5. CONCLUSIONS

The following conclusions can be drawn from the site water balance investigations:

- The water balance modelling framework used provides a simulation for planning level assessment of the variance in water cycle behaviour over time for each of the three elements of the water cycle:
  - Water demands;
  - Wastewater flows; and
  - Stormwater flows.
- The modelling results indicate:
  - There was some disagreement between the WATHNET and PURRS models in the volume of water saved with the use of rainwater tanks. This was most likely the result of the shorter six minute time step utilised by PURRS;
  - The range of water cycle management measures to be employed in the Googong New Town results in a reduction in demand of approximately 60% for the case where rainwater tanks are adopted;
  - At full development, the recycled water system uses between 62 and 65% of the wastewater generated in the new town for the case where rainwater tanks are adopted;
  - Eliminating the use of rainwater tanks as a substitute for some water uses, in preference to the use of recycled water, increases the volume of wastewater recycled in the new town to 80% at the same time as decreasing the reduction in water demand to approximately 55%.
  - Other options for further reducing the volume of potable water use on site including using rainwater in hot water systems, utilising stormwater ponds on site for storing recycled water and harvesting stormwater increases the volume of water saved to between 61% and 68%.
- The results clearly show that there are trade-offs in the management of the water cycle on the site. The use of rainwater tanks:
  - Reduces stormwater discharges;
  - Increases recycled water system discharges; and
  - Increases the total volume of potable water saved in the new community.
- Comparisons between the MUSIC modelled cases indicate that the proposed WSUD measures are effective in reducing annual pollutant loads. Compared to the existing development case, the water quality modelling results also indicate a reduction in annual suspended solids and gross pollutant loads, and an increase in nutrient loads and annual flows. Initial assessment of theoretical nutrient dilution, indicates similar nutrient concentrations to existing development.

6. REFERENCES

AGSOL 2009, Googong Water Cycle Management, Water Salt and Nutrient Balance Analysis

Anderson, J.M., Ruge, T.J. (1994), *Effluent Re-use: Land and Wet Weather Storage Requirements*, Urban Water Research Association of Australia, Research Report No. 80, July 1994.

Coombes, P.J., (2006). *On-Site Water Balance Modeling using PURRS (Probabilistic Urban Rainwater and wastewater Reuse Simulator) User Guide.* Urban Water Cycle Solutions

MWH 2004, *Googong New Community Integrated Water Cycle Management Report*

MWH 2006, *Googong New Community - Impact of Storage on Recycled Water System Reliability*

MWH 2007, *Googong New Community – Design Standards of Service for Potable and Recycled Water Systems*

MWH 2009a, *Daily Water and Wastewater Trend Tracking Version 12.0 User Manual.*

MWH 2009b, *Googong Integrated Water Cycle Management Strategy, Water and Wastewater Concept Design*.

APPENDIX A

DAILY DEMAND FLUCTUATIONS

Daily water demand fluctuations have been generated using a daily water demand regression equation derived on the basis of correlating daily fluctuations in demands from the ACT water supply system with climate factors using the MWH WaterTrac model (MWH 2009).

The regression equation takes the following form:

$$P_t = \beta_0 + \beta_1 f_1(v_{1,t}) + \beta_2 f_2(v_{2,t}) + \ldots\ldots + \beta_n f_n(v_{n,t})$$

Where: P_t = the observed per capita water demand at time step t;

β_0 to β_n are regression model coefficients

$f_n(v_{n,t}) = v_{n,t}$ if linear; or

$$f_n(v_n) = \tan^{-1}\left(\left(v_{n,t} - \frac{(v_{U,n} + v_{L,n})}{2}\right) \times \left(\frac{\pi}{v_{U,n} - v_{L,n}}\right)\right) \quad \text{if non-linear}$$

Where: $v_{U,n}$ and $v_{L,n}$ are upper and lower shape constants for the transformation of variable n

$v_{1,t}$ to $v_{n,t}$ are independent variables at time step t

The regression equation parameters for the ACT water supply system are set out in Table 6-1.

