FLOODED WITH OPPORTUNITIES - TURNING FLOOD MITIGATION SCHEMES INTO COMMUNITY ASSETS

A. Murphy (Beca Ltd), K. Hyde, A. Shadbolt & P. Christensen (Christchurch City Council)

ABSTRACT

Traditional flood mitigation schemes typically involve conveyance and storage systems such as waterway widening, pump stations, and basins. These systems are intrinsically land-hungry; flow and volume design parameters necessitate the use of substantial land areas.

When flood mitigation schemes need to be located within existing developed areas, these land-hungry and high capital cost projects need to provide justifiable benefits to the communities they service. Additional challenges are the unavailability of large areas of land, the close proximity of properties and roads, and the multiple demands for use. Any proposed land utilisation for infrastructure must compete with other uses (such as residential or commercial development and community facilities) and values (such as ecology, recreation and heritage).

These challenges present designers with an opportunity and a potential new mantra: to create infrastructure serving multiple purposes for our communities. When land is so valuable, can we afford to use it 'just' for flood management? If we are going to occupy land and invest in substantial flood management infrastructure, can we make that land provide multiple benefits to the community? This paper will present two project examples where Christchurch City Council staff identified and developed opportunities to implement flood mitigation infrastructure in spaces whilst also improving the social, ecological and cultural values of these spaces for the community. The examples are Edmonds Park sports fields, and the Te Oranga Waikura Urban Forest, from council's Bells Creek Stage 1 project.

KEYWORDS

Flood mitigation, multi-use, land availability, amenity, value, social values, design adaption, community

PRESENTER PROFILE

Amber is a Senior Environmental Engineer at Beca Ltd in Christchurch and works on a range of stormwater, water, and wastewater projects through the country. Her focus is on catchment assessment, identification and development of design solutions, and implementation of design and construction projects.

Karissa Hyde is a Project Manager with Octa Associates Ltd. Karissa is currently working for the Christchurch City Council in the Land Drainage Recovery Programme (LDRP) as the Project Manager for the Bells Creek project. She has a background in civil engineering including structural, geotechnical and project management.

1 INTRODUCTION

All infrastructure projects require investment by communities, in order to construct, maintain and upgrade the infrastructure that provide service to those communities. The question of how we can create infrastructure that serves multiple purposes for our communities is a complex one. However flood mitigation projects in particular lead to opportunities to achieve just that. The utilisation of sought-after land, and the required capital and operational investment, raises another question: can we afford to use it 'just' for flood management? Or can we make that land provide multiple benefits to the community? The opportunity to incorporate multiple benefits to the community, through flood mitigation projects, has been realised through Christchurch City Council's Bells Creek project.

A detention basin at Edmonds Park has been constructed by excavating the park by approximately one metre to increase flood water storage. The park will be used to detain flood water in large infrequent rainfall events, thereby reducing flooding to properties in the surrounding area. The park will otherwise operate as two sports fields. Sports facilities in the Linwood / Woolston suburbs are under severe pressure and the few sports fields in the area frequently need to be closed during winter. To enable Edmonds Park to be used as both flood detention and sports fields, the works included new grass turf, a drainage system (including a small underground dewatering pump) and timber retaining walls with in-built seating, and the realignment of a section of Bells Creek running through Linwood College towards the park.

The second example in the Bells Creek project is Te Oranga Waikura Urban Forest and Stormwater Basin. This basin will also be used to detain flood water in large rainfall events, reducing flooding to surrounding properties. In addition a 2.75 hectare urban forest with pools and a waterway has been planted providing shading and water quality treatment. The forest's name was gifted to the Community Board: "Te Oranga" meaning rejuvenation, "Waikura" –wai denoting flow of water and kura reflecting leadership. More than 16,000 native trees and plants including kahikatea, totara and matai have been planted. The forest will eventually grow into a habitat for native bush birds such as bellbird/korimako and kereru. The space is accessible to the public with a gravel pathway and boardwalk bridges to allow the community to explore and enjoy the park and all that it has to offer.

2 FLOOD MITIGATION SCHEMES

2.1 DRIVERS AND CHALLENGES

Throughout New Zealand, flooding and drainage issues are becoming increasingly high profile, seemingly more frequent, and the impact of these issues on individuals and communities are severe. These impacts are requiring service providers to invest heavily in catchment studies and construction works to mitigate these issues for communities. In recent years, significant flood events have been experienced in Christchurch, Waimakariri, Tasman, Nelson, Dunedin, Edgecumbe, Coromandel, and Whanganui, to name a few. Notwithstanding the harm caused by these events, one outcome is that, following these events, the heightened community and council awareness results in prospects for flood mitigation projects to receive funding, prioritisation, and publicity.

One stormwater mitigation project driver may be known existing and historic flood issues. Post- flood events, new information of how a drainage catchment functions (or does not function) and the hazards within it may be another driver. Additionally, projects may arise from new land development activities responding to growth of the community.

Projects aiming to address the impact of climate change effects will also be evident. Climate change is likely to result in an increase in the distribution and intensity of rainfall, changing and more intense extreme weather events, as well as increasing risks from flooding, coastal inundation and coastal erosion. In addition, sea-level rise, tides, waves and storm surges will reach further inland, impacting the drainage of low-lying areas, increasing flood risk and groundwater levels, causing more frequent and extensive flooding.

Regardless of the key project driver, all stormwater mitigation projects have attributes in common that give opportunity to incorporate multi-benefit and additional uses of spaces. There is likely to be a significant investment in flood mitigation projects in the future, given the expected development growth, the impacts of climate change, and the nature and presence of existing issues to address.

Stormwater mitigation projects often have common challenges that need to be overcome to produce successful outcomes for communities. These include land availability, project capital and operational cost, impacts of other hazards on any infrastructure of drainage schemes, tie-ins and close proximity of other assets, and operational and maintenance requirements with ongoing upkeep.

2.2 AFFORDABILITY

Individual flood mitigation projects require capital investment and operational expenditure to operate and maintain the infrastructure. There have been multiple historic occurrences throughout New Zealand where early studies by councils have established that the investment required to complete flood mitigation projects has been unaffordable to the communities they aim to service. Project option assessments have in places concluded that although a project is technically achievable, the cost of that project outweighs the benefits it offers, thus making that project not feasible. For example if the cost of a project, pro-rata distributed over the properties it addresses the flood risk of, is significantly higher than the value of those properties and the indirect costs to the community of flooding (such as stress and health impacts), this project would be considered ‘not value for investment’ and unlikely to proceed.

A key prerequisite for local government expenditure is that these land-hungry and high capital cost projects need to provide justifiable benefits to the communities they service. Flood mitigation projects often require large areas of land for their proposed infrastructure. Particularly in our developed cities, this amount of land is often unavailable, or has a large cost associated with it.

