STORMWATER MANAGEMENT PLAN: SYDNEY ZOO

Project No.00012082
Date: 3 December 2015

Prepared for:

Sydney Zoo
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Client: Sydney Zoo
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Contents

1. Introduction

1.1 Project Background

Sydney Zoo is seeking approval under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the construction of a zoo (Sydney Zoo) within the Bungarribee Precinct in the Western Sydney Parklands.

The project was declared to be State Significant Development (SSD). Assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's Environmental Assessment Requirements (SEARs) for the project have been issued and set out the environmental assessment requirements for the project.

This Stormwater Management Report has been prepared by Lindsay Dynan Consulting Engineers (Lindsay Dynan) to address the relevant SEARs in relation to the preparation of the EIS for the Project.

1.2 The Project

The proposed development of Sydney Zoo will include:

- Animal exhibits across several enclosures of varying design for a range of native and exotic animals,
- Back-of-house buildings for exhibits,
- Main entrance building comprising entry/exit, and gift shop,
- Restaurant and café,
- Kiosks and amenities,
- Show arena,
- Picnic areas and gardens,
- Wetlands and waterways,
- Service building containing:
    - Administration areas;
    - Curatorial and food preparation areas; and
    - Veterinarian space.
- Service yard with maintenance shelter,
- Main car park for approximately 800 vehicles, with an overflow car park for approximately 490 vehicles, access via an internal road connecting to the Great Western Highway, and
- Bus parking.

Construction of the project is expected to take approximately 8 – 12 months to complete.

1.3 Site Description

The site is located within the Bungarribee Precinct in the Western Sydney Parklands. The site covers an area of approximately 16.5 hectares (ha) and is located within the Local Government Area (LGA) of Blacktown City Council within Lot 101 of Deposited Plan (DP) 1195067. As part of the development, Sydney Zoo intends to subdivide the lot.

The proposed site boundaries have been negotiated with Western Sydney Parklands Trust (WSPT) and are shown in the below locality map.

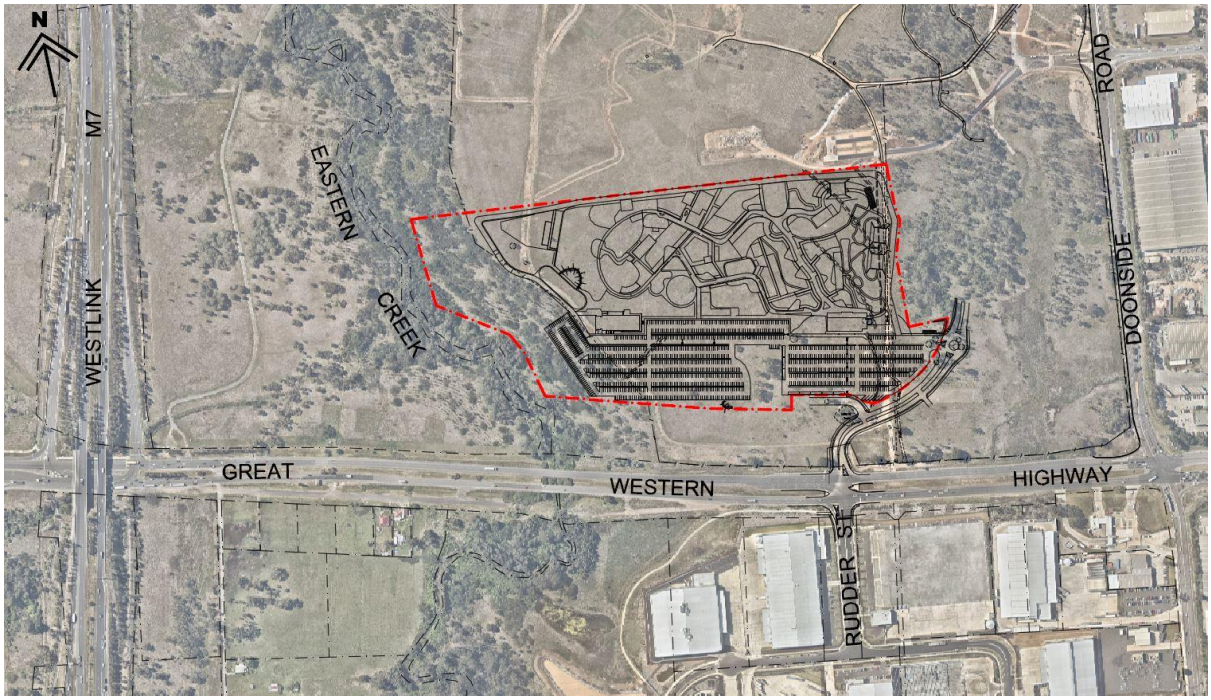

Figure 1 – Locality Map

Future access to the site will be via an extension of the north leg of the existing intersection of Great Western Highway and Rudders Street.

