PATTLE DELAMORE PARTNERS LTD
Level 4, PDP House
235 Broadway, Newmarket, Auckland 1023
PO Box 9528, Auckland 1149, New Zealand

Tel +9 **523 6900** Fax +9 **523 6901**
Web Site **http://www.pdp.co.nz**
Auckland Wellington Christchurch

***solutions** for your environment*

6 October 2014

Bernie Chote
General Manager
Fletcher Developments
Private Bag 92114
AUCKLAND 1142

Dear Bernie

THREE KINGS RENEWAL, ADDENDUM TO STORMWATER MANAGEMENT PLAN, OPTION 15H1

This letter forms an addendum to the Three Kings Renewal Stormwater Management Plan produced by Pattle Delamore Partners in September 2014. The addendum addresses questions identified by Auckland Council in their correspondence to Fletcher Residential Ltd of 26th August 2014 and 24th September 2014. The points addressed by PDP are items 48, 51, 54 relating to correspondence on 26th August and items 5.4, 8.1, 8.2, 8.5, 8.6, 8.13 relating to correspondence on 24th September 2014.

1.0 Clarification of Flood Levels provided in SMP

Figure 11 of the Stormwater Management Report identifies flood levels for the development. These are highly conservative and were developed for setting minimum floor levels in the development. The expected flood levels as a result of extreme rainfall events are much less than these flood levels.

Modelling to produce these levels assumed that some upper catchment areas use soakage to dispose of up the 2 year peak storm event. Excess stormwater beyond this event is then contributed to storage within the catchment. No other soakage was assumed to occur within the development.

In practise, soakage will occur across the development whenever stormwater is present. This is described further below.

2.0 Flooding of Sportsfields

Item 5.4 (24th September)

Please provide further information on the expected flooding frequency/duration of the proposed sportsfields and the likely impact on use of the fields (i.e. field closures, additional maintenance and field repair following storm events).

2.1 Soakage Trench Design

This is an assessment of the time taken to fully discharge stored stormwater from the fields to ground at the proposed Three Kings Renewal development for a range of rainfall events and soakage rates. This requires a conceptual design of the soakage method to the local and wider ground conditions.

Ultimate stormwater disposal from the sportsfields has been assumed to occur via soakage trenches excavated into the scoria at the south side of the field areas (as shown in Figure 1 below). For this conceptual design, five soakage trenches of length 50m each have been used (for a total of 250m of actual trench). Infiltration has been assumed to occur only through one wall towards the perimeter of the site and through the base of the soakage trenches (green on Figure 1).

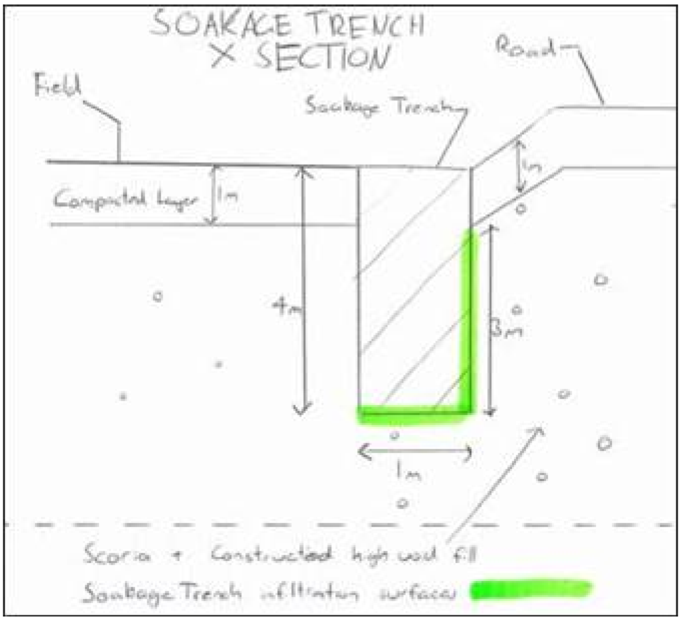

Figure 1: Soakage Trench

Table 1: Soakage Trench Dimensions	
Development Option:	15H1
Surface Level (m)	59
Depth to Free draining Scoria (m)	1
Depth of Trenches (m)	4
Width (m)	1
Length (m)	250

2.2 Determining Soakage Capacity

There are two key potential factors affecting the design of the soakage trench:

1. The rate at which water can be conveyed through the walls and floor of the trenches; and
2. The rate at which water can be conveyed into the wider groundwater without locally raising the groundwater level above the surface water ponding level.