Table 6-1: Daily Demand Regression Equation Parameters

PARAMETER	COEFFICIENT	UPPER SHAPE CONSTANT (V_U)	LOWER SHAPE CONSTANT (V_L)
Intercept	2400.00	NA	NA
Soil Moisture Index	-1974.13	327.776	-247.216
Maximum temperature	436.94	44.992	16.855
Rainfall	-21.19	0.379	-0.162
Evaporation	356.41	18.815	-0.348

The soil moisture index uses the following equation:

$$S_t = SMI_{t-1} + M_R \times R_t - M_E \times E_t^P \times \frac{SMI_{t-1}}{100}$$

$$SMI_t = 0 \quad \text{if } \mathrm{S_t} < 0$$

$$SMI_t = 100 \quad \text{if } \mathrm{S_t} > 100$$

$$SMI_t = \mathrm{S_t} \quad otherwise$$

Where SMI_t = Soil moisture index at time t

R_t = Rainfall at time t

E_t = Evaporation at time t

M_R = Rainfall multiplier

M_E = Evaporation multiplier

P = Evaporation power

The soil moisture index parameters derived during the calibration of the model are shown in Table 6-2.

Table 6-2: Soil Moisture Index Parameters

PARAMETER	VALUE
Rainfall multiplier	3.90
Evaporation multiplier	0.34
Evaporation power	2.32

External water demands (typically irrigation and water cooling uses) are generated by scaling the regression equation and adding a random demand component:

$$D_{e,t} = D_{e,av}\left(\frac{P_t - P_{\min}}{P_{av}} + R_{e,t}\right)$$

Where: $D_{e,t}$ = external demand on day t

$D_{e,av}$ = average daily external demand

P_t = per capita demand prediction on day t

P_{min} = minimum per capita demand prediction

$P_{av} = \frac{\sum_{t=1}^{n} P_t - P_{\min}}{n}$, the average deviation above the minimum P_t

$R_{e,t}$ = random external demand component on day t

$$D_{i,t} = D_{i,av} + R_{i,t}$$

Where: Di,t= internal demand on day t

$D_{i,av}$= average internal daily demand

$R_{i,t}$= random internal demand component on day t

APPENDIX B

WATHNET MODELLING

This Appendix provides details of the modelling of the urban water balance using WATHNET. The schematic of the model is shown in Figure 6 with the description of each model component provided in Table 3.