Topographically, the site encompasses the peak of a hill with gradual falls away from the peak in all directions. Typical existing grades across the site are in the range of 3-5%. The site generally comprises open grassy paddocks with patches of Cumberland Plain Woodland. Immediately to the west of the site boundary is Eastern Creek, including a corridor of Riverflat Eucalypt Forest (remnant and planted).

2. Blacktown City Council (BCC)

A detailed list of SEARs has been prepared by the NSW Department of Planning & Environment (DP&E). These were received in a letter issued by the DP&E dated 16 September 2015. This letter consolidates the review comments from several government authorities. On reviewing the SEARs relating to stormwater management, we consider that the requirements of Blacktown City Council (BCC), as nominated in their Development Control Plan (DCP) and associated guidelines, generally cover stormwater management points raised by the other authorities.

In this sense, the stormwater management plan adopted for the site has been designed primarily on the requirements of BCC.

2.1 BCC Engineering Guide for Development

The BCC Engineering Guide for Development 2005 was used to determine the Stormwater Quantity and Stormwater Quality requirements for the proposed zoo. In general, the guideline identifies the following requirements:

- Stormwater Drainage Design must be undertaken by an experienced designer and submitted in accordance with BCC's Drainage Design Manual – Appendix D and Onsite Detention General Guidelines – Appendix B, and

- BCC's requirements for Water Sensitive Urban Design (WSUD) may be obtained from BCC's DCP 2006 – Part R: Water Sensitive Urban Design and Integrated Water Cycle Management.

2.2 BCC Drainage Design Manual & Onsite Detention General Guidelines

The requirements from the Drainage Design Manual and the Onsite Detention General Guidelines have been summarised below:

- All minor drainage systems must be designed for an Average Recurrence Interval (ARI) of 20 years (Commercial),

- The major drainage system (100 year ARI) must have a safe "escape route" if the minor system fails,

- Rational Method Calculations will be suitable to determine flows using the approved deemed-to-comply methodology, however, due to the nature and scale of the development, a more rigorous software analysis has been undertaken for calculating site runoff using Drains.

- The maximum Permissible Site Discharge (PSD) must be limited to **101 L/sec/Ha** (based on 90% catchment) using the approved deemed-to-comply methodology, however, due to the

nature and scale of the development, a more rigorous software analysis has been undertaken for calculating PSD using Drains.

- The proposed development must provide a minimum Site Storage Requirement (SSR) of **301 m³/Ha** (based on 90% catchment) using the approved deemed-to-comply methodology, however, due to the nature and scale of the development, a more rigorous software analysis has been undertaken for calculating SSR using Drains.

2.3 BCC DCP 2006 - Part R: WSUD and Integrated Water Cycle Management

The Water Sensitive Urban Design (WSUD) requirements for the proposed development have been summarised below:

- The proposed development must meet the guidelines outlined within Sections 4.3, 4.4, 4.5 and 4.6.

- Section 4.3 – Water Conservation: the proposed development must supply 80% of their non-potable demand using non-potable sources, however, due to the nature and scale of the development and the corresponding demand on water, a reduced target has been proposed.

- Section 4.4 – Stormwater (water quality and waterway stability): WSUD must be utilised to achieve a minimum reduction of the post development average annual load of pollutants to achieve the following targets:

Pollutant	Reduction Target
Gross Pollutants	90 %
Total Suspended Solids	85 %
Total Phosphorous	65 %
Total Nitrogen	45 %
Total Hydrocarbons	90 %

Table 1 – Pollutant Reduction Targets

- Section 4.4 – Stormwater (water quality and waterway stability): A MUSIC model, prepared in accordance with Council's Developer Handbook for Water Sensitive Urban Design, must be submitted with any proposed developments that demonstrate the above reduction targets.

- Section 4.5 – Stormwater (detention): Designed in accordance with BCC's Engineering Guide for Development (see above),

- Section 4.6 – Stormwater (erosion, sediment and pollution controls): An Erosion and Sediment Control Plan must be prepared for the proposed development.

3 Stormwater Management Plan

3.1 Existing Site

The site encompasses the peak of a hill with gradual falls away from the peak in all directions. Typical existing grades across the site are in the range of 3-5%. The site generally comprises open grassy paddocks with patches of Cumberland Plain Woodland. Immediately to the west of the site boundary is Eastern Creek, including a corridor of Riverflat Eucalypt Forest (remnant and planted).

