URBAN DEVELOPMENT STORMWATER MANAGEMENT – HOW COLLABORATION ACHIEVES EXCELLENT OUTCOMES

B Norton (Christchurch City Council) and N Raynor (Aurecon New Zealand Ltd)

ABSTRACT (500 WORDS MAXIMUM)

The creation of exceptional stormwater outcomes for new urban developments doesn't just happen. It requires a bit of art, technical innovation, and a whole lot of collaboration to create healthy stormwater management facilities and urban waterways that also are places of amenity.

In this paper the stormwater journey to achieve excellent outcomes through collaboration is illustrated using the Prestons Development in Christchurch.

The demand for new urban growth areas in post-earthquake Christchurch put pressure on developers, Councils and their respective teams to produce new sections.

The Prestons development was one of those areas that was part way through a plan change process and stormwater management was an unresolved issue that required innovative thinking, and an understanding of the objectives of both developer, designer and Council to create a sustainable stormwater management system to provide the treatment and attenuation required as well as creating amenity that enhanced the living environment.

Through this journey there were many opposing opinions on the stormwater treatment systems that were required. For example wet first flush basins vs dry, many treatment facilities vs single large basins, and the operating level of the northern wetland, are a few of the technical differences that needed resolution.

Through this paper the overall stormwater context will be explained and some of the challenges will be expanded to describe how seemingly opposite goals can be worked through and eventually resolved to achieve exceptional outcomes for stormwater management and community amenity areas.

The Prestons development overall is 200ha was a combination of:

- Ngai Tahu Property north of Prestons Road (Prestons),
- CDL Land Limited South of Prestons Road (Prestons Park), and
- Foodstuffs SI Ltd in a smaller site to the west of Prestons Park adjacent to Prestons Road.

The development contributed to two separate catchments, The Styx River taking most of Prestons North, and Snellings Drain (a tributary of the Avon River) taking up the rest.

The whole site had very little fall from one end to the other and any unnecessary grading of the landform to the stormwater facilities resulted in significant volumes of imported filling.

The Styx River was considered to be less critical in terms of flow management but critical in terms of quality. Therefore the stormwater management required primary and secondary treatment utilizing a wetland.

The Snellings Drain had a proposed catchment wide wetland treatment facility that was proposed but had not been commenced at that time requiring patience. Downstream landowners were flood prone and therefore attenuation was required until an upgraded conveyance capacity to the proposed wetland was in place.

The final solutions, with a lot of help and input from the landscape designers, were developed through design processes and workshop and even a facilitated mediation process with the outcome being stormwater assets vested in Council that are assets to the community.

Keywords

Wetlands, Amenity, Urban Design, Collaboration

PRESENTER PROFILE

Brian is a Senior Stormwater Planning Engineer within Christchurch City Council's City Services Group. Brian is heavily involved with many of the stormwater works within the City including comprehensive stormwater network consents for major catchments and also the development of stormwater infrastructure both Council and privately developed systems.

Neill is a Technical Director with Aurecon New Zealand Limited. Neill is involved in design and construction urban development work for both private developers and territorial authorities, with an interest in stormwater management.

1 INTRODUCTION

The creation of exceptional stormwater outcomes for new urban developments doesn't just happen. It requires a bit of art, technical innovation, and a whole lot of collaboration to create healthy stormwater management facilities and urban waterways that also are places of amenity.

In this paper the stormwater journey to achieve excellent outcomes through collaboration is illustrated using the Prestons Development in Christchurch.

2 WHY MANAGE STORMWATER?

Stormwater is the result of rainfall on surfaces that aren't fully permeable leading to surface flows.

When it rains hard, excessive runoff can overcome stormwater infrastructure resulting in stormwater going where it's not meant to go.

When it's not raining as hard, stormwater will still transport pollutants mobilized from the urban surfaces.

2.1.1 STORMWATER FLOODING

Storm flows have a history of overcoming the infrastructure that was intended to manage these flows. Unfortunately, stormwater flows won't be stopped or take advice to "steady on”. Floodwaters continue to head downhill and not via the most convenient route (from our point of view).

Figure 1 below shows flood waters exiting some commercial buildings via a rear access door in New Lynn in West Auckland recently.