The more conservative of these two should be taken as the limiting rate.

2.2.1 Rate of conveyance through walls and floor of trenches

This assesses the rate at which stormwater can infiltrate through the trench walls into the ground assuming no groundwater interference. In these scenarios the vertical infiltration rate is assumed to be double the horizontal infiltration rate (i.e. water flows through the base twice as fast per square metre of soakage area as it does through the walls). Three different soakage rates have been assumed to characterise this limitation; "Low", "Medium" and "High":

- "Low" soakage rate assumes a worst case scenario of a low initial soakage rate and a further allowance for clogging of the soakage devices.
- "Medium" soakage rate assumes a soakage rate determined during a soakage test into scoria at BH01 adjacent to Mt Eden Rd. This design soakage rate was reduced by a factor of safety of 1.65 (the AC Soakage Design Manual requires this factor to be at least 1.4). Infiltration rates were determined based on the surface area of soakage and an additional factor of safety of 10 has been applied to the soakage rate to account for the different location of the soakage test and soakage trench, the potential variability of soakage rates across the site, and the potential reduction in performance of the soakage trench over time with sediment accumulation.
- "High" soakage rate is calculated in the same way as medium soakage rate *without* the factor of safety of 10.

2.2.2 Rate of conveyance to groundwater in the wider aquifer

This "Groundwater Limited" soakage rate is based on the localised groundwater mounding which can occur without exceeding the surface water level. This soakage rate was assessed based on the local groundwater mounding which would result from discharging runoff for the 100 year rainfall event to the soakage trenches and the 100 year short term groundwater design level. This is conservative for smaller events.

The Hantush (1967) method was used for the calculation assuming a hydraulic conductivity of 17 m/day, effective porosity of 0.08, and trench dimensions of 50m by 1m discharging one fifth (to account for five trenches) of the required runoff. The aquifer thickness was assumed to be 100 m (which is conservative as the actual aquifer thickness is considered to be as deep as 400 m in previous modelling carried out by PDP). This hydraulic conductivity value represents the current assessment of the wider aquifer within the volcanic material (which is being updated through further calibration). It is considered conservative in that it is representative of basalt rather than scoria.

The time period of this discharge was changed iteratively to identify how quickly the stormwater could be discharged to ground without causing groundwater mounding to exceed the surface water level. For 15H1 the average event surface water level was assumed to be 0.5 m above the surface (this level is based on the previous conservatively modelled flood levels which are expected to be refined further and subject to design of final ground levels). It was assumed (to account for interaction between the trenches) that they could only discharge water to groundwater in one direction away from the centre of the development, i.e. the trenches could only convey half the stormwater which was calculated by the Hantush method. It was also assumed that the five proposed trenches would otherwise act independently.

PDP is currently monitoring the response of groundwater levels in the quarry to rainfall events. This will allow refinement of the rate of conveyance into the wider aquifer and further analysis will then be carried out to assess in more detail the effects on soakage capacity that may occur as a result of interaction between the trenches.

Table 2: Soakage Rates

Soakage Rate Option	Low	Medium	High	Groundwater Limited
Vertical Soakage Rate (m/hr)	1	9	88	NA
Horizontal Soakage Rate (half vertical rate) (m/hr)	0.5	4	44	NA
Total Soakage Rate (m^3/hr)	625	5,502	55,017	551

2.2.3 Time to fully discharge rainfall events

Table 3 below shows the time it would take for all ponded surface water to be discharged through the wall and floor of the trenches.

5500 m^3 has been allowed for subsurface storage beneath Superlots C and D and a further allowance has been made for stormwater draining to the wetland/swale on the eastern side of the site. Water in both of these underground storage areas will be stored and discharged to soakage areas separately from the five trenches. The volumes listed in the tables below are the volumes which are stored above the sportsfield/park surface not including subsurface storage.

Table 3: Option 15H1 Time to discharge water stored on fields from 24 hour rainfall events

24 Hour Rainfall Event ARI (years)	**2**	**10**	**50**	**100**
Runoff Stored Above Surface (m^3)	2,207	8,039	14,463	21,177
Time (hours) taken to dispose of stormwater at different soakage rates				
Low	3.5	12.9	23.1	33.9
Medium	0.4	1.5	2.6	3.8
High	0.0	0.1	0.3	0.4
Groundwater Limited	**4.0**	**14.6**	**26.2**	**38.4**

It is noted that if the time to discharge the water is less than the 24 hour rainfall event duration, then minimal ponding is anticipated to occur on the fields. That is, soakage is occurring throughout the 24 hour rainfall event and will discharge the runoff volume within that 24 hour period. Table 4 below summarises the amount of time ponded water will be present on the fields after the storm event. Only the 50 year and 100 year rainfall events will result in ponding beyond the rainfall event duration.