Runoff from the existing site has been modelled on these existing conditions. The hill peak has been accounted for in the modelling by separating the existing site into four quadrants: north-east (NE), south-east (SE), north-west (NW) and south-west (SW).

3.2 Proposed Development

Similar to the analysis of runoff from the existing site, the post-developed site has been designed utilising the four quadrants:

Area 1 – NW
Area 2 – SW
Area 3 – NE
Area 4 – SE

The areas of site associated with these four quadrants are shown below:

Figure 2 – Site Catchments

The boundaries between each quadrant are generally defined by the delineation between the carpark and the zoo in an east-west direction, and the alignment of the existing ridgeline in a north-south direction.

A brief description of the proposed development in each quadrant is provided below:

- Area 1 (NW)
  Development generally comprising the zoo, including exhibits, footpaths, public spaces, roads, buildings and open basins.
- Area 2 (SW)
  Development generally comprising the main carpark (in part) consisting of a sealed asphalt surface, overflow carpark consisting of an unsealed gravel surface and areas of existing Cumberland Plain Woodland to remain.
- Area 3 (NE)
  Development generally comprising the zoo, including exhibits, footpaths, public spaces, roads and buildings.
- Area 4 (SE)
  Development generally comprising the main carpark (in part) and site entry road, consisting of a sealed asphalt surface.

3.3 Stormwater Management Philosophy

The philosophy of stormwater management on the site for the proposed development can be summarised as follows:

- Runoff from the zoo catchments (Area 1 and Area 3) will be managed by breaking the vast zoo areas up into sub-catchments. Each sub-catchment incorporates grassy buffers/swales as primary treatment of stormwater pollutants. Sub-catchment runoff would then be directed to bioretention basins for secondary treatment. Treated water exiting the filtration media of the bioretention basins will be collected via a pit and pipe subsurface network and directed to the stormwater harvesting storage areas.

- Runoff from new roof catchments, all of which are located within the zoo, will be collected and diverted (via a first flush device) directly to the pit and pipe subsurface network connecting bioretention basins and onward to the stormwater harvesting storage areas.

- Runoff from the carpark catchments (Area 2 and Area 4) will be conveyed via sheetflow to various stormwater inlet pits fitted with a proprietary insert for primary treatment of stormwater pollutants. A pit and pipe network will collect the runoff and divert it to a proprietary gross pollutant trap (GPT) for secondary treatment before it is directed to the stormwater harvesting storage areas.

- Harvested stormwater will be generally collected at two locations; a large open water Storage Basin at the western end of the zoo, and a small underground Storage Chamber in the north-east corner of the zoo. Refer to Figure 2 for these locations.

- Harvested stormwater will be pumped on demand from both locations to a Holding Basin adjacent the restaurant building (refer to Figure 2 for location). Stormwater re-use demands for the site (irrigation, top up of wet moats, greywater for toilet flushing and hose down areas) will be drawn via a pump from the Holding Basin. Greywater demand and moat top up will receive additional treatment via proprietary mechanical filtration and UV disinfection prior to reticulation through the site.

- The stormwater pit and pipe system will cater for the minor runoff events (for storms up to and including a 1 in 20 year ARI). In the event that the stormwater harvesting storage volumes are full, runoff will be re-directed to onsite detention (OSD) storages, located at three locations around the site.

- OSD Storage 1, in the form of a large open basin, is the primary OSD facility for the site detaining runoff from Area 1 and Area 2. OSD Storage 2 detains runoff from Area 3 and OSD Storage 3 from Area 4, both of which will consist of a combination of below ground and above ground storage. Refer to Figure 2 for these locations.

- Runoff from major rainfall events will be conveyed to the OSD storages via overland flow paths, located in areas so as not to present a safety hazard to zoo visitors and animals.

- Points of stormwater discharge for the site are generally located close to the OSD storages. OSD Storage 1 will discharge to the west via multiple low level piped culverts to help disperse the flow to the natural ground surface uphill from the alignment of Eastern Creek. OSD Storage 2 will discharge via a piped culvert to a proposed easement to the east. OSD Storage 3 will discharge via a piped connection to the stormwater pit and pipe network for the new access road to the east of the site boundary.

The proposed features associated with stormwater management for the site shown in more detail in Lindsay Dynan drawings 12082-DA06-DA09.

3.4 Stormwater Harvesting

In accordance with BCC DCP 2006 - Part R: WSUD and Integrated Water Cycle Management Section 4.3 – Water Conservation, the proposed development must supply 80% of its non-potable demand using non-potable sources. Due to the nature and scale of the development and the corresponding demand on non-potable water, it was considered that achieving the 80% target may require an unreasonable amount of harvesting storage. As such an investigation was carried out to determine if an optimal re-use efficiency was apparent when considering the specific rainfall and re-use demands for the site and the proposed development.

