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WHAT IMPACT COULD CLIMATE CHANGE HAVE ON STORMWATER HARVESTING SCHEMES?

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ABSTRACT

The Stormwater And RAinwater Harvesting Assessment tool (SARAH) was developed for Hornsby Shire Council to facilitate the sizing and costing of concept schemes for stormwater harvesting and/or rainwater harvesting for sportsgrounds/parks/open space. This tool allows Council to quantify the trade-off in storage volume and the volume of water harvested for re-use (reliability). In order assess the impact of less frequent but more intense storm events under climate change, a climate change version of SARAH ie. SARAH Version CC was created.

This was achieved by adjusting the current adopted 20 year rainfall record to create a synthetic climate change rainfall sequence and by adjusting the average monthly pan evaporation rates. Non-dimensional daily irrigation demands under climate change over a 20 year period were also calculated. SARAH was adjusted to incorporate the unit area runoff sequence and non-dimensional irrigation demand patterns that were adjusted for climate change to create SARAH CC.

The application of SARAH V2A CC is demonstrated for the case of harvesting stormwater from a 20 ha catchment with low density residential development. The stormwater is stored in a single storage tank and to be used for irrigation of a 1 ha sports facility.

It was concluded from the results of the worked example in the Hornsby LGA that broadly:

- If the same average annual volume of water is to be supplied under the adopted climate change scenario then the reliability of a stormwater harvesting scheme would decrease by around 7%;
- If the same average annual volume of water was to be supplied under the adopted climate change scenario but the reliability of a stormwater harvesting scheme is to remain the same as under 2010 conditions then the storage tank volume would need to increase by around 56%;
- If the average annual volume of water to be supplied under the adopted climate change scenario is increased by around 40% to maintain the same level of vegetation coverage then the reliability of the stormwater harvesting scheme would decrease by around 13%; and
- If the average annual volume of water to be supplied under the adopted climate change scenario is increased by around 40% to maintain the same level of vegetation coverage and the reliability of the stormwater harvesting scheme is to remain the same as under 2010 conditions then the storage tank volume would need to increase to increase by around 137%.

1. INTRODUCTION

The Stormwater And RAinwater Harvesting Assessment Tool (SARAH) was developed for Hornsby Shire Council because it plans to implement rainwater and/or stormwater harvesting schemes to reduce its usage of potable water to irrigate sports fields and parks across the LGA. To facilitate the costing of concept schemes as part of the preparation of grant applications Council needed a software tool to size storages required for stormwater harvesting schemes.

The aim of the assessment tool was to facilitate the sizing and costing of concept schemes for stormwater harvesting and/or rainwater harvesting for sportsgrounds/parks/open space. It is also intended that this tool will allow Council to quantify the trade-off in storage volume and the volume of water harvested for re-use (reliability).

The tool can be used to assess:

- A stormwater harvesting scheme only eg. harvesting of stormwater from a channel or watercourse for irrigation of a playing field,
- A rainwater harvesting scheme only eg for toilet flushing and hand basins in an amenities block, or
- A combined stormwater and rainwater harvesting scheme.

The features of SARAH are described in Cardno Willing, 2008.

1.1 Background

As outlined by Phillips, 2009 Cardno Willing was commissioned to develop a base stormwater quality MUSIC model of a selected catchment within the Hornsby LGA in 2007 to assist Council to convert the **xpaqualm** models developed previously for Council during the Stormwater Catchment Management Plan (SCMP) studies. The selected catchment was the Berowra Creek catchment. An aim was to calibrate the base MUSIC model using gauged flows and pollutant loads at four locations in Berowra Creek catchment in order to identify model parameters that would provide reliable estimates of runoff and pollutant exports.

The landuses within the Hornsby LGA that were identified in the 2007 study included:

- Low density Residential,
- High density Residential,
- Special use (community use, school, hospital);
- Industrial;
- Business and Commercial;
- Forest (bushland, reserve);
- Open Space (parks, golf course); and
- Agriculture

For assessment purposes these landuses were aggregated into the following categories: HiRes Ind Comm Bus; LoRes; OpenSpace&Agriculture; Native Bush and Roof.

A runoff sequence over a 20 year period was generated for each of the aggregated landuses and was incorporated into the assessment tool.