Table 4: Option 15H1 Duration of ponding after 24 hour rainfall events

24 Hour rainfall event ARI (years)	**2**	**10**	**50**	**100**
Runoff Stored Above Surface (m^3)	2,207	8,039	14,463	21,177
Time (hrs) taken to dispose of stormwater at different soakage rates				
Low	0	0	0	9.9
Medium	0	0	0	0
High	0	0	0	0
Groundwater Limited	0	0	2.2	14.4

2.2.4 Management of the groundwater level

Further assessment has been carried out to determine what level the groundwater table would have to be at the beginning of the rainfall event to discharge the entire 100 year event below ground within the 24 hour rainfall event duration. The soakage trenches have been assumed to have the same design as above. The Hantush (1967) method was used in the same way as above with a fixed time period of 24 hours to determine the depth of groundwater mounding which would occur in this event.

If the soakage trenches fully drain the surface water within the 24 hour period of the 100 year design event, between 1.85 m and 2.5 m of groundwater mounding is anticipated to occur. The groundwater level is anticipated to rise by 1.25m during a storm event in addition to this, for a total of up to 3.75 m of rise. The field surface level is at 59 m for option 15H1, and therefore to ensure no ponding after a 100 year event, the water level would have to be maintained reliably below 55.25m (taking into account any fluctuations in water level) prior to the event.

2.2.5 Summary

Table 3 shows the time for different rainfall events to discharge all surface stored storm water to ground. For most events, this time is less than the 24 hour duration of the rainfall event, indicating minimal ponding will occur on the sports fields. Where the time to discharge surface stored water to ground is greater than 24 hours, Table 4 indicates the duration of this ponding after various rainfall events.

In all scenarios the “groundwater limited” soakage rate is the most conservative, and should be used to assess the amount of time that stormwater will pond.

The design and soakage rates here are conceptual only. Further soakage testing and geological mapping is required to assess local soakage rates and further inform the design of the soakage trenches. Further assessment of the interaction between the soakage trenches and the groundwater level is also required to confirm the extent to which their proximity to each other reduces their capacity.

The ability to provide soakage, either at soakage pits themselves, or to the wider aquifer will be managed by ensuring there are sufficient soakage areas distributed around the perimeter of the development and storage to ensure soakage occurs without groundwater mounding longer than 24 hours and interference between dispersal trenches. The extent of soakage trenches used in this assessment could be increased by directing flows to further trenches along the western boundary of the site or providing further connections to existing scoria zones.

This assessment is based on very conservative modelling assumptions and is appropriate at this stage of the analysis. Even with this conservative modelling once the rainfall event stops there is no ponding on the sportsfield except in the 50 and 100 year events. The maximum duration of ponding after the 50 year rainfall event is 2.2 hours and 14.4 hours after the 100 year event. The reality is that in these extreme events areas all over Auckland will be subject to similar or worse ponding issues.

3.0 Storage Areas B and C, 15H1

Item 48: 26th August

In diagram 11 of the stormwater report, it is unclear where the boundaries of area B and C start and finish. It is also unclear where the stormwater underground storage is proposed. How will that impact on park use, and future buildings (such as club rooms)?

Flood storage areas B and C were separated by a road in a previous design iteration. This is no longer the case, and they are effectively one storage area. Underground storage is proposed under the beige and blue areas indicated in Figure 11 of the stormwater report. The underground storage will extend down to the design groundwater level.

4.0 Options Analysis

Item 54: 26th August

An analysis of alternative options will be required for the discharge consent in order to demonstrate that the proposal is the best practicable option.

From 24th September request:

It is common that a network discharge consent is applied for and heard in conjunction with a plan change to ensure the proposed solution is the best practical option and environmental effects have been fully considered. This would include an analysis of alternative options in order to demonstrate that the proposal is the best practicable option. Alternatively, please ensure all effects that would be considered at the time of the discharge consent, and that are relevant to the consideration of the proposed plan change should be considered. It is not sufficient to deter consideration of effects to a future consent process.

An assessment of options for the stormwater management approach has been carried out (refer Appendix D of the September version of the Stormwater Management Plan).