A water balance modelling of stormwater re-use has been carried out using the software package MUSIC (Model for Urban Stormwater Improvement Conceptualisation). The rainfall data used within the water balance was obtained from the Bureau of Meteorology and consisted of over 45 years of daily rainfall from the Quakers Hill Treatment Works (6.0km away from the site).

Information relating to the intended usage for the proposed development when operational has been provided by the client and has been summarised below:

Activity	Usage	Usage (L/day)
Irrigation (Tropical)	22.7 L/m^2/week	11,850
Irrigation (Turf)	22.7 L/m^2/week	17,300
Toilet Usage	100 L/day/toilet	5,300
Back of House Hose Down	5mm/ m^2/day	5,750
Basin/Moat Evaporation	1500mm/year/m^2	17,150

Table 2 – Stormwater Re-use Demands

The water balance was analysed over the last 45 years and a Storage Volume v Re-Use Efficiency graph was developed:

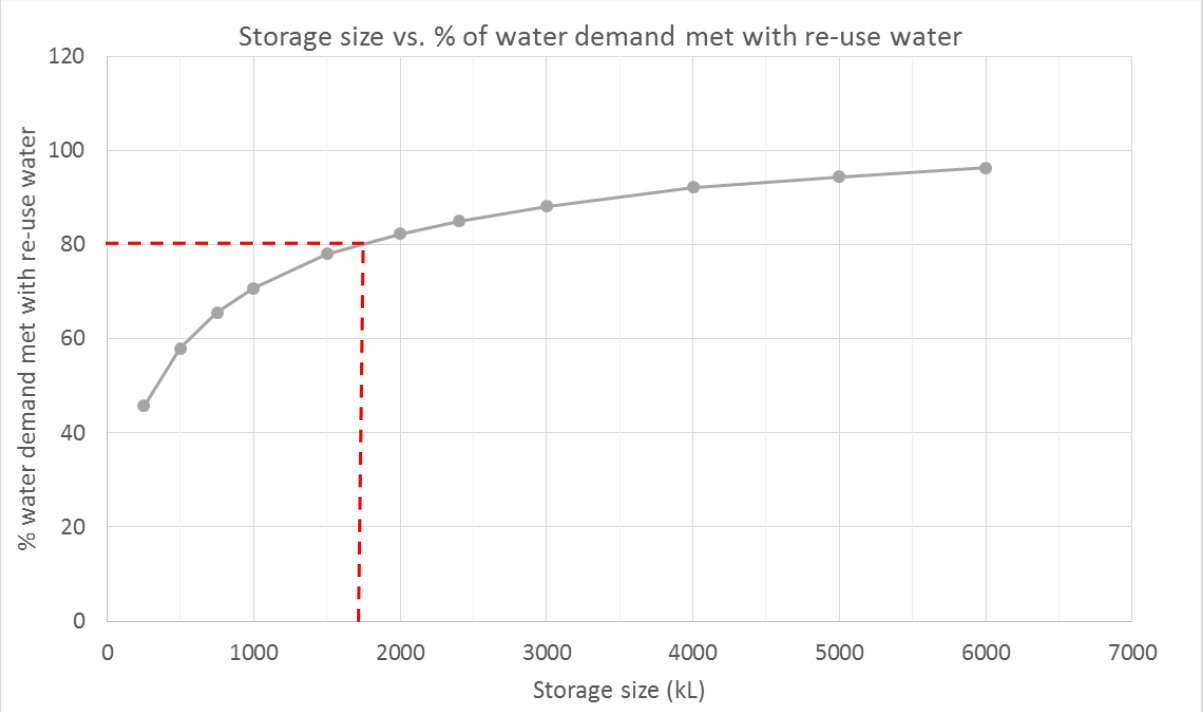

Figure 3 – Re-Use Efficiency Curve

A review of Figure 3 suggests that the target set by BCC of 80% appears to be a reasonable target with regard to the point of diminishing return for the specifics of this site. It is considered that adopting a total stormwater harvesting storage volume of 1,750m^3 (approximately 81.5% re-use efficiency) for the development will provide an efficient result for the project that meets the water conservation intent that has been established by BCC.

In addition to the volume above, BCC requires a further allowance of 20% of the live volume to account for sediment build up and minimum pump levels. This has been provided as part of this design.

