- Manage the quality and quantity of stormwater at or near the source, which will involve a significant component of public education and community involvement. Treatment practices such as precinct scale wetlands and detention basins to manage water quality could be provided downstream or close to the point of discharge from development areas, before discharge to key riparian and waterway areas; and
- Provide 'structural' stormwater quantity and quality management practices that provide flood management, flow attenuation and volume reduction, along with water quality management. Typical structures include detention basins, bioretention basins, lakes, ponds, wetlands, rehabilitated waterways and water re-use schemes. Furthermore provide primary stormwater treatment measures that target litter, gross pollutants and coarse sediments and secondary treatment measures that target fine sediment, nutrients and bacteria.

5.1.4 Creeks and Site Discharge Points

The presence of numerous watercourses through the site provides the opportunity to maximise the retention and designation of riparian corridors. The proposal seeks to encompass the intent of the Water Management Act where riparian corridors have been identified based on the stormwater conveyance and management requirements coupled with the desire to provide a diversity of habitat types for terrestrial and aquatic flora / fauna (further discussion on riparian corridors and corridor widths have been dealt with in the Ecological Assessment Report). The proposed riparian corridors widths allow for the conveyance of stormwater, management of water quality and flooding requirements, being cognisant of the topography and ecological value of the creeks. The Concept Plan identifies a range of buffer areas to creeks based on these corridor functions. In some instances the corridors are proposed to be rehabilitated and revegetated, improving bed and banking stability and reducing bank and channelling erosion. The enhancement of vegetation within these areas will therefore assist in protecting water quality by additional trapping of sediment, nutrients and other contaminants as part of an overall comprehensive WSUD strategy. In general the flooding is contained within the assigned riparian corridor widths throughout the development.

The site topography results in a number of discharge points corresponding to existing drainage corridors. Stormwater runoff would be controlled within the precinct in accordance with Council's requirements prior to discharging from the site. This applies to both stormwater quantity and quality.

5.1.5 Strategy Drivers

The proposed WSUD strategy for the Minmi Link Road site is provided in Appendix C. A number of specific "drivers" were identified, which have guided the WSUD strategy development. These include the following

- Requirements of the relevant Council DCP's.
- The steep site topography and incised riparian corridors in the upper reaches:
  - Does not favour large detention or bioretention basins before discharge to creek lines;
  - Favours on-lot treatment before discharge to the local stormwater system in the roads and discharge to the riparian corridors;
  - Does not favour in-street swales unless grades are less than 4%;

- Provides opportunity to locate stormwater treatment facilities (for example detention or bioretention basins) upstream of local road crossings using the road embankment at a discharge control;
- Requires careful consideration of increased runoff quantity and peak flow on the erosion potential in creeks; and
- Favours smaller cascading basins (for example detention or bioretention basins) in creeks to detain and dissipate energy of flow and prevent erosion.

» The undulating site topography:

- Requires management of stormwater at a number of discharge points corresponding to existing drainage lines.

» The flatter site topography in the lower reaches:

- Favours larger co-located bioretention and detention basins offline before discharge to creeks;
- Favours opportunistic provision of swales in the street; and
- Favours co-located open space/public amenity and stormwater treatment measures.

» The residential nature of the proposed development:

- Favours provision of on-lot detention using designated storage in rainwater tanks or separate stormwater detention tanks;
- Favours maximised on-lot treatment of runoff, however does not favour total reliance on this strategy, as limited control on maintenance of the systems can be exercised; and
- Favours precinct scale for road runoff, using swales and basins.

5.2 Stormwater Quality Management

The proposed WSUD management plan for the Minmi/Link Road site is provided in Appendix C and includes the followings strategies:

» Runoff will be treated on individual lots, before discharge to the street drainage system. This can be achieved using:

- Roof water tanks;
- Infiltration and retention devices;
- Permeable paving;
- Using crushed gravel or other treatments instead of paving
- Swales & other landscape measures;
- Sand/gravel filters for runoff from car parks and driveways;
- Reducing the area of paving (for example, driveway strips); and
- Diverting runoff from driveways onto garden beds before leaving the property.

