SQUEEZING IN STORMWATER

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ABSTRACT

Often achieving low impact stormwater outcomes for a new development can be a difficult task, especially when modifying an existing site. This was the case in 2012 for the Hawke's Bay Airport Business Park where the site has a very flat topography, shallow groundwater affected by tides and the receiving environment is a sensitive Department of Conservation (DOC) natural wetland. The site is less than 1m above sea level but was previously estuary prior to the 1931 earthquake that lifted the land significantly.

Providing stormwater collection, conveyance and treatment with minimal fall available limited the options for a gravity system and created significant constraints for the Business Park design. A design that integrated the Business Park buildings, car parking, roading, and landscaping with the stormwater conveyance and treatment systems was required.

A series of wide open planted stormwater channels provide soakage to groundwater along with conveyance to banded bathymetric wetlands to achieve a low impact system. The outcome is a cost-effective system that provides function and improves overall site amenity.

This paper describes the objectives, site constraints, tight timeframes, options considered, stormwater solution designed and constructed and the lessons learnt for the new Business Park and existing Airport landside development.

KEYWORDS

Low impact stormwater design, shallow groundwater, soakage, banded bathymetric wetlands

PRESENTER PROFILE

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1 INTRODUCTION

The Hawke's Bay Airport had been planning a Business Park development for a number of years. In late 2011 with an anchor tenant keen to develop within the Business Park the planning and design of services for the Business Park needed to be rapidly advanced.

MWH were initially engaged to provide access road designs which was then expanded to assist with confirming the stormwater servicing approach, developing designs, consents and implementing works for stage 1 of the Business Park.

This paper provides details of the stormwater solution developed and implemented, with reference to site constraints, objectives for the stormwater system, design process followed and lessons learnt.

Background information is included on the history of the site, including the significant change in landform following the 1931 Napier earthquake, the development of the land for farming and then the development of the Airport. Some background information is also included on the stormwater assessment work that MWH have assisted the Hawke's Bay Airport with over the last 5 years or so, prior to the Business Park being advanced.

The solution implemented is expected to take several years to become fully functional, allowing for the planting to grow and develop. Actual performance is yet to be confirmed and expected to be the subject of a future paper.

2 BACKGROUND

2.1 SITE HISTORY

Prior to 1931 the area the Airport is now developed on was within the Ahuriri Lagoon which covered an area of around 4000 hectares. Refer to Figure 1 below.

As a result of the 1931 Hawke's Bay earthquake the land within the lagoon dramatically altered being raised over two metres, and becoming almost dry land. With extensive drainage works and separation from the main estuary by stop banks this area was developed into farmland forming the Ahuriri Basin. The Airport runway and facilities were developed in the 1960's within a higher elevation area.

A separate drainage system was created from the adjacent farmland with large open channels excavated along the runway to drain tidal groundwater and stormwater from the site. These were connected to a new pump station (separate to the wider drainage area), pumping into the Ahuriri Estuary.

2.2 EARLIER DRAINAGE ASSESSMENTS

Several investigations and reports have been prepared for the wider Ahuriri Basin in previous years. This included separate investigations by Landcorp and Napier City Council in 2008 on drainage management and separation of the Napier City areas from the Landcorp Farm and also the Airport from the Landcorp Farm.

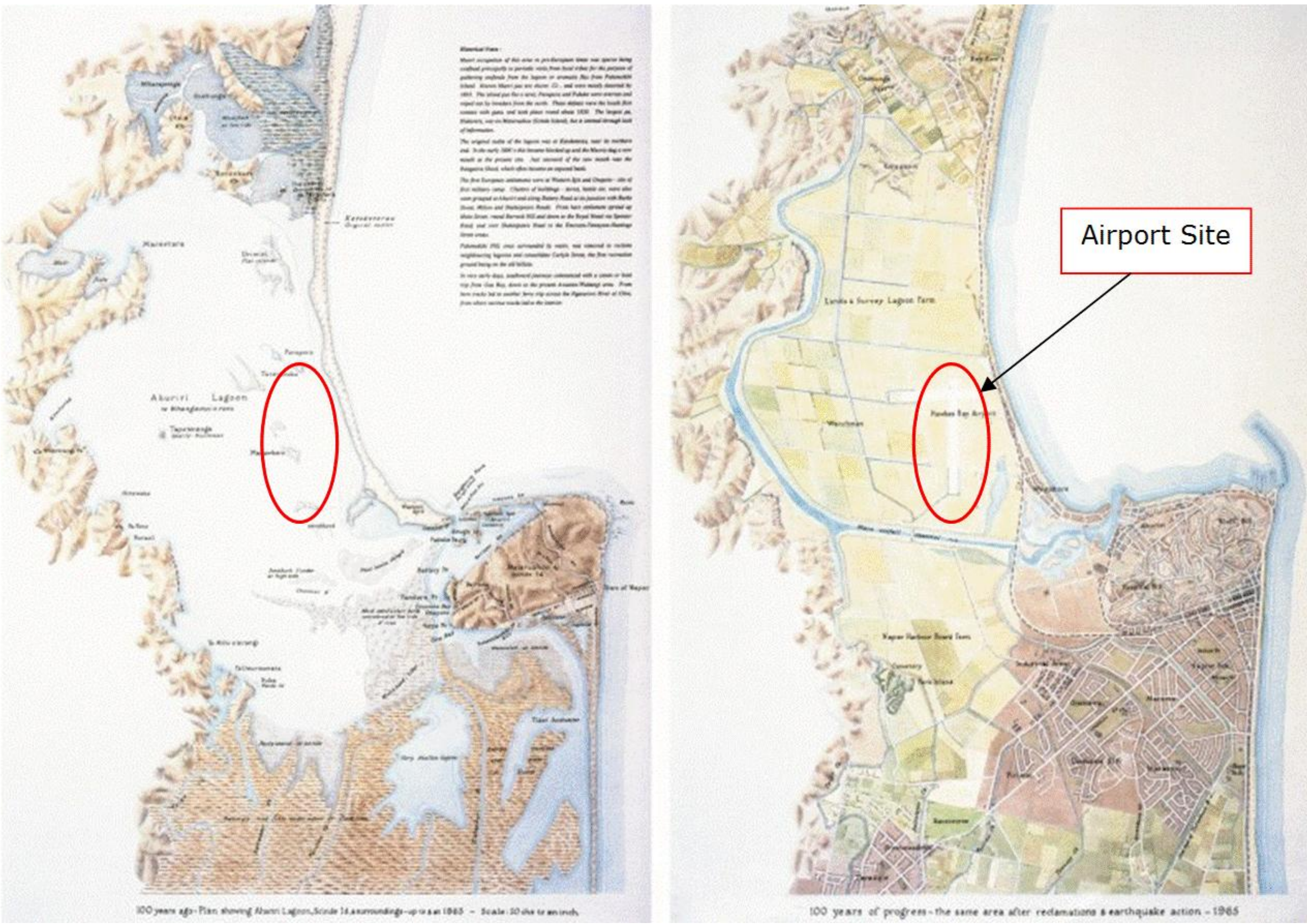

Figure 1: Napier and Ahuriri Lagoon/Estuary Pre and Post 1931 Earthquake

These assessments identified the importance of storage ponding for handling large storm events for the relatively low flow rate capacity of the installed pump stations servicing the drainage basin. It is assumed that this was the original design intent for the drainage systems installed.

Design parameters for stormwater runoff, including surface retention and infiltration values were presented in the reports.

2.3 INITIAL STORMWATER MANAGEMENT PLAN

In 2009 MWH prepared an initial stormwater management plan for the Airport. This was driven by concerns from Napier City Council on how future development would be managed at the Airport and by Landcorp regarding drainage of Airport land by the Landcorp pump station, and associated operating costs.

Figure 2 below shows the air-side and land-side catchments and the ground elevation at the site and surrounds. This shows the wider area is generally at or below mean sea level.

The scope of the initial stormwater management plan was limited to confirming catchment and sub-catchment boundaries, identifying the existing stormwater and land drainage systems, hydrological and hydraulic assessments of the catchments and a review of receiving environments issues, constraints and possible stormwater contaminants and risks. In addition an assessment was made of the interaction of runoff to and from the farmland owned by Landcorp.

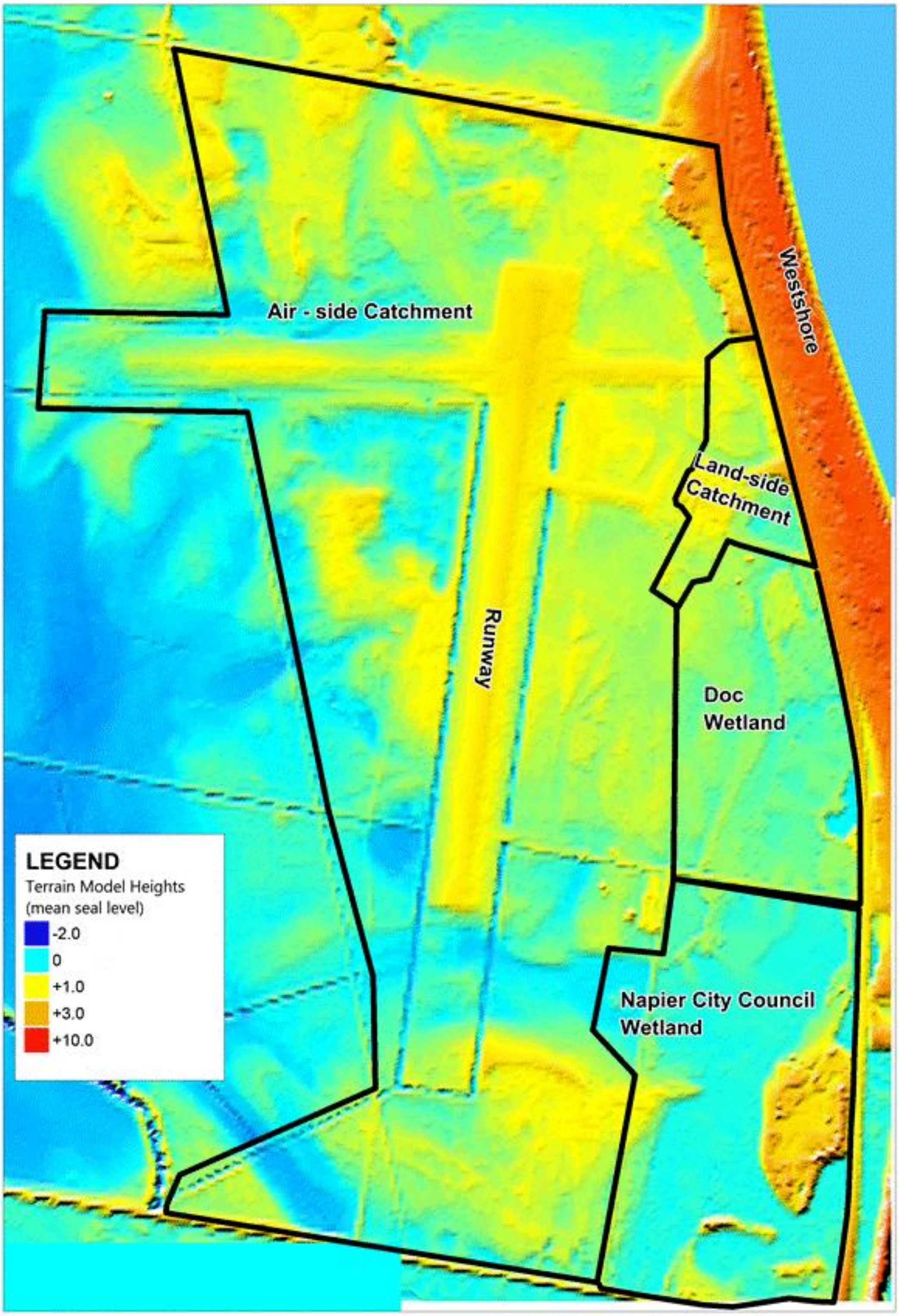

Figure 2: Airport Catchments and Ground Elevation

Some of the main findings from this assessment were:

- Limited conveyance capacity and uncertainty in soakage for the landside catchment and discharges.
- Potential significant contaminant concentrations and discharges from the landside catchment to the sensitive Department of Conservation (DOC) natural wetland.

- Runoff from SH2 entering the landside catchment area.
- Airside catchment and conveyance systems of adequate capacity and of generally low risk and contaminant levels.
- Stormwater consents are required for stormwater discharges from the site.
- Minor additional stormwater runoff from the Airport (air-side) to the Landcorp land

The plan identified the focus for further investigation and management to be on the landside catchment for both current and future development within the catchment area. Specific aspects to be addressed included spill risk management, actual stormwater environmental effects, associated stormwater treatment improvements, and understanding of ponding design levels for extreme events.

2.4 STORMWATER DISCHARGE CONSENT

A stormwater discharge consent was prepared in 2010 following liaison with the Hawkes Bay Regional Council (HBRC) and consultation with Department of Conservation (DOC) and local iwi. The application was based on effects assessed from a monitoring programme for the existing stormwater and drainage facilities.

2.4.1 MONITORING PROGRAMME

A monitoring programme was carried out in 2009 to characterise the dissolved contaminant concentrations in first flush, post first flush stormwater and in the receiving environment, and also sediment quality in environments immediately downstream of discharge points. Likely effects on water quality and aquatic ecosystems and habitats were determined in comparison to ANZECC guidelines, local background sites and comparison to other Airport sites.

The monitoring supported the earlier assessments of low contaminant levels for the air-side catchment. However for the landside catchment elevated levels of heavy metals were detected in stormwater discharged to the existing Airport constructed wetland pond and overland flow treatment areas. The receiving environment water and sediment quality was well below ANZECC low trigger levels. The overall conclusion was that the existing treatment devices were adequate and that water quality and sediment effects were minor. On-going monitoring was recommended to check on future accumulation or changes.

2.4.2 BEST PRACTICABLE TREATMENT METHOD

Following technical assessment of the discharge consent application by the HBRC, concern was raised that the limited monitoring information, collected over one year, may not be representative of actual or potential effects, specifically for the land-side catchment. This lead to a revised pragmatic approach. Rather than proving or otherwise the effects on the environment were minor (or otherwise), by an extensive and expensive monitoring programme over several years, implementing best practicable treatment in accordance with HBRC guidelines was proposed. This meant that money could be invested in improving the discharge and site amenity rather than extensive environmental monitoring.

An assessment of the treatment options for the Airport site was completed in 2010. This considered the theoretical contaminant loads for the subcatchments based on the Auckland Regional Council contaminant load model. Treatment option improvements compared to a typical residential baseline developed for Hastings were made.

The outcome from this options assessment as agreed with the HBRC was for treatment upgrades and stormwater management that included bathymetric banded wetlands.

The use of bathymetric wetlands for the Airport site was confirmed as the preferred approach given the significant site constraints. These are covered in more detail in section 4 of this paper.

Designs for conversion of the existing constructed wetland treatment device and new separate bathymetric wetlands were prepared. These discharged into a common planted drain prior to discharge beyond the Airport site to the DOC natural wetland. Ultimately the final designs were modified as part of the Business Park development, with an associated variation to the discharge consent.

3 AIRPORT BUSINESS PARK DEVELOPMENT

In January 2012 MWH began assisting the Airport with designs for a new access road to the Business Park and associated stormwater drainage. This was subsequently widened to incorporate developing options and designs for the Business Park stormwater system.

Limited design work had been done historically for the Business Park, and when an anchor tenant was identified in January 2012, with a desire to be operational at the site in mid to late 2012, the design and consenting needed to be advanced rapidly.

This required a coordinated approach with a number of parties involved in the design and consenting aspects including the need for a major power supply upgrade to supply the Airport site.

A number of wider Business Park design elements, scenarios and servicing approached needed to be considered, with uncertainty on the type, scale and nature of the remaining development. These elements are noted in Section 4.

Figure 3 shows the layout of the Business Park, with the stage 1 area and future development extents highlighted.

4 DESIGN APPROACH

4.1 PROCESS

The design approach for the Airport Business Park stormwater development was unconventional and was influenced by the timing constraints, the nature of the available information, the assumptions that had to be made and how the scope of design grew during the project. In general a sequential staged approach as noted below was proposed. However some reiteration and reworking of designs was necessary and some design elements were completed in advance to suit wider Business Park development requirements.

Stage 1 - A concept assessment of the overall Business Park potential effects, including additional runoff rates, volumes and potential contaminants. As part of this a key element was to understand the objectives, site constraints and wider interfaces.

Stage 2 - Addressing uncertainties, through investigations and assessments where cost effective and practical.

