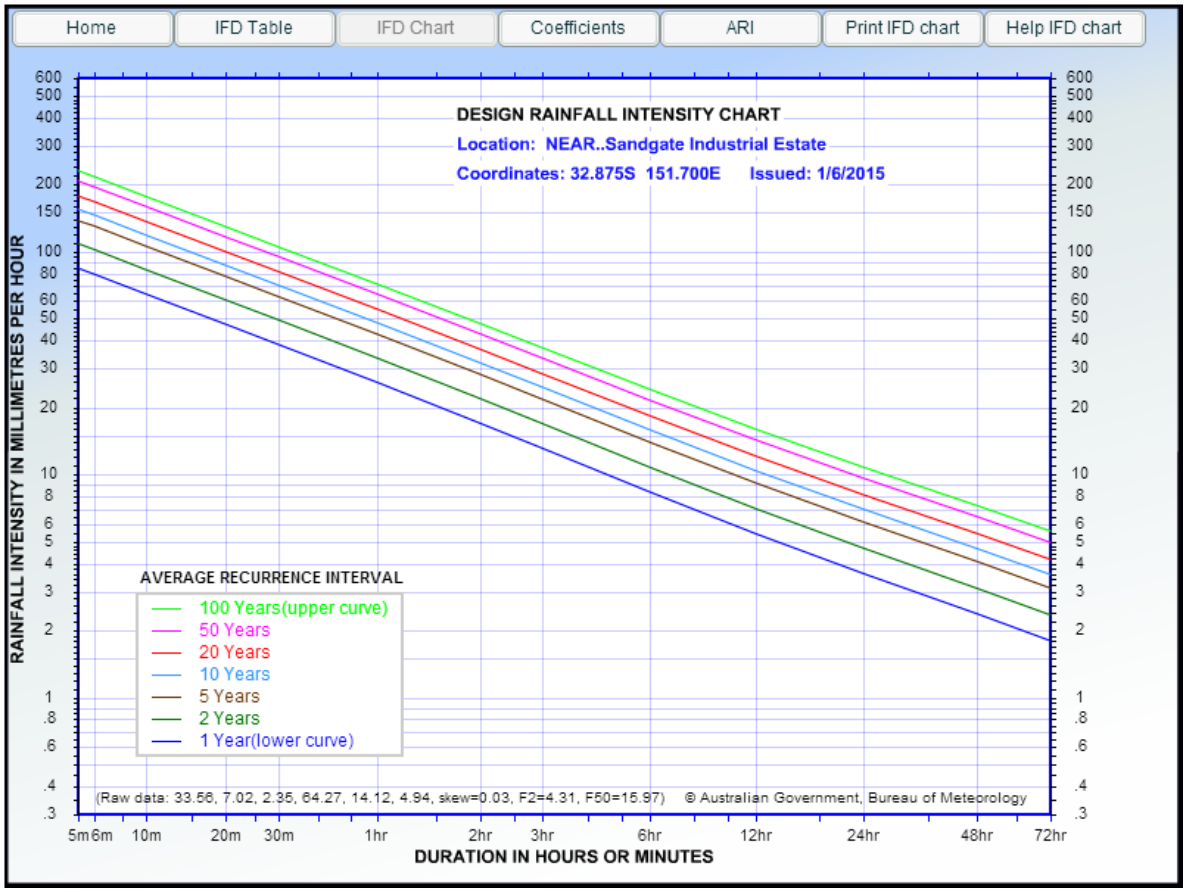


Figure A-1: Design Rainfall Curves for Sandgate Industrial Estate

Table A.1: Design Rainfall Table for Sandgate Industrial Estate

Duration	1 year	2 years	5 years	10 years	20 years	50 years	100 years
5Mins	84.5	109	138	155	178	208	231
6Mins	79.2	102	130	146	167	195	217
10Mins	64.7	83.1	106	119	137	160	177
20Mins	47.2	60.6	77.2	86.8	99.7	116	129
30Mins	38.3	49.3	62.8	70.7	81.1	94.8	105
1Hr	26	33.4	42.7	48.1	55.3	64.7	71.8
2Hrs	17	21.9	28.1	31.7	36.5	42.7	47.5
3Hrs	13.1	16.9	21.7	24.6	28.3	33.3	37
6Hrs	8.38	10.8	14	15.9	18.4	21.6	24.2
12Hrs	5.43	7.04	9.17	10.4	12.1	14.3	16
24Hrs	3.6	4.68	6.13	7	8.13	9.64	10.8
48Hrs	2.38	3.09	4.08	4.67	5.44	6.48	7.27
72Hrs	1.8	2.35	3.11	3.57	4.17	4.97	5.59