The matrix of the options in Appendix D shows that all options have common stormwater infrastructure requirements such as an internal stormwater pipe system and stormwater quality treatment. All options also require some form of flood storage on site – either because the proposed development levels are below the surrounding area's ground levels or because flow detention is required to avoid effects on downstream pipe systems and flood prone areas. Therefore these are assumed to be generally similar in terms of cost.

Options where the quarry is filled to the surrounding ground levels incur additional time to obtain fill and reduced development yield. These have therefore been discounted.

Of the options where the development is constructed at levels of approximately RL 59m to 65m, the tunnel option incurs significantly greater cost in terms of tunnel construction. Furthermore significant flow detention and possibly also downstream pipe upgrades are expected indicating additional cost and practicality issues. This has therefore been discounted. The two soakage options are considered broadly similar in terms of stormwater capital cost - however the pumping option introduces ongoing operational cost. A soakage system can be designed without pumping being required and this is considered preferable in terms of long term robustness and certainty. Soakage systems receiving high sediment loads are susceptible to blockage. However in this case, long term sediment loads are expected to be relatively low as they are from residential development and stormwater treatment will manage the loads generated.

Iwi have identified that they prefer the discharge to be to the Meola catchment. This means that they prefer a discharge to soakage without on-going pumping.

The "soakage without ongoing pumping" option avoids potential effects on existing flooding areas off-site and is considered to a practical solution for stormwater management on site. This option is therefore used as the basis for the development.

5.0 Offsite Catchments

Item 8.1 (24th September)

The catchment boundaries used in the stormwater management plan don't reflect the natural catchment boundaries. The natural catchment appears to be approximately 65ha. Council's overland flow path mapping layer indicates significant overland flow enters the site from the residential area to the east of the site. It's assumed that this flow will be contained within the council land south of the site (section 3.1.1 of the stormwater report).

Please provide further information on the specific location of this overland flow path, how this overland flow will be managed within the site and where it discharges; how it has been incorporated into the design, and if it is to be redirected to council's land, how it will affect the use (including future development potential) of that land. Similarly, information of this nature is required for any other overland flow paths affected by the development.

Three depression storage areas with potential overflows to the Three Kings development have been assessed, as shown in the figure below. Table 5 presents the assessment results.

Figure 2: AC GIS overland flowpaths across the site

During the 100 year rainfall event the catchment to depression D generates 13800 m^3 of runoff volume. The primary drainage is via soakage. If it is assumed this soakage caters for up to peak flow for the 2 year rainfall event (as per the global soakage system capacity), this water could be drained in much less than 24 hours. In addition, significant storage is available to store the water should the actual soakage rate be less than this. No overland flow into the Three Kings Renewal site is therefore expected.

The catchment for Depression E, to the east, has 41,740 m^3 of runoff volume during the 100 year event. The primary drainage is via a 1200 dia public stormwater pipe running south-east towards Hillsborough Rd. Conservatively assuming this pipe is 50% blocked an outflow rate of 1.1m^3/s would occur and up to 95,000m^3 of water would be drained in 24 hours. In addition, significant storage is available to store the water should the actual pipe discharge rate be less than this. No overland flow into the Three Kings Renewal site is therefore expected.

Depression F, a local athletics track, collects water from the south from around the Three Kings library, Fickling Centre and potentially south of Mt Albert Road. During the 100 year event the catchment has a runoff volume of 15680 m^3. The primary drainage is via soakage and/or combined sewers. Conservatively assuming only soakage occurs and this caters for up to peak flow for the 2 year rainfall event, up to 75,000m^3 of water could be drained in 24 hours. In addition there is some 5,700m^3 of storage available to store flow if required. No overland flow into the Three Kings Renewal site is therefore expected.

Table 5: Overland flow paths shown on AC GIS

Offsite OFP catchment, shown on AC GIS	Location	Area, ha	Primary Drainage system	100 year 24 hour runoff volume, no primary drainage outflow, m^3	Primary drainage outflow volume over 24 hours, m^3	Net volume stored, m^3	Storage volume available before OFP shown on AC GIS operates, m^3
D	Commercial area on north boundary of site	6.6	Soakage	13,800	66,000	0	11,770
E	Residential area east of Mt Eden Road	20.6	Public Stormwater reticulation	41,740	95,000	0	24,900
F	Field south east of Graham Breede Drive	7.5	Soakage Combined Sewer?	15,680	75,000	0	5,700

Notes:

1. *Outflow volume for Catchment D assumes soakage only and this operates at the 2 year ARI peak rate for 24 hours*
2. *Outflow volume for Catchment E assumes 1200 dia pipe operates at 50% of capacity for 24 hours*
3. *Outflow volume for Catchment F assumes soakage only and this operates at the 2 year ARI peak rate for 24 hours*
4. *Storage volume for Depression D assumes 0.3m deep ponding on athletics field.*

6.0 Long Term Soakage Performance

Item 51: 26th August

Discharging the up to the 100yr ARI event into an aquifer via soakage is a drainage methodology that has not been used in Auckland before (typically the maximum to soakage is the 10yr ARI event). This is a high risk strategy if no redundancy is allowed for, if soakage systems block the basin can fill up flooding the development. A pumping station or new gravity outfall may be required as a failsafe measure.

Item 8.2, 24th September

There are some risks associated with discharging stormwater up to the 100 ARI event to soakage. If the soakage inlets block the basin could flood beyond the attenuation area. Please provide more information/consideration outlining risk management strategies including redundancy in the system, multiple inlets, soakhole spacing, a pumping station or gravity outfall. More detail is required around the inlet capacity and spacing of soakholes and the effect on discharge rates into and through the aquifer. Information is sought on the effect adjacent soakholes will have on each other's discharge rates to the aquifer and confirmation that this effect has been taken into account in any modelling of the flows. Sufficient detail is required to satisfy council that the flood risk is acceptable because this kind of solution hasn't been used in Auckland before.

Redundancy

A large amount of redundancy has been provided in the proposed stormwater system through a series of conservative assumptions, including:

- generous and conservative flood storage volumes,

- setting floor levels with additional freeboard above those conservative flood storage volumes,
- providing stormwater treatment in addition to that required by AC Plan requirements,
- setting the development above the long term ground water levels that would occur without pumping.

Further details in response to specific issues identified in Item 51 and 8.2 are provided below.

Soakhole Spacing

As discussed in the response to question 5.4 there are two major factors which limit the discharge of stormwater to ground. These are:

1. Rate of conveyance of water through walls and floor of trench.
2. Rate of conveyance of water to groundwater in the wider aquifer.

Even in an extremely conservative case of vertical soakage rates being reduced by sediment clogging from a tested rate of 88m/hr to 1m/hr (Table 1), the limiting factor is still the capacity to convey groundwater to the wider aquifer (see Tables 3 and 4) not the capacity within the proposed soakage trench. Therefore it is proposed to site soakage trenches around the edge of the former quarry to directly discharge via soakage pits and trenches with in situ scoria zones. These soakage areas will be spread out to reduce high flows at individual locations and allow water to disperse into the groundwater aquifer with the minimum of groundwater mounding.

The extent of soakage trenches used in this assessment could be increased by directing flows to further trenches along the western boundary of the site or providing further connections to existing scoria zones. This would allow additional contact to the wider aquifer.

Inlets

Inlets to the stormwater system are distributed throughout the development. On roads adjacent to the wetland cells, inlets are via catch-pits. In other areas, inlets will be direct from roofs, or from roads and paved areas via swales or rain-gardens. Each apartment block would have multiple inlets and each terrace house would have an individual inlet for roof water with further inlets to pick up paved area water at local low points. Given that inlets are distributed widely throughout the development and there will be a large number of inlets the total or substantial blockage of all inlets simultaneously would not occur.

Protection of Soakage Areas against Blockage

Sedimentation and clogging can occur where stormwater with high sediment loads is directed to unprotected soakage pits. Over time discharges containing sediment can fill interstitial cracks and reduce the capacity of soakage bores and soakpits. This is particularly an issue where sediment loads are high such as from industrial sites, heavily trafficked roads and eroding landscaping areas.

The Three Kings development will not generate high volumes of sediment once the construction phase is complete.

During construction a high degree of erosion and sediment control will be provided and final soakage systems will be constructed late in the construction programme to minimise the risk of construction related sediment blockage.

Following construction the residential development and low traffic volumes on the internal roads will not generate large volumes of sediment. Significant treatment (through sedimentation basins and wetlands) will be provided to reduce the sediment that is generated. Prior to the outlet diversions to soakage, water will be flowing slowly through the wetlands allowing sediment to both settle and be filtered by wetland vegetation. At the diversions, flows will drain from the surface (where the cleanest water will be) and graded filters will be provided at the entrance to soakage pits to further catch any floatables and sediment. Finally, monitoring wells will be installed within underground storage areas and soakage pits to allow soakage rates to be monitored, identify any reductions in soakage capacity and trigger maintenance if required.

