

MEOLA CREEK IMPROVEMENT CONCEPTS FROM THE CENTRAL AUCKLAND STORMWATER INITIATIVE

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ABSTRACT (200 WORDS MAXIMUM)

This paper describes conceptual stream enhancement options considered for Meola Creek as part of the Central Auckland Stormwater Initiative (CASI) in Auckland.

Catchment wide options included in the CASI options analysis for flood mitigation required either naturalization, or naturalization and widening of the main stream. This project considers opportunities to meet the required conveyance objectives, as well as opportunities for naturalisation, day-lighting of piped sections, culvert upgrades and improved floodplain storage.

The channel widening concepts explored in this project reveal opportunities to achieve objectives of habitat creation, floodplain engagement, lowered velocities and increased opportunity for amenity and naturalisation. This is achieved by design of wide shallow multi-stage channels which slow flows. These show less vulnerability to future changes than pipes or incised channels as they are less sensitive to blockage or extreme events, with a small additional freeboard catering for a greatly increased flow.

Purchase of flood prone and stream side properties would be required to implement such stream widening concepts. However these could potentially be redeveloped as higher density residential alongside the new stream “green belt” access corridor. Urban design benefits of this redevelopment could include increased amenity, and a more compact urban form.

The wider options assessment of the CASI project is proposing catchment solutions that do not require significant stream widening. However the naturalization options will be progressed with consideration of the hydrological regimes required to optimise environmental objectives for the Meola Creek.

KEYWORDS

Stream Restoration and Naturalisation, Floodways, Stream Day-lighting, Property Purchase, Urban Design

PRESENTER PROFILE

Caleb Clarke: Caleb is a Director of Morphem Environmental Ltd and an environmental engineer with 12 years experience in environmental and three waters design. Caleb has a focus on integrative solutions that meet diverse objectives, including water sensitive urban design and sustainability.

1 INTRODUCTION

Auckland Council is carrying out the Central Auckland Stormwater Initiative (CASI). This project is looking at stormwater infrastructure upgrades that may provide greater community benefits and savings by co-ordinated planning with the Central Interceptor (CI) project currently being carried out by Watercare Services Ltd (WSL).

Meola Creek is an urban waterway which flows from Mt Albert through to Point Chevalier, in the western suburbs of Central Auckland. Meola Creek is approximately 5.2 km long (including ~1.8 km of piped length) and flows through a highly modified urban watershed with approximately 45% existing catchment imperviousness. Figure 1: Meola Creek Layout indicates the key features of the Meola Creek relating to this Paper. Further background to the area and the wider CASI programme can be obtained in Sharman, Captain, Miselis, and Davis (2012) and Miselis, Sharman, Ursem, and Captain (2012).

The high level of catchment imperviousness is reflected in the modified nature of the watercourse, particularly in the channelised, concrete lined and piped sections. The creek is fed predominantly by overland surface flows, stormwater from the piped network and receives combined sewer overflow (CSO) discharges from the combined sewer system. Importantly, flow from the Western Springs Groundwater Aquifer contributes to baseflow via springs throughout the length of the watercourse.

Numerous environmental studies have been conducted in the catchment including the Meola Watercourse Management Plan (WMP) (Coup, Young, & Eivers, 2009), Creek catchment and receiving environment water quality monitoring 2010/11 (Coup & Clarke, 2012) and several Stream Ecological Valuations (SEVs) as part of the Ecological assessment of central Auckland creeks. (Coup, 2010; Coup & Pearce, 2012).

The lower Meola Creek below the Alberton Culvert has a higher ecological value than the upper Meola, a likely function of the higher dissolved oxygen and lower temperatures due to increased baseflow from aquifer inputs (Coup & Clarke, 2012). The upper section of Meola is subject to regular CSO discharges and when baseflows are low, does not provide life-supporting capacity.

The creek has significant community interest in both the upper and lower catchment with restoration and replanting projects currently underway by multiple groups.