Appendix B – Field Monitoring Program

Table B.1: Summary of the Field Monitoring Program at Jersey Avenue Wetland

Sampling Commence Date		Sample Site	Start Time	Sampling Frequency	Sample Collection Date	Comments
Trial Event 1	19/01/2015	Rural Drive (R)				Equipment unable to be located
	19/01/2015	Jersey Avenue (J)	10:00 am	Every 1 hr for 24 hrs	Sampling Programming Error. Samples not collected	
	19/01/2015	Komatsu (K)	10:20 am	Every 1 hr for 24 hrs	Sampling Programming Error. Samples not collected	
Trial Event 2	27/01/2015	Rural Drive (R)				Equipment unable to be located
	27/01/2015	Jersey Avenue (J)	Unable to commence Sampling. Battery charge insufficient due to Sampler continuously sampling from previous event.	Every 3 hrs for 24 samples		
	27/01/2015	Komatsu (K)	Unable to commence Sampling. Battery charge insufficient due to Sampler continuously sampling from previous event.	Every 3 hrs for 24 samples		
Event 1	12/03/2015	Rural Drive (R)				Equipment unable to be located
	12/03/2015	Jersey Avenue (J)	13:50 pm	Sample every 2 hrs, 1 bottle per sample event	16/03/2015	Collected by Jamie (UNSW WRL) 16/03/2015
	12/03/2015	Komatsu (K)	14:15 pm	Sample every 2 hrs, 1 bottle per sample event	Blockage in hose line. Samples not collected	

Event 2	31/03/2015	Rural Drive (R)				Equipment unable to be located
	31/03/2015	Jersey Avenue (J)	14:45 pm (Approx.)	Sample every 1 hr, 1 bottle per sample event	01/04/2015	Collected by Doug (UNSW WRL) 09/04/2015
	31/03/2015	Komatsu (K)	15:00 pm (Approx.)	Sample every 1 hr, 1 bottle per sample event	01/04/2015	Collected by Doug (UNSW WRL) 09/04/2015
Event 3	03/04/2015	Rural Drive (R)				Equipment unable to be located
	03/04/2015	Jersey Avenue (J)	18:00 pm	Sample every 2 hrs, 1 bottle per sample event	07/04/2015	Collected by Doug (UNSW WRL) 09/04/2015
	03/04/2015	Komatsu (K)	18:00 pm	Sample every 2 hrs, 1 bottle per sample event	07/04/2015	Collected by Doug (UNSW WRL) 09/04/2015

