RESIDENTIAL SUBDIVISION; CLOSE- TO- SOURCE STORMWATER MANAGEMENT APPLICATION

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Abstract

A South Auckland residential subdivision, for a private developer, has adopted a close- to-source approach to the stormwater management. This paper will describe the background to the project, which includes a summary of the catchment characteristics and the previously proposed and consented catchment management plan (CMP). It was necessary to develop options that were an alternative to those suggested in the catchment management plan to provide a workable solution and a subsequent variation to the consented CMP was required.

A discussion of the design of the close-to-source stormwater management options will include the various natural and built environment constraints as well as large rainfall event management.

Close liaison with Council and the client was integral to the project and resulted in a requirement for an assessment of performance risk as well as operation and maintenance costs for the medium and long term operation of the proposed treatment devices.

This project required exploring and analysing an extensive array of considerations to ensure that implementing a non-conventional approach to stormwater management met both the client and Council’s needs. Risk and benefit analysis was undertaken to ensure the best practical approach was adopted for this project using treatment devices that have a very limited track record in New Zealand.

1 INTRODUCTION

A South Auckland residential subdivision has adopted a close-to-source approach for stormwater management, which implements the principles of low impact design. The original catchment management plan implementation proved to be impractical and difficult due to the natural site constraints, such as flat topography, high ground water table and peat sub soils.

Several options for stormwater management were investigated to determine the best practical approach. A “local sub-catchment management” (LSM) approach was adopted and design criteria developed to ensure that the built environment was serviced for the larger storm events. These criteria were discussed in detail with the local authority to address their concerns about long term viability, operation and maintenance requirements and flood management. Measures have been incorporated to ensure future proofing of the stormwater system. It has also been necessary to address maintaining groundwater recharge by roof water soakage and ensure proposed stormwater infrastructure does not adversely affect the recharge and cause increased ground settlement.

2 BACKGROUND OF PROJECT

2.1 Site characteristics

The area of the development is approximately 14 hectares. The subsurface conditions are predominantly peat based with a high ground water table. The winter ground water table is
between 0.5m to 1.0m below the ground surface and the average summer level of 1.5m below the ground surface.

The site has a very flat slope, which falls toward the catchment outlet in a westerly direction at an average grade of approximately 0.2%. This gradient allows the site to be developed, with respect to earthworks, with relative ease when working down-slope, e.g. from east to west, however when working across the slope (parallel with the contours) in a north-south direction, the proposed gradients require careful engineering of road and finished ground levels to achieve efficient stormwater disposal.

These conditions impact on the viability of both stormwater treatment options and subdivision construction techniques.

2.2 Catchment Management Plan

The Takanini South Stormwater Catchment Management Plan (TSCMP) was developed in 2000 for Papakura District Council (PDC) as a guideline for the stormwater management requirements for future development. This catchment management plan formed the basis of the granted Auckland Regional Council (ARC) stormwater discharge consent.

The TSCMP prescribed the stormwater management for the catchment and encouraged the implementation of low impact design (LID). The overall stormwater management for the catchment was based on the discharge to a central swale system which provided treatment and attenuation in conjunction with ponds.

The implementation of the TSCMP and the various intended structures has proven to be problematic from a site development implementation perspective; a variation to the TSCMP for part of the catchment was therefore proposed and subsequently granted by ARC under manager’s approval.

3 AT-SOURCE MANAGEMENT

At-source management techniques were investigated for this site as a means of providing treatment and conveyance for the built environment. The three main characteristics that had to be achieved for the site were as follows:

- Treatment
- Conveyance
- CMP application

The site characteristics also played a major part in endorsing at source management due to the flat nature of the site and the construction constraints in peat sub soil conditions.

The outlet for the stormwater discharge is a tunnel under the North Island Main Trunk railway (NIMT railway) some 900m from the site over a shallow grade, therefore end-of-pipe or large catchment treatment and conveyance facilities were problematic in terms of lack of clearance above shallow ground water levels.
4 OPTIONS AND ANALYSIS

Several options for stormwater management were considered to ensure that the best practical application would be applied for the site. There were several iterations to the original TSCMP theme as well as diverse applications, with the options described as follows:

4.1 Artificial Stream

Papakura District Council developed an option which is referred to as the Artificial Stream. The concept of the stream was to provide a central conveyance system, similar to the Greenway Swale as per the TSCMP, which collected runoff and conveyed it through the catchment and incorporated treatment and attenuation through the ponds on route.