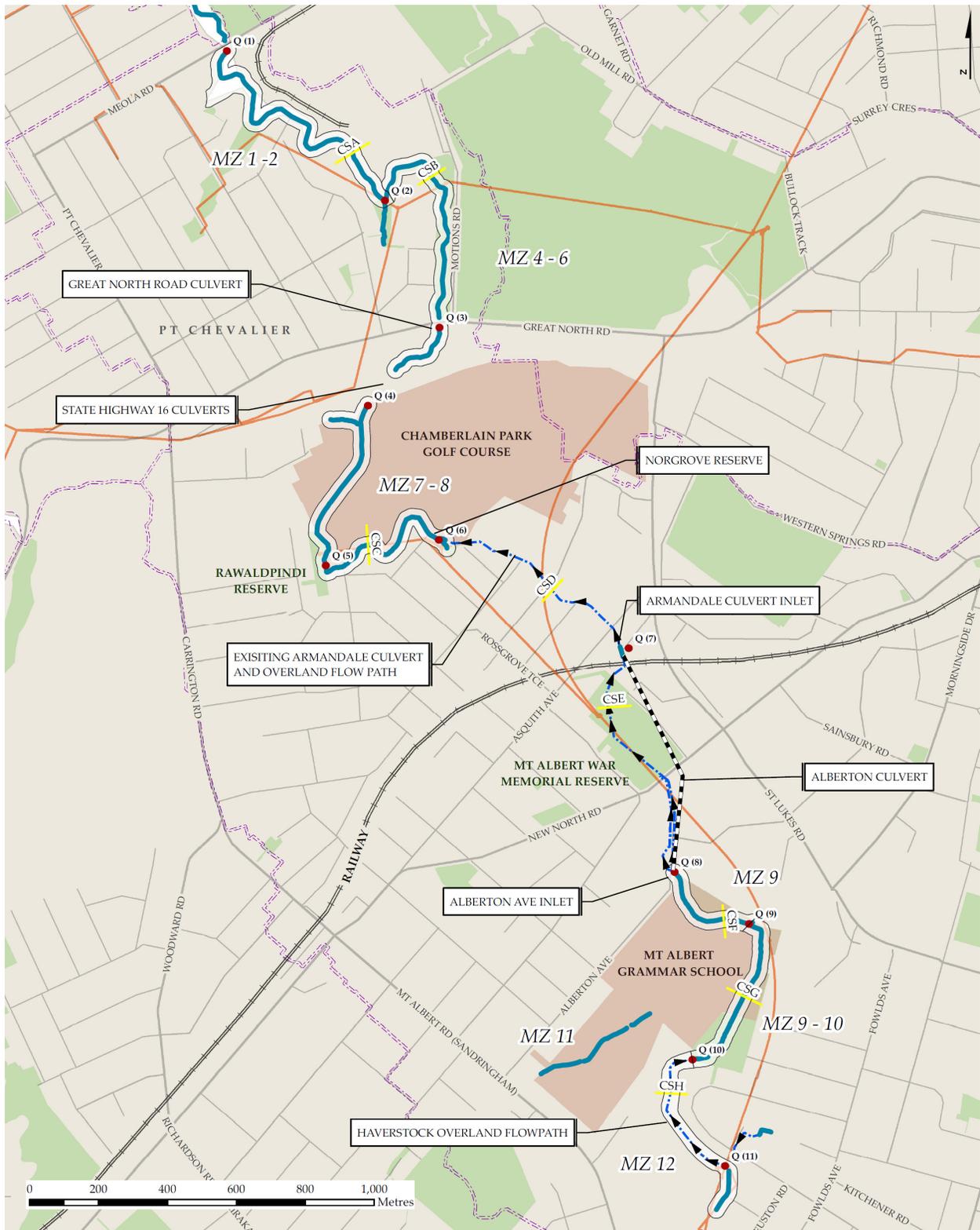
A set of options (CASI Options) have been developed as part of the wider programme. The CASI Options are aimed at addressing the important issue of flooding of approximately 500 properties in the catchment. These options are summarised as follows (for more detail refer to Sharman et al. (2012)):

1. Conveyance to soakage across the catchment.
2. Detention and attenuation using LID principles, property purchase and house raising and overland flow path management.
3. Full conveyance including stream widening and naturalisation.
4. Full conveyance with discharge tunnel and stream naturalisation.

Assessing the feasibility of these CASI Options includes understanding the impacts to the stream receiving environments, how they relate to the four wellbeing values and the requirement of physical works to the stream channel to mitigate any of these impacts. This paper describes a set of stream work concepts that were developed and assessed

against four wellbeing objectives for consideration in the CASI programme for the Meola catchment.

Figure 1: Meola Creek Layout



2 STREAM WORK OPTIONS

A set of Four Wellbeing Objectives were identified that are considered in the development and assessment of stream works concepts. These draw on regional best practice in addition to previous reports relating to the Meola catchment including the Meola Creek WMP (Coup et al., 2009) and Catchment Management Project (SKM, 2000).

2.1 OBJECTIVES

Table 1 below indicates the objectives defined for the development of options and their four wellbeing assessment.

Table 1: Four Wellbeing objectives for Meola Stream Works

ID	Objective	Explanation
Environmental Objectives		
Env 1	Environmental Awareness	Naturalise or daylight stream where feasible in line with conveyance objectives to improve awareness of ecology and environment.
Env 2	Riparian Ecology and Connectivity	Enhance riparian margins to improve and maintain connectivity and provide stream shade, with improved biodiversity.
Env 3	In-stream Habitat Enhancement	Naturalise channel and substrate heterogeneity via channel reshaping and substrate addition using natural materials and 'alternatives' that provide ecological benefit (e.g. improve bank stability through planting and soft engineering options wherever possible).
Env 4	Fish Passage	Provide for fish passage along the stream length and improve habitat for aquatic (and riparian) flora and fauna
Social Objectives		
Soc 1	Reduce Flood Risk	Reduce risk of flooding to habitable floors including stream morphological improvements and consideration of resilience.
Soc 2	Enhance Recreation	Improve urban design including recreation and green space which enables a community 'meeting place' including improved amenity value.
Soc 3	Improve Pedestrian Connectivity	Improve connectivity and access such as developing pedestrian and cycleways along the creek and between reserves.
Soc 4	Address Public Health and Safety	Address public health and safety for deep and high velocity waters and potentially dangerous engineering structures (e.g. culverts).
Cultural Objectives		
Cul 1	Improve Groundwater Interactions	Maintaining the Mauri (life force) of water by promoting groundwater interaction and avoiding modification of natural flowpaths/catchments
Cul 2	Improve Integrity of (Mauri) of	Increase the integrity of the ecosystem by daylighting and naturalising the watercourse to improve the Mauri of the stream