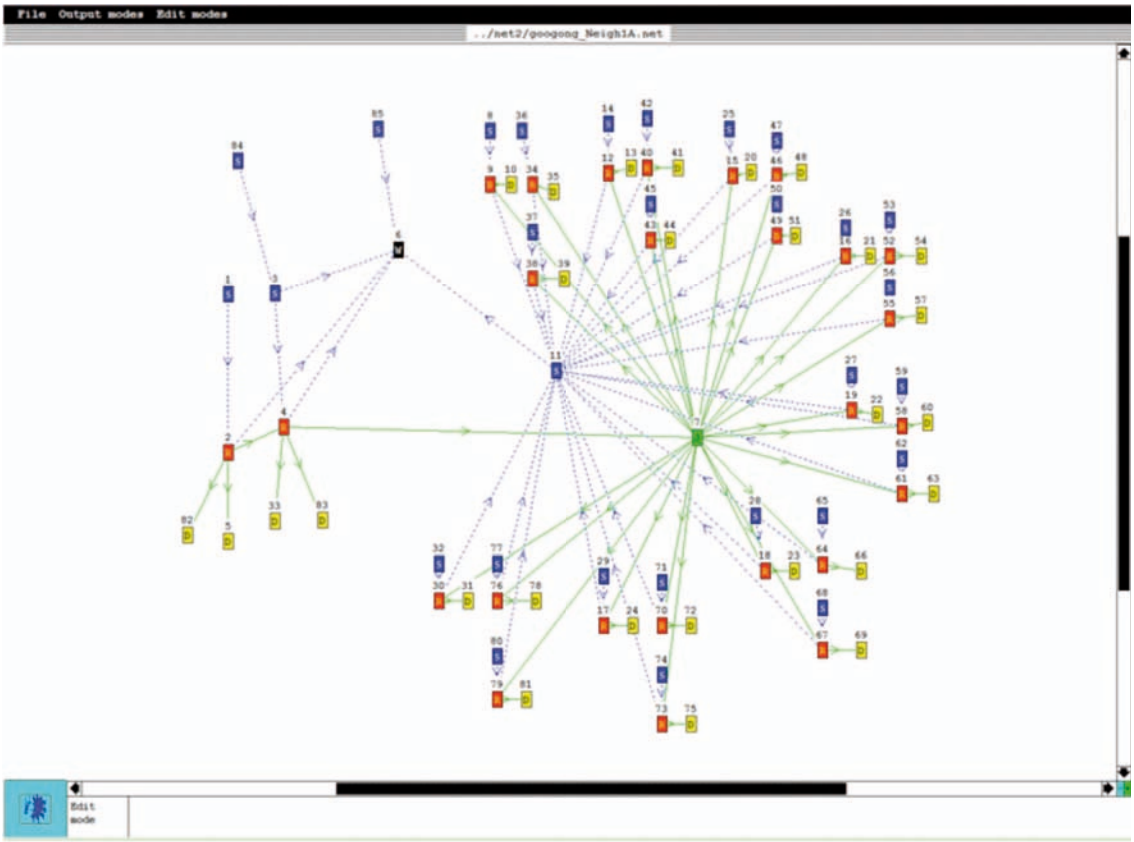

Figure 6: Schematic Layout of the WATHNET Model

Table 3: Description of Components of WATHNET Model

Nodes & Links	Description	Capacity	Comment
1-2	Potable water supply	unlimited	Unlimited for modelling purposes.
2	Potable water reservoir	35,000 kL	Nominal value only to allow unrestricted supply of potable water to development
2-6	Potable water reservoir overflow	unlimited	All unused potable inflows directed to waste for modelling purposes
2-5	Potable water demand	variable	Potable demand for both residential and non-residential customers
2-82	Potable water system losses	10%	10% of total potable demand

Nodes & Links	Description	Capacity	Comment
2-4	Potable water top-up to recycled water system	unlimited	Cost penalty of 70 included to ensure recycled water used in priority to potable water.
84-3	Inflows to water recycling plant	variable	Based on the Anderson Ruge Equation
3-4	Outflows from water recycling plant	3.5 x DWF	Capacity of water recycling plant limited to 3.5 times dry weather inflows
3-6	Water recycling plant bypass flow	unlimited	All flows above capacity of water recycling plant (3.5 times dry weather inflows)
4	Recycled water reservoir	0 kL	No recycled water is stored
4-6	Recycled water overflow	unlimited	All unused treated recycled water inflows directed to 'waste'
4-33	Direct recycled water demand	variable	Direct recycled water demand for both residential and non-residential customers
4-83	Direct recycled water system losses	10%	10% of total direct recycled water demand
4-7	Total recycled water top-up to rainwater tanks	unlimited	Cost penalty of 10 included to ensure rainwater used in priority to recycled water
9 / 10	Rainwater tank (reservoir) / rainwater tank demand	172 kL/ variable	Total rainwater tank volume and rainwater tank demands for Apartments, low elevation
34/35	Rainwater tank (reservoir) / rainwater tank demand	86 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Apartments, medium elevation
38/39	Rainwater tank (reservoir) / rainwater tank demand	25 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Apartments, high elevation
12/13	Rainwater tank (reservoir) / rainwater tank demand	193 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Town House, low elevation
40/41	Rainwater tank (reservoir) / rainwater tank demand	180 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Town House, medium elevation
43/44	Rainwater tank (reservoir) / rainwater tank demand	104 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Town House, high elevation
15/20	Rainwater tank (reservoir) / rainwater tank demand	814 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Duplex Small, low elevation
46/48	Rainwater tank (reservoir) / rainwater tank demand	679 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Duplex Small, medium elevation