Non-dimensional daily irrigation demands over a 20 year period were calculated using an irrigation calculation spreadsheet. The irrigation daily demand calculations take into account:

- Daily rainfall;
- Daily evaporation;
- Crop factor,
- Irrigation efficiency; and
- Rainfall effectiveness

The daily irrigation (external) demand is calculated by multiplying the non-dimensional daily irrigation demand by the user input average annual irrigation demand and by the area to be irrigated.

1.2 User Inputs

The primary user inputs for SARAH include (refer Cardno Willing, 2008):

Catchment Runoff:

- User input of the areas of representative landuses upstream of the site of the harvesting scheme (ha)

Scheme components

- User input of the low (environmental) flow below which harvesting of stormwater can not be undertaken
- User input of the adopted pump rate and average duration per day for transfer of stormwater to an off-line storage (tank)
- User input of a trial storage volume

Re-use demands

- User input of the adopted average daily internal re-use demand
- User input of the adopted average annual unit area external irrigation rate
- User input of the area to be irrigated

Economic

- User input of the adopted unit cost of potable water
- User input of the assumed life of the scheme
- User input of the three discount rates

1.3 Reliability Assessment Results

The assessment results summarise the internal demand and external demand that is met each year of the 20 year period that was adopted for assessment purposes. The reliability is calculated as the internal or external demand met divided by the internal or external total demand.

The calculated spill from the storage for each year each year of the 20 year period that was adopted for assessment purposes is also tabulated. In the case of rainwater harvesting, roof runoff is directed to the storage tank and is uncontrolled ie. spills can occur from the storage tank. In the case of stormwater harvesting, it is assumed that a float control would limit any pumping such that the storage tank would not spill.

The average annual rainfall, internal demand (met and unmet), external demand (met and unmet), reliability of water supplied for internal use(s), reliability of water supplied for external use(s) and spill from the storage are also tabulated.

1.4 Economic Assessment of Water Savings

The value of the average annual water savings are calculated by multiplying the average annual harvested water (that meets internal and/or external demands) by the user input unit cost of mains water that is replaced by the harvested water.

The Nett Present Worth of the average annual water savings over the life of the scheme are calculated based on the user input life of the scheme and user input discount rates.

If the aim is to achieve a benefit cost ratio of 1.0 or greater then the cost of implementing and maintaining a scheme should not exceed the Nett Present Worth of the average annual water savings.

The approach adopted for the estimation of irrigation demand and patterns of irrigation demand are described in Phillips, 2009 and Cardno Willing, 2008.

1.2 Impact of Climate Change

The original version of SARAH is unable to assess the impact of climate change because the rainfall sequence is fixed for assessment purposes. In order assess the impact of less frequent but more intense storm events under climate change, the simplest approach was to develop a climate change version of SARAH ie. SARAH Version CC as follows.

2. RAINFALL SEQUENCE AND PAN EVAPORATION UNDER CLIMATE CHANGE

The annual rainfall statistics for Station 67052 adopted in SARAH are summarised in **Table 1**. The average annual rainfall over this period was 1232 mm while the median annual rainfall is 1193 mm.

Table 1 - Annual Rainfall recorded by the Berowra Gauge (Station 67052) for the period 1980 – 2001

Year	Rainfall (mm)	Comment	Year	Rainfall (mm)	Comment
1982	747	Dry	1992	1362	
1983	1129		1993	817	
1984	1304		1994	766	
1985	1254		1995	1238	Close to Average
1986	1149	Close to Average	1996	971	
1987	1398		1997	879	
1988	2078	Wet	1998	1434	
1989	1694		1999	1547	
1990	1891		2000	927	
1991	1064		2001	986	

The first steps were to adjust the current adopted 20 year rainfall record to create a synthetic climate change rainfall sequence and to adjust the average monthly pan evaporation rates.