	Watercourse	
Cul 3	Opportunities for Cultural Involvement	Provide opportunities for cultural involvement in the naturalisation of streams
Cul 4	Traditional Knowledge Awareness	Promote awareness of traditional knowledge.
Economic Objectives		
Eco 1	Reduce Flooding Risk	Reduce risk of flooding to habitable floors and property
Eco 2	Commercial Opportunities	Enhance commercial and recreation opportunities along the length of the stream
Eco 3	Reduce Maintenance Costs	Reduce cost of maintenance including naturalisation and planting of streams
Eco 4	Improved Property Values	Improve value of real estate through urban design including provision of community green space and amenity connections to creek and riparian margins

2.2 OPTIONS

Stream work options were broken down by reach scale for seven main reaches of the stream relating to the Meola Creek Watercourse Management Plan (WMP) Management Zones. In addition there are six main culvert crossings with four that were considered for necessary culvert upgrades.

The CASI Options result in two main conceptual alternatives for the stream channel. These options and sub-options are considered to span the possible scale of stream works for the purpose of this report as follows:

Option A - Naturalisation: If additional flood peak flows are routed away from the stream channel by CASI Options 1, 2 and 4, the required flow conveyance of the stream will not increase. As such, there will be limited requirement for channel widening. Long term management objectives of the stream would still need to be met through naturalisation, riparian planting, erosion stabilisation and daylighting of some piped sections of the Meola Creek.

Option A1 – Naturalisation and Key Culvert Upgrades: Culverts represent key hydraulic constraints in the catchment. In particular the following culverts are undersized for the current situation and independent of design hydrologies may require upgrade. Their upgrade has been included in Option A1.

- Alberton Ave inlet,
- beneath the North Western Railway tracks,
- Great North Road culvert.

Option B - Naturalisation and widening: Given increased flood peak flows that would result from CASI Option 3, Meola Creek would require widening to prevent

flood impacts along the channel. This widening would include naturalisation and also facilitate increased access, amenity and ecological outcomes.

Option B1 - Naturalisation and widening including daylighting Armandale Section: The Armandale culvert which runs from Asquith Ave to Norgrove could be daylighted to complete restoration of the full length of Meola Creek outside of road carriageway.

There are two main existing flooding zones where large scale detention of floodwaters in the main watercourse system is possible. These detention sites are at Mount Albert Grammar School and Chamberlain Park Golf Course and were recommended in the Auckland City Council 1994 Catchment Management Plan (CMP) to both manage peak flows within capacity of downstream culverts and provide ecological, aquifer interaction and water quality benefits. These sites have not been included in the options however may be feasible based on detailed hydraulic design.

The costs and Four Wellbeing Scores of the options are detailed within the report and are assessed in Table 2:

Table 2: Costs and Four Wellbeing Scores for the CASI Meola Stream Works Options

Option	Description	Cost (\$)	Four Wellbeing Score
A	Stream Naturalisation	9 million	74
A1	Stream Naturalisation including duplication of Key Culverts	(Opt A = 9 million) + 19 million = 28 million	78
B*	Stream Naturalisation and Widening	67 million	86
B1*	Stream Naturalisation and widening including Daylighting Amandale to Norgrove	(Opt B – 9.56 = 57.06M) + 19.6 million = 77 million	98

*NB Includes property purchase but no resale of residual properties

Key constraints and opportunities that relate to these costs have been identified relating to the potential stream work options for the Meola catchment and are indicated in Section 4 of this paper.

3 RESTORATION CONCEPTS

3.1 MORPHOLOGICAL IMPROVEMENTS

The morphology of Meola Creek has been altered significantly. In many locations there has been modification of the channel through straightening and lining which has resulted in reduced heterogeneity. This is likely to have altered the hydraulics, and consequently in-stream ecological functions. A natural stream has a range of morphological features, including pools, runs and riffles, which provide habitat and refuge for animals. Although these modifications to the natural stream state are significant, this waterway has great potential for retrofitted improvements.

Floodplain engagement is an important feature of a functioning stream system. This is the spilling of water from the main channel onto floodplains which can act to entrain sediment, reduce downstream contaminant loadings and reduce velocities. The lower reaches of the creek still retain floodplains and natural channel features as compared to the mid catchment, in particular, which has lost these features through channel modifications such as lining.

Removal of artificial channel lining and replacement with appropriate natural substrate and channel shape will act to improve the habitat function of the waterway. However, because lining was probably originally installed to cope with higher urban flows the lowering of bank angles and the creation of a wider cross-section profile is necessary, specifically designed for the design hydrograph. A toolbox of morphological treatments including rock riffles, point bars and vortex weirs were costed based on a set rate for a feature every 10-20 metres of stream length.