» Runoff from roads will be treated using:

- In flatter areas, vegetated infiltration swales (bio-retention in the invert) along the identified main overland flow routes adjacent to the road. The required width of the vegetated swales are approximately 4 to 6 m and road cross-fall would need to convey runoff to the swales; and
- Smaller bioretention basins upstream of local road crossings in steeper areas. In other areas, the basins would be located offline, discharging to riparian corridors. The basins would provided both

detention and water quality treatment function. The bio-retention basins may need to be lined to prevent contamination with groundwater;

» Gross pollutant traps and other structural measures would be provided throughout critical locations as required, before discharge to the basins; and

» Provision of rainwater tanks in all areas should be maximised in accordance with Council's requirements.

Three "pilot" catchments, two in the Minmi and Link Road North development areas, and one in the Link Road South development area were configured in the MUSIC model, to test the effectiveness of the proposed strategy. Since hydrological conditions and proposed development are similar for this site, the results were transposed for the entire development. To this end this "pilot" approach was deemed acceptable.

The results listed in Table 5 to Table 7, show that the proposed treatment satisfies Councils nominated target pollutant removal requirements, in particular LMCC DCP 1. Opportunities for configuring on-lot treatment are provided in Appendix D. In general the required treatment area is approximately 2% of the developed footprint. However additional land needs to be provided to allow for embankments and local landscaping associated with the facilities. Thus approximately 4% of the developed area may need to be provided. The required area will be dependant on the local topography. It is proposed to co-locate the stormwater quality treatment areas (bioretention areas) within detention basins.

Table 5 Stormwater Treatment Measure Effectiveness South of Link Road

	Post Development (kg/yr)	**Post-development (with WSUD) (kg/yr)**	**% Reduction using WSUD**	**Target Pollutant Removal Efficiency**
Total Suspended Solids	111000.00	5040.00	95	Moderate – High (30 – 80%)
Total Phosphorus	227.00	38.50	83	Moderate (30 – 50%)
Total Nitrogen	1640.00	767.00	53	Moderate (30 – 50%)
Gross Pollutants	16700.00	143.00	99	High - Very High (80 – 100%)

Table 6 Stormwater Treatment Measure Effectiveness North of Link Road (Catchment 1)

	Post Development (kg/yr)	**Post-development (with WSUD) (kg/yr)**	**% Reduction using WSUD**	**Target Pollutant Removal Efficiency**
Total Suspended Solids	6640.00	256.00	96	Moderate – High (30 – 80%)
Total Phosphorus	13.60	2.22	84	Moderate (30 – 50%)

Total Nitrogen	93.20	46.00	51	Moderate (30 – 50%)
Gross Pollutants	961.00	0.00	100	High - Very High (80 – 100%)

Table 7 Stormwater Treatment Measure Effectiveness North of Link Road (Catchment 2)

	Post Development (kg/yr)	Post-development (with WSUD) (kg/yr)	% Reduction using WSUD	Target Pollutant Removal Efficiency
Total Suspended Solids	69000.00	3250.00	95	Moderate – High (30 – 80%)
Total Phosphorus	141.00	23.60	83	Moderate (30 – 50%)
Total Nitrogen	980.00	468.00	52	Moderate (30 – 50%)
Gross Pollutants	10300.00	133.00	99	High - Very High (80 – 100%)

The results listed in Table 8 show, that the proposed treatment results in TN and TP pollutant concentrations that are below the ANZECC trigger values.

Table 8 ANZECC Guideline Trigger Values for Aquatic Ecosystems

Catchment	TP mg/L	TN mg/L	Guideline Trigger Values	
South of Link Road	0.019	0.42	TP = 0.05 mg/L	TN = 0.5 mg/L
North of Link Road (Catchment 1)	0.018	0.38		
North of Link Road (Catchment 2)	0.016	0.37		

5.2.1 Managing Construction Phase Stormwater Quality Impacts

Construction phase water quality impacts will be managed through the implementation of a Soil and Water Management Plan detailing stormwater management strategies in accordance with 'Soils and Construction, Managing Urban Stormwater' (Landcom 2004). Specific strategies may include:

- Material management practices;
- Stockpile practices;
- Topsoil practices; and

» Erosion control practices (earth sediment basins, straw bales, sediment fences, turbidity barriers, stabilised site accesses, diversions and catch drains).