Conversely, as our communities develop, there is an increasing amount of land, property, amenity, and other infrastructure that needs flood protection, and thus flood mitigation project investment is needed in order to provide a level of service. It has been suggested that as our communities’ infrastructure develops and the level of service increases, infrastructure has a more brittle response to stressors. That is, failures are more abrupt, catastrophic, and have cascading impacts on communities. In the case of flood mitigation infrastructure, the consequences of failure can be severe; there is risk to life, property, economies, and health and wellbeing. This suggests the level of service and resilience, and ongoing maintenance, of flood mitigation infrastructure needs high investment, so that standards are met into the future, and failures are not experienced.

Climate change will also impact required investment in flood mitigation projects. The Climate Change Adaptation Technical Working Group (2017) states: *“The mid-range projected sea-level rise over the next 50 years is 30 cm. Such a rise in sea level would have impacts on all coastal areas to varying extents. Under this scenario, in Wellington a* *one in 100 year inundation event would become an annual event, in Dunedin this would become a one in two year event, and in Auckland a one in four year event."* Putting this in context in New Zealand, the value of assets affected by sea level rise is estimated to be in the billions of dollars, and the annual cost of weather events to the land transport network alone has increased in the last ten years from $20 million to $90 million (*ibid.*). In Christchurch, up to 25,000 properties could be at risk of coastal inundation by 2120 (Tonkin & Taylor, 2017).

Due to the characteristics of flood mitigation projects, and the known future investment requirements to protect land and respond to climate change impacts, the affordability of future projects is an important consideration and concern for service providers. Multiple-uses of land, which provides additional benefits to communities, can be a mechanism to increase the benefits of future projects to our communities.

2.3 TYPICAL FEATURES AND OPPORTUNTIES

Traditional flood mitigation schemes typically involve conveyance and storage systems such as waterway widening, pump stations, and basins. These systems are intrinsically land-hungry. Flood mitigation projects typically aim to achieve flow and volume design parameters to achieve the desired flood mitigation benefits; meeting these design criteria often necessitates the use of substantial land areas.

Flood mitigation infrastructure is often located amidst our communities and developed areas; constructed adjacent to the properties and facilities they service. Accordingly this infrastructure is located in close proximity to houses, parks, roads, and all the areas our communities frequently use and inhabit. The land where flood mitigation works could be located, is often already or desired to be utilised for public use. They will often have existing amenity values to communities. Land availability in developed areas is scarce, and any proposed land utilised for infrastructure must compete against other uses (such as residential or commercial development and community facilities) and values (such as ecology, recreation, and heritage).

Any existing waterways and drains are clearly also part of the drainage network, and their function may in the future need to be extended. Waterways have existing landscape, ecological, heritage, cultural and recreational values. Often, though, these values have been marginalised through historic development. The opportunity always exists to enhance the values of these existing waterways.

Due to the nature of typical flood mitigation infrastructure, locating infrastructure in existing low-lying land and close to the discharge point (rivers, estuary, and coastal areas) is technically beneficial. Low-lying, coastal, and land adjacent to rivers also provides significant opportunity to enhance values such as landscape, heritage and cultural amenity. Conversely these land areas have technical challenges to be addressed, such as potential high groundwater levels, lateral spread and liquefaction risk, poor ground conditions, and exposure to other hazards.

Another common attribute of a flood mitigation project is that there will be a volume of water involved. Technical challenges are again evident in terms of the water quality, the intermittency of supply, and the quantity. However the presence of water gives rise to opportunities to create additional benefits from its use.

Significant work and publicity has been completed into the benefits of Low Impact Designs and Sustainable Urban Drainage System, which aim to minimise capital and operational costs, and reduce undesirable impacts that hard engineering structures may inadvertently cause. Designers achieve their aims by imitating natural processes, and, through this, realise other benefits that natural systems generate, such as improvement to water quality and reduction in peak flows. The benefits of these systems have been studied in detail over the last decade, and in cases the cost/benefits have been quantified in order to give a business case for such designs. This paper suggests that we should take this philosophy a step further in flood mitigation projects. Rather than just the environmental benefits from imitation of natural process, let us also think intently about the potential benefits that can be achieved by combining uses with other community features and assets, as well as the benefits of incorporation of natural systems.

3 BELLS CREEK STAGE 1

3.1 SCHEME OVERVIEW

Christchurch City Council's Land Drainage Recovery Programme aims to repair damage to drainage and flood protection infrastructure, restore pre-earthquake flood risk, and to seek options for enhancement. The Bells Creek catchment is subject to increased flood risk since the earthquakes due to subsidence to the ground. The Bells Creek Stage 1 Flood Remediation Project seeks to restore the flood risk in the catchment to pre-earthquake levels. As such, the project includes repair of damaged pipelines and waterways, a stormwater detention basin at Edmonds Park, a stormwater detention wetland at Lower Linwood Fields, a coarse debris screen at Woolston Park, and at Richardson Terrace a large 4m³/s stormwater pump station, stormfilter treatment device and new outfall structure to the Heathcote River.

Figure 1: Plan of Bells Creek Flood Mitigation project

Detailed design by Beca and WSP-Opus commenced in January 2016. The proposed concept designs of the detention basins at Edmonds Park and Lower Linwood Fields had some technical challenges to be overcome. As part of the design process, Council identified opportunities to enhance both sites by incorporating multiple uses for the community. Options assessment and feasibility studies were undertaken, followed by preliminary and detailed design. Early engagement with the multiple stakeholders was led by Council, and the multi-disciplinary design team was empowered to revisit options to produce a design solution maximising community benefits. Construction of the Bells Creek Stage 1 project commenced in October 2016. The Te Oranga Waikura Urban Forest at Lower Linwood Fields was presented to the community at an opening ceremony on 16 October 2017 and a football game was played at Edmonds Park south field in the same month.

3.2 EDMONDS BASIN

3.2.1 BACKGROUND AND FLOOD MITIGATION DESIGN PARAMETERS

Edmonds Park is located to the south of Bells Creek, which runs east to west through Linwood College to the north of the park, between Ryan Street and Aldwins Road. The Edmonds Park site is owned by Council. Bells Creek runs east to west to the north of the site. The site has good access from Linwood College to the north, from Ferry Road in the south, or pedestrian access from Ryan Street to the west.

Figure 2: Edmonds Park location

During large storm events, the offline Edmonds Park basin will receive high stormwater flow from the Bells Creek catchment, attenuate peaks flows, and discharge slowly back to Bells Creek. Effectively, the basin will act to 'take the top off the storm' hydrograph and allow upstream areas to drain via Bells Creek. The required detention was confirmed by 2D hydraulic modelling of the catchment, which included an allowance for climate change on rainfall intensity.