The storage volumes for stormwater re-use will primarily be created via two open water basins. The largest of these has been designated the Storage Basin, located in Area 1, which will generally be fed from the Area 1 and Area 2 catchments. The smaller of the two basins has been designated the Holding Basin, located next to the restaurant in Area 3. The Holding Basin accepts pumped water from the Storage Basin (west) and Storage Chamber (east).

The Storage Basin and Holding Basin have been modelled as a 3D surface to confirm their capacity. The results achieved are as follows:

Location	Live Volume (m^3)	20% Settlement Zone (m^3)	Total (m^3)
Storage Basin	1,050	210	1,260
Holding Basin	700	140	840
COMBINED	1,750	350	2,100

Table 3 – Harvesting Storage Volumes

The Storage Chamber (refer to Figure 2 for location) will be a relatively small temporary storage for runoff from Area 3 and Area 4 catchments. A float switch in the chamber will systematically transfer this runoff directly to the Holding Pond. Due to the small size of this element, its volume has not been included in the total design storage for the site.

The location and arrangement of all the above features are presented in more detail in Lindsay Dynan drawings 12082-DA06/7.

3.5 Stormwater Quality

In accordance with BCC's DCP 2006 - Part R: WSUD and Integrated Water Cycle Management, WSUD must be utilised to achieve a minimum reduction of the post development average annual load of pollutants to achieve the targets contained in Table 1. The stormwater quality for the proposed development was assessed using MUSIC software.

The MUSIC model was developed using BCC's Developer Handbook for WSUD, with rainfall data and Catchment Nodes provided in a Blacktown Council MUSIC file provided by BCC. Default parameters for Treatment Nodes were also specifically modified to suit the requirements of the Handbook.

It should be noted that, in lieu of BCC having a particular 'Agricultural' node, consideration was given to using the MUSIC default parameters for 'Agricultural' source nodes. However it was determined that there were no discernible differences between the default MUSIC 'Agricultural' source node and the BCC 'Residential' nodes, the reason being that BCC approved nodes are generally set with higher pollutant nodes than the MUSIC defaults. As a result, the BCC 'Residential' nodes were adopted.

A model was developed to simulate the conditions which would be expected once the site is fully developed. The model generally covers the following:

- Runoff from the zoo sub-catchments (Area 1 and Area 3) is treated by primary grassy buffers/swales (generally located outside of exhibits that will house potentially dangerous animals) before being directed to secondary bioretention basins which have been sized to generally be 2% of their respective subcatchment area,

- Runoff from new roof catchments, all of which are located within the zoo, will be collected and diverted (via a first flush device) directly to the pit and pipe subsurface network, and
- Runoff from the carpark sub-catchments (Area 2 and Area 4) will be treated by primary proprietary pit insert before being directed to a secondary proprietary gross pollutant trap (GPT) and cartridge filters.

The MUSIC model layout schematic can be seen below:

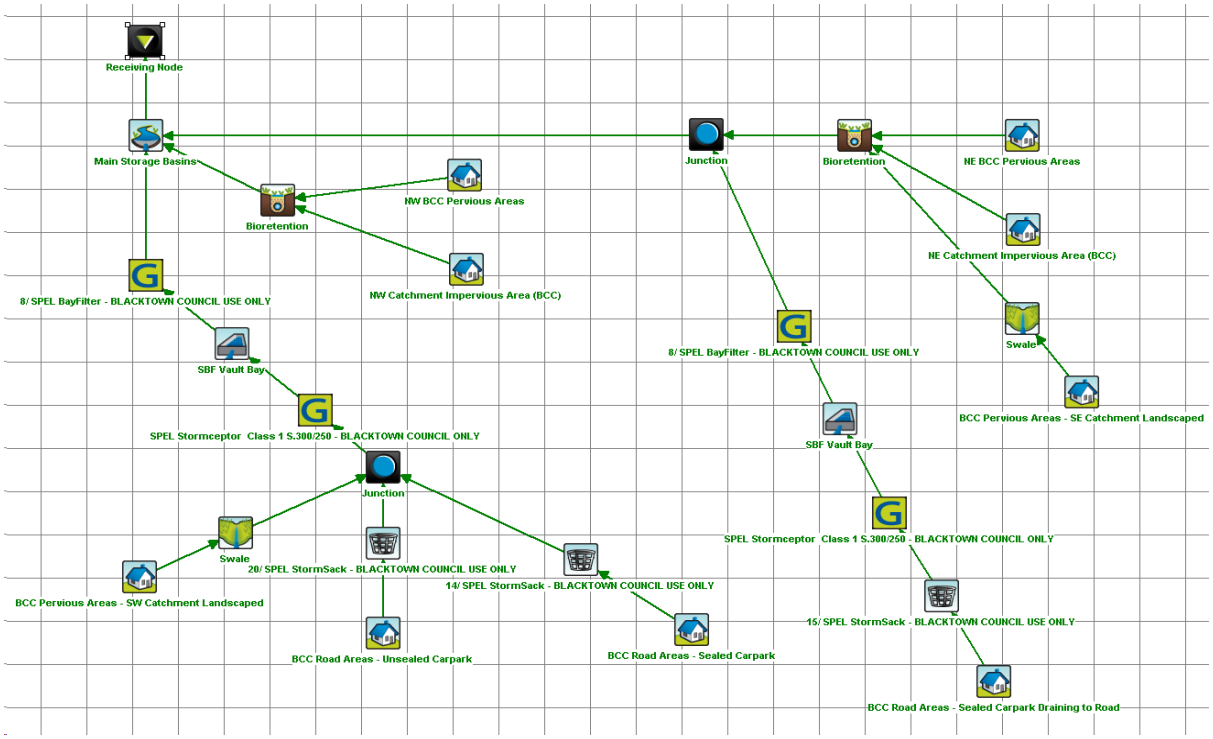

Figure 4 – MUSIC Layout Schematic

The developed MUSIC model for the site was run based on the input parameters identified above. The following table provides a summary of the pollutant runoff generated from the developed catchments and the effectiveness of the proposed treatment:

Pollutant	Sourced	Residual	Reduction	BCC Requirements
	kg/yr	kg/yr	%	%
Total Suspended Solids	33,600	3,750	88.8	85
Total Phosphorus	24.3	5.39	77.8	65
Total Nitrogen	141.0	38.9	72.5	45
Gross Pollutants	1,310	0	100	90

Table 4 – Pollution Reduction Results

Based on the above MUSIC modelling results, it has been demonstrated that the treatment train as identified in this report, and the attached model, meets and exceeds BCC's stormwater pollutant treatment targets.

In fact, the results indicate that the proposed treatment train will deliver a pollutant removal efficiency far greater than the set targets. The design approach has been to provide a high degree of stormwater runoff treatment, in order to minimise final media filter and UV treatment of the stored stormwater prior reticulation for the site. Further, the site is relatively open and highly suited to implementation of bioretention basins, so they have been adopted throughout.

The MUSIC model has been provided as a .sqz file as part of the DA submission.

3.6 Onsite Detention (OSD)

OSD storages will be located at three locations around the site. OSD Storage 1, in the form of a large open basin, is the primary OSD facility for the site detaining runoff from Area 1 and Area 2. OSD Storage 2 detains runoff from Area 3 and OSD Storage 3 from Area 4, both of which will consist of a combination of below ground and above ground storage. The location and details of these storages are shown in Lindsay Dynan drawings 12082-DA06-DA09.

Appendix B of BCC's Engineering Guide for Development defines the design approach for the deemed-to-comply calculation of OSD (including PSD and SSR) however, due to the nature and scale of the development, a more rigorous software analysis has been undertaken for calculating OSD using Drains.

The following tables provide a summary of the geometric features of each storage as well as the peak rainfall runoff rates for a range of design storm ARI's associated with their contributing catchments. Runoff rates have been calculated for both the pre-developed and post-developed site to demonstrate that the detention is effectively attenuating peak flows to pre-developed levels.

OSD Storage 1 – Area 1 and Area 2

Contributing Catchment	104,100m^2
Percentage Impervious	56.7%
Proposed Storage Volume	2,930m^3
Proposed Outlet	4/DIA225 piped culverts

ARI	Pre-Developed Peak Discharge (m^3/s)	Post-Developed Peak Discharge (m^3/s)
1	0	0.31
2	0.11	0.35
5	0.46	0.41
10	0.99	0.46
20	1.31	0.78
50	2.10	1.46
100	2.43	1.87

Table 5 – Pre-Dev and Post-Dev Peak Site Discharge (OSD Storage 1)

OSD Storage 2 – Area 3

Contributing Catchment	26,770m^2
Percentage Impervious	45.3%
Proposed Storage Volume	800m^3
Proposed Outlet	1/DIA225 piped culvert

ARI	Pre-Developed Peak Discharge (m^3/s)	Post-Developed Peak Discharge (m^3/s)
1	0	0.11
2	0.05	0.13
5	0.18	0.18
10	0.39	0.20
20	0.50	0.22
50	0.77	0.24
100	0.90	0.42

Table 6 – Pre-Dev and Post-Dev Peak Site Discharge (OSD Storage 2)

OSD Storage 3 – Area 4

Contributing Catchment	8,680m^2
Percentage Impervious	83.4%
Proposed Storage Volume	210m^3
Proposed Outlet	1/DIA225 piped culvert

