The consumption needs to be divided between indoor and outdoor and the indoor consumption in turn needs to be further disaggregated between kitchen, bathroom, toilet and laundry.

Coombes et al has estimated the internal water disaggregation (based on a study undertaken in the Hunter area). Indoor water consumption is broken down as follows:

Table 8: Water disaggregation by number of occupants

Household Occupancy	Outdoor/ Exhouse (L/day)	Kitchen (L/day)	Bathroom (L/day)	Toilet (L/day)	Laundry (L/day)	Total Indoor and Outdoor (L/day)
2 (medium density)	27	25	123	101	56	332
3 (low density)	207	33	176	140	102	658

Table 8 is based on estimates of total water consumption by Hunter Water (June and September 2003) and then split between internal and external. The internal/external split was determined by subtracting indoor consumption (based on Coombes et al, 2001) from the Hastings total for both medium and low density lots.

There is very little available evidence to quantify the outdoor consumption from medium density developments in the Hastings Area.

Hot Water use is disaggregated to determine how much hot water is estimated to be consumed versus how much cold water is estimated to be consumed. The usage for the kitchen, bathroom and laundry is shown in

Table 9 Hot water disaggregation (expressed as a percentage of total use per room)

Kitchen	Bathroom	Laundry
70%	80%	35%

3.3. Drainage Corridor – Width Determination

The objective was to ensure that drainage corridors were sized to ensure that post development flows can be fully contained within the defined drainage corridor. Flows were modelled using XP-RAFTS followed by solving the Manning equation to estimate the uniform flow depth. The parameters listed in Table 9 were adopted for modelling purposes.

Table 10: RAFTS modelling criteria for the drainage corridor determination

Parameter	Value
Initial Loss/Continuing Loss (assumes wet antecedent conditions and is a conservative approach)	5mm/1mm
Roughness (overland flows) for natural areas	0.04
Roughness (overland flow) for urban impervious areas	0.015
Roughness (overland flows) for urban pervious	0.025
Manning's n values for creek values (assuming rough creek – lots of natural vegetation to slow down velocities	0.08

3.4. MUSIC Modelling Parameters

As part of the scope of works undertaken, a stormwater quality management strategy was developed. The strategy was based on the results from MUSIC water quality modelling for Area 14. The following assumptions for Event Mean Concentrations (EMCs) were adopted for modelling as shown in Table 11.

Table 11: MUSIC Modelling EMCs

Land Use[1]	EMC (mg/L)		
	TSS	TP	TN
Rural	90	0.22	2
Roofs	20	0.13	2
Roads	270	0.5	2.2
Lots (residential)	140	0.25	2
Reserves/parks (general urban)	140	0.25	2

[1] Fletcher, T., Duncan, H., Poelsma, P. & Lloyd, S. (CRC, 2004)

These rates are based on recent work undertaken by the CRC for Catchment Hydrology on behalf of the NSW Department of the Environment and Conservation.

3.5. Recycled Water Reticulation Design

The minimum head requirements for recycled water mains are as noted in Table 4.

In order to determine the peak instantaneous demand for recycled water the number of fixture units per dwelling that would use recycled water were calculated and then divided by the total number of fixture units on each dwelling. All values for fixture units were based on those in AS3500.

This provided a fraction of the peak instantaneous demand that would represent the peak instantaneous demand for recycled water.

The fraction attributable to the demand for recycled water was then multiplied by the design peak flow rate for each dwelling as specified in Table 1, i.e. 0.15 L/s/tenement. For the low density lots this resulted in a peak demand of 0.063 L/s/tenement when the recycled water is used for toilet, outdoor and laundry uses (Option 1) and 0.055 l/s/tenement when used only for toilet and outdoor (Option 3).

The peak demand for recycled water in the regional sports fields was determined by:

- Assuming that the field would need a maximum depth of 20mm irrigation in one week.
- Assuming that 10mm would be irrigated in 2 separate irrigation events.
- We broke the sports fields into 4 separate zones and assumed that only one zone would be irrigated on one day allowing for the peak design flow to be reduced significantly. We assumed based on the use of Hunter pop-up heads that irrigation would take place over a period of 2 hours. This would actually allow for more than one zone to be irrigated on one day provided the timing was scheduled appropriately.
- Assuming that there would be an amenity block at the sports fields, with 10 toilets and up to 16 hose taps for other irrigation or wash down purposes.