Nodes & Links	Description	Capacity	Comment
49/51	Rainwater tank (reservoir) / rainwater tank demand	211 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Duplex Small, high elevation
16/21	Rainwater tank (reservoir) / rainwater tank demand	2192 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Duplex Large, low elevation
52/54	Rainwater tank (reservoir) / rainwater tank demand	1830 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Duplex Large, medium elevation
55/57	Rainwater tank (reservoir) / rainwater tank demand	568 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Duplex Large, high elevation
19/22	Rainwater tank (reservoir) / rainwater tank demand	4375 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Single Lot, low elevation
58/60	Rainwater tank (reservoir) / rainwater tank demand	3653 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Single Lot, medium elevation
61/63	Rainwater tank (reservoir) / rainwater tank demand	1134 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Single Lot, high elevation
18/23	Rainwater tank (reservoir) / rainwater tank demand	3906 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Single Lot Large, low elevation
64/66	Rainwater tank (reservoir) / rainwater tank demand	3261 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Single Lot Large, medium elevation
67/69	Rainwater tank (reservoir) / rainwater tank demand	1012 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Single Lot Large, high elevation
17/24	Rainwater tank (reservoir) / rainwater tank demand	2013 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Estate, low elevation
70/72	Rainwater tank (reservoir) / rainwater tank demand	1680 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Estate, medium elevation
73/75	Rainwater tank (reservoir) / rainwater tank demand	522 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Estate, high elevation
30/31	Rainwater tank (reservoir) / rainwater tank demand	554 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Rural, low elevation
76/78	Rainwater tank (reservoir) / rainwater tank demand	462 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Rural, medium elevation
79/81	Rainwater tank (reservoir) / rainwater tank demand	144 kL/ variable	Total rainwater tank volumes and rainwater tank demands for Rural, high elevation

Nodes & Links	Description	Capacity	Comment
85-6	Total rainwater tank overflows	unlimited	Dummy inflow to waste equal to total of inflows to all rainwater tanks (Sum of inflow to nodes 8, 36, 37, 14, 42, 45, 25, 47, 50, 26, 53, 56, 27, 59, 62, 28, 65, 68, 29, 71, 74, 32, 77, 80)

APPENDIX C

WATER RESTRICTIONS POLICIES WITH RESPECT TO RECYCLED WATER AND RAINWATER

Table 4: Overview of Australian Water Restrictions Policies with Respect to Recycled Water and Rainwater Use

Authority	Policy	Source
Sydney Olympic Park	Water management at Sydney Olympic Park will be fully compliant with conditions imposed by Sydney Water and will also showcase the benefits of recycled water. The mandatory water restrictions do not apply to the use of recycled water supplied by the Authority's Water Reclamation and Management Scheme (WRAMS) or water sourced via rainwater collection systems at the Park. The main water features at Sydney Olympic Park (Fig Grove, Cauldron, Northern Water Feature and Misting Masts at Holker Street) operate on recycled water and are signed in accordance with NSW Health approvals to indicate the use of recycled water. Operating times for these water features have been significantly reduced to conserve water. Water features still connected to drinking water supplies will not be operated until they are reconfigured to operate using recycled water.	http://www.sydneyolympicpark.com.au/education_and_learning/environment/water/water_restrictions
Sydney Water	Exclusions: Recycled water, bore water and water used for testing fire systems, fire fighting and related activities are exempt from the Water Wise Rules. Water from rainwater tanks is also exempt if it is not topped up from Sydney Water's supply.	http://www.sydneywater.com.au/SavingWater/WaterWise/
Sydney Water	Water Wise Rules do not apply to recycled water. Recycled water can be used when Water Wise Rules or drought restrictions apply to the drinking water supply. Water Wise Rules have replaced drought restrictions. These are simple, common sense actions for using drinking water responsibly. Recycled water, like drinking water, is a precious resource that should not be wasted. Recycled water should be used wisely, as over watering (with either recycled or drinking water) can damage the soil and be harmful to plants.	http://www.sydneywater.com.au/Publications/FactSheets/RecycledWaterFAQ.pdf
Sydney Water	If a rainwater tank is not topped up by drinking water from the Sydney Water supply, mandatory restrictions do not apply. If a rainwater tank is topped up by drinking water from the Sydney Water supply, mandatory water restrictions still apply.	http://www.sydneywater.com.au/Publications/FactSheets/RainwaterTanksQAs.pdf#Page=1

Authority	Policy	Source
ACTEW	Stage 4 Restrictions: • Lawns/parks: External watering of lawns and plants only permitted using non-potable water; • Public ponds and fountains: Ponds must not be filled or topped up with any water; • No fountains may be operated or filled or topped up with any water; and • Can access recycled water at Lower Molongolo Water Pollution Control Plant.	http://www.actew.com.au/publications/TemporaryWaterRestrictionsScheme.pdf
ACTEW	Since the introduction of Stage 3 Water Restrictions, ACTEW has made available recycled water from the Lower Molonglo Water Quality Control Centre. The initiative aims to provide assistance to commercial activities and for maintaining public areas.	http://www.actew.com.au/SaveWaterForLife/AlternativeWaterSources/accessing_recycled_water.aspx#Accessing_recycled_water
ACTEW	No water restrictions apply to the use of rainwater and greywater. Water restrictions only apply to the use potable (water from the ACTEW mains).	http://www.actew.com.au/SaveWaterForLife/WaterRestrictions/faqs.aspx#9
Queanbeyan City Council	See ACTEW	http://www.qcc.nsw.gov.au/page.aspx?page=65
Yarra Valley	Greywater and Class A recycled water can be used freely under current water restrictions. However, while Class A recycled water will be free of restrictions; it is still a valuable resource that needs to be used with conservation principles in mind.	http://www.yvw.com.au/yvw/Home/AlternativeWaterSources/RecycledWater/RecycledWaterFAQs.htm