Given the volcanic origin of much of the natural substrate in Meola Creek, use of similar material in any restoration projects would be preferable. This will not only provide substrate consistency for morphological purposes, but will provide an 'eco-sourced habitat' structure for the existing unique flora and fauna, such as the rare moss *Fissidens berteroi* (Bodmin & Wells, 2009) and locally abundant inanga (*Galaxias maculatus*).

Meola Creek is fed by groundwater aquifers that act to maintain baseflow. Where channelisation and concrete lining has been constructed, the interactions between surface and groundwater are modified. Returning the channel to a more natural state through removal of lining and replacement with substrates which facilitate infiltration is expected to improve the interactions between groundwater and baseflows.

3.2 CHANNEL WIDENING

The primary objective for open stormwater channels has been to convey storm flows as quickly and efficiently as possible to minimise the effects of potential flooding. This often leads to deep channels with reduced surface friction or increased grade. Typically this has undesirable hydrological side effects such as increased velocity, reduced time of concentration, reduced surface/groundwater interactions and modified habitat structures. Alternatively, increasing channel width while still meeting conveyance objectives allows for the retention of important morphological and habitat structures such as high substrate heterogeneity and regular floodplain engagement.

A wider shallower channel and floodplain configuration typically integrates with riparian vegetation function and ecological health. (Shaver, Harrison Grierson Consultants Ltd, Beca Valuations Ltd, & Turner, 2000). The key parameters for stream bank erosion are bank steepness, stream velocity and substrate material. Channel widening results in

lower bank angles and lower velocities, therefore reducing the need for bank lining allowing natural vegetated stream banks with increased ecological value.

The opportunities to widen stream channels are often constrained by topographical or geological conditions and access. For example the true right bank (right bank facing downstream) of the Meola Creek is largely composed of higher basalt rocks which are part of the western extent of the Three Kings lava flows. Consequently opportunities exist for channel widening on the lower, flatter true left bank within Meola Creek, as these banks are largely composed of older Mt Albert lava flows which are more weathered within the required depths (

Figure 2).

Figure 2: Example of potential stream widening and amenity access along Meola Creek.



Bank angles of 3:1 were used as the default geometry for channel widening as part of the options assessment, while more detailed design of bank angles may allow for consideration of steeper angles and, where space permits, flatter profiles to accommodate flood benches.

Channels were sized to convey the 100 year ARI peak flows. Flood benches have also been considered that engage in the two year storm peak flows. Detailed design of channel widening would need to further optimise dimensions for the routing of storm flows given floodplain storage.

Figure 3 and Table 3 below indicate the hydraulic geometry of the general stream widening concept. This demonstrates the outcome of a wide, shallow, well-planted cross section with a low hydraulic radius (area/wetted perimeter) in reducing velocities. For the general concept, average velocities in events up to a 100 year ARI storm can be kept below 1 m/s. This is likely to limit the impacts of extreme events in causing erosion, hazards to people and habitat flushing compared to higher velocities (typically between 2-3 m/s) associated with lined or incised channels of similar grade.

Figure 3 - Indicative Widened Cross Section Showing Flood Levels

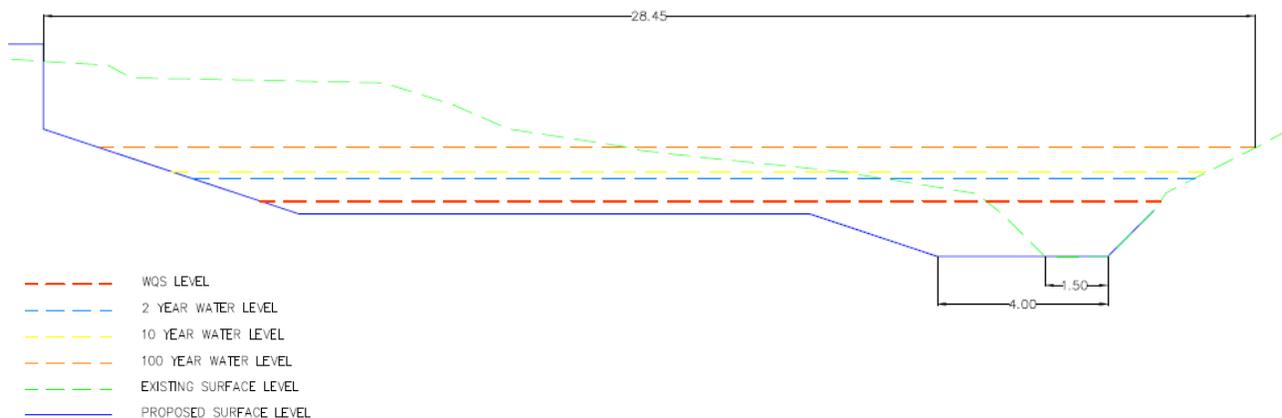


Table 3 - Conceptual Stream Hydraulic Geometry

ARI Event	Flow (m ³ /s)	Channel Water Depth (m)	Floodplain Water Depth (m)	Hydraulic Radius (m)	Average Velocity (m/s)
WQS*	7.6	1.3	0.3	0.6	0.5
2 Year	21.8	1.8	0.8	1.0	0.8
10 Year	27.7	2.0	1.0	1.1	0.9
100 Year	36.8	2.3	1.3	1.3	0.9
Maximum Capacity	74.0	3.0	2.0	1.8	1.2

3.3 RIPARIAN PLANTING

When preparing restoration planting plans it is important to integrate ecological, amenity and network infrastructure requirements. Established riparian planting can improve bank stability, reduce pest plant management requirements, enhance aquatic habitat, increase local biodiversity and provide for increased amenity values (Collier et al., 1995). Additionally water quality can be improved through the planting of stream margins and surface inflow channels.