4.0 OPPORTUNITIES & CONSTRAINTS

Early in the life of the project STORM created a compendium of information on Area 14 that would be pertinent to the preparation of the water cycle management plan for this Area. A copy of the compendium was sent to Council.

A literature review of the information in the compendium was undertaken by STORM with the aim of assessing the opportunities and constraints for development of Area 14. Note that these are not the broad opportunities and constraints to development that have been covered in the LES and Masterplan studies for the site. Instead the opportunities and constraints in this report specifically focus on the water cycle.

There are a number of issues that present either an opportunity and/or a constraint that may potentially affect the implementation or operation of a *successful* water cycle management plan for the area. These issues include:

- Soils
- Groundwater
- Flooding
- Land Capability Assessment Viz Recycled Water
- Wastewater management
- BASIX SEPP – Competing Provisions
- Geology
- Topography
- Population
- Water supply
- Stormwater runoff - Receiving
- SEPP 26 – Littoral Rainforests

4.1. Soils

The draft Infrastructure Assessment Report by Ardill and Payne (2002) included in the Area 14 LES, presents the draft 1:100,000 Camden Haven soil landscapes map by DIPNR. The soil landscape map shows different soil landscapes across the site, each bearing differing characteristics. Soils in the area are generally derived from sandy Pleistocene deposits.

The residential areas north of Ocean Drive indicate that the soil is defined as the Cairncross and Moripo landscapes. At higher elevations, the soils are moderately well drained but have the potential to become waterlogged and are subject to erosion. The lower elevations following drainage lines are poorly drained soils, have low wet bearing strength and strong acidity. This area is also subject to foundation hazards.

The remaining areas are generally the Cairncross and Moripo landscapes, but also include the Harrington, Crowdy Bay, Burrawan and disturbed landscapes.

Table 12 Soil Landscape Characteristics

Soil Landscape	Type of soil	Erodibility	Permeability	Drainage	Other Characteristics
Burrawan	Podzolic soils, organic topsoils	High Water erosion hazard	Low (subsoil)	Localised poor drainage, localised seasonal waterlogging	Low wet bearing strength, strong acidity
Cairncross	Podzolic soils, organic topsoils	Erosion hazards	Low	Poor, localised flood hazard, seasonal waterlogging	High subsoil plasticity, low wet bearing strength, sodicity, strong acidity, low fertility, foundation hazard
Crowdy Bay	Sandy soils	High	High	Rapid, seasonal waterlogging	Low fertility, high landscape fire hazard
Harrington	Sandy soils	High (wind erosion hazard)	High	Localised impeded drainage, seasonal water logging	Strong acidity, low fertility, localised acid sulphate soils
Moripo	Stony soils, localised shallow soils	High Gully erosion risk		Localised seasonal waterlogging	Neutral to moderate alkalinity
Disturbed Terrain	Various Anthroposols, landfill	Wind erosion hazard	Impermeable	Poor drainage	Foundation hazard, low fertility, toxic materials

SOILS Water Cycle Management Implications:

- Most of the site is covered by clayey, impermeable soils. Therefore infiltration is not likely to be a viable option in these areas to manage significant quantities of stormwater. The sandy soils on the site are located in the lower lying areas. These areas may be highly suitable for infiltration.
- The clay soils on the site will present an erosion risk that will need to be managed. If swales are used, these will need to be drained with subsoil drainage. During construction, sediment basins may need to be flocculated. Road pavements may need good subsoil drainage on upslope sides to ensure pavements do not become saturated. Amelioration of Cairncross soils using Gypsum may help to increase fertility, reduce dispersibility and sodicity. The construction of wetlands on sodic soils can also trigger an EIS.
- The Cairncross soils indicate that dispersible soils may be present and any wetlands that are constructed

to treat runoff or for aesthetic purposes may be permanently milky in colour.

- Foundation investigations should be undertaken to ensure that all proposed designs and infrastructure are suited to the area.
- WSUD designs should be complementary with the existing soil landscapes and work around problem areas such as potentially eroded shallow topsoil areas.
- There are salt scalds visible in aerial photos. These may be in areas of high sodicity. Care should be taken with disposal of effluent in these areas. Soil amelioration may be required.