To achieve both treatment and attenuation of the runoff from the catchment, the ponds would need to be large which would have correspondingly significant impacts on the urban form and planning. Other implications such as earthworks volumes and construction of this in organic soils suggested that this was problematic with respect to construction.

4.2 Swale network

A system of swales would be established across the site that would discharge through a pipe network to the receiving environment. Treatment and attenuation would be undertaken within the swales which have a low impact device approach to the stormwater management, as per the intention of the original TSCMP. The swale catchment width is typically 120m therefore a series across the catchment would be required.

The benefits of this system are that the low impact design (LID) principles of the TSCMP are met along with the integration of an overland flow path network, which would follow the swales. However there would be interruption to the urban form with many laterals required on the site and difficulty connecting to the downstream catchments.

4.3 Ponds and pipes

A series of ponds would provide treatment and attenuation within the catchment and discharge through a pipe network to the NIMT railway culvert. The treatment and attenuation would occur close-to-source in compliance with the TSCMP principles.

This system required multiple shallow ponds involving a large land take with limited distance between ponds to achieve surface flow to the ponds.

4.4 Local sub-catchment management

This approach provides stormwater treatment and attenuation within relatively small sub-catchments, typically less than 1 hectare. The outflow from each sub-catchment is piped via a pipe network to discharge to the NIMT railway culvert.

The proposed treatment and attenuation is implemented close to source and follows LID principles, as per the original TSCMP. The attenuation is provided throughout the catchment rather than a small number of points, as with a pond system.

This local sub-catchment management approach is flexible enough to suit the proposed urban form and has been considered the best practical application for the site.
5 LOCAL SUB-CATCHMENT MANAGEMENT DETAILS

Various aspects of the local sub-catchment management (LSM) approach such as boundary definition, quality and conveyance is described in the following sub sections.

5.1 Sub catchment definition

The topography is very flat, as opposed to the traditional subdivision where natural topographical grade delineates the catchment boundaries very clearly. This results in the sub-catchment boundaries being defined by the road alignment. These sub catchments are small, typically less than 1 hectare, as distances between the crest and sag of roads is typically approximately 100 m. There are a total of 32 sub-catchments for this site.

The developed site lots adjacent to the roads rise above the road surface, rather than fall away, therefore all runoff falls toward the road. Sub catchment boundaries are thus located at the back of the lots and it is unlikely that any future modification to the ground surfaces within individual lots will significantly alter sub-catchment boundaries and areas.

5.2 Stormwater quality

The proposed overall approach for the stormwater runoff prior to discharge to the receiving environment is as follows:

- Source control for roof runoff by prohibiting the use of roof materials that can provide a source of zinc or copper in runoff, or provide on-site treatment for runoff from roof materials containing zinc or copper.

- Treatment of runoff from paved and vegetated ground surfaces (not roofs) to achieve 75% removal of suspended solids. This treatment can be achieved within the sub-catchments by one or a combination of the following stormwater management devices, which are located close to the source of stormwater runoff:
  - Grassed swales
  - Raingardens

- Permeable pavers as a long-term solution have been considered during the options process. The issues that have been raised and resulted in the pavers not being considered the best practical application for the site are:
  - Uncertainty regarding long term maintenance requirements and practicality; reliance on individual lot owners
  - No credit for treatment capacity from ARC
  - Costly sub grade construction

- Stormwater treatment devices are to be located within the road reserve or designated PDC owned reserve areas. The design of the treatment devices is to be generally in accordance with ARC TP10, as per the TSCMP and best engineering practice.
• The site has a defined urban form, which can accommodate the LSM application of stormwater management. The optimisation of the total number of rain gardens and swales has been achieved to ensure a balance of earthworks, infrastructure and community amenity.

5.2.1 RAINGARDEN AND SWALE DESIGN AND OPERATION

The raingarden design has been based on the ARC TP10 guidelines with the time to pass the Water Quality Volume through the soil bed is chosen as 36 hours (1.5 days). This time (tf) has been adopted in accordance with ARC TP10, where choice between 1.0 and 1.5 days is based on considerations of amenity.