ARI	Pre-Developed Peak Discharge (m^3/s)	Post-Developed Peak Discharge (m^3/s)
1	0	0.06
2	0.02	0.07
5	0.07	0.07
10	0.15	0.08
20	0.19	0.08
50	0.29	0.23
100	0.34	0.34

Table 7 – Pre-Dev and Post-Dev Peak Site Discharge (OSD Storage 3)

Based on the above Drains modelling results, it has been demonstrated that the OSD facilities adequately reduce peak site discharges to pre-developed rates for all design storms, except for the low intensity rainfall events for the 1 and 2 year ARI. The results obtained for the pre-developed peak site discharge for the 1 and 2 year ARI storms is considered to be unrealistically low, likely due to the adoption of BCC's requirement for antecedent moisture content (AMC) of 2.5 in the Drains modelling.

The AMC is a measure of the pre-storm soil moisture and a value of 2.5 could be considered conservative, with 3 being typical. The natural soils on the site are highly reactive clays which would unlikely warrant an AMC of 2.5. A more appropriate value would be 3-3.5. To assess the sensitivity of the results for the 1 and 2 year ARI, the model was re-run for these storms with the AMC changed to 3. The results are presented below:

ARI	Pre-Developed Peak Discharge (m^3/s)	Post-Developed Peak Discharge (m^3/s)
OSD Storage 1		
1	0.12	0.32
2	0.38	0.37
OSD Storage 2		
1	0.05	0.13
2	0.16	0.16
OSD Storage 3		
1	0.02	0.06
2	0.06	0.07

Table 8 – 1 and 2 Year ARI Pre-Dev and Post-Dev Peak Site Discharge (AMC 3)

The sensitivity analysis results highlight the effect of AMC on the peak site discharge, particularly for the pre-developed case. The 1 year ARI post-developed results are still higher than the pre-developed discharge, however, it should be noted that the Drains analysis conservatively assumes that the stormwater harvesting storage volumes incorporated into the design are completely full at the start of the design storm. In reality it is likely that a percentage of this storage volume will be available to offset the peak post-developed runoff, particularly for the 1 year ARI event.

Whist not specifically meeting the deemed-to-comply requirements of BCC in terms of their PSD and SSD approach, the design using Drains analysis that has been adopted for the OSD is industry standard and considered to be appropriate for application in this situation.

The Drains model has been provided as a .drn file as part of the DA submission.

3.7 Points of Discharge

The points of stormwater discharge from the proposed development have been distributed around the site to mimic the pre-developed site runoff. Any stormwater discharges from the site will meet the BCC requirements for water quality and water quantity as outlined above.

Points of stormwater discharge for the site are generally located close to the OSD storages:

- OSD Storage 1 will discharge to the west via multiple low level piped culverts to help disperse the flow to the natural ground surface uphill from the alignment of Eastern Creek. Erosion controlling rock mattresses provided at each of the outlet locations will stabilise the outlet and facilitate dispersion of concentrated flows in a manner that ensures no adverse impacts
- OSD Storage 2 will discharge via a piped culvert to a proposed easement to the east. Due to the nature of the development, and its interaction with proposed neighbouring development occurring simultaneously, the details of this proposed easement are not confirmed at this stage. The easement would drain water, either below or above ground, to the existing wetlands to the east.
- OSD Storage 3 will discharge via a piped connection to the stormwater pit and pipe network for the new access road to the east of the site boundary. Due to the nature of the development, and its interaction with proposed infrastructure design occurring simultaneously, the details of this proposed road connection are not confirmed at this stage.

4 Flooding

4.1 1 in 100 Year ARI Event

Flooding information for the site has been provided by BCC and has been translated onto the stormwater plans. This information shows that the 1 in 100 year ARI flood event impacts the western portion of the site as defined by the formal lease boundaries. The extent of proposed development works have been purposefully limited to the line of the 1 in 100 year ARI flood. This is demonstrated in Lindsay Dynan drawings 12082-DA06 and 12082-DA08. BCC require that all building finished floor levels are set with a minimum freeboard of 0.5m to the 1 in 100 year flood extents and we confirm that this has been achieved.

4.2 Probable Maximum Flood (PMF) Event

Flooding information for the PMF event has also been provided by BCC and translated onto the stormwater plans. Designing to avoid development within the PMF flood extents is generally not a consideration in NSW. Nonetheless, an opportunity was identified whereby buildings and back of house areas could be located such that they were above the PMF level. This has been adopted.