4.1.1. Acid sulphate soils

The Acid Sulphate Soils (ASS) map presented in Hastings LEP 2001 indicates that most of the site exists on Class 4 land, with small pockets of Class 5 land and a small area towards the eastern boundary as Class 3 land.

Classes 3, 4, and 5 are defined below with respect to encountering Potential Acid Sulphate Soils (PASS) during construction works:

- Class 3 –beyond 1 metre below the natural ground surface; or works by which the watertable is likely to be lowered beyond 1metre below natural ground
- Class 4 - works beyond 2m below the natural ground surface; works by which the watertable is likely to be lowered beyond 2 metres below natural ground
- Class 5 - works by which the watertable is likely to be lowered to below 1metre AHD in adjacent Class 1,2,3, or 4 land

PASS are characterised by sedimentary deposits containing high levels of residual sulphides capable of being oxidised to sulphates when exposed to the air. When sulphates dissolve in water they create acidic conditions which are toxic to living creatures and aggressive towards construction materials. Triggers for this process include a lowering of the watertable by human activities such as drainage, tide and flood mitigation works for new development, excavation or dredging, or natural processes such as drought.

Preliminary testing of soils on land adjacent to the existing open waterbodies on the south side of Ocean Drive identified the presence of Potential Acid Sulphate Soils (PASS).

PASS Water Cycle Management Implications:

- Further investigation will be required to determine whether designed infrastructure (including proposed Luke & Co wetland) will intersect groundwater. An acid sulphate soils management plan may be required if excavations occur at or below groundwater level.

4.2. Geology

There are a few exposed rocks at the surface comprising of sedimentary siltstones. According to the 1:250,000 Hastings Geology Map, the area is founded on schist, phyllite, greywacke and slate of Permian age on the southern portion of the site and more recent quaternary era sand, silt, mud and gravel on the northern portion of the site. The Aboriginal Sites Survey (Cox and Corkill, 1983) provided the following description of the geology of the area:

- The site is comprised of 4 basic units (1. Lower Devonian schist, phyllite, slate 2. Quaternary sand, silt, mud, gravel 3. Quaternary quartzose sand, silt 4. Triassic conglomerate sandstone, shale) Outcrops of rock are generally not present
- Jolly Nose in the west, is a conglomerate and igneous intrusive formation

Borehole logs presented in the Environmental Impact Statement for St Vincents Foundation Land (Luke and Company, 2005) drilled within the proposed wetland area were reviewed - bedrock was not encountered within 6m of ground surface (termination of borehole). Based on the limited number of borehole logs, it appears that the bedrock system is not shallow, however it has been documented that the soil profile is subject to seasonal waterlogging.

GEOLOGY Water Cycle Management Implications:

- No need to maintain shallow infiltration systems, however it is noted that soils are subject to seasonal waterlogging

4.3. Groundwater

Groundwater levels sit around 3 to 3.8mAHD during the summer months, but gradually rise to between 4.2mAHD & 5mAHD in the winter months (variations of over 1m at each borehole location). If any of the proposed works are going to disturb the groundwater table (e.g. dewatering, groundwater injection, excavations, etc), it is recommended that groundwater monitoring be undertaken to establish baseline data for groundwater levels prior to development, and to assess whether the development will impact on groundwater levels and/or potential for ASS disturbance. This is obviously the case for the proposed wetland.

Groundwater quality testing has been undertaken by Holmes and Holmes within the proposed Luke & Co wetland area. Two monitoring rounds (summer 2002 and winter 2003) show that the groundwater tends to be slightly acidic ($pH < 7$), and generally has high electrical conductivity (EC) levels (up to a maximum of 13,000μS/cm). The very high EC levels may affect the ability of freshwater wetland species to survive in such in saline conditions. Salt marsh or estuarine species would be better suited.

During the summer monitoring round, conductivity levels averaged 4000μS/cm whilst in winter months, conductivity levels averaged 1750μS/cm. Conductivity appears to be higher in summer due to lower groundwater levels (less rainfall + higher evaporation = less water = lower dilution factor) The EC of freshwater is usually between 0 to 1500μS/cm whilst seawater is $>$ 50,000μS/cm. Based on the average groundwater EC over summer, moderately salt-tolerant plants (between 1,900μS/cm & 4,500μS/cm) can be grown.