Hydraulic modelling assumed a storage volume of approximately 6,700m³ at Edmonds Park, and the operation of the downstream proposed Richardson Terrace Pump Station (currently under construction). Sensitivity modelling confirmed that detention at Edmonds Park was the most effective means and location to achieving flood mitigation targets in this part of the catchment. Downstream works such as channel capacity upgrades, or increasing the proposed pump station capacity were either prohibitive in terms of cost, feasibility, or community disruption, or often the hydraulic conditions of the catchment meant that minimal improvements to flood risk were realised by downstream works.

Calibration of the hydraulic modelling defined the peak water level in a 50-year event as being 11.14m RL in Edmonds Park basin, in order to achieve upstream flood mitigation measures. The peak inflow rate to the basin is $0.8m^3/s$. Existing ground levels of the park are approximately 11.5m RL in comparison. The land area available is approximately $11,400m^2$ (59m by 192m). Thus, in order to achieve these hydraulic design parameters via gravity, excavation of roughly 1m was required in Edmonds Park.

3.2.2 OPPORTUNITIES

The eastern suburbs of Christchurch have an acute lack of sports fields, in particular Mainland Football has struggled to provide local soccer fields to meet the demand in the Woolston and Linwood suburbs following the earthquakes. Edmonds Park has historically frequently required closing due to inadequate ground conditions during the soccer season (winter), and the field was known to be poorly draining; further restricting the available sports fields in the eastern suburbs.

Besides Mainland Football, the park is used by the adjacent Linwood College for sports and physical education activities. The College is currently completing Master Planning activities to respond to growth and earthquake damage. They have identified that space restrictions on their site is placing them under pressure, and further utilisation of Edmonds Park is desirable. They also aspire to be able to utilise for redevelopment, the land currently traversed by Bells Creek to the north of the sports fields. Moving the creek to the southern boundary of the school would open up the land for future development, and would also simplify the complexity and cost of inletting and outletting from the detention basin to the creek.

Although Christchurch has plenty of passive recreational areas part of and adjacent to stormwater reserves, it does not have any other combined sports fields flood detention areas. With climate change, retrofitting sports fields into combined detention basins is desirable in many Christchurch locations. The Edmonds Park project should be considered a 'flagship' design to improve community-wide flood mitigation opportunities.

Facilities should be designed to provide long-term value for council. Designed plantings and structures are to present a pleasing appearance to passers-by and adjoining properties. Safety and resilience is to be considered when designing all aspects of the project. The design should incorporate Safety in Design principals to improve safety during construction, operation and maintenance, activities, demolition, and use/access by the general public.

3.2.3 TECHNICAL CHALLENGES AND RESOLUTION

Early in design, a piezometer was installed in the field to monitor groundwater levels. After four months of monitoring, we were able to identify that the groundwater levels will be 0.3m above the proposed invert of the basin. Furthermore seasonable variation could be expected. This groundwater condition is not conducive to the use of soccer fields and, if not drained, the flood storage volume is significantly reduced in a storm event. To address this challenge, various options were investigated including a reduction of storage volume, changing to a bunded raised basin with pumped inflow, or continuing with an excavated basin design. A multi-criteria assessment identified the preferred solution was an excavated basin, with the depth minimised and area maximised by adding retaining walls, along with a subsoil drainage system and pumping for groundwater control.

Various sports field turf and drainage options were considered and their relative merits reviewed for this site. These ranged from a full sand profile system, a sand carpet system, a reused topsoil layer and subsoil drainage system, an artificial pitch, or sub-surface storage cells. The key parameters reviewed were: time to return to service (as a sports field) following inundation, risks to turf from inundation and siltation, capital cost, and operating and maintenance cost. A full sand profile or sand carpet system would provide the best playing surface performance, and would have higher performance relating to the time to return to service following inundation. However these options, the subsurface storage, and the artificial pitch had high or very high risk and impacts from siltation, as they are susceptible to damage and contamination. A full sand profile would likely require scarification and surface removal and turf re-establishment after silt deposition during flood events. The capital and operation costs (including irrigation, fertilisation, mowing etc.) for these options were also significantly higher. Therefore a topsoil and subsoil drainage system was recommended as it was the most resilient option, and the lowest cost to construct and maintain.

The subsoil drainage system comprises of a grid of subsoil pipes within free-draining gravel surround and free-draining topsoil. The subsoil system was designed to aid maintenance; with flushing points installed along every subsoil pipe, and the main collector pipes given intermediate inspection chambers to improve access and maintenance cleaning activities.

A key design parameter for the soccer field is protection of the grass turf. Following a flood event and inundation of the basin from Bells Creek, a design criterion of a basin drain-down duration of 24 hours was prescribed. To achieve this, a 450mm pipeline will discharge, via gravity to Bells Creek, the majority of the basin volume in less than 24 hours once levels in Bells Creek have lowered sufficiently to allow gravity discharge. Large sump inlets (Humes Hush Pits) were used to convey the flood water from the fields to the gravity outflow. The final volume below the Bells Creek invert level uses a small discharge pump of approximately 35L/s capacity in order to meet the 24-hour criterion. A submersible pump was located within a wet well in the park. Also connected to this wet well is the soccer field subsoil drainage system, which will requires dewatering pumping during most conditions.

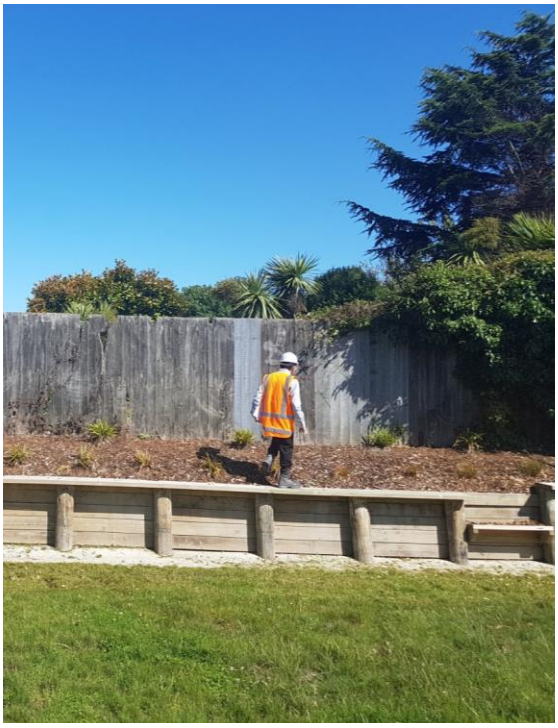
The discharge pump is also required to provide drainage for rain falling on the field. To achieve effective drainage of the field, a 1V:100H crossfall on the basin, and a 1V:500H longfall was provided. A concrete dish channel along the retaining walls (longfall) was installed to collect surface water and direct this to the large sump inlets at the northern end of the field near Bells Creek. The provision of grade on the fields meant the volume and excavation depths were revised (the far southern end needed to be further excavated), in order to meet flood mitigation aims. The installed discharge pump meets the dewatering, local drainage, and final flood discharge requirements. Due to the low head in the system and the multiple duty requirements of the pump, ideal pump efficiency is not achievable. However the proposed pump was low cost, low power, and so deviation from the usual Council performance standards was accepted in this case.