Treated stormwater from areas outside the fields will pass via catchpits into manholes located within the soakage trench. A perforated pipe will connect each manhole to the next and allow distribution of stormwater throughout the soakage trench, particularly during high flow events. As part of regular maintenance, the manholes will be inspected and any accumulated sediment will be removed. For high flow events, a French drain system will be located on the surface of the soakage trench. It will direct stormwater from the field into the soakage system. Sediment protection will be provided by graded filter separation and filter cloth layers if required.

Pumping Back-up

The stormwater system proposed does not rely on long term groundwater pumping and soakage is expected to provide suitable long term drainage. Notwithstanding this, if required by AC, it would be feasible to provide a connection point and rising main for a temporary pump that could be brought on to site in a short term situation. The details of such a system are currently being considered.

7.0 Wetland Alternatives

Item 52: 26th August

The proposed wetlands are very large for the catchment area the served, they may be vulnerable to dying in dry summers (algal blooms, anaerobic conditions, odours) the design will need to be assessed for durability in drought conditions.

Please consider reviewing the proposed stormwater treatment design to assess it against alternatives, including on-going operational costs and durability in drought conditions. Consider alternative bio-filtration such as a vegetated swale (or wetland swale) that may be more resilient to seasonal changes in hydrology. Consider whether the planting palette requires amendment to suit dryer conditions. A full assessment of treatment alternatives is required and should form part of a Network Discharge Consent application.

In dry periods open water will be present in the main channel sections and any margin sections that do not also operate as soakage areas. Vegetation along the wetland edges will be drought tolerant. To maintain permanent water levels within the wetland cells it may be necessary to line the wetland cells. A small constant feed of water inflow is also being considered at the head of the wetland in the north-west corner of the site to top up water levels and discourage stagnant pools forming.

Discussion with AC is continuing to identify an agreed long term stormwater treatment system. For more information regarding the wetland channel refer to the Stormwater Management Report (Section 5.2.4).

8.0 Treatment Train Schematic

Item 8.13, 24th September

There would be benefit in producing a schematic showing the proposed treatment train for consultation purposes.

The approach to stormwater quality treatment is summarised as follows:

- Source control of roof materials
- Swales and tree-pits (in some locations)
- Sedimentation basins (prior to entry to the wetland)
- Wetlands
- Filtration layer at entry to soakage pits/trenches
- Soakage trenches/pits

Refer to the Stormwater Management Plan (Section 5.2.4) for further details.

The approach for apartment buildings is as follows:

- Source control of roof materials
- Sedimentation chamber for paved areas
- Rain-gardens
- Soakage trenches/pits

Refer to the Stormwater Management Plan (Section 5.3) for further details.

It is agreed that a schematic would be beneficial. PDP will discuss the stormwater treatment elements further with AC and will provide the schematic in due course.

9.0 Monitoring Wells

Item 8.5, 24th September

Section 5.5.3 refers to Fig 10 (PDP report) for details of monitoring wells for underground storage and soakage areas. Fig 10 does not contain these details. If soak holes are grouped they may not work as intended. Please provide the details for monitoring wells for underground storage and soakage areas provide spacing details.

Soakage trenches will be spaced as far apart as is feasible to ensure the discharge is spread over as wide an area as possible. The final location of soakage trenches has yet to be confirmed.

Monitoring wells will be installed within underground storage areas and soakage pits to allow soakage rates to be monitored, identify reductions in soakage capacity and trigger maintenance if required. Final locations of monitoring wells will be determined based on the final locations for storage and soakage devices, as well as access considerations.

10.0 Emergency Egress

Item 8.6, 24th September

Please clarify that access to and from the apartment buildings can be maintained in a 1:100 year event for emergency egress.

Flooding up to the 100 year ARI rainfall event will be contained within the flood storage areas either underground, on the wetland channel or within flood storage areas A and B/C. Floodwater in the wetland cells is below adjacent road levels. The only roads potentially affected by ponded flooding are adjacent to the sports fields. Final levels on this road will be set to ensure that the road is passable in the 100-year rainfall event.

Overland flow paths are provided down roadways. The depth of this flow will be confirmed at detailed design and will be kept to acceptable levels for vehicle traffic.

Vehicle access to all dwellings is therefore available for emergency services under the 100-year rainfall event conditions. In addition to this pedestrian access to the upper levels will also be available.

Yours faithfully

PATTLE DELAMORE PARTNERS LIMITED

Matthew Lillis **Roger Seyb**