GROUNDWATER Water Cycle Management Implications:

- Any works potentially affecting groundwater levels will require groundwater monitoring to be undertaken to assess the impacts of groundwater disturbance
- Any works below the groundwater table will require further investigation for acid sulphate soils disturbance
- Vegetation in the area may need to include salt tolerant plants (where plant roots intersect with groundwater tables)

4.4. Topography

The site elevation varies between 5mAHD to 20mAHD. Most of the site consists mainly of gentle slopes with a few steep slopes or deep defined gullies (Deicke Richards, 2003). Part of the IWCM strategy will be to design and implement stormwater treatment and control measures which include swales, raintanks and stormwater pipes, while allowing sufficient areas for natural corridors, buffers and public open spaces.

A geotechnical engineer will need to be employed to assess the suitability of the soil and bedrock for housing, raintank construction (if implemented), etc.

TOPOGRAPHY Water Cycle Management Implications:

- The road and lot layouts have been prepared taking into account the topography with its implications for drainage, solar orientation and general trafficability.

4.5. Flooding

Lake Cathie forms the northern boundary of Area 14, whilst Duchess Creek is the only defined watercourse located within the Area 14 site. A drainage channel and secondary gully also drains to Duchess Creek prior to its exit at Rainbow Beach.

The impacts of the Area 14 development on Duchess Creek will be highly dependent on the outcomes of the IWCM modelling and design i.e. Duchess Creek water quality (creek health) and flow regimes will be reliant on planning and modelling outcomes regarding both stormwater and effluent discharge quantities to the creek.

Flood extents from Lake Cathie and Duchess Creek are also critical to the design and development of infrastructure. Lake Cathie Flood studies (DPWS, 1984) have suggested that flood heights may change by 0.6m depending on whether the ocean opening follows a closed or closed/open regime. Flooding along the southern boundary of Lake Cathie has the potential to impact on residential development and environmental corridors.

Urban development will also impact on flow regimes through Duchess Creek. Flood studies by Cardno (Cardno MBK, 2001) have indicated that a peak discharge from the existing site is $65.9m^3/s$, and may increase to $73.2m^3/s$ with the proposed development.

Council's flood mapping indicate that the proposed areas for residential development are not subject to flooding, however there may be some localised flooding in the vicinity of Lake Cathie and Duchess Creek. Flooding will be a constraint to development on low lying land within the floodplain. Filling of the floodplain to raise the developed areas out of the floodplain will be required if development is proposed in the lower lying flood prone areas. The road and lot layouts do make an allowance for some development to occur within the floodplain and this land will need to be filled to raise it out of the floodplain.

WATERCOURSES – Water Cycle Management Implications:

- Water quality and quantity controls are to be applied to developed areas to ensure that discharge into waterways does not detrimentally affect the natural environment.
- A buffer zone should be established around waterbodies to minimise flooding impacts on development.
- Waterways (i.e. Duchess Creek) to be assessed and rehabilitated to an appropriate form to ensure they do not degrade further as a result of development.
- It is important to replicate the wetting and drying cycles of Lake Cathie (for its catchment) and to maintain wetting and drying for the Duchess Creek Catchment by managing both the volume and frequency of runoff rather than simply managing peak flows.

4.6. Population

The population of Area 14 was approximately 3,900 in 2001. By 2021, the proposed population in Area 14 will be about 9000. The anticipated infill rate is 300 persons/annum over the next 20 years.

The proposed residential development road and lot layouts produced by STORM (drawings L428/P01 to L428/P08) have achieved densities of 15 dwellings/ha and 25 dwellings/ha for low and medium densities respectively in accordance with State Government development requirements.

POPULATION Water Cycle Management Implications:

- The proposed population density in the Masterplan has been achieved with potential for higher population capacity through the road and lot layout design. Infrastructure and services will need to be designed to achieve maximum capacity for the proposed population. The population can not be allowed to exceed the planned limits of the water supply and waste water infrastructure.
- Design of infrastructure, services etc should be staged to have an ultimate capacity for population predictions in accordance with both the Masterplan and this report. In the interim, infrastructure should be designed for staged integration with lower populations.

4.7. Water supply

Council has already undertaken much of the sizing of the water supply infrastructure proposed for Area 14. The capacity of this infrastructure may pose one limit on the population that can be served. However, the high level of planning that has been undertaken for Area 14 should ensure that water supply capacity issues will not limit potential development in Area 14.