An example of the estimated seasonal changes in rainfall and evaporation for the ACT are given in **Table 2.**

Table 2 Estimated Changes in Rainfall and Evaporation in the ACT under Climate Change

	Change in Rainfall				Change in Evaporation			
Season	Predicted Worst Case	Predicted Best Case	Modelled	Observed Since 2000	Predicted Worst Case	Predicted Best Case	Modelled	Observed Since 2000
Summer	-9%	12%	-8.9%	-4.2%	11.0%	0.5%	8.7%	1.2%
Autumn	-5%	5%	-4.9%	-39.6%	10.8%	0.8%	8.5%	5.2%
Winter	-11%	2%	-10.9%	-4.7%	12.8%	2.2%	10.5%	3.7%
Spring	-11%	0%	-10.9%	-9.4%	12.0%	2.1%	9.7%	6.5%
Annual	**-9%**	**2%**	**-9.0%**	**-13.6%**	**9.1%**	**1.4%**	**9.1%**	**4.6%**

Drawing broadly on the ACT experience, two approaches to creating a synthetic 20 year rainfall record under climate change were tested for Council's consideration.

2.1 Scenario 1

The approach adopted to reduce average seasonal rainfall was to set any days with less than 7.5 mm of rainfall to 0 mm and to then increase all remaining rainfall by 10%. As indicated in the **Table 3** this gave an average decrease of 9.6% in annual rainfall. This approach also gave a dramatic decrease in the average number of rain days per year (from 134.9 days to 40.5 days)

The potential evapo-transpiration (PET) was increased uniformly by 9.0%.

The ramifications for estimated irrigation demand (based on a monthly assessment over 20 years) is also summarised in **Table 3**. It is estimated that under this scenario that irrigation demands would increase by 32% to 79% depending on the irrigation regime that is adopted.

2.2 Scenario 2

Under Scenario 2 the approach adopted to reduce average seasonal rainfall was to subtract 2.1 mm from each day of rainfall and to then increase all remaining rainfall by 10%. As indicated in **Table 4** this gave an average decrease of 9.4% in annual rainfall.

This approach also gave a less dramatic decrease in the average number of rain days per year (from 134.9 days to 80.5 days).

The potential evapo-transpiration (PET) was increased uniformly by 9.0%.

The ramifications for estimated irrigation demand (based on a monthly assessment over 20 years) is also summarised in **Table 4**. It is estimated that under this scenario that irrigation demands would increase by 30% to 68% depending on the irrigation regime that is adopted.

Based on a review of the ramifications of Scenarios 1 and 2, Council adopted Scenario 2 for incorporation into SARAH Version CC.

Table 3 Theoretical Climate Change Scenario 1

Days on which Rainfall <7.5 mm set to 0 mm
All remaining rainfall increased by 10%

		Summer	Autumn	Winter	Spring	Annual
Rainfall (mm)	No CC	358.7	370.1	256.5	246.4	1231.7
	With CC	326.9	340.0	229.1	218.0	1114.0
	Difference	-8.9%	-8.1%	-10.7%	-11.5%	-9.6%
Raindays	No CC	36.1	38.8	30.0	30.1	134.9
	With CC	10.9	12.8	7.6	9.3	40.5
	Difference	-25.3	-26.0	-22.4	-20.8	-94.4
PET (mm)	No CC	415.1	273.0	193.0	322.9	1204.0
	With CC	452.4	297.6	210.3	352.0	1312.4
	Difference	9.0%	9.0%	9.0%	9.0%	9.0%

Irrigation Demand (ML/ha/yr)

	High	Medium	Low	Minimal
No CC	6.23	4.06	2.19	1.16
With CC	8.21	5.67	3.38	2.08
Difference	31.8%	39.7%	54.3%	79.3%

Table 4 Theoretical Climate Change Scenario 2

2.1 mm subtracted from rainfall recorded each day
All remaining rainfall increased by 10%

		Summer	Autumn	Winter	Spring	Annual
Rainfall (mm)	No CC	358.7	370.1	256.5	246.4	1231.7
	With CC	329.2	339.9	230.9	216.4	1116.4
	Difference	-8.2%	-8.2%	-10.0%	-12.2%	-9.4%
Raindays	No CC	36.1	38.8	30.0	30.1	134.9
	With CC	22.1	23.2	16.8	18.5	80.5
	Difference	-14.1	-15.6	-13.2	-11.6	-54.4
PET (mm)	No CC	415.1	273.0	193.0	322.9	1204.0
	With CC	452.4	297.6	210.3	352.0	1312.4
	Difference	9.0%	9.0%	9.0%	9.0%	9.0%