Figure 1: Flood water exiting some commercial buildings in New Lynn, Auckland

Flooding of private properties can be a traumatic experience, expensive and, unfortunately, sometimes deadly.

However, the purely capacity based engineered solutions aren’t enhancing our urban environment, natural eco systems or creating amenity areas.

Figure 2: Example of an Engineered Conveyance channel

2.1.2 POLLUTION PREVENTION

Stormwater flows can transport pollutants and soils from exposed surfaces and relocate them to a new place. This is a natural occurrence in the natural world that results in some spectacular topography over millions of years.

However, in modified landscapes this is accelerated, and additional unnatural contaminants or levels of contaminant are also transported. From Urban areas this includes rubbish and chemical contaminants from vehicles and industries, and higher concentrations of sediment from more erodible surfaces.

Figure 3: Water transported pollution

Figure 4: Sediment flows

While these two photos are more extreme examples, this type of pollution can occur incrementally with a negative result on our ecosystems.

So, the answer to “why do we manage stormwater” is to control heavy rainfall events while providing pollution protection from all the other rains, in a way that enhances our environment, has positive outcomes on ecosystems, and creates urban amenity areas that enhance our live, work and play lifestyles.

2.2 CAN WE DO IT – A CASE EXAMPLE

The demand for new urban growth areas in post-earthquake Christchurch put pressure on developers, Councils and their respective teams, to produce new residential sections.

The Prestons development was one of those areas that was part way through a plan change process when the earthquake occurred and stormwater management was an unresolved issue.

The Prestons Plan Change Area was a 200ha block of relatively flat, low lying pasture and cropping land adjacent to Burwood on the northern side of Christchurch City.

The Prestons development overall is a combination of:

- Ngāi Tahu Property north of Prestons Road (Prestons);
- CDL Land Limited south of Prestons Road (Prestons Park); and
- Foodstuffs SI Ltd in a smaller site to the west of Prestons Park adjacent to Prestons Road.

This plan change required a minimum overall yield of residential properties and the original layout did not include for large areas for stormwater management relative to the development.

The development contributed to two separate catchments, the Styx River taking most of Preston's north of Preston's Road, and Snellings Drain (a tributary of the Avon River) taking up the rest to the south.

The whole site had very little fall from one end to the other and any unnecessary grading of the landform to the stormwater facilities resulted in significant volumes of imported filling, creating a less sustainable development and potentially impacting the commercial viability of the project.

The stormwater management system required innovative thinking, and an understanding of the objectives of both developer, designer and Council to create a sustainable stormwater management system to provide the treatment and attenuation required as well as creating amenity that enhanced the living environment.

The overall concept was to incorporate the stormwater management system into a linear park that ran along a central spine through the middle of the large blocks. The linear park was to create an open and landscaped central area for walking, cycling and generally enjoying. The linear park was to be flanked on at least one side by a road to enhance the openness of the park.

Of the receiving environments the Styx River was considered to be less critical in terms of flow management but critical in terms of quality. Therefore, the stormwater management required primary and secondary treatment utilizing a wetland, with partial attenuation proposed.

The Snellings Drain catchment was to be treated by the Clare Park stormwater management facility which was on Council's capital works programme. However, timing was not known as landowner negotiations were required to achieve the necessary conveyance channels. The stormwater system within the Snellings catchment needed to have primary treatment and attenuation as a standalone system, or primary treatment only if undertaken in conjunction with Clare Park.

Christchurch City Council's Philosophy for Sustainable Management is based on six values:

- Ecology;
- Landscape;
- Recreation;
- Heritage;
- Culture;
- Drainage.

Any stormwater management system needs to incorporate these 6 values into the overall design and outcomes.