4.8. Wastewater management

Investigation of the current Lake Cathie/Bonny Hills Sewerage Treatment Plan (STP) has been undertaken by PPK (PPK, 2002). The current system was designed in 1983 for a population loading of 6,000 EP (equivalent persons). It has been assessed that the current system cannot cope with the proposed future population and the STP will be augmented to cope with the increased inflows. As such, PPK have designed a system which has the capacity to be augmented to approximately 9,000EP as Stage 1 in the short term, and then to 12,000EP as Stage 2 in the longer term.

Council's preferred option was "*Secondary Clarifiers rated for 10ADWF with Membrane Tertiary Filters*". The advantage of such a system includes the ability to accept storm flows up to 10 x average dry weather flows (ADWF), thereby producing improved quality effluent during wet weather. The system upgrade would also include a new inlet works, a secondary bypass structure, a selector tank, membrane tertiary filters, additional sludge lagoons and an ultraviolet disinfection system for overflows into Duchess Creek.

It is noted however that wet weather overflows to Duchess Creek will occur and that sand exfiltration will remain the predominant means of disposal. There has been a history of problems associated with the sand exfiltration system at the STP including clogging due to algal build up and exfiltration rates that are lower than design values.

PPK (PPK, 2002) undertook a literature review of work on the STP to date. This included the 1995, Australian Water and Coastal studies (AWCS) report which noted:

- The 850m long exfiltration trench had rarely worked to capacity,
- 1992 remedial works were not successful,
- Overflows would occur in storm events of greater than the 1 in 2 year storm,
- Faecal coliform bacteria levels which exceeded ANZECC guidelines have been found on Rainbow Beach in seepage areas.

The local community has expressed significant opposition to an ocean outfall at Bonny Hills and as a result the treatment plant currently disposes of its effluent into coastal sand dunes. There are significant issues (noted above) associated with infiltration that makes the long term viability of this approach questionable. The predicted increases in waste water flows due to the increase in population may certainly exacerbate this problem.

Recycling the treated effluent from the new development in Area 14, would significantly reduce the volume of wastewater that needs to be disposed of via infiltration. This may enable longer periods of drying out of the exfiltration trenches enabling them to perform better and to a loading rate better matched to their long-term capacity.

PPK (2002) make a number of recommendations on future investigations that may ultimately enable the exfiltration system to perform to design capacity. However, given the poor history of the trench performance, a risk remains that the exfiltration system may not function to design capacity resulting in greater frequency of sewer overflows to Duchess Creek.

Effluent will need to be treated to standards identified in Section 2.7 for potential re-use. There is scope for recycled water to be supplied to residences for garden irrigation and toilet flushing and for the irrigation of public open spaces.

The predicted levels of TDS in the treated effluent from the STP are about 600 mg/L. TDS levels of less than 500 mg/L would enable the reuse of the effluent on gardens without much further consideration of the impacts of salts. There are two approaches that could be used to address this issue. The first is to reduce the salt level in the recycled water through reverse osmosis. The second is to assess how much salt can actually be tolerated through outdoor watering. Higher TDS also has implications for the groundwater which is already high in salts.

Council indicated that it would be adopting the use of a reverse osmosis (RO) plant to ensure that TDS levels were reduced below 300 mg/L to ensure that plumbing would not corrode. This would also ensure that salinity of the recycled effluent would not be a constraint to its use.

EFFLUENT MANAGEMENT Water Cycle Management Implications:

- Effluent from the system must comply with strict quality guidelines to enable reuse. Salt loads after removal in a reverse osmosis plant would enable unassessed reuse.
- Lake Cathie/Bonny Hills STP will need to undergo augmentation in order to cope with future loads and to reduce the environmental impact of the effluent flows in the environment. Overflows will be disinfected in the future reducing the environmental risk of the development.
- The local community has expressed significant opposition to an ocean outfall at Bonny Hills and as a result the treatment plant currently disposes of its effluent into coastal sand dunes. There are significant issues associated with infiltration including clogging of the infiltration trenches that makes the long term viability of this approach questionable. The predicted increases in waste water flows due to the increase in population may certainly exacerbate this problem.
- The exfiltration system operates with a number of limitations and which has caused water quality targets to be exceeded.
- Recycling of the effluent into the new development would reduce the loading rate on the existing exfiltration trench system.