5 Civil Works

5.1 Sediment and Erosion Control

The proposed development will require large areas of land disturbance. It is recognised that construction works for the development will need to be managed in parallel with an effective Sediment and Erosion Control Plan (SECP). In accordance with the guidelines specified by the NSW Department of Environment & Heritage, the two reference guidelines in developing the SECP are:

- Managing Urban Stormwater Soils and Construction, Volume 1, 4th Edition, 2004 (the Blue Book), and
- Managing Urban Stormwater Soils and Construction Volume 2A Installation of Services.

At this point in time there is no information available regarding the likely construction sequencing or staging for the development. However, it is recognised that the natural topography of the site will require erosion control measures to be implemented in various locations of the site. For the purposes of assessment at the DA stage, sediment and erosion controls have been designed assuming the site is being developed in full in one stage. A more likely scenario will be that a contractor will establish controls for smaller portions of the development and augment/remove these controls in accordance with their prior approvals.

Similar to the breakup of the site for assessing OSD requirements (Section 3.6), sediment and erosion controls have been designed to consolidate Area 1 and Area 2 catchments and direct them to a sedimentation basin. This basin has been designated Sedimentation Basin 1 and its location and size are shown indicatively in Lindsay Dynan drawing 12082-DA02. Similarly, Sedimentation Basin 2 is proposed to service runoff from Area 3 and Sedimentation Basin 3 from Area 4 with details also shown on Lindsay Dynan drawing 12082-DA02.

Calculations in accordance with the above guidelines have been undertaken using the following key parameters:

Volumetric Runoff Coefficient (C_v)	0.25
Rainfall Depth (R)	19.4mm
RUSLE R-Factor	2500
RUSLE K-Factor	0.038
RUSLE P-Factor	1.3
RUSLE C-Factor	1.0

The resulting sedimentation basin volumes, comprising the settling zone and sediment storage zone, have been calculated to be:

Sedimentation Basin 1	775 m^3
Sedimentation Basin 2	148 m^3
Sedimentation Basin 3	54 m^3

The proposed SECP also incorporates a perimeter silt fence and stabilised site access for construction vehicles.

5.2 Bulk Earthworks

The general intent of the civil design for the site was to maintain the existing topography and work with existing levels where possible. Features in the design that have required notable earthworks include:

- Excavations for the wet/dry moats and pools within specific enclosures,
- Filling required for the creation of the raised service road around the north western perimeter, which also acts to create the basins for OSD and stormwater harvesting,
- Filling required for the creation of the raised service road around the north eastern perimeter, which also acts to create the basins for OSD, and
- Filling required for the overflow carpark to create finished surface levels that are compliant with AS2890 – Car Parking Facilities.

Areas and depths associated with bulk earthworks for the proposed development have been shown visually in Lindsay Dynan drawing 12082-DA05. This colour map generally does not show any works for the main carpark and vast areas within the zoo. This is consistent with areas that will generally be constructed to match existing grades. It is recognised that minor grading in these areas will need to occur to create desired fall to stormwater pits, walkway grades, etc however this level of detail has not been considered in the bulk earthworks analysis at DA stage. The results of the bulk earthworks analysis are summarised on Lindsay Dynan drawing 12082-DA05 and are also provided below:

- Excavations for moats, ponds and bioretention basins = approx. 12,700m^3 CUT
- Net earthworks for north west service road and basins = approx. 8,500m^3 FILL
- Net earthworks for north east service road and basins = approx. 2,500m^3 FILL
- Net earthworks for overflow carpark = approx. 15,500m^3 FILL
- TOTAL NET BULK EARTHWORKS = approx. 13,600m^3 FILL

It can be seen in the above results that a large quantity of fill will be required to be imported to the site. This is an intentional approach in the design of finished site levels as it is expected the fill will be obtained at an economy much better than if site regrading adopted a typical cut/fill balance approach. This expected access to inexpensive clean fill is due to the large infrastructure works that will be occurring in the Sydney metropolitan area during the expected time of construction of the zoo.

5.3 Wet/Dry Moats

The layout of the zoo incorporates wet and dry moats that act as a physical barrier between exhibits and public viewing areas. The size and location of the moats is very specific to the animals contained in the respective exhibit. The intent of the stormwater management for the site is to keep the moats in isolation, ie to avoid surface runoff from any areas of the site getting into the moats due to the very specific clearances required and the need to have a reliable top water level profile.

In this light, the hydraulic design of the moats is intended to be developed with specialist input as part of the detailed design of each enclosure. Notwithstanding, a conceptual arrangement of the various closed loop systems for the moats has been developed and is presented in Lindsay Dynan drawing 12082-DA13.

Should you require any further advice or clarification of any of the above, please do not hesitate to contact us.

Yours faithfully
LINDSAY DYNAN
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