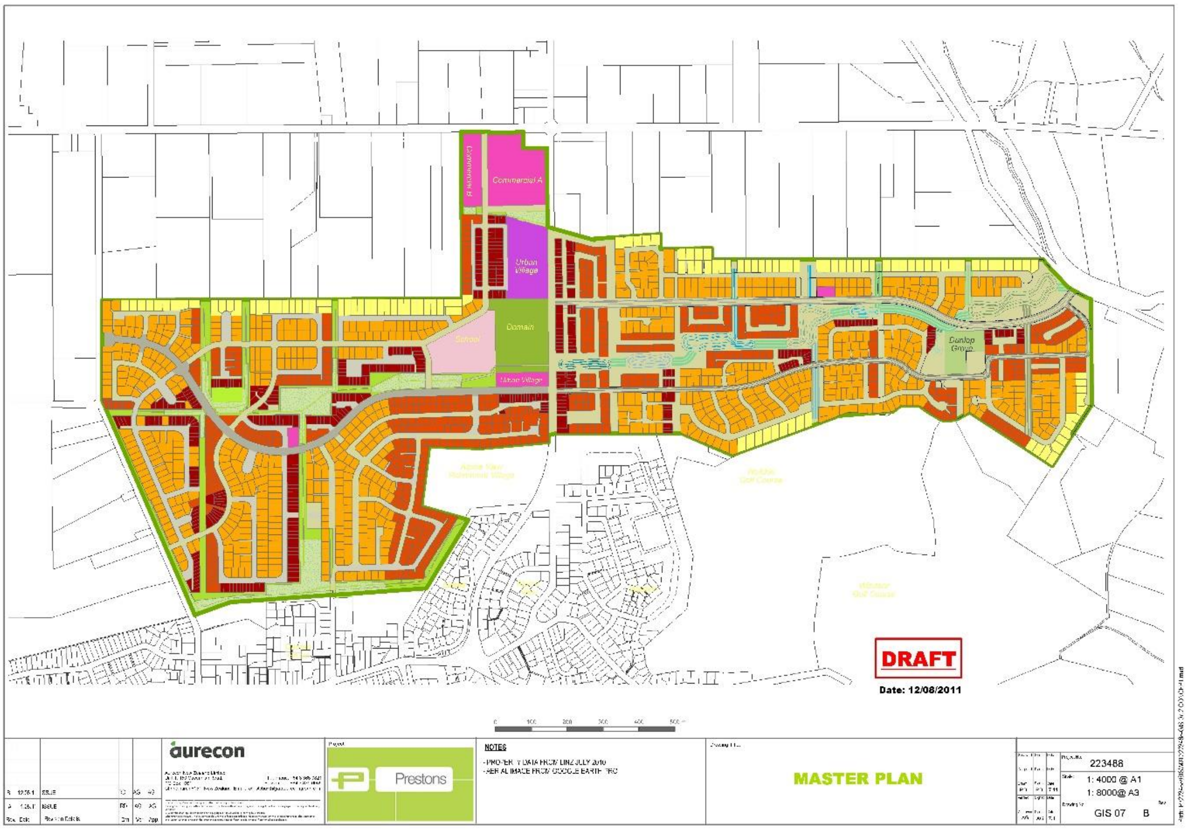

Figure 5: Prestons Plan Change Area

The design guideline for stormwater management was the Christchurch City Council's Waterways Wetland and Drainage Guide (WWDG).

2.3 DESIGN DIFFERENCES

Through this journey there were many opposing opinions on the stormwater treatment systems that were required. For example, wet first flush basins vs dry, many treatment facilities vs single large basins, and the operating level of the northern wetland, are a few of the technical differences that needed resolution.

Through this paper the overall stormwater context will be explained and some of the challenges will be expanded to describe how seemingly opposite goals can be worked through and eventually resolved to achieve exceptional overall outcomes for stormwater management and community amenity areas.

2.3.1 FIRST FLUSH DESIGN PARAMETERS

The purpose of first flush basins is to contain and provide primary treatment of the initial runoff. This contained volume is then released slowly for secondary treatment, usually through a wetland. Additional flows preferable bypass the first flush basins.

Christchurch City Council (and many others) prefer dry basins to wet basins, particularly when they are not large bodies of water. This allows easier maintenance by mowers and vehicle access in dry periods. However, for flat sites such as this, there is limited height range to accommodate the required volumes and the "dry" base loses potential live storage volume compared to wet basins, therefore the base needs to be as low as possible to avoid large basin areas. However, to be too close to the water table results in wet zones that cannot be mown in the winter or even worse, do not grow grass at all due to the proximity to groundwater levels.