4.9. Land Capability Assessment Viz Recycled Water

4.9.1. Soil Landscapes and Sodicity

The site soils in Area 14 are mostly comprised of two distinct soil types, the Cairncross and Harrington soil groups. The more dominant soil type is the Cairncross soil group which covers most of Area 14. It is a clay based soil type. The Cairncross soil does have some level of sodicity. When effluent containing elevated levels of sodium is added to the soil through watering this may result in a reduction in the hydraulic conductivity of the soil and potentially cause clogging of the soil. However if recycled water is to be used in Area 14 then a reverse osmosis plant will be deployed to remove salts from the recycled water and therefore soil sodicity will not be an issue of concern in Area 14.

4.9.2. Nutrient Uptake

Initial calculations have indicated that the soils on the site, if well vegetated, can effectively use the nutrients (phosphorus and nitrogen) that may be applied through the use of recycled water. Calculations of expected application rates of phosphorus and nitrogen were based on the expected average concentrations from the effluent and compared against Total Nitrogen and Total Phosphorus uptake rates of 2.5kg/100m^2 (i.e. 250kg/ha/annum) and 0.3kg/100m^2 (i.e. 30kg/ha/annum) respectively. Expected application rates were assessed to be 1.6kg/yr and 0.2kg/yr over 100m^2 irrigable area for nitrogen and phosphorus respectively. These calculations indicate that the soils are able to use all the nutrients likely to be contained in the wastewater.

4.9.3. Potential Groundwater Contamination

The lower parts of the site are situated on very free draining sandy soils known as the Harrington soil group. These areas should only receive recycled water which is treated using reverse osmosis technology otherwise it may result in the contamination of the groundwater. Given that an RO plant would be used if recycled water is to be used in Area 14, this is not likely to be an issue of concern.

LAND CAPABILITY ASSESSMENT – Water Cycle Management Implications:

- Expected phosphorus and nitrogen application rates are less than uptake rates (therefore no constraints for effluent disposal from a nutrient uptake perspective).
- Opportunities exist for effluent application across the site provided that reverse osmosis is used.
- Groundwater is not likely to be an issue of concern provided that reverse osmosis is included in the recycled water treatment system.

4.10. Stormwater runoff - Receiving Environment?

The hydrological cycle is a complex interaction of rainfall, evaporation, evapotranspiration, overland flow, through-flow or interflow and groundwater flow. Urban development can lead to dramatic changes on the hydrological regime of a catchment through the removal of vegetation and construction of impervious surfaces which reduce natural stores of water in the soil profile. These changes can lead to significant changes in the:

- Frequency of runoff;

- Peak flows for runoff events; and
- Volume of runoff.

Stormwater from Area 14 will discharge into a number of sensitive environments including the wetlands of Lake Innes and Duchess Creek. It will be critical that Water Sensitive Urban Design (WSUD) be implemented to minimise the nutrient loads from the stormwater.

Section 2.2 noted that objectives for development of Area 14 would be prepared based on the results a field investigation carried out by STORM. Note that the Area 14 development drains into two separate catchments. The southern half of the development (110 Ha) located mostly on the southern side of Ocean Drive drains to Duchess Creek. The northern part (52.8 Ha) of the development drains into Lake Cathie.

The objectives for urban development determined as a result of the field investigation are noted below.

4.10.1. Duchess Creek

Duchess Creek is a typical coastal lowland creek and forms a perched water table above Rainbow Beach. Most of the creek has permanent water covering the bed of the creek and there is little evidence of erosion with the banks appearing to be in a stable condition. The creek has a good capacity to convey flows. The permanent presence of water in the creek indicates that it is by definition a wet environment however it is noted that not all creeks have permanent water and are not considered to be wet.

As such increased levels of wetness associated with urban development are not likely to cause dieback of vegetation in or adjacent to Duchess Creek. The steep banks of the creek result in a smaller area inundated and this will also assist in minimising the impact of altered wetting and drying regimes. The gradient and distance to the ocean is short and so periods of extended wetting within the creek are not likely to be experienced. In conclusion the impact of low flows and in particular the increase in the frequency of low flows is not likely to impact on the long term stability of the lower section of Duchess Creek.

This statement is based on the assumption that water quality measures will be put in place to control the additional nutrients that may be exported into the creek following urban development. If the nutrients are not stripped from the flow then a weed plume may spread along the creek. This can, under some circumstances, result in bank instability as the weed infestation may result in the loss of soil binding vegetation which is prevalent on the banks of the creek. The loss of soil binding vegetation can then lead to bank instability and erosion.