Edmonds Park has private houses along its eastern and western boundaries. To cost-effectively limit any instability or increased risk to these properties, battering of the excavated basin edges was required. Geotechnical assessments identified that battering the excavated field no steeper than 3H:1V will result in minor to negligible ground deformation to adjacent private property in both static and seismic (ULS) events, due to a 3m thick layer of cohesive silts with low liquefaction potential. 4H:1V slopes are considered mowable, whilst 3H:1V are more difficult to maintain. However, the flatter the slope, the lesser the eventual base area (which in this case equates to the soccer field width) that can be attained. In this case, the requirement to provide soccer fields meant that batters were impractical on the east and west lengths of the field. More expensive, engineered timber retaining walls were incorporated into the design to provide additional width for the soccer fields. The walls were offset a minimum of 1.5m to limit potential ground deformation and lateral spread risk to adjacent property.

The installation of a timber wall alongside the soccer field introduces a hard vertical edge to the sports area. Upon investigation, international guidelines suggest that a minimum of 3m is provided between the sideline and any hard feature, to provide a 'run-off' zone for players to slow down and avoid impact. In this project, the timber walls, and the inlet sumps were considered to be hard features. Another field width restriction identified was the existence of a channel along the eastern side of the park that provided drainage service to the eastern adjacent properties. If the function of this drain was compromised, works would need to be undertaken to reinstate lower than Bells Creek. Additionally, a line of existing mature trees along the eastern edge provide amenity, and it was desired they were retained as they would be in keeping with the final use of the park. Soccer fields for intermediate grade matches are recommended to be 70m length by 50m width. In this project, the aforementioned constrictions meant that a 49m field was the maximum achievable. Although not meeting the technical standard, a field of this width will be fully functional and, in this area, the 49m fields would be well utilised by the local club.

Figure 3: Artist's impression of Edmonds Park, including in-built seats and landscaping

Photograph 1: Constructed Edmonds Park retaining wall (photo: WSP-Opus)



For the basin to operate effectively as a soccer field, it was determined that the basin should not be utilised for flood detention during every small rainfall event. Flooding of the basin from Bells Creek renders the field unusable until it has drained, puts the turf at risk of grass kill (if inundated too frequently), and deposits silt, debris, and other stormwater contaminants onto the base of the field. Long term, the silt deposition will permeate through the basin substrate, reducing permeability, clogging the drainage system, and impacting the turf quality requiring remediation. Hydraulic modelling of a 10-year flood event showed that an inlet weir at this level is not feasible or practical due to the corresponding water levels in Bells Creek and the catchment. Therefore, a manually controlled gate/weir triggered by level sensor will allow flow to spill into Edmonds Basin in approximately a 5-year storm event (or top of bank event). High contaminant-loaded first-flush flows will continue down Bells Creek, and so a large portion of catchment rubbish, debris, and suspended sediment will not pass into the basin. This inletting arrangement was supported by hydraulic modelling, showing that spill into Edmonds Basin only occurs once the trigger level is reached in Bells Creek, meet the flood mitigation requirements of the catchment.

Manual opening of the gates and weir and operation of spill to Edmonds Basin, rather than automation, was preferred as it gives council more control over the decision to flood the soccer fields. It also adds to the safety of the system, by the ability of operators to check for any public use of the basin and employ warning measures prior to releasing any stormwater to the basin.

Other safety considerations were incorporated into the design, to reflect the future public and recreational uses of the basin. Grassed area for spectators were included along the western boundary, the northern and southern embankments, and between the two fields. On the eastern edge, the narrow 1.5 m strip was considered to pose a fall risk from the wall, was too narrow to be easily mown, and the close proximity to private buildings over the boundaries raised concerns on the impact to those properties. Thus this strip of land was landscaped with low maintenance plants to dissuade public use of the strip and to reduce maintenance requirements. A top plank was installed along the length of the retaining walls, so that the walls could function as a seat. Furthermore, every 12 m, an intermediate height plank was installed on the wall spanning two posts. This plank acts as a lower seat for spectators, and more importantly, provides a step for persons to exit the basin, where the wall is too high to them to easily climb. This function was considered important, due to the close proximity of a school, the use of the park for children’s soccer matches, and the intrinsic actuality that the basin will at times be flooded abruptly. A final safety function was that the north and south embankments/batters, were flattened to 1V:10H, this allows ambulances to traverse the embankments and provides direct access to any injured persons on the field.

3.2.4 CONSTRUCTION

It was identified that control of groundwater, and planning of the construction staging was important in order to mitigate the risk of damaging the drainage and turf growth function of the sports field media. Flooding, over consolidation of the subsurface, and over compaction were key risk. The contractor needed to manage works, so that heavy plant did not track over installed topsoil.

Rainfall and flood events did occur during the construction period, in particular there were periods of heavy rain in April 2017. The wet conditions limited the construction activities able to be undertaken during that time, both in terms of safety and construction quality. The excavated basin during this time required temporary pumping for drainage.

During April, the sown grass was flooded for an extended period of time as the pipe connecting with Bells Creek would not accept any pumped water from the fields. Water sat within the basin then became turbid and needed to be detained for quality treatment before being pumped for discharge. During this time the grass fell over, stunting growth. The extent of the area that was flooded was clearly observed by the stark difference in grass growth between the ponded area, and the higher (southern) areas. It was also observed that the ponded water had created a hardpan layer which was impeding infiltration and water flow though the turf. Also impacting the vertical drainage potential of the topsoil, was that the topsoil stripping, screening and replacement activities had impacted the structure of the soil. Once construction was complete, the northern field was observed to at times have ponding water. Although root growth and soil maturation will improve the soil structure, remediation was also required to improve the condition of the topsoil. This encompassed installation of verti-drains: where a specialist turf machinery punches or tines vertical sand drains which then allow water to move from the ground surface deeper into the soil profile, where it then has a better ability to move vertically and horizontally through the soil until it reaches the subsoil drainage system. This process is also typically practiced during regular sports field maintenance.

The local drainage of the fields was a key design feature with tight tolerance on the grades of the fields (crossfall and longfalls) requested, in order to reduce the risk of ponding or saturated soils. Construction to meet these specified tolerances was difficult, and construction management needed to check the quality conformance throughout in order to address any inadequacies quickly.