Ngai Tahu property have a cultural desire to be near water and to see water, therefore the initial proposals included excavating deeper zones to include wet first flush basins. Discussions started with these opposing views.

One of the key elements to support a wet pond design is the availability of baseflow to keep the water fresh (and full) through dry periods.

A series of groundwater monitoring locations were installed in boreholes and a period of up to 18 months of groundwater levels were obtained. Council had its own long term bore within its active reserve on Prestons Road and the short duration of the site groundwater levels were compared against the long-term levels of the Council monitoring and an indicative seasonal range of groundwater levels were determined along the linear park and through the majority of the stormwater management devices.

This showed that many of the proposed wet basins could have a permanent water level that was at or below groundwater levels throughout the year. This, in conjunction with a water extraction test, provided confidence that baseflow would occur all year around.

To maximize the first flush basin capacity within as small a footprint as possible required a relatively steep sided area to accommodate a first flush and attenuation basin.

Specific design input was undertaken to ensure inflow locations were located closer to overflows for larger events but further from the slow release outlets to avoid short circuiting

In the end there was agreement for the smaller catchments to have dry first flush basins and a wet attenuation basin adjacent. Slightly larger first flush basins were agreed to be wet and were accompanied by a specialist landscape design.

Good landscape design will transform a potentially square / engineered design into an asset without significant volume or area sacrifice. An established first flush basin in Prestons is shown in Figure 6 below.

Figure 6: Wet First Flush basin in Prestons

Figure 7 below shows the dry first flush basin in Prestons with the wet attenuation basin on the other side of the footpath topped bund on the right. The development has included a café and seating / playground area overlooking this first flush basin.

Figure 7: Dry First Flush basin in Prestons

A key factor in getting to an agreed solution was through technical discussion and workshopping between the representatives of each party was to outline and explain the reasoning behind current design outcomes to then enable a better overall design solution to be agreed.

2.3.2 WETLAND OPERATING LEVEL

The northern Prestons development discharged to the Styx River, which required primary and secondary treatment. The secondary treatment wetland was intended to be at the northern end adjacent to Lower Styx Road.

The Styx River has a 50yr flood level of RL 12.0m while the normal water level in the river was below RL 10.5m.

The Council design requirements for wetlands was that no more than 500mm of attenuation depth could occur above the normal operating level of the wetland. This meant that an operating level of RL 11.5m was required without mechanical separation to avoid over depth ponding over the wetland.

However, there was concern that the expected groundwater level in the summer was 300mm or so below RL11.5m and the wetland vegetation would be in danger of dying. Initial responses from the botanical teams from both sides supported this concern.

The proposed solution was to have the lower operating level with a backflow preventer to limit the height of water over the operating level in the larger storms. Council were adamant that mechanical devices were not to be included within a greenfields development as such devices required a maintenance regime and have potential operational issues that would affect performance. There are also limited future opportunities to retro fit devices if necessary to accommodate future change when a device is already in place.

This difference in opinion led to a facilitated mediation where the different concerns and requirements were aired by both sides. The resulting workshop saw some design elements being compromised to accommodate a better overall outcome. The mini workshop that was held that resulted in two key outcomes.

- The plant specialists from both sides agreed that after the first two seasons the wetland plants would survive long term as long as the groundwater level did not lower more than 300 below the bed level
- The combining of the first flush basin and the first wetland cell would result in a better overall landscape and amenity outcome without compromising the treatment function of the system. This first flush basin had twice the storage required by the design guidelines.

The end result did require some redesign but achieve an agreed outcome which can be seen now as an asset from an infrastructure and an amenity perspective. Some pumping of water from the first flush basins higher in the catchment was required during the first summer or two until the plants were established.

Figure 8: Prestons wetland cells (front and upper left) and first flush basin (upper right)

Some clever design thinking was required to take the first flush flows from the upstream basin from the open vegetated channel bypassing the site into the wetland, without the wetland being overwhelmed with additional volume in flood flows. This was also worked through along with ongoing wetland management items to bypass some wetland cells for maintenance.

2.4 PRESTONS PARK

The Snellings Drain had a catchment wide wetland treatment facility that was proposed but had not been commenced at that time requiring patience. Downstream landowners were flood prone and therefore attenuation was required until an upgraded conveyance capacity to the proposed wetland was in place.