The swales and raingardens will be generally located adjacent to roads. Alternative locations are in the other reserve areas. The side slopes proposed for the swales are 8.5H:1V. The subdivision layout has wide road reserves, which allows the raingardens to be constructed using a formed batter, rather than vertical walls, thus achieving an economical design.

Runoff will be detained within the raingarden filter media and will pond up to a depth of 200mm above the raingarden surface to ensure that the first flush is treated to remove 75% suspended solids.

The preferential path for the water flow is through the filter media within the raingarden, exiting to the under drain which discharges to the pipe network.

Swale and raingarden depths are kept shallow to minimize any lowering of adjacent groundwater levels and any associated increases in settlement of the peat soils. A review by geotechnical consultants of the likely effect of the proposed swales and raingardens on groundwater levels and potential settlement indicated minimal effects.

Stormwater runoff for the design water quality volume (WQV) storm event for a typical sub-catchment has been modelled using HEC HMS through the swale and raingarden combined. The results of the modelling with respect to depths and duration of ponding above the raingarden surface are as follows:

• Maximum depth 214mm for a period less than approximately 10 minutes
• Depth of 200mm or greater; approximately 6 hours
• At or above 100mm depth 19 hours

These results show shallow depths of ponding, which will essentially be masked from view by the vegetation within the raingarden. This is considered acceptable from a general public amenity point of view.

The velocities within the raingarden and swales have been assessed. The swales have a low velocity, maximum 0.25m/s, to encourage treatment facilitation of the runoff and will not cause erosion. The raingarden experiences a standing water situation and the overtopping of the outflow structure would have localised increased velocity (ovetopping velocity) during the entry to the structure. The increase in the overtopping velocity is localised and unlikely to reach the raingarden surface, some 200mm below.
Localised erosion may occur where there sheet flow enters the swale or raingarden. This can be addressed at the detailed design stage of the project through mitigation measures such as placement of small rip rap or geotextile fabrics.

Operation and maintenance procedures will be implemented for the swales and raingardens. These will address any potential problems and allow remediation to be carried as required to ensure optimum operation of the devices.

5.3 Conveyance

Runoff from paved and other ground surfaces is conveyed initially by swales, which discharge through a raingarden to a primary piped network.

Roof water is piped to recharge pits, with overflow piped to the primary piped network. This is to maintain groundwater recharge, which is naturally occurring within the site under pre-development conditions. Recharge requirements and recharge pit design guidelines have been developed by consultants, which provide pit design dimensions in relation to roof area.

The overall constraint on primary pipe network is that the receiving environment, being a piped system, has an invert level constraint.

The network is to be sized for 10yr +10% capacity within the site; however the main trunk lines that service the site and the upstream catchment are to be sized for an un-attenuated 100 year ARI peak flow rate. This was at PDC’s request to ensure that the network is future proofed with respect to increasing the built environment and to minimize the risk of overland flows over a main road immediately downstream of the site. The current PDC standard for pipe network design is for a 5 year ARI level of service.

5.3.1 Attenuation

Attenuation will occur due to the nature of the catchment, in particular the very flat natural ground surfaces and the associated need to provide a “hump and hollow” road alignment to ensure adequate road drainage. This in turn creates a series of small sub catchments.

Attenuation is to be provided close to the source of runoff within and above raingardens, swales, parks, reserves or roads. Attenuation is to be hydraulically designed to avoid adverse effects on public amenity and private land as well as avoiding hazards including vehicles using roads. These specific design criteria can be achieved by specifying maximum depths of ponding on publicly accessible areas and on private land. Design criteria for maximum depths of ponding are shown in Table 1.
Table 1: Maximum allowable depths of ponding during flood events

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum depth</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 year ARI</td>
<td>100 year ARI</td>
</tr>
<tr>
<td>Raingarden</td>
<td>280 mm</td>
<td>400 mm</td>
</tr>
<tr>
<td>Swale adjacent to road (for 200 mm deep swale)</td>
<td>180 mm</td>
<td>300 mm</td>
</tr>
<tr>
<td>Swale adjacent to park (for 200 mm deep swale)</td>
<td>200 mm</td>
<td>450 mm</td>
</tr>
<tr>
<td>Parks, reserves</td>
<td>Zero</td>
<td>250 mm</td>
</tr>
<tr>
<td>Road carriageway and road reserve</td>
<td>Zero</td>
<td>200 mm</td>
</tr>
<tr>
<td>Private land</td>
<td>Zero</td>
<td>Zero</td>
</tr>
</tbody>
</table>

The various design rainfall events were modelled through the sub-catchments together with the swales and raingardens using HEC HMS software. The results of the typical sub-catchment are shown in Figure 3 with extent of the 100 year ARI flood event shown in Figure 4.