The importance of the final finish on the timber retaining wall was also highlighted during construction. It is a key visual element of the completed field. The retaining wall was simple post and panel structure, however due to the long fall on the field and variation in the ground level adjacent, the amount of panels required constant adjustment. It was important that the top plank was installed horizontally in order to function as a seat. Therefore the panels under it needed to be trimmed to fit the basin profile. The timber posts were 3m long, and it arose that it was inevitable some were installed at slightly different angles. This meant care needed to be taken to packout sections of the panels, to achieve a uniform look, and ensure the panels functioned to retain the soil behind.

Photograph 2: Completed Edmonds Park sports fields (photo: WSP-Opus)

3.2.5 BENEFITS REALISED

The project's catchment flood risk mitigation aims have been met. In addition, the Edmonds Park basin and sports fields have realised multiple benefits to the community. Both sports fields are operational, and utilised as part of Mainland Football's weekend competitions, as well as used by Linwood College and the local community for informal activities. The upgraded sports fields are expected to perform better than the existing fields, due to the presence of the subsoil drainage system and groundwater control.

The landscaping, new grass turf, and provision of seating and spectator areas along the walls and embankments have improved the recreational and visual amenity of the park. The realignment of Bells Creek will facilitate future development of Linwood College, and has given the opportunity for the previously utilitarian drain section of the creek to have landscape and ecology improvements through planting, shading, variation of channel alignment, and the supplementation of the baseflow.

3.3 TE ORANGA WAIKURA URBAN FOREST

3.3.1 BACKGROUND

The Lower Linwood Fields are located at the lower end of Bells Creek between Smith Street and Tilford Street. Access is from Ferry Road. The land area potentially available for the project was approximately 25,000 m². The site was owned by the Ministry of Education but was no longer in use as a sports field due to earthquake damage. Bells Creek runs outside of the site boundary, from the west to south of the site.

Figure 4: Location of Lower Linwood Fields

Like Edmonds Park basin, during larger storm events, the Lower Linwood Fields basin will receive high stormwater flow from the Bells Creek catchment, attenuate peaks flows, and discharge slowly back into Bells Creek, via Arran Drain. The required detention volume was refined and confirmed by 2D hydraulic modelling of the catchment as requiring 6,500 m³, and it was confirmed the inlet and outlet configurations would perform acceptably. Again like Edmonds Basin, sensitivity modelling confirmed the benefits of flood detention at this location in the catchment, over other potential flood mitigation works.

Calibration exercises of the hydraulic modelling defined the peak water level in a 50-year event as being 10.9 m RL in Lower Linwood Fields, existing ground levels are approximately 11.2 m RL in comparison. The area available was more than sufficient to achieve the required storage volume, however design parameters around preferred water depths, landscaping, embankment batters, and buffers to other features meant the area requirements expanded through the design process.

3.3.2 OPPORTUNITIES

The Lower Linwood Fields site was a relatively large, and currently unused area of land post-earthquake. Council had been communicating with the previous property owner (Ministry of Education) throughout the project lifecycle, and purchase of the undeveloped portion of the site by Council was arranged. The portion of the site housing the Kimihia

Parents College and Early learning Centre was retained by the Ministry of Education. This purchase gave rise to the opportunity for this project to advance.

The original concept design proposed an excavated dry detention basin at Lower Linwood Fields with an outlet into Arran Drain. Further geotechnical investigations indicated this option was not feasible due to groundwater levels being 0.5-1 m above the proposed invert of the basin. In fact, later in design, groundwater levels at this site were found to be at times near ground level. Knowing this, concept design options were considered for a stormwater treatment wetland. However a stormwater quality treatment (a stormfilter device) was later included downstream at the proposed pump station site at 12 Richardson Terrace for these catchments (and the larger Ferry Road Brick Barrel catchment). It was therefore determined that this site should primarily provide flood detention, and with respect to quality treatment, should target simply a pre-treatment forebay and base flow turnover. Although not specifically designed for, the intrinsic nature of a planted basin will result in some stormwater quality benefits.

Arran Drain runs along the eastern boundary of the site, before flowing into Bells Creek at Ferry Road. Arran Drain is fairly utilitarian in structure and apart from its drainage purpose, of low value. The proposed basin and physical site parameters meant that the Arran Drain catchment could be diverted through the proposed basin, thus providing some pre-treatment to this additional sub-catchment, and contributing to the base flow turnover of the basin.

With the requirement for wetland treatment removed, this provided the opportunity for other landscaping of the site to be considered. A grassed dry basin was not appropriate as previously discussed. Without treatment requirements, a smaller basin volume was required, leaving additional land area available for other purposes, such as recreational, landscape and ecological features. In this instance, the opportunity to incorporate an urban forest to the basin site was selected.

3.3.3 COUNCIL TREE AND URBAN FOREST PLAN

The Lower Linwood Fields forest project complements the City's proposed 'Christchurch and Banks Peninsula Tree and Urban Forest Plan' (TUFP) that is currently being prepared by the Christchurch City Council Parks Planning Unit's Biodiversity Team. Amongst the broad range of ecosystem related services that trees and forests provide, the TUFP seeks to restore viable indigenous forest ecosystems across the city. It is envisioned that these forests will one day provide viable habitat for a range of bush birds and other indigenous fauna, many of which have been locally extinct in the Christchurch area since not long after European colonisation.

At the time of European arrival, the area of Christchurch supported just two patches of native forest: Papanui Bush (30 ha), and Riccarton Bush/Putaringamotu (22 ha). While approximately 6.5 hectares of Riccarton Bush/Putaringamotu has been preserved, the entire Papanui Bush was felled for timber within five years of European settlement. While still relatively small forests, both were abundant in birdlife, and attracted large flocks of kaka, kakariki, wood pigeon, bellbirds and tui. Today, through restoration efforts by the Council and community, the area of indigenous forest planting in the city far exceeds the extent of forest in the early 1800s, and there is now more planted indigenous forest (>53 ha) in the Styx and Otukaikino catchments alone than the former extent of Papanui Bush and Riccarton Bush/Putaringamotu combined.

However New Zealand's bush birds have evolved to inhabit extensive tracts of relatively undisturbed forest, and indeed long-term viable bush bird populations are likely to require forest areas in the order of several thousands of hectares. However, urban environments like Christchurch do not allow for forests of this magnitude to be established. Instead, restoration planners need to consider how a range of smaller fragmented forest patches distributed strategically across the landscape could support landscape scale restoration of both indigenous forest and associated faunal communities, particularly bush birds.

Meurk and Hall (2006) provide guidance for restoration planners in terms of forest reserve design and spatial arrangement in the landscape. These guidelines seek to improve and maintain the population viability of both the forest tree and plant species themselves, and also the viability of forest fauna, particularly bush birds. They recommend that forest reserves of 6.25 ha - the approximate size of Riccarton Bush/Putaringamotu - be located at five-kilometre centres across modified landscapes to provide core forest habitat. They also recommend that 1.56 ha forest patches be located at one-kilometre centres across these landscape to provide resource patches, and to support viable populations of other fauna such as herpetofauna (skinks and geckos), and invertebrates.