Riparian buffers can result in more naturalised channel morphology and hydrological processes. In particular riparian vegetation can increase friction and reduce velocities. This increases water levels for the same flow capacity. Where possible, channels were considered to have a Manning's "n" value of 0.09 representing dense brush where this does not have an adverse effect on flooding.

Meola Creek, although having highly modified riparian margins, still retains areas that provide good shading to the stream and stability to the banks. Of particular note are the patches of mixed vegetation that cover the basaltic lava flows along the length of the open sections. Therefore existing well vegetated areas were considered in all conceptual options to be maintained through weed removal and minor enhancement plantings.

The Auckland Regional Council TP148 (ARC, 2001) planting guideline units were used for the purposes of defining the planting unit and species types. This guide provides species compositions typically found in the Auckland area. The unit types most representative of Meola Creek include saline and freshwater stream edges, back wetlands, alluvial slopes and volcanic slopes. Plantings that do not significantly reduce conveyance are preferable.

3.4 BANK STABILISATION AND NATURALISATION

More than minor rates of erosion result in deleterious effects on riparian and in-stream habitats structures of waterways. Reducing bank angles can reduce susceptibility to erosion. In addition, natural stream systems have a high diversity of substrate structures which include both biotic in the form of plants/trees and abiotic in the form of rocks that can increase resistance and mitigate erosion.

Stabilisation works were included where banks are currently considered to be unstable, as indicated by recorded bank erosion. The naturalisation of otherwise modified manmade channels, for example through the mid reaches including those through Chamberlain Park, has also been included. This includes introduction of natural bank treatments, planting, battering and soft engineering techniques including the use of seed impregnated geotextile socks.

3.5 DAYLIGHTING

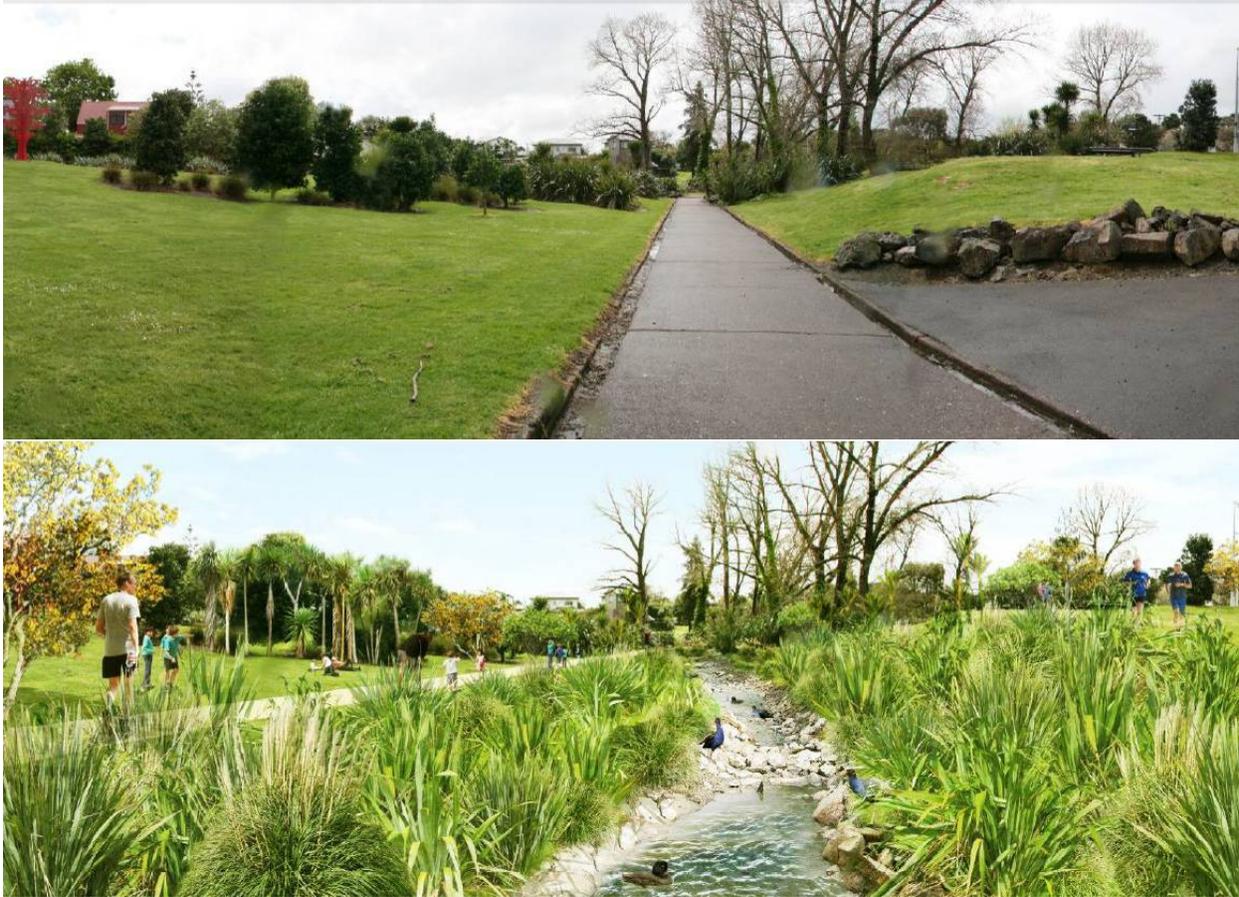
Stream daylighting is the practice of 'bringing buried streams to the surface in an effort to restore their natural systems and processes' (Lewis, 2008).