5.4 Overland flow paths

PDC have adopted a 100 year ARI for the overland flow path provision. 100 year flood levels are those estimated to occur during a 100 year event taking into account a combination of flow in the primary pipe network and overland flow paths or the flow in an open channel.

The LSM approach to management of a 100 year ARI event is to provide storage within the sub-catchments for attenuation. Designing the raingardens and swales together with road alignment and grades to accommodate ponding above the surface provides this storage. This storage provision will avoid flows in excess of the capacity of the primary pipe network to discharge from the sub-catchments by overland flow.

The proposed design of the swales, roads, raingardens and raingarden overflow outlets for the site addresses flooding as follows:

- The 100 year ARI event
  - Can be safely attenuated by temporary ponding within the road reserve within the site, which also avoids private property. Hydraulic modeling has been carried out which shows that the maximum depth of floodwaters on the road surface is less than 200mm, which does not adversely affect amenity or cause public hazard.
  - There is no overland flow across the downstream sub-division site boundary

Rainwater 2007
Provision of 300mm free board above the top water level during a 100 year ARI event is recommended by PDC for all building finished floor levels, ensuring protection to the built environment.

- For extreme events, such as rainfall events larger than the 100 year ARI or if pipes become blocked during a 100 year ARI event, the flood mechanism would be as follows:
  - Ponding depth would increase until overflow occurred via road and swales.
  - Overflow paths link to head in a southerly direction toward adjacent recreational reserve.
  - Overflows will be shallow and with low velocities.
  - Modelling shows that in the probable maximum flood (PMF), ponding would occur to no higher than approximately 150 mm above the design 100 year flood level. Provision of 300mm freeboard above the 100 year ARI top water level would ensure an adequate factor of safety for house floor levels during the large and extreme events.
  - Sufficient storage is provided within the subcatchments of the site to attenuate extreme flows, which results in relatively small flows crossing the downstream boundary.

6 COUNCIL LIAISON AND REQUIREMENTS

There has been extensive liaison between PDC and the developer to ensure that PDC concerns are addressed with regard to ongoing operation and maintenance of the rain gardens and swales, which would become a PDC responsibility as they are within the road reserve. Extensive studies have been undertaken as to the long-term costs with respect to physical resources and monetary contributions for the implementation of the local subcatchment management approach for this development.

7 PROJECT STATUS

The roads are currently under construction, at the time of writing, with Council approval of stormwater management under consideration. The stormwater management system will be constructed within the next season once Council has granted approval.

The downstream stormwater connections are currently under construction in conjunction with the wastewater system upgrade.

8 SUMMARY

The original catchment management plan stormwater management design was difficult to implement for this site and the upstream catchment options were explored. There were several catchment constraints to consider such as flat terrain and peat sub soil conditions combined with a high water table.
A local sub-catchment approach has been implemented for the site to provide appropriate stormwater quality and flow management compatible with the physical site constraints and to considerably enhance the built environment.

The treatment of the stormwater runoff is through raingardens and swales forming a treatment train approach, which meets the ARC requirements of 75%, suspended solids removal. This approach also aligns with the original TSCMP approach for low impact design.

Main trunk lines allow for conveyance of 100 year ARI peak flows to ensure that the upstream catchments are fully serviced to the requirements of PDC rather than a necessity of the LSM design.

ACKNOWLEDGEMENTS
Thanks to McConnell Properties Ltd for understanding that stormwater management in flat peat sites is complex and requires a committed team to find a workable solution.

We wish to acknowledge Papakura District Council staff for their valuable input to the design options for the catchment and development of operation and maintenance regimes.

REFERENCES AND BIBLIOGRAPHY

ARC TP108:Guidelines for stormwater runoff modelling in the Auckland Region, Auckland Regional Council, Technical Publication 108, April 1999, ISSN 1172 6415


Figure 8: Northern Block Subcatchments and Extent of 100yr Flood

Legend

Sub-Catchment Boundary

Extent of 100yr Flood above and adjacent to rain garden