APPENDIX D

MUSIC MODELLING

Job No: X07008.03

28 January 2010

Montgomery Watson Harza Pty Ltd
Level 2
39-41 Chandos Street
ST LEONARDS NSW 2065

Attention: Rachel Perrin

Dear Rachel,

RE: MUSIC Water Quality Modelling – Googong New Town – Googong Creek

This letter report outlines the stormwater quality monitoring undertaken for the Googong New Town, Googong Creek. The performance of the proposed water quality treatment strategy has been modelled using the *MUSIC* water quality model (Version 3.0). The parameters adopted for *MUSIC* modelling are as recommended in Appendix B of the *ACT Planning and Land Authorities Water Sensitive Urban Design General Code* (March, 2008).

A series of *MUSIC* models has been developed to establish the treatment targets required to compensate for development within Googong Creek catchment. A model of the existing catchment, based on rural land use, was developed to set baseline pollutant export conditions. This existing condition model is discussed on page 3. A model of developed catchment with no water sensitive urban design treatment features was developed to calculate pollutant export loads from the site. This developed with no treatment is discussed on page 5.

Models were developed for various treatment options the catchment, including rainwater tanks and roadside swales along with bioretention were modelled. Input parameters into the *MUSIC* models were:

- **Lot Layout** - UD1104 rev H, dated 24.06.09 (see Attachment A)
- **Rainfall** – Queanbeyan Bowling Club (070072) for the period 1967 - 2007
- **Evaporation** – Canberra monthly averages within *MUSIC* (from the Bureau of Meteorology)
- **Basin dimensions** – Googong Creek - from 12D model dated Dec 08 – permanent water volume in Basins 3 and 4 is the total runoff from the 3 month 90 min ARI event

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- **Bioretention and swales** – from the drawing "Trunk Stormwater Drainage Concept Plan for Neighbourhood 1 and Town Centre" X07008.02.SK01 Issue C (see Attachment B)
- **Wetland dimensions** – from drawing dated 16 Dec 08 (C8006/DE/SW)
- **Catchment areas and impervious areas** – from *XP-RAFTS* modelling for the project
- **Catchment break up** – from Roberts Day – Yield Analysis Table dated 24 June 09 (see Attachment C)
- **Runoff parameters and pollutant concentrations** – ACT Planning and Land Authorities Water Sensitive Urban Design General Code Appendix B (March, 2008).

Pollutant removal targets are taken from Queanbeyan City Council Development *Design Specification D7 – Erosion Control and Stormwater Management*. These removal targets are:

- **Suspended Solids (SS)** – 80% retention of average annual load
- **Sediment** – 100% retention of sediment greater than 0.125 mm for flows up to the 3 month ARI peak flow
- **Oil and Grease** – No visible oils for flows up to the 3 month ARI peak flow
- **Litter** – 100% retention of litter greater than 5 mm for flows up to the 3 month ARI peak flow
- **Total Phosphorous (TP)** – 65% retention of average annual load
- **Total Nitrogen (TN)** – 65% retention of average annual load

Note that the nutrient removal targets (TN and TP) are set from the Googong New Town Development Control Plan, which sets pollutant removal targets above the requirement of Queanbeyan City Council Development *Design Specification D7 – Erosion Control and Stormwater Management* of 45% retention of average annual load.

The cases modelled are as follows –

CASE 0: Existing Case
CASE 1: Developed Case Without Treatment (No WSUD)
CASE 2: Developed Case With Treatment (WSUD)

The developed option with WSUD was modelled incorporating the use of recycled water from the Googong wastewater treatment plant as environmental flow in Googong Creek is discussed on page 11.