Counterintuitively the larger (6.25 ha) forest patches have proven relatively easy to plan for in Christchurch compared with the 1.56 ha patches. This is because many potential areas already exist (e.g. Riccarton Bush/Putaringamotu, The Groynes, Styx Mill Conservation Reserve, 303 Radcliffe Road Horseshoe Lake, Travis Wetland, South New Brighton Reserves and others). However planning for and locating 1.56 ha patches at one-kilometre centres across an already developed urban environment has proven almost impossible in Christchurch.

The Linwood Lower Fields project presented a novel opportunity. Its size ideally supported one of the smaller forest patches recommended by Meurk and Hall (2006), and would act as an exemplar for further initiatives across the city. Furthermore the Linwood area itself also has the second lowest tree canopy coverage (11.20%) of the City’s 15 wards. The stormwater project therefore provided a unique opportunity to increase tree coverage in the area, supporting a key goal of the TUFP to increase canopy coverage, and also supported the range of other values including drainage, landscape, ecology, recreation, culture and heritage.

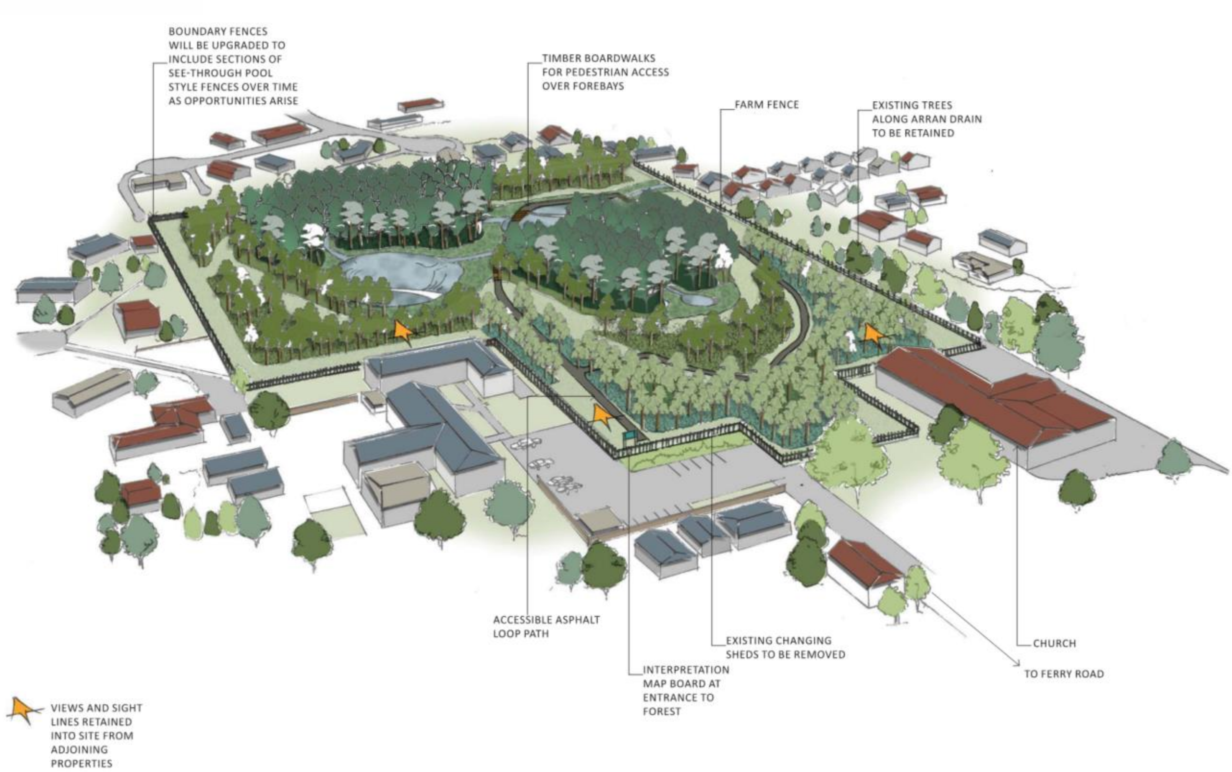
3.3.4 TECHNICAL CHALLENGES AND RESOLUTION

Primarily, the basin needed to meet the flood mitigation aims, in this case the design parameters defined through hydraulic modelling: the detention volume, the inlet and outlet parameters, and a 24-48 hour draw down time to protect vegetation, and accommodate successive storm events.

When the main Bells Creek channel (40 ha impervious catchment) backs up in a flood (to the pipeline in Smith Street), it will start spilling into the basin through a weir (at 10.3 m RL) and inlet pipe from Smith Street down Bray Street to the basin. The first flush/base flow does not enter the basin, it continues down Bells Creek, and instead the basin takes the storm volume from the top of the hydrograph.

The inlet forebay has been sized as approximately 10% of the basin volume to provide some pre-treatment, reduce re-suspension of accumulated sediment, deter erosion of the basin from inlet flows, and consolidate coarse sediment deposition and thus debris cleaning activities to a smaller area. The smaller catchment from Arran Drain (9.5 ha impervious) will also be diverted into the basin, for both base flow (full diversion), and storms flow. Its inlet forebay has been sized to provide 15% of the water quality volume (25 mm runoff from impervious areas). Both forebays have a gabion wall installed around the inlet pipes. These gabions will diffuse energy from the inletting, and further consolidate the trapping of debris and silt to a smaller region within the forebays. All weirs and walls have been made adjustable, giving flexibility to change to operation of the detention basin, flood diversion, and base flow diversion in the future.

Figure 5: Birds-eye schematic of the Te Oranga Waikura Urban Forest



The outlet pipe is set at an invert level of 9.9 m RL which acts as a base flow water level control. The outlet structure itself acts as a 'baffle' to restrict floating material and debris, and trapping floating scums or hydrocarbons from passing downstream to Bells Creek. A deep pool (1 m) at the outlet acts as a sediment forebay to minimise re-suspension of accumulated sediment. Both the outlet pool and the two inlet forebays will require maintenance and clearance of silt and debris. The structure, including the pipe outlets, the outlet structure, and the gabions will require inspection and clearance of debris. It was a concern that due to the urban forest landscaping, that these areas may become inaccessible. To mitigate this issue pathways were designed to pass near to key access points, and compacted gravel 'maintenance' stand areas were created to give operations staff a clear area to undertake activities from.