Monitoring, including visual inspections and water quality sampling, will be required as part of any development consent to ensure that management strategies are working effectively.

5.3 Flooding and Stormwater Quantity Management

5.3.1 Detention

» Onsite detention for individual lots requiring approximately 4 % of the lot area. These detention areas would be combined with bioretention to provide the dual purpose of stormwater quantity and quality management;

» Precinct scale detention basins are proposed at key locations. The required detention areas are estimated based on the contributing developed sub-catchments. In some locations these detention facilities could be co-located with bioretention to provide the dual purpose of stormwater quantity and quality management; and

» Rainwater tanks would be provided for each dwelling. The size of the tanks will be decided as part of the lot development process. While the purpose of rainwater tanks is for roof water harvesting and reuse, they also detain the stormwater flows to a certain extent. However this function was not included in assessing the required detention storage volume.

To test the effectiveness of the strategy, detention basins were configured in the RAFTS model for three pilot catchments. In general it was found that the permissible site discharges and minimum storage requirements in Table 9 and Table 10 generally satisfy Council requirements in terms of detention.

The required detention storage for the off-site portion equates to approximately 3% of the developed footprint, however additional land needs to be provided to allow for embankments and local landscaping associated with these basins. Thus approximately 5% of the developed area may need to be provided. This result generally compares favourably with detention requirements for other land developments undertaken by GHD in the region.

It is proposed to co-locate the bioretention stormwater quality treatment areas with these detention storage facilities. It is anticipated that as these detention basins will be community-based facilities to achieve the detention requirements and that they will be allocated to Council ownership at the completion of the construction. As such these structures will then be operated and maintained by Council.

Table 9 Detention Strategies Link Road South (after LMCC design criteria)

Catchment	Maximum permissible site discharge (l/s/ha)	Minimum required detention storage (m^3/ha)
On-Lot	80	280
Precinct Basin	90	140

Table 10 Detention Strategy for Minmi and Link Road North (after NCC design criteria)

Catchment	Maximum permissible site discharge (l/s/ha)	Minimum required detention storage (m^3/ha)
On-Lot	NCC DCP (see Table 4)	NCC DCP (see Table 4)
Precinct Basin	170	280

Table 11 shows the effectiveness of the detention strategy for the typical pilot catchment in Link Road South. The table shows that the developed 20-year ARI flood peak flow is generally throttled to the existing 5-year ARI peak flow.

Table 11 Effectiveness of Detention Strategy – Link Road South (LMCC area)

Pilot Catchment Area	Flood Peak (m^3/s) for critical duration			
	Existing – 5 year ARI	Developed with mitigation – 20 year ARI	Existing – 100 year ARI	Developed with mitigation – 100 year
83 ha	5.69	5.93	10.05	7.80

Table 12 shows the effectiveness of the detention strategy at the other two pilot catchments. The table shows that the developed 10 year ARI and 100 year ARI flood peak flows are throttled to the existing peak flows.

Table 12 Effectiveness of Detention Strategy – Link Road North (NCC area)

Pilot catchment Area	Flood Peak (m^3/s) for critical duration			
	Existing – 10 year ARI	Developed with mitigation – 10 year ARI	Existing – 100 year ARI	Developed with mitigation – 100 year
4 ha	0.42	0.38	0.72	0.58
49.3 ha	4.53	3.92	7.81	6.24

5.3.2 Flooding and Flood Risk

Existing conditions flood maps are provided in Appendix B. In general, the results show:

» Figures 1 to 5: In the upper reaches of the catchment, floodplains are confined in many cases within the deeply incised creek channels;

» Figures 1 to 5: A significant flood plain exists in the lower reaches, where floodplains open up to Hexham Swamp;

- Figures 1 to 5: The PMF flood extents are only marginally larger in flood extent compared with the 100-year ARI flood extents due to the steeper terrain; and
- Figures 1 to 5: Flood extents on certain tributaries are dominated by culverts under roadways, which result in backwater upstream of the culverts.