The upper sections of Duchess Creek, which have a defined and dry bed and bank may be less stable than the wetter, lower parts of the creek. It is essential not to increase the catchment area draining to this section of the creek as doing so will increase the flow rate and volumes entering the creek system and risk causing scour and erosion. It was considered beneficial for flow volume reducing measures such as the use of rainwater tanks, infiltration systems, vegetated buffer strips, stormwater end of pipe solutions such as sand filters to be used reduce the volume of urban runoff. Such measures will reduce the risk of degrading the creek.

Some sections of the creek located within the proposed caravan park area are considered to comprise a bog like ecosystem that is they are considered to be hanging wetlands with an ecology similar in nature to that of bogs. These areas are wet for extended periods of time due to seepage of groundwater out of rock outcrops. These wetland areas must be protected when the caravan park is developed by ensuring that flows are not directed to these areas, by ensuring that the rock outcrops are left in place (removing rock can be considered a key threatening process) and by limiting activities immediately above these areas. The establishment of riparian buffer zones in which no development can occur will ensure that these areas remain protected.

If WSUD measures are implemented together with the establishment of a viable riparian corridor, the creek is likely to be able to adjust to the impacts of urban development without the need for continuous human intervention. Viable in this context means that the corridor has its own reproductive capacity.

The provision of a well developed riparian corridor to enhance the present remnant elements of the riparian corridor is considered essential for protecting the creek from the impacts of urban development in the long term.

STORMWATER – Water Cycle Management Implications for Duchess Creek:

- A viable riparian corridor needs to be established to protect Duchess Creek from the impacts of development.
- Increasing the catchment draining to the upper part of the creek is to be avoided.
- Various WSUD features will need to be designed to minimise nutrient loadings on the creek.
- WSUD measures that lead to the reduction of flows into Duchess Creek should be implemented.

4.10.2. Lake Cathie

The field investigations of Lake Cathie showed evidence of sandy soils in some areas around the wetland where infiltration of urban runoff will occur. These areas experienced small weed plumes and relatively minor ecological impacts. However, where there was direct drainage to a wetland or waterbody - weed plumes were large and invasive and the ecology was significantly altered.

It was concluded that a well structured stormwater treatment regime would prevent this situation from occurring. Effectively removing nutrients was likely to have prevented the weed plumes from spreading in areas draining existing development.

There was little evidence of die back of native vegetation due to changes in the wetting and drying of the wetland – most of the changes appeared to be the influx of exotic plant species into the wetland and catchment. It is noted that the dense vegetation prevented observations on what was occurring well within the wetland. Analysis of aerial photographs however indicates little evidence of dieback of vegetation.

One reason to use sand filters as opposed to wetlands is that sand filters are more likely to prevent the spread of weeds by trapping their seeds. Wetlands on the other hand may actually provide habitat for weeds to spread unless they are managed appropriately.

It appears that changes to the existing wetland ecology near Lake Cathie are more likely to occur from:

- an increase in the level of bio-available nutrients as a result of urban development, and
- an increase in the introduction of weed species associated with urban development activities such as gardening, deliberate planting of weeds, disposal of lawn clippings into waterways etc.

and less likely to occur as a result of changes in the wetting and drying (hydrological regime) of the wetlands.

Based on the evidence of the condition assessment of the waterways leading to **Lake Cathie,** which drain the existing urban development, it was concluded that provided there is adequate stormwater quality treatment, the changes to the hydrological regime will have less of an impact on the SEPP14 Wetland.

It should be noted that STORM has not undertaken a detailed ecological assessment on Lake Cathie and our conclusions are based on anecdotal evidence.

It is widely acknowledged that wetlands not only provide wildlife habitat but also play a vital role in flood mitigation, filtering stormwater, maintaining the soil and providing opportunities for recreation, enjoyment and education. **State Environmental Planning Policy No.14 (SEPP14) – Coastal Wetlands** was established in 1985 to preserve and protect coastal wetlands in the environmental and economic interests of the state.

Section 2.1.1 noted that Lake Cathie is a SEPP 14 protected wetland and provided specific objectives for development.