Appendix C – Catchment Properties

C.1 – Sampling Event #1

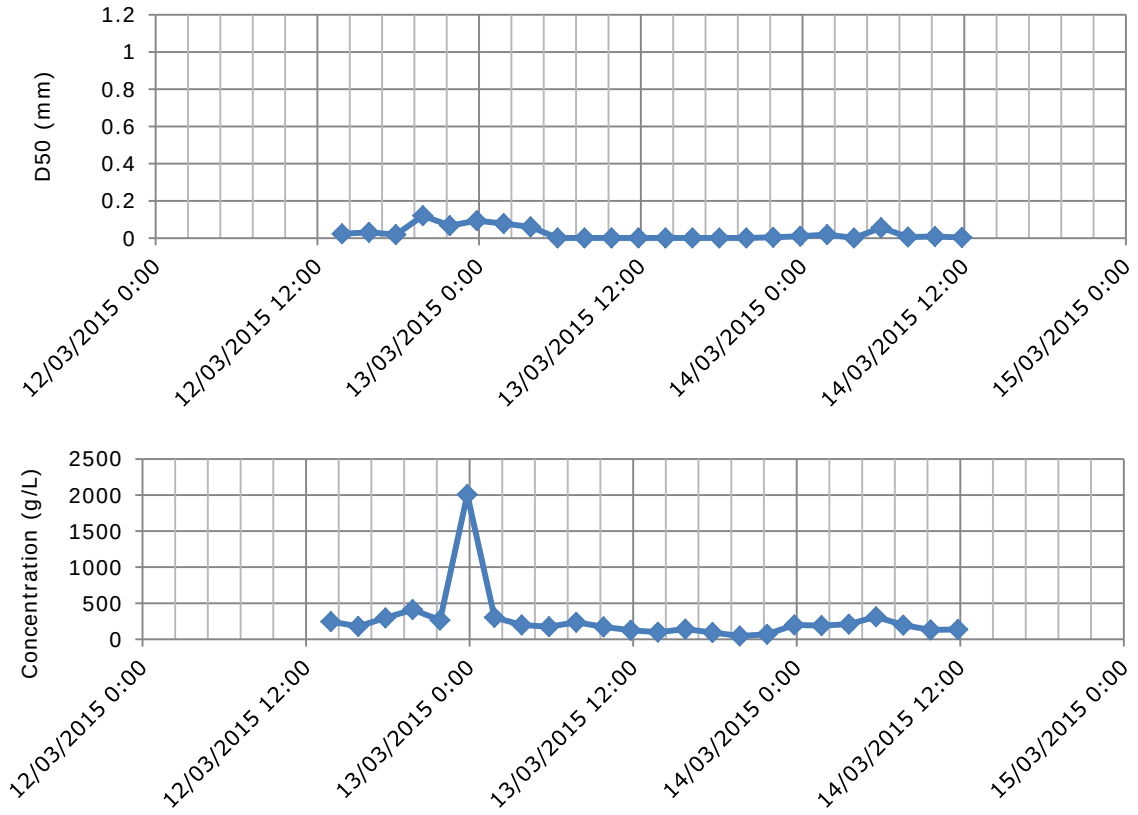


Figure C-1: Median Grain Size and Concentration Versus Rainfall Measured at Jersey Avenue Outlet