Open watercourses, as opposed to pipes or culverts, offer multiple functions and benefits, including providing for community well-being through amenity value, ecological habitat, stormwater treatment (polishing), and flood management (Lewis, 2008).

There are sections of Meola Creek where the historically open channel has the potential to be daylighted. This would typically involve removal of surface cover material and reinstatement of an open channel. Existing culverting could be retained in part as reinforcing or an entirely new naturalised channel geometry could be established (Figure 4).

Alternatively daylighting can involve retaining the closed piped system as a secondary flood conveyance. This may involve constructing appropriately configured weirs and piping to convey baseflows into a constructed surface channel. This technique allows for the improvement of stream function while providing for flood conveyance within the retained deeper pipe system. This method may require provision of an impermeable layer to prevent loss of base flow to groundwater or the piped network. It is noted that stream daylighting requires careful detailed design to include ecological and hydrological systems in order to increase the likelihood of success.

Figure 4: Example of potential daylighting opportunity within Meola Creek.



3.6 AMENITY ACCESS

As the stream is naturalised or daylighted, access should be improved as a priority to enable the public to use the green space. Walkways adjacent to the creek and recreational space can improve connectivity between reserves. Raised boardwalks and viewing platforms would serve to link streets and reserves and also provide access along the creek. The boardwalks would serve pedestrians and cyclists and would follow the path of the creek. Typically, 10 year ARI water levels in the floodplains would be less than 1 metre deep, allowing boardwalks to have a 10 year ARI flood protection without requiring safety balustrades.

Viewing platforms can also provide educational value with signage highlighting the value of the creek, the work undertaken and any significant features (such as exposed lava flow or springs) that may be present.

Where floodplains are wide, picnic areas with recreational value can provide a focal point for urban neighborhoods to congregate, instilling a sense of place and community feeling. These types of assets would typically be funded from transport or park budgets and costs have been included in the concept budgets.

3.7 DETENTION STORAGE

The hydraulic buffering of natural wetlands and floodplains is often lost when these are developed and/or infilled. Flood waters that flow into storage rather than down a stream channel or into a culvert inlet can reduce the required downstream conveyance capacity.

Detention storage could be achieved to a small degree by channel widening, riparian planting and morphological improvements, and potentially to a greater degree in storage areas such as the lower golf course and the Mount Albert Grammar School (MAGS) fields above the Alberton inlet. These locations could also achieve additional benefits in terms of riparian/wetland ecological habitat and amenity integration.

3.8 FLOOD PROTECTION (HOUSEHOLD SCALE)

There are several locations where flood prone houses adjacent to the widened stream could be retained, however may still require mitigation for specific flood risks. This may include raising houses, filling parts of the property, or securing easements for widened channel floodplains. Where these exist, an allowance has been made of \$200,000 per property.

4 FURTHER CONSIDERATIONS

4.1 CONSTRAINTS

4.1.1 EXISTING INFRASTRUCTURE NETWORKS

Physical wastewater, water supply, gas and other infrastructure services crossing and parallel to the stream alignment may impact on the detailed design geometry. Earthworks are likely to impact trunk sewer protection zones in the War Memorial Reserve, Amandale Culvert and MZ 7-8 sections. There is potential to negotiate with Watercare regarding the protection of these wastewater assets. In addition, options such as aerial sewers, or steepening and reducing friction for sections of the stormwater conveyance channels could be employed.

Allowance has been made for costs relating to the modification of existing pipe bridges. However technical constraints may exist that limit the ability to pass flood flows and site specific variations to stream geometry may be required. An example of this is the aerial sewer adjacent to Motions Road and Pasadena that forms an obstruction to high flows.

There is a potential for collaboration with Watercare in the management of specific Central Interceptor work sites relating to the stream naturalisation or widening, with the potential to integrate these work to great benefit.

4.1.2 PROPERTY CONSTRAINTS

Stream widening and naturalisation will require purchase of property along piped and open reaches of Meola Creek. Previous experience and lessons learnt from Project Twin Streams has identified that a conciliatory approach is arguably more cost effective and collaborative than engaging in lengthy legal battles and forcing property purchase under the Public Works Act.