Any flow diversion or creation of a detention basin, changes the position of stormwater in the catchment. In this case we needed to check that the works would not inadvertently change the risk in an over-design flood or overflow event, to other properties or the arterial road (Ferry Road) to the south. Here, the levels surrounding Lower Linwood Fields are such that flow would back up on Smith Street as it currently does, and overflow through the existing overflow paths. There are no additional secondary flow path risks identified as a result of the basin design. The existing ground levels of 11.2 m RL means that 0.3 m of freeboard is provided, furthermore the Arran Drain high flow channel could operate in reverse as a spill if required. In addition the basin has a small fetch, is not exposed, and has the 10 m buffer to any property.

A base flow channel was constructed to meander through the basin transferring base flow, and providing a drainage route for the main base of the excavated land. Base flow in the urban forest is important in order to reduce stagnation, thermal gain, an algal bloom risk, and to manage midge infestation risk. It was estimated that 2 L/s inflow is required to provide turnover. The Bells Creek channel reach adjacent to Lower Linwood Fields was the only section of the creek that provided adequate water depths and cover for fish, thus baseflow is not to be diverted from that reach of Bells Creek. A base flow assessment was undertaken after a period of extended dry weather. The base flow of Arran Drain was estimated to be 3 L/s (whilst Bells Creek was estimated to be 3.5 L/s). Groundwater flows into the wetland are expected to be minor and should not be relied upon for maintaining wetland base flow. Diversion of Arran Drain base flow into the basin should be adequate to maintain the required turnover. The groundwater flow rate could increase if sand lenses connecting to the underlying Christchurch formation sands are intersected. If additional flow supplementation is required for ecological or landscape benefits, simple bored well(s) into this layer could be included to provide additional base flow. Simple gravel cores could be retrospectively installed at minor cost and difficulty if desired.

The urban forest is open to the public, and a gravel walkway and boardwalk bridges have been provided for a recreational loop walkway. Care was taken that the public walkway will not impede on maintenance access or operational requirements, and that the walkway did not direct persons to areas of the basin where there are safety risks due to the operational aspects of the flood mitigation infrastructure. Following communication with the neighbouring residents, it was determined that the site would be fenced, and access closed at night. Fencing and access gates for pedestrian and operational vehicles were located to ease access to the site, and not disrupt the activities and privacy of the adjoining Kimihia Early Learning Centre and Parents' College. Signage and interpretive information has been provided along the pathway describing the urban forest and the flood mitigation scheme. A CPTED study identified that a key method to improve the safety of the forest is to increase access and visibility. As such Council offered the neighbouring properties the option of replacing their boundary fence with new 'see-through' secure fencing. The increased visibility into the forest and reduces the risks of disreputable and antisocial behaviours within the forest. Council has also undertaken to consider future opportunities to purchase adjacent properties, with the intention to provide additional access routes into the forest in the future.

The basin has a batter of 1V:4H, for maintenance access, ground stability, and safety. The basin excavation is below the existing groundwater level, and the existing soils have low permeability. A 10 m buffer from property boundaries to the top of any excavation was included to minimise lateral spread risk.

The buffer around the boundary of the site includes a minimum 5m wide grassed strip. This strip has multiple purposes: it provides an access route around the site for operational vehicles, and provides a buffer between properties and the forest planting; improving visibility, and mitigating any shading impacts or fire risk. In this case the orientation of the site is such that most properties are to the north. Shading modelling was undertaken and used to communicate the minimal impact on properties.

In terms of plant selection, the forest includes low level wetland plant species that will be low growing and suitable for submergence in water. Plant species have been chosen for their low maintenance requirements and robustness. Stands of a kahikatea predominant forests blocks are positioned on the lower benches of the basin, then totara and matai predominant stands on the higher areas. The stands of forest plants have been selected to reflect natural species combinations, and reflecting the intermediate growth phases that will be experienced. A planting volume of approximately 15% (1000 m^3) within the basin has been allowed for in the basin design to achieve the flood detention volume. This calculation reflects the density of the lower wetland planting. Once established, the mature trees will actually take up less flood volume. An urban forest has the advantage over wetland planting or grassed basins, that the requirements for plant maintenance are actually far less. The forest canopy (once mature) effectively suppresses weed growth and controls soil moisture.

3.3.5 CONSTRUCTION

Construction of the basin was difficult due to the ground conditions, and the weather experienced. The Contractor's view is that they had "an unprecedented wet period, followed by an unprecedented dry period" during the construction. Techniques employed to aid construction included excavating and trimming/topsoiling to finished levels in stages, so that the excavators don't need to walk out over the saturated silty soils. The inlet and outlet structures were modified to control flows during construction. The planting required the lay down of the planting medium in 'virtually' dry conditions, requiring dewatering and staging. Storm events during construction resulted in the large 'habitat' logs moving through the site. In response the logs were moved to higher ground, and embedded and secured using rebar.

Photograph 3: The Constructed Te Oranga Waikura Urban Forest (photo: WSP-Opus)

Key lessons learnt were that timing the project such that excavation during the summer months when groundwater levels and rainfall volumes are lower will improve construction efficiency and quality. Likewise planting during winter (April – September) will improve the success rate and reduce maintenance requirements. Plant maintenance is ongoing and irrigation, weeding and base flow water level has been important. Watering needs to penetrate a minimum of 0.2m into the topsoil order to prevent shallow rooting. Regular and frequent weeding is required on the site until the plants establish. Manual frequent weeding has the best success; use of sprays has caused some plant death from spray drift.

A community planting day was held during construction to give a chance to engage with the community and learn from their experience and knowledge of the area. In addition the community gained a sense of ownership and 'caretakership' over the future forest. Other community engagement events included an ecological site visit with local schools to view the electro-fishing of the eels and other fish in Arran Drain for relocation and a community opening ceremony.

3.3.6 BENEFITS REALISED

Te Oranga Waikura Urban Forest and Stormwater Basin was opened on 16 October 2017 at a formal opening ceremony attended by Christchurch City Councillors and members of the Linwood-Central-Heathcote Community Board, along with members of the public. At this site, the Council has taken the opportunity to turn this flood mitigation measure into a forested reserve that will also bring ecological and community benefits. Over 16,000 native trees and plants are on the site, and birdlife is being observed already. It's hoped the forest will attract bellbird, kereru, fantail, grey warbler and in the future, even tui, kakariki and kaka, back to the area.

Photograph 4: Official opening of Te Oranga Waikura, ribbon cutting by councillors, and representatives of both the longest and newest neighbouring residents

Community engagement with the site is high. The forest walkway is listed on Council's walkways website. Enthusiasm for the future forest is high, residents likening the amenity, ecological and property value benefits the forest will bring to that which is enjoyed by Riccarton Bush: *"We're looking at having an urban forest in Linwood . . . it's going to start making Linwood great again"* (Councillor Yani Johanson).