Irrigation Demand (ML/ha/yr)

	High	Medium	Low	Minimal
No CC	6.23	4.06	2.19	1.16
With CC	8.09	5.55	3.24	1.95
Difference	29.9%	36.7%	47.9%	68.1%

3. CATCHMENT RUNOFF UNDER CLIMATE CHANGE

The calibration of MUSIC model parameters using data recorded at four gauging locations within the Berowra Creek catchment is described in detail in Cardno Willing, 2007 and is outlined in the SARAH User Guide (Cardno Willing, 2008).

The model parameters calibrated during the 2007 study was adopted for the purpose of creating unit area MUSIC models of a number of land uses to create runoff sequences over a 20 year period for incorporation into the assessment tool. These unit area models were re-run using the rainfall sequence and pan evaporation rates that were adjusted for climate change to generate unit area runoff sequences under climate change. The estimated change in average annual unit area runoff is summarised in **Table 5**.

Table 5 Average Annual Unit Area Runoff (ML/ha)

Aggregated Landuse	Without Climate Change	With Climate Change
HiRes Ind Comm Bus	7.43	6.82
LoRes	7.04	6.45
OpenSpace Agriculture	2.43	2.39
Native Bush	2.34	2.33
Roof	11.7	10.8

4. IRRIGATION DEMAND UNDER CLIMATE CHANGE

Non-dimensional daily irrigation demands over a 20 year period were calculated using an irrigation calculation spreadsheet. The irrigation daily demand calculations take into account:

- Daily rainfall;
- Daily evaporation;
- Crop factor,
- Irrigation efficiency; and
- Rainfall effectiveness

The daily irrigation (external) demand is calculated by multiplying the non-dimensional daily irrigation demand by the user input average annual irrigation demand and by the area to be irrigated.

The irrigation assessments incorporated in SARAH V2 were based on an average crop factor of 67% which was applied to the daily pan evaporation.

In the case of the SARAH V2A the constant crop factor has been replaced by the variable crop factors given in **Table 6**.

The impact of climate change on average annual irrigation demands is indicated in **Tables 1** and **2.**

Table 6 - Adopted Crop factors by Month

Month	Crop Factor	Month	Crop Factor	Month	Crop Factor
Jan	1.0	May	0.8	Sept	0.8
Feb	0.93	Jun	0.67	Oct	0.87
Mar	0.93	Jul	0.67	Nov	0.95
Apr	0.87	Aug	0.73	Dec	1.0

Based on the results given in **Table 4** the following equation was fitted to the data to provides a means to estimate the change in average annual irrigation demand due to climate change (where irrigation demand under current conditions exceeds 1.0 ML/ha):

Irrigation Demand (ML/ha) = 1.21 x Irrigation Demand (ML/ha) + 0.577 (1)
(under Climate Change) (under Current Conditions)

Non-dimensional daily irrigation demands under climate change over a 20 year period were calculated using an irrigation calculation spreadsheet with the rainfall sequence and pan evaporation rates that were adjusted for climate change.

5. SARAH VERSION CC

SARAH V2A was adjusted to incorporate the unit area runoff sequence and non-dimensional irrigation demand patterns that were adjusted for climate change to create SARAH V2A CC.

6. CASE STUDY

The application of SARAH V2A CC is demonstrated in the following worked example.

It is proposed to harvest stormwater from a 20 ha catchment with low density residential development. The stormwater is to be stored in a single storage tank and to be used for irrigation of a 1 ha sports facility. Rainwater is not harvested from the sports facilities and harvested stormwater is not used for internal re-use in the sports facilities.