A community based approach whereby the public are helped to understand the problems involved with flooding and are encouraged to participate in the solutions can improve relationships with Council.

Project risk associated with property purchase also includes how price and timing is influenced by the real estate market. If property cannot be successfully acquired, there may be design variations with associated reduction in the meeting of objectives.

Use of land for channel widening will also require 'landowner' approvals which could include MAGS, Ministry of Education and/ or Auckland Council Parks Department, as well as general public consultation with parks users and sport clubs. If the options of

detention within the MAGs and Golf Course ponding areas are pursued, landowner approvals will also be required. Failure to achieve successful negotiation with these parties may limit implementation feasibility. However as the land in question is currently flood impacted, in each case there may be mitigations or mutually beneficial outcomes reached that will allow the works to proceed.

4.1.3 PLANNING CONSTRAINTS

Meola Stream Works will need to take into consideration planning constraints under the Resource Management Act (1991)(RMA) and relevant regional and district plans, which provide for preservation and maintenance of Auckland's natural and built resources and protection of their intrinsic values and finite characteristics. The rules of the following plans will need to be considered:

- The City of Auckland – District Plan Isthmus Section (Operative 1999)
- Auckland Regional Plan: Air, Land and Water (Operative in part, October 2010)
- Auckland Regional Plan: Coastal
- Auckland Regional Plan: Sediment Control

Meola Creek runs alongside a variety of zoned areas, including residential, open space and recreation, business, and special purpose activity zones. Stream naturalisation and widening constraints will therefore vary along different reaches. Works within the watercourse constraints can be expected consistently along the entire length of Meola Creek.

Meola Creek discharges to the Waitemata Harbour, therefore any proposed works within the coastal interface will need to be managed in collaboration with Auckland Council Coastal Team and taking into account the rules of the Auckland Regional Plan: Coastal. This will require an assessment of effects on the receiving environment as a result of stream widening and/or naturalisation. The identified options should take into account the preservation of the natural character of the coastal environment, wetlands and their margins, and the protection of them from inappropriate subdivision, use, and development.

Constraints can be expected to include rules regarding:

- Volcanic Cones and Craters
- Views
- Coastal Environments
- Urban Streams
- Archaeological Sites
- Waahi Tapu areas
- Heritage Buildings
- Hazardous Facilities
- Scenic Ways
- Geological Sites
- Individual and groups of Trees
- Indigenous Vegetation and Fauna
- Habitat
- Conservation Areas
- Natural Hazards – land subject to instability

4.1.4 GEOTECHNICAL CONDITIONS

The Meola catchment is volcanic in origin and the creek itself flows alongside a significant lava flow. Basalt rocks are present throughout the catchment and may restrict the applicability of some options in particular areas. Whilst no specific subsurface investigations were sourced for the purposes of concept development the geology has been considered. In general the true right bank (Northern and Eastern Bank) of the Meola Creek is largely composed of higher basalt rocks which are part of the western extent of the Three Kings lava flows. Consequently better opportunities exist for channel widening on the lower, flatter true left bank within Meola Creek, as these banks are

largely composed of older Mt Albert lava flows which are more weathered within the required depths. In these locations, excavated depths would be up to 3 metres into the basalt which is likely to be in more readily excavated fractured rock material. Excavations on the Three Kings lava flow sides would be significantly deeper into massive basalt material.

The concepts in this report assume up to 80% of rock encountered will be basalt with a per m³ rate of \$130 which represents the large, easily accessible nature of the required excavation works and the fractured material expected. Further investigations are required to accurately define geology and the likely impacts on the costs of the options.

4.1.5 HYDRAULIC DESIGN

The extreme event flows that were used for the widening concepts were preliminary model outputs provided by AECOM. Modelling for infrastructure modifications has not been completed. Therefore there is potential for variations in assumed flow rates, impacting on the design. The flows utilised in the option concepts downstream of the railway were increased by approximately 15 m³/s in order to allow for the release of mid catchment ponding areas that occur with the existing network.

It is noted that in general the open channel concepts utilised are resilient to further increased design flows as their wide shallow shape allows significant additional conveyance within the high stage freeboard zone. This means that revised flows are unlikely to increase the required width considerably. If design proceeds, it will need to include modelling of upgraded infrastructure and optimisation of proposals for routed peak flows.

The naturalisation proposals associated with Option A have assumed that extreme event flows will not increase, and may be reduced in the stream by the alternative catchment controls or conveyance methods (Tunnel). Detailed flow splits will need to be assessed for potential impacts on the stream hydrology, and any likelihood of negative impacts from too little or too great wet weather flows in the stream would need to be considered in detailed design of naturalisations, including weirs and section designs to manage velocity for erosion protection and re-oxygenation.

4.2 OPPORTUNITIES

There are several key opportunities that can be taken advantage of through the design and implementation of some of the stream work concepts included in this report.