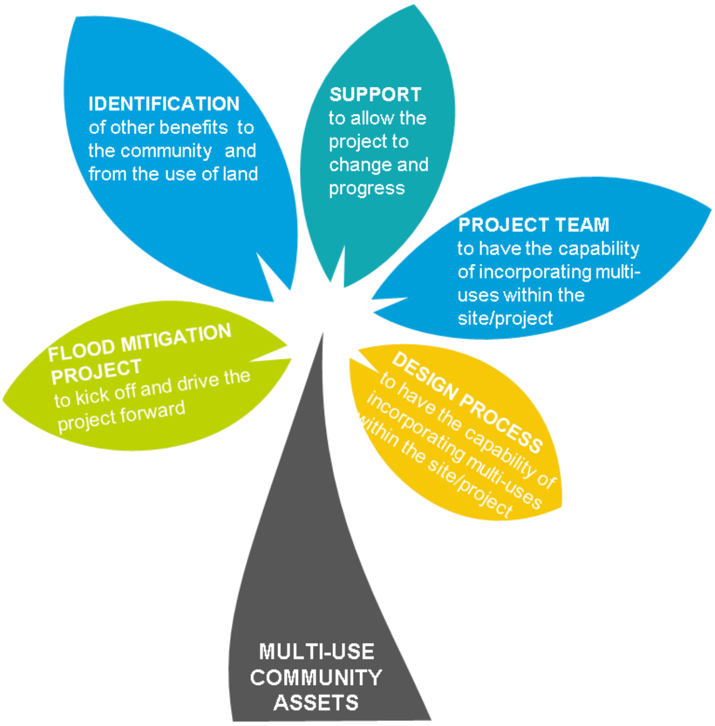
The name of the forest Te Oranga Waikura was gifted to the community board by the runanga. Newline videos by Council have raised awareness and support for the forest within the community. Videos are available at https://ccc.govt.nz/news-and-events/newsline/show/1611, https://ccc.govt.nz/news-and-events/newsline/show/2098.

4 POTENTIAL OPPORTUNITIES FOR COMMUNITY MULTI-ASSET PROJECTS

Many local authorities, which are significant providers of infrastructure assets, are approaching a period of infrastructure renewal, and opportunists exist for additional benefits to be incorporated. Flood mitigation projects lend themselves to multi-benefit uses of land, although as demonstrated the mixed usage requires changes to the design and operation of the infrastructure. Suggestions for combined use include sports fields, parks, gardens and forest. Sports fields and other recreation uses raise the opportunity for smart irrigation (such as water re-use on a golf course) as well as combined use of land for flood mitigation. Any community amenity spaces such as playgrounds, cycleways, pathways and learning/information/education sites can also be incorporated into flood mitigation infrastructure such as waterway corridors, basins and pump stations.

Other infrastructure projects can also be combined with flood mitigation projects. Land sharing may mean that both projects become more feasible, add more overall benefits to community, and are more cost effective. Infrastructure projects such as roading, cycleways and parking areas use significant areas of land, and multiple uses could be investigated.

Figure 6: Framework for implementing a Flood Mitigation project with multiple-uses for the community



Flood mitigation PROJECT
Flood mitigation projects have the opportunity to incorporate other benefits and uses. If a project has been identified and funded, this can form the basis and 'go-forward' for a multi-use project.

IDENTIFICATION of other opportunities
Other existing council strategies? Any communities desires expressed? Master planning activities? Any other infrastructure projects planned in same area?

What other ways could this land be used?

SUPPORT for the project
Can funding be approved? Can the project programme be adjusted? Can the design process be modified? Can other stakeholders (asset owners, community groups, ministries other agencies) lend support, funding, or technical knowledge? Multi-benefits can be more difficult to prove, can a MCA or NPV help? Will a better business case add weight? Is there community engagement and support?

Project TEAM
Multi-disciplinary team required in order to make multi-use of sites a success. Willingness to re-visit design options. Communication skills important (within team, and with other stakeholders).

DESIGN process
Clarity of design aim and design strategy. Bring on board the other stakeholders. Bring on board experts. Design process needs to facilitate collaboration. Requirements for some compromises and pragmatic design due to the sharing of land. Careful consideration of operation, and safety in design.

On a smaller scale, any flood mitigation project can pursue opportunities to incorporate additional benefits. Typical applications could include the provision of access points for the public to enjoy the space, along with bridges / wharves / viewing platforms. Incorporation of mahinga kai and ecological features also add value. Energy generation or water re-use are also conceivable on projects were there exists the flow of water or other materials.

Challenges and suggestions for the successful incorporation of multi-asset projects include: identification, support and proof of benefits, design with multi-disciplinary teams, a flexible and collaborative design process and engagement with other stakeholders. A potential framework for project success is shown in Figure 6. A key aspect of the design process is the collaboration, and willingness to accept compromises due to the shared use of land. For example if a cycleway is installed along a waterway bench, the cycleway asset owner needs to accept that the path will be flooded at times, whilst the water asset owner needs to accept that the public will have access. In this example, the level of maintenance may need to be increased to provide an amenity level of service, rather than a functional level.

5 CONCLUSIONS

Flood mitigation projects are complex, often high cost, and have many inherent challenges to achieve a successful outcome. However the projects are also becoming more important as our communities develop, respond to flood events and historic flood risk, and address the impacts of climate change. The opportunity, and potential mantra, to make our flood mitigation projects and our use of that land provide multiple benefits to the community, is an important and attainable goal. Christchurch City Council has achieved this goal in two recent examples in the Bells Creek flood mitigation project; Edmonds Park sports fields, and Te Oranga Waihora urban forest and flood detention basin. Both projects and been designed and constructed, and are providing value to the community. As our communities come under increasing pressure to fund infrastructure projects, land-hungry and high capital cost projects such as flood mitigation projects need to provide justifiable benefits to the communities they service. The answer to the question: can we afford to use it for 'just' flood management or can we make that land provide multiple benefits to the community? Is undoubtedly 'no we cannot, and yes we can'.

ACKNOWLEDGEMENTS

The authors wish to thank a number of people, who contributed to this paper:

- The Christchurch City Council staff and Council, whose project is featured, and who's initiative and support delivered it

- The Bells Creek project team (WSP-Opus, Beca, Christchurch City Council), for their design and project management effort, commitment, and vision

REFERENCES

Climate Change Adaptation Technical Working Group (2017) 'Stocktake Report from the Climate Change Adaptation Technical Working Group'

Meurk, C.D. and Hall, G.M.J. (2006) 'Options for enhancing forest biodiversity across New Zealand's managed landscapes based on ecosystem modelling and spatial design' New Zealand Journal of Ecology 30,131–146.

Tonkin & Taylor Ltd (2017) 'Coastal Hazard Assessment for Christchurch and Banks Peninsula'