C.2 – Sampling Event #2

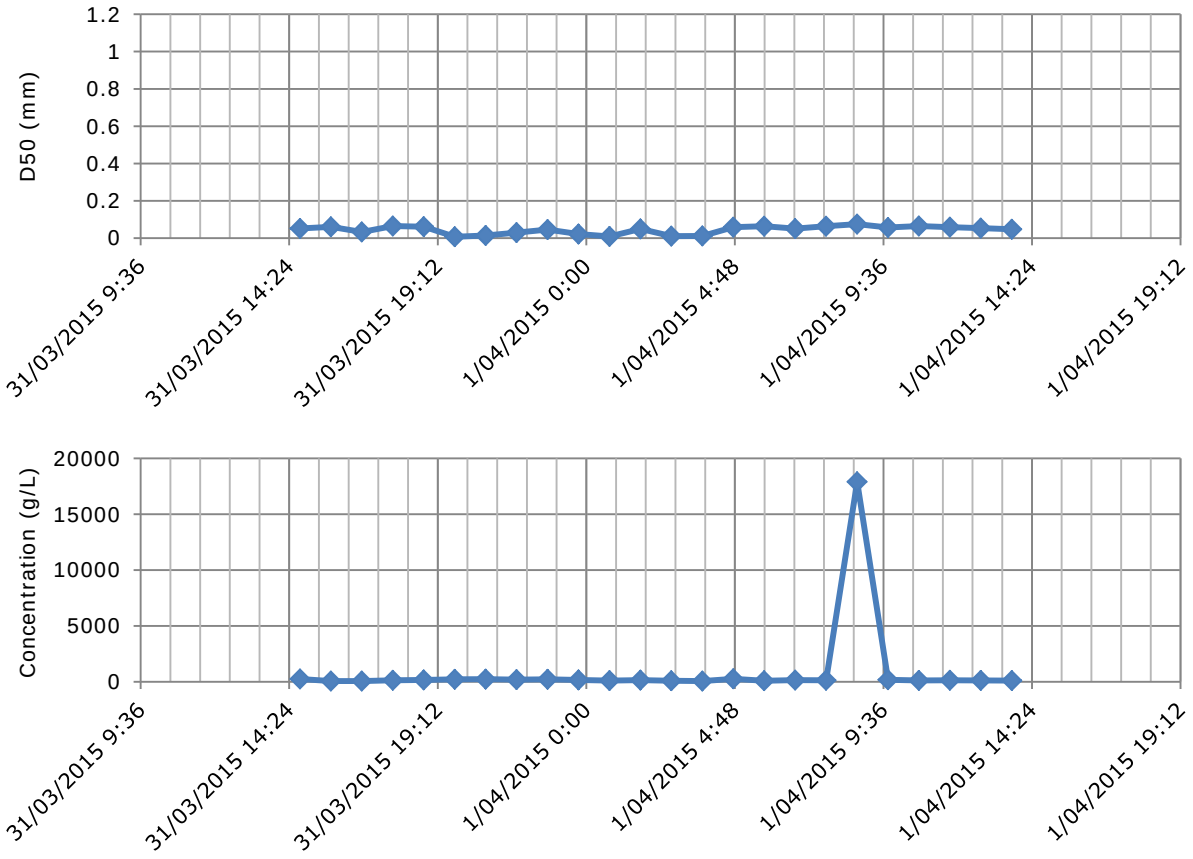


Figure C-2: Median Grain Size and Concentration Measured at Jersey Avenue Outlet

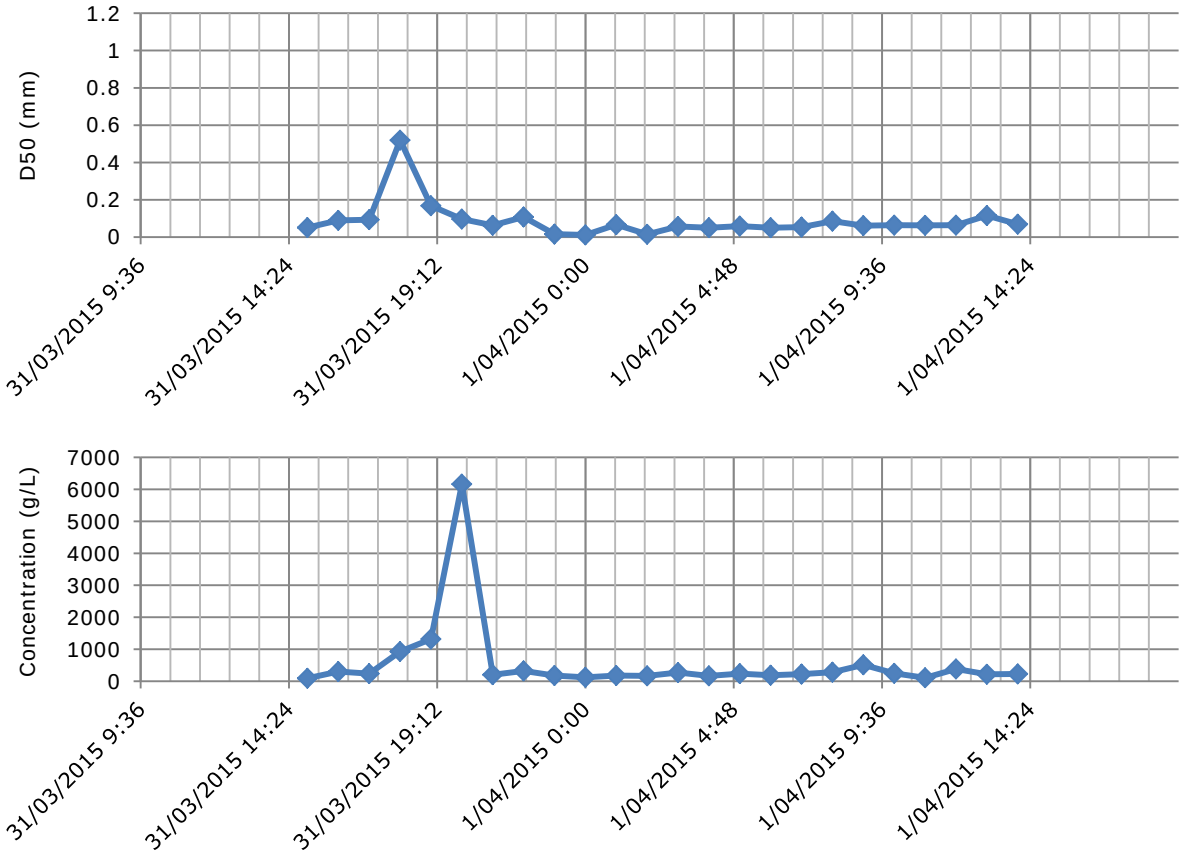


Figure C-3: Median Grain Size and Concentration Measured at Komatsu Outlet

C.3 – Sampling Event #3

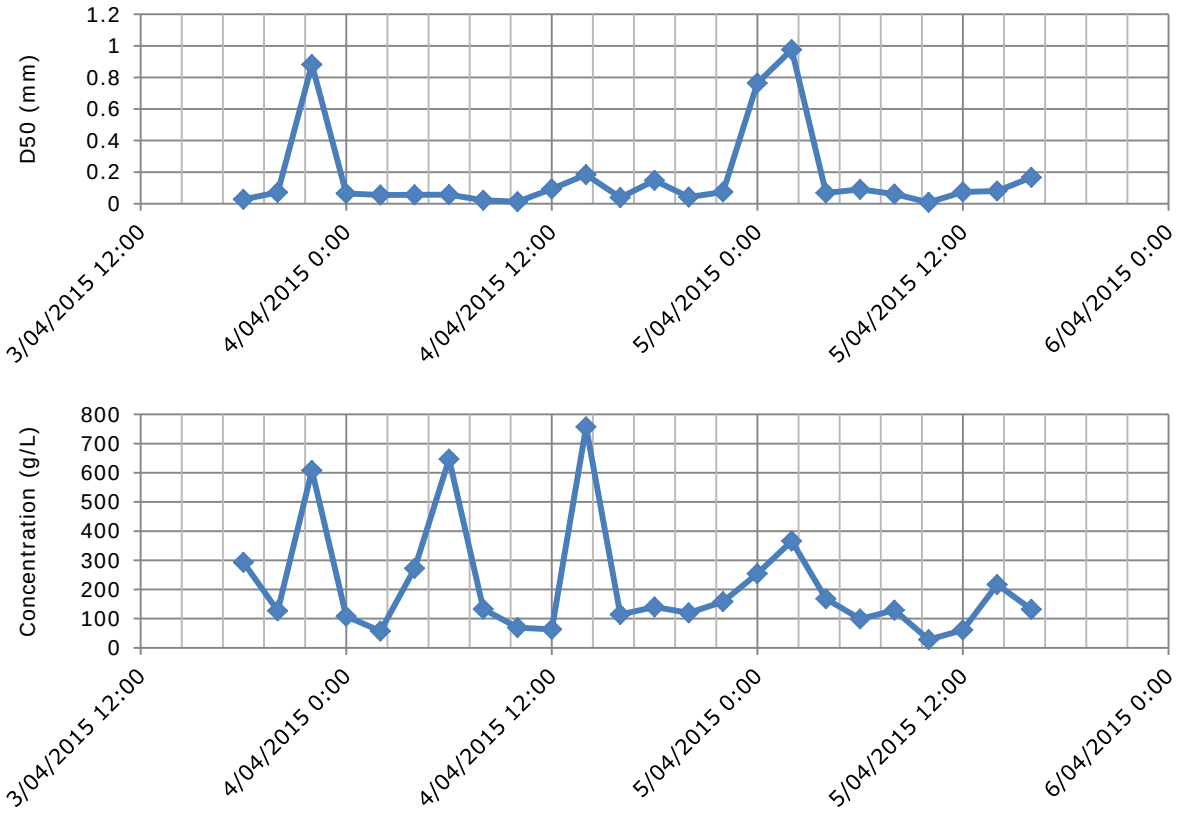


Figure C-4: Median Grain Size and Concentration Measured at Jersey Avenue Outlet

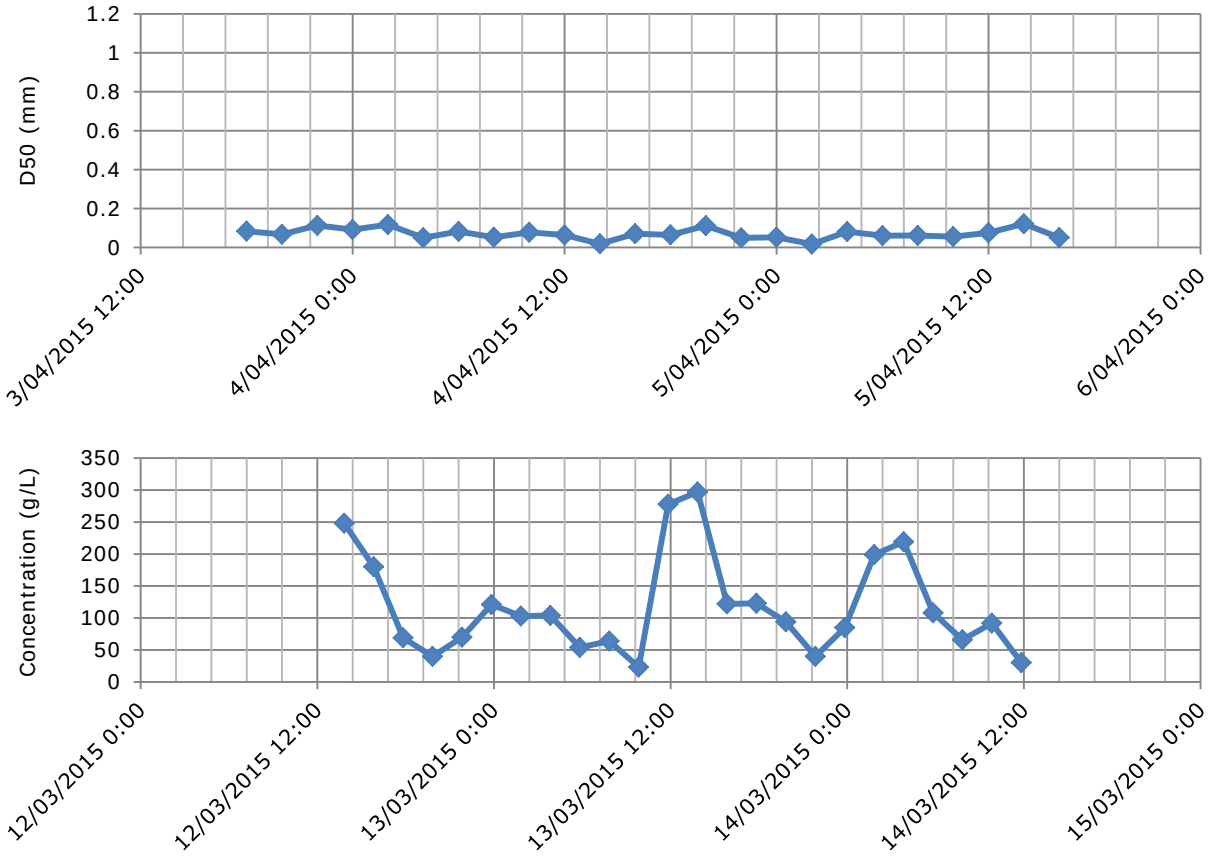


Figure C-5: Median Grain Size and Concentration Measured at Komatsu Outlet

Appendix D – Example of MasterSizer Result Analysis Report

MASTERSIZER 2000

Result Analysis Report

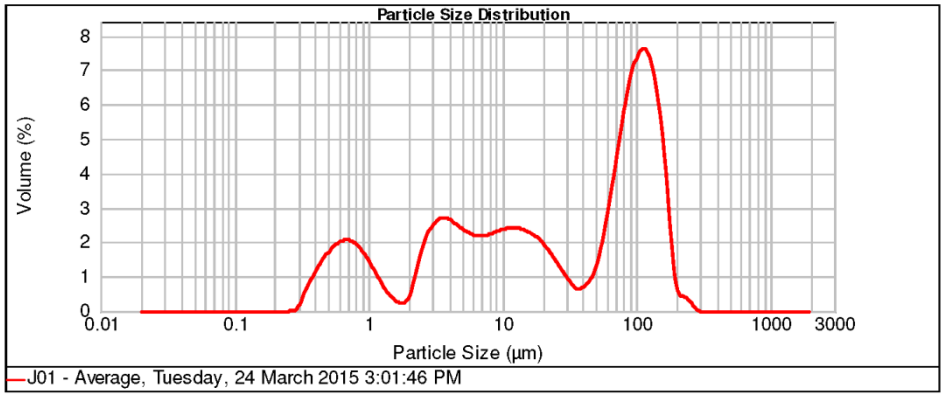
Sample Name: J01 - Average
SOP Name:
Measured: Tuesday, 24 March 2015 3:01:46 PM