The initial design concept was for a standalone stormwater management system where attenuation and treatment were all provided on site. This required multiple first flush basins around the site that discharged onto an open channel that provided conveyance to the outlet.

There were several inefficiencies in this design philosophy.

To limit the length of primary reticulation a series of first flush basins were scattered around the development. Each first flush basin required the conveyance channel to pass around the basins requiring additional width of land. In some locations the open channel separated the basin from the catchment requiring inverted siphons or the channel passing between adjacent fist flush basins.

The onsite attenuation requirement resulted in land levels being driven upwards, or stormwater management facilities increasing in area impacting the overall yield.

At the time the detailed design was about to start, the developer (CDL) of the southern block met with Council engineers and stated they were there to work collaboratively with the engineers at Council as a team and not to butt heads and demand approvals for substandard local stormwater management solutions at the expense of superior catchment wide solutions.

The issues that Council were having with commencing the Clare Park treatment facility were related primarily to negotiating with the landowners located between Prestons Park and the Council owned land, where Clare Park was to be located, to construct a realigned and enlarged open channel to convey flows to the proposed wetland. As owners of the Prestons Park development block for some years, CDL had already been conversing with one of the key landowners and offered to assist Council with landowner discussions to negotiate a land purchase agreement for the proposed conveyance channel.

By working with the Council and landowner and having assurances of Clare Park capital works being within the LTP, Clare Park was able to be included within planning of the development and a staged development plan was agreed.

With Clare Park available for secondary treatment and attenuation for the long-term solution, a revised site development layout that incorporated a single large first flush basin at the discharge location and an open channel conveyance within the site was proposed.

This provided a much improved stormwater management infrastructure.

This open channel still aligned with the linear park concept of a landscaped amenity area and also provided a low head loss conveyance channel to the outlet. This maintained lower platform levels which minimized imported fill requirements and maintained total development yield.

Figure 9: Prestons Park – vegetated open channel

The single large first flush basin provided the ability to fully attenuate the initial stages of development while the Clare Park wetland and conveyance upgrades was designed and constructed.

The low flow outlet from the first flush basin is at the far end of the basin, however the overflow spillway, for when rainfall exceeded first flush volumes, is located adjacent to where the vegetated open channel discharges into the first flush basin. This allows for overflow to leave the site via a separate bypass channel and not flow through the first flush volume, remobilizing sediment.

Figure 10 Prestons Park First Flush Basin with overflow spillway and bypass channel.

Figure 11: Prestons Park – Single large first flush basin. The overflow spillway is in the front adjacent to the inflow channel

2.6 DID IT WORK?

Visually there is no argument that the result is an enhancement of the new built environment with a variety of plantings, open water spaces and connections to walking and resting areas.

Figure 12: Prestons - Larger first flush basin (left) and wetland cell (right)

Figure 13: Prestons wetland

In terms of water quality improvement some sampling has been commenced in the Prestons wetland with some interesting results. The tables below are from sampling and analysis done by PDP for Christchurch City Council and compares the wetland inlet and outlet contaminant concentrations.

Table 3: Pollutant Removal at Prestons between the Wetland Inlet and Wetland Outlet Sampling Locations

Pollutant	Partition	Wetland Inlet Concentration (g/m^3)		Observed Percentage Removal		WWDG Wetland Removal[1]
		24 September	11 October	24 September	11 October	
Total Suspended Solids (TSS)	-	52.5	< 3	7%	-[3]	60%-80%
Dissolved Inorganic Nitrogen (DIN)	-	0.088	< 0.011	88%[2]	-[4]	20%-60%
Total Nitrogen (TN)	-	2.35	0.655	6%	-32%	
Dissolved Reactive Phosphorus (DRP)	-	0.018	< 0.004	78%[2]	-[4]	40%-80%
Total Phosphorus (TP)	-	0.56	0.029	49%	-14%	
Arsenic	Dissolved	0.0011	0.00145	-45%	-28%	40%-80%
	Particulate	0.0016	0.0002	-181%	-100%	
	Total	0.0027	0.00165	-126%	-36%	
Copper	Dissolved	0.00065	0.0006	23%[2]	17%[2]	
	Particulate	0.00117	0.00014	49%	-[5]	
	Total	0.00182	0.00074	40%	28%	
Lead	Dissolved	< 0.00010	< 0.00010	-[4]	-[4]	
	Particulate	0.00165	-[4]	2%	-[3]	
	Total	0.00175	< 0.00011	2%	-[3]	
Zinc	Dissolved	0.00135	0.00285	11%	65%[2]	
	Particulate	0.02465	0.00175	60%	94[3]	
	Total	0.026	0.0046	58%	76%	

Figure 5: Wetland inlet concentrations and observed removal efficiencies

Table 4: Prestons Wetland Outlet Pollutant Concentrations

Pollutant	Partition	Average Concentration[1,2] (g/m^3)			Guideline (g/m^3)	Hardness Adjusted Guideline[5] (g/m^3)
		Low Flow	24 September	11 October		
pH (in pH Units)	-	-	-	7.7	6.5-8.5[6]	-
Total Suspended Solids (TSS)	-	<3	49	3	25[4]	-
Arsenic	Dissolved	0.0011	0.0016	0.00185	0.013[7]	-
	Total	0.00115	0.0061	0.00225		-
Copper	Dissolved	0.0006	<0.0005	< 0.0005	0.0014[3]	0.00212
	Total	0.00066	0.0011	<0.00053		-
Lead	Dissolved	<0.0001	<0.0001	<0.0001	0.0034[3]	0.00634
	Total	<0.00011	0.001715	0.00012		-
Zinc	Dissolved	0.00225	0.0012	< 0.0010	0.008[3]	0.01214
	Total	0.0028	0.01095	0.0011		-

Notes:

1. *Average of two composite samples.*
2. *These results have not been adjusted for pH or hardness.*
3. *ANZECC 2018 95% Level of Protection Guideline Value (ANZECC, 2018).*
4. *Environmental effects of sediment on New Zealand streams: a review (Ryan, 1991).*
5. *Table 3 of the Draft Environmental Monitoring Programme (CCC, 2018).*
6. *Land and Water Regional Plan (LWRP) (ECan, 2017).*
7. *For conservatism the guideline value for Arsenic V (AsV) has been used.*

Figure 65: Wetland outlet pollution levels and guidelines concentrations

There is a range of efficiencies that varies between events and in some situations increased.

The result is shown here are of the wetland alone and doesn't report pollutant removals from the first flush basins that occurred prior to the wetland inlet sampling location.

The TSS removal event shows limited removal efficiencies and greater discharge concentrations than the guideline value of $25g/m^3$. The October event and low flow recordings both have very low TSS amounts. Without knowing what the source of the sediment in the September event was, a conclusion can't be made as to the long term efficiency of the wetland. Factors such as high winds causing greater water disturbance across the wetland may have resulted in finer sediment remaining in suspension. It will be interesting to see future sampling to better understand these.

The increase in arsenic is an interesting result however the concentrations never reach any higher than about 50% of the guideline value. It is known that arsenic was found in higher concentrations within the surface soils in some isolated locations, and the known areas were managed by placement into reserves, however unknown locations of higher contaminant areas may have been placed into the wetland as part of the bulk earthworks.

Overall the review of the two weather events and the low flow sampling are not sufficient to provide a guide to the overall efficiency of the overall stormwater management system.

As a comparison the Knights Stream wetland was also sampled in the same rainfall events.

The Knights Stream wetland showed consistently higher levels of pollutant removal as a percentage, however it showed a greater number of pollutants were still above the guideline levels in both rainfall events. In contrast, the Prestons wetland had no discharges exceeding guideline levels in the October rainfall event, and TSS and Total Zinc only exceeded guideline values in the September event.

Ongoing testing will provide a greater dataset to review trends in removal efficiencies and actual pollutant levels.

3 CONCLUSION

This case study has highlighted the benefits of a collaborative approach to stormwater management and treatment between all parties and involving many specialists can achieve excellent outcomes and create healthy stormwater management facilities and urban waterways that also are places of amenity.

REFERENCES

- Christchurch City Council - Waterways. Wetlands and Drainage Guide February 2003
- PDP - Stormwater Treatment Facilities – Sampling Report for Christchurch City Council November 2018