4.2.1 LAND USE PLANNING

Integration with Land Use Planning in terms of the Spatial and Unitary Planning processes has the advantage of integrating with transport networks and land use. Naturalised and widened stream corridors create access and ecological linkages called "Green Belts" through the catchment with significant urban design benefits. In particular the Pt Chevalier Precinct Plan involves expansion of mixed use higher density activity alongside the lower Meola Creek. A transport linkage along the stream has the potential to connect to development and the Western Springs recreational areas via a pedestrian motorway over bridge previously considered.

It is expected that property purchase will be required for whole lots to accommodate stream widening and/or naturalisation. Residual land that is outside of the footprint for Meola stream works can therefore be utilised in a number of ways, including re-zoning and on-selling land for high density units, combining residual lots for existing medium density residential land use, and re-zoning as open space areas for recreational and

access purposes. Council could choose to develop such land areas for profit to offset the capital investment in infrastructure, provide leadership in urban design, and contribute to increased density for planned population growth. Additional areas such as the residual golf course land on the western bank of the Meola could be considered in this context.

4.2.2 GEOLOGICAL FEATURES

Use of existing geological features can be a key element in the design of naturalisation. Improved access can provide amenity value by highlighting exposed lava flows, springs and unique vegetation associations as significant natural features.

Much of the potential excavation associated with the stream works concepts could generate a useful rock resource close to a source of demand. The excavated rock may also be recycled into natural stream channel and bank protection to achieve cost savings.

4.2.3 WATER QUALITY IMPROVEMENTS

There are several tributary stormwater lines to the Meola within the subject reaches. The naturalisation and widening provides an opportunity to daylight tributary sections, such as in Rawalpindi Reserve, to improve erosion or to implement off line treatment within the widened stream corridor. This could take the form of swales, wetlands or raingardens to remove stormwater contaminants before discharge to the stream. This would require an assessment of subcatchment contaminant loads and technical feasibility of treatment provision.

4.3 NEXT STEPS

The Meola stream works are being considered as part of a range of catchment scale options. The refinement of these options is currently underway. The current thinking is that for the separated portions of the Meola Catchment the most likely Best Practice Option (BPO) is to maintain a primary system of stormwater management discharging to the aquifer via soakage and the stream for smaller events, and manage flooding with a deep tunnel to convey secondary flows (Miselis et al., 2012) This will most likely negate the need for the wholesale stream widening explored in this study. However the naturalization is still likely to form part of the integrated BPO for the catchment. In isolated locations, other drivers for stream enhancement may look to the stream widening concepts from this study to be implemented on a reach basis to achieve other objectives. Likewise, other catchments may require stream widening that could follow a similar approach to those investigated in this study.

The catchment scale water networks and land use patterns represent a complex system. Therefore the optimal longer term approach may be a blend of varying solutions, targeted to the sub-catchment locations where the most feasible instances are available. This could include a mix of distributed control at source largely implemented through development controls, optimised soakage to the aquifer, flood detention and secondary flow path management in conjunction with increasing capacity of the trunk network. These catchment management measures used in combination offer an ability to control frequent flows and to best meet ecological objectives in the stream. Additional benefits for resilience may also be obtained by the diversity of response of these different systems, providing greater adaptive capacity for various scenarios.

The impact of integrations between the potential catchment management measures will provide further detail of the hydrological regimes expected in the stream. This will enable the definition of optimal configurations for the naturalization treatments put forward in this concept study in terms of meeting objectives such as:

- Limited velocities for protection against erosion protection and habitat flushing
- Sufficient velocities to allow for re-oxygenation and sediment transport processes
- Morphological heterogeneity to provide varied habitat
- Interaction with streamside vegetation and the aquifer systems
- Achieving wider objectives relating to public access and amenity in the development of urban greenways.

This further work currently underway is also likely to generate hydrological targets that can drive refinements of the detail of the BPOs for the upper catchment management measures. This integration and optimisation is the focus of current ongoing work streams under the CASI project.

5 CONCLUSIONS

In conclusion, the widening of channels and upgrades of infrastructure to cater for increased flows in the catchment appears generally feasible, although at high capital cost. However on the basis of catchment scale Best Practice Option (BPO), stream naturalization but not widening is likely to be required.

The stream widening concepts assessed in this study are based on a benched channel with a wide shallow floodplain. This floodplain area provides for riparian vegetation, greater interaction with groundwater and development of accessways. The wide, shallow, vegetated floodplain also reduces the velocity of water during extreme events to provide reduced risk of habitat flushing, erosion, and danger to people.

While requiring excavation in rock, property purchase and potentially impacting on infrastructure networks, widening concepts have the ability to achieve additional benefits that may not be available from other major reticulated options. These potential benefits include urban design improvements from redevelopment of residual land, cycling and walking access, amenity and ecological linkages as well as resilience to extreme events.

The optimal solution for the Meola catchment may be a blend of the many potential catchment management measures from land use and source controls to detention and conveyance improvements. This may result in the requirement of stream works in some and not all reaches of the Meola Creek, as well as potentially resulting in scale changes from the identified high level options.

Ultimately this project brings a potential to restore the integrity of Meola Creek as a watercourse from headwaters to the sea, providing a restored green belt through the city, and breathing life into an urban environment.

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