It was further assumed that:

- All low flows up to 0.02 ML/d bypass the harvesting system;
- stormwater can be effectively harvested on average over four (4) hours at a harvesting (pumping) rate of 10 L/s;
- The stormwater storage is 5% full at the start of the assessment and abstraction ceases when the storage volume reduces to 5% of the storage volume

Five cases were assessed as follows:

Case 1	Base case under current conditions. It is assumed that the average annual volume of water supplied for irrigation is 3 ML/ha and that the storage tank volume is 80 kL.
Case 2	Base case under future climate change conditions. It is assumed that the average annual volume of water supplied for irrigation remains 3 ML/ha and that the storage tank volume remains at 80 kL.
Case 3	Base case under future climate change conditions. It is assumed that the average annual volume of water supplied for irrigation remains 3 ML/ha but that the storage tank volume is increased to 125 kL to achieve the same average annual reliability as achieved under **Case 1.**
Case 4	Base case under future climate change conditions. It is assumed that the average annual volume of water supplied for irrigation is increased to 4.2 ML/ha in response to climate change but that the storage tank volume remains at 80 kL..
Case 5	Base case under future climate change conditions. It is assumed that the average annual volume of water supplied for irrigation is increased to 4.2 ML/ha in response to climate change but that the storage tank volume is increased to 190 kL to achieve the same average annual reliability as achieved under **Case 1.**

The adopted data and the results of the assessments of Case 1 using SARAH V2A and Cases 2, 3, 4 and 5 using SARAH V2A CC are summarised in **Table 7.**

It should be noted that using Equation 1, it was estimated that climate change would increase an average annual irrigation demand under current conditions from 3 ML/ha to around 4.2 ML/ha.

Table 7 Summary of Data and Results for Worked Example

		Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
		No CC	With CC			
Water Demand Data						
External Demand						
Ave Annual Irrigation Demand	(ML/ha)	3.0	3.0	3.0	**4.2**	**4.2**
Concept Scheme Data						
Concept Storage Tank Volume	(kL)	**80**	**80**	**125**	**80**	**190**
Assessed Reliability						
	1986	98.4%	95.3%	99.5%	91.2%	100%
	1995	92.0%	92.1%	97.0%	86.5%	97.3%
	1994	70.6%	54.5%	68.1%	45.6%	67.8%
	Ave	**90.7%**	**84.1%**	**90.7%**	**77.6%**	**90.5%**

It was concluded from the results of the worked example that:

- If the same average annual volume of water was to be supplied under climate change then the reliability of the stormwater harvesting scheme would decrease from 90.7% to 84.1%;
- If the same average annual volume of water was to be supplied under climate change but the reliability of the stormwater harvesting scheme was to remain at 90.7% then the storage tank volume would need to increase to 125 kL (ie. by around 56%);

- If the average annual volume of water to be supplied under climate change is increased to 4.2 ML/ha to maintain the same level of vegetation coverage then the reliability of the stormwater harvesting scheme would decrease from 90.7% to 77.6%; and
- If the average annual volume of water to be supplied under climate change is increased to 4.2 ML/ha to maintain the same level of vegetation coverage and the reliability of the stormwater harvesting scheme is to remain at 90.7% then the storage tank volume would need to increase to 190 kL (ie. by around 137%).

6. CONCLUSIONS

In order assess the impact of less frequent but more intense storm events under climate change, a climate change version of SARAH ie. SARAH Version CC has been created.

This was achieved by adjusting the current adopted 20 year rainfall record to create a synthetic climate change rainfall sequence and by adjusting the average monthly pan evaporation rates. Non-dimensional daily irrigation demands under climate change over a 20 year period were calculated using an irrigation calculation spreadsheet with the rainfall sequence and pan evaporation rates that were adjusted for climate change.

It was concluded from the results of the worked example in the Hornsby LGA that broadly:

- If the same average annual volume of water is to be supplied under the adopted climate change scenario then the reliability of a stormwater harvesting scheme would decrease by around 7%;
- If the same average annual volume of water was to be supplied under the adopted climate change scenario but the reliability of a stormwater harvesting scheme is to remain the same as under 2010 conditions then the storage tank volume would need to increase by around 56%;
- If the average annual volume of water to be supplied under the adopted climate change scenario is increased by around 40% to maintain the same level of vegetation coverage then the reliability of the stormwater harvesting scheme would decrease by around 13%; and
- If the average annual volume of water to be supplied under the adopted climate change scenario is increased by around 40% to maintain the same level of vegetation coverage and the reliability of the stormwater harvesting scheme is to remain the same as under 2010 conditions then the storage tank volume would need to increase to increase by around 137%.

7. REFERENCES

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