Sample Source & type: Lab = WRL
Measured by: Priom
Analysed: Tuesday, 24 March 2015 3:01:47 PM

Sample bulk lot ref:
Result Source: Averaged

Particle Name: Water droplets	**Accessory Name:** Hydro 2000MU (A)	**Analysis model:** General purpose	**Sensitivity:** Normal
Particle RI: 1.330	**Absorption:** 0.01	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 5.18 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 15.207 %	**Result Emulation:** Off
Concentration: 0.0245 %Vol	**Span :** 5.899	**Uniformity:** 2.09	**Result units:** Volume
Specific Surface Area: 1.78 m²/g	**Surface Weighted Mean D[3,2]:** 3.362 um	**Vol. Weighted Mean D[4,3]:** 54.571 um	

d(0.1): 0.838 um **d(0.5):** 23.110 um **d(0.9):** 137.168 um



Size (µm)	Volume In %
0.010	0.00
0.011	0.00
0.013	0.00
0.015	0.00
0.017	0.00
0.020	0.00
0.023	0.00
0.026	0.00
0.030	0.00
0.035	0.00
0.040	0.00
0.046	0.00
0.052	0.00
0.060	0.00
0.069	0.00
0.079	0.00
0.091	0.00
0.105	0.00

Size (µm)	Volume In %
0.105	0.00
0.120	0.00
0.138	0.00
0.158	0.00
0.182	0.00
0.209	0.00
0.240	0.00
0.275	0.08
0.316	0.54
0.363	0.92
0.417	1.30
0.479	1.60
0.550	1.80
0.631	1.87
0.724	1.80
0.832	1.58
0.955	1.26
1.096	

Size (µm)	Volume In %
1.096	0.89
1.259	0.55
1.445	0.31
1.660	0.21
1.905	0.40
2.188	1.21
2.512	1.92
2.884	2.32
3.311	2.46
3.802	2.38
4.365	2.23
5.012	2.09
5.754	2.00
6.607	1.98
7.586	2.03
8.710	2.11
10.000	2.16
11.482	

Size (µm)	Volume In %
11.482	2.18
13.183	2.15
15.136	2.05
17.378	1.88
19.953	1.64
22.909	1.35
26.303	1.03
30.200	0.73
34.674	0.58
39.811	0.72
45.709	1.06
52.481	1.90
60.256	3.06
69.183	4.38
79.433	5.64
91.201	6.56
104.713	6.90
120.226	

Size (µm)	Volume In %
120.226	6.46
138.038	5.23
158.489	3.12
181.970	0.76
208.930	0.38
239.883	0.22
275.423	0.01
316.228	0.00
363.078	0.00
416.869	0.00
478.630	0.00
549.541	0.00
630.957	0.00
724.436	0.00
831.764	0.00
954.993	0.00
1096.478	0.00
1258.925	

Size (µm)	Volume In %
1258.925	0.00
1445.440	0.00
1659.587	0.00
1905.461	0.00
2187.762	0.00
2511.886	0.00
2884.032	0.00
3311.311	0.00
3801.894	0.00
4365.158	0.00
5011.872	0.00
5754.399	0.00
6606.934	0.00
7585.776	0.00
8709.636	0.00
10000.000	

Operator notes:

Malvern Instruments Ltd.
Malvern, UK

Mastersizer 2000 Ver. 5.40
Serial Number : MAL1015901

File name: Newcastle Rainfall Distributions.mea
Record Number: 67