Water Cycle Management Implications for SEPP14 Wetland 509 - Lake Cathie:

Preserve and protect coastal wetland (No. 509) by:

- Providing viable riparian buffers on all waterways leading the wetland.
- Minimising nutrient loads draining to the wetland arising from urban development.
- Trapping weed seeds prior to discharge into the wetland – use sand filters for this.
- Controlling the quantity, frequency and duration of stormwater runoff into the wetlands by using flow reduction measures without the need to develop specific flow management measures.
- Actively preventing the planting of non-native vegetation in all public areas.
- Promoting the use of native vegetation and dissuading the use of exotic plants among the existing and new communities.

4.11. BASIX SEPP – Competing Provisions

The BASIX SEPP states that *"The competing provisions of a development control plan under section 72 of the Act, whenever made, are of no effect to the extent to which they aim:*

(a) to reduce consumption of mains-supplied potable water".

This means that the NSW State government has effectively taken control over the degree to which any development must implement water conservation measures. That is Council can not impose any water conservation measures upon a developer, BASIX, requiring 40% water conservation must simply be complied with. The implementation of BASIX should therefore be included in the water cycle planning of the subdivision.

Where a provision in a DCP aims to achieve something other than the reduction in mains water consumption, for example environmental protection measures that aim to reduce the volume of stormwater runoff, it will remain effective as long as the reduction in mains water consumption is coincidental and not a principle aim of the provision.

4.12. SEPP 26 – Littoral Rainforests

SEPP 26 protects littoral rainforests, a distinct type of rainforest well suited to harsh salt-laden and drying coastal winds. The policy requires that the likely effects of the proposed development on littoral rainforests be thoroughly considered.

An important littoral rainforest community listed under SEPP26 is present in the study area (identified as SEPP26 Littoral Forest No 116). The littoral rainforest area is located on the eastern boundary of the site.

Certainly no irrigation of any water would be carried out in the SEPP 26 areas. There is also need to ensure that drainage paths through the SEPP26 forest, if there are any, should not become avenues for weed propagation into the forest.

STATE ENVIRONMENTAL PLANNING POLICIES 14 & 26 Water Cycle Management Implications:

Preserve and protect littoral rainforests (No. 116) by:

- Limiting development surrounding the rainforests and maintaining a buffer zone
- Ensuring that runoff through the SEPP26 forest does not become an avenue for weed propagation

5.0 IWCM OPTIONS

Based on the objectives, constraints and opportunities identified for Area 14, STORM has developed four IWCM options for comparative assessment, namely:

- Option 0 – **which reflects current practice** – rainwater tanks and constructed wetlands
- Option 1 –Reticulated recycled water and constructed wetlands
- Option 2 –Rainwater tanks, WSUD and stormwater reuse
- Option 3 – A Combined Approach – Rainwater for hot water and laundry, recycled water for toilet and outdoor consumption and WSUD

Note well that each option would include the provision for a traditional potable water service to the estate and a sewerage system to convey the waste water to the existing treatment plant. This does not differ in any option.

5.1. Option 0 – Rainwater tanks and Constructed Wetlands

Option 0 represents what is currently practiced with the LGA. Current practice consists of rainwater tanks to comply with BASIX and the use of constructed wetlands located at the end of the pipe for stormwater quality treatment.

Below is the list of stormwater treatment measures used in this Option. (Refer to Drawing P09 in Appendix B which details the stormwater treatment measures).

- Rainwater tanks were modelled on each of the detached dwellings to supply toilet, laundry, hot water and outdoor uses. A range of raintanks sizes were explored and the most efficient tank size results were reported.
- Rainwater tanks were modelled on the medium density dwellings for supply of the same.
- CDS or similar gross pollutant traps were used upstream of each wetland. The gross pollutant traps were to be used to reduce the inlet zone of the wetland – effectively to zero. That is CDS units would primarily serve the purpose of capturing coarse sediment as well as any gross pollutants.
- Constructed wetlands to treat stormwater at the end of the pipe. We assumed 1m depth of temporary storm flow ponding was possible within the wetlands – this may not be possible in reality due to the flat nature of the site. Where this is not possible, larger wetlands would be required to ensure the equivalent total volume was still available.
- Extensive establishment of riparian corridors some of which are adjacent to Duchess Creek would be established with some new creek construction to ensure that flows can be conveyed from Ocean Drive to the existing waterbody. This would also enable future overland flow paths or drainage corridors to tie into Duchess Creek.