Development and land-use in flood prone areas should be in accordance with the NCC Flood Management Technical Manual, Lake Macquarie Floodplain Management Policy and the NSW Floodplain Development Manual. In assessing the flood risk, consideration needs to be given to the full range of risks to people and property, for a full range of flood events up to and including the PMF. Interim development guidelines specify, amongst others:

- Habitable floor levels should either be at or above the Flood Planning Level (500 mm above the 100-year ARI event flood level) or be flood proofed to this level, making additional provision for potential subsidence;
- In flood storage and flood way areas, development must not lead to a significant increase in flood levels, flood damages, flood behaviour or flood hazard at the site or elsewhere. Provision of adequate and acceptable compensating works to offset must be provided; and
- In high flood hazard areas, effective evacuation procedures must be provided.

For the Minmi Link Road site, all dwellings would be located above the 100-year ARI flood level associated with the creeks, local overland flow paths and stormwater management facilities across the site. It is proposed that Flood Planning Levels be adopted that locate floor levels of dwellings with a freeboard of 500 mm above 100-year ARI flood levels. Referring to Appendix C, where the 100-year ARI flood is overlayed with the WSUD strategy and the Concept Plan, the following is noted:

- Areas of inundation are primarily associated with riparian corridors. In a few isolated areas in the northern precincts the 100-year ARI event extends into the development footprint. In these locations, minor filling of the flood fringe would be required to ensure roadways and selected areas on lots remain flood free. However the final lot usage could incorporate the edge of the floodplain in the lot planning as open space;
- In a number of locations, minor tributaries, would be incorporated in the development footprint as part of the stormwater system. In these cases, the capacity of both the overland flow paths and underground stormwater system will be designed to provide a level of service that minimises the flood hazard. Flood hazard is a product of both overland flow depth and velocity. In order to limit the hazard both of these need to be controlled. For the underground system, this would be achieved by providing a sufficient number of surface inlet pits. For the overland system, the flood hazard reduction would be achieved through the incorporation of lower grade swales and rock protection of the steeper swales through the riparian corridors; and
- In general the flooding is contained within the assigned riparian corridor widths throughout the development.

5.3.3 Climate Change and Flooding

The impacts of the climate change scenarios are shown in Appendix B, Figures 6 to 15. In general the figures show that:

- Flood extents in the 100-year ARI climate change scenario increase by a small amount adjacent to the precincts in the steeper upper reaches of the creeks. In the lower reaches, the impact is slightly more given the larger floodplain;
- In a 100-year ARI event climate change scenario, flood levels adjacent to the site are expected to increase by less than 0.3 m in the upper reaches. While this does not cause a significant increase in flood extent, dwelling floor levels would need to consider these impacts; and
- In the lower reaches flood levels, where creeks discharge to Hexham Swamp, flood level impacts increase to 0.7m. Again dwelling floor levels will need to consider these impacts

5.3.4 Evacuation Strategy

The management of floods and floodplains are the responsibility of State Emergency Service (SES) and Council. SES is mainly responsible for dealing with floods while flood planning and land management rest with Council.

The arrangements for managing flood prone land are detailed in the State Government's Flood Prone Lands Policy and the Floodplain Development Manual. The main considerations for the evacuation strategy are:

- The areas within PMF flood extents to be evacuated;
- Number of people to be evacuated and the time available (at this stage, it is difficult to estimate the number of people);
- Muster areas and evacuation routes; and
- Resources and transport means necessary to meet these needs and access to hospitals.

The most "at risk" properties are adjacent to the creek. Given the timing of flood peaks, evacuation will likely be required at short notice. The strategy and operations must be pre-planned during design stages. It is considered, that the site has sufficient space and locations to assemble and evacuate during flood events.

5.4 Total Life Cycle Costs

GHD has proposed co-located bio-retention/detention basins in residential development areas to manage stormwater water quantity and quality. These systems achieve the following common goals:

- The treatment area is optimised;
- Total acquisition cost is minimised;
- The area could be landscaped without hindering its function; and
- Annual maintenance cost would be less compared to open water bodies such as wetland.

GHD has proposed vegetated swales at a number of locations. Vegetated swales are open channels system, which could be designed to treat water quality with low capital and maintenance costs. At this stage, any water quality treatments along arterial and local roads and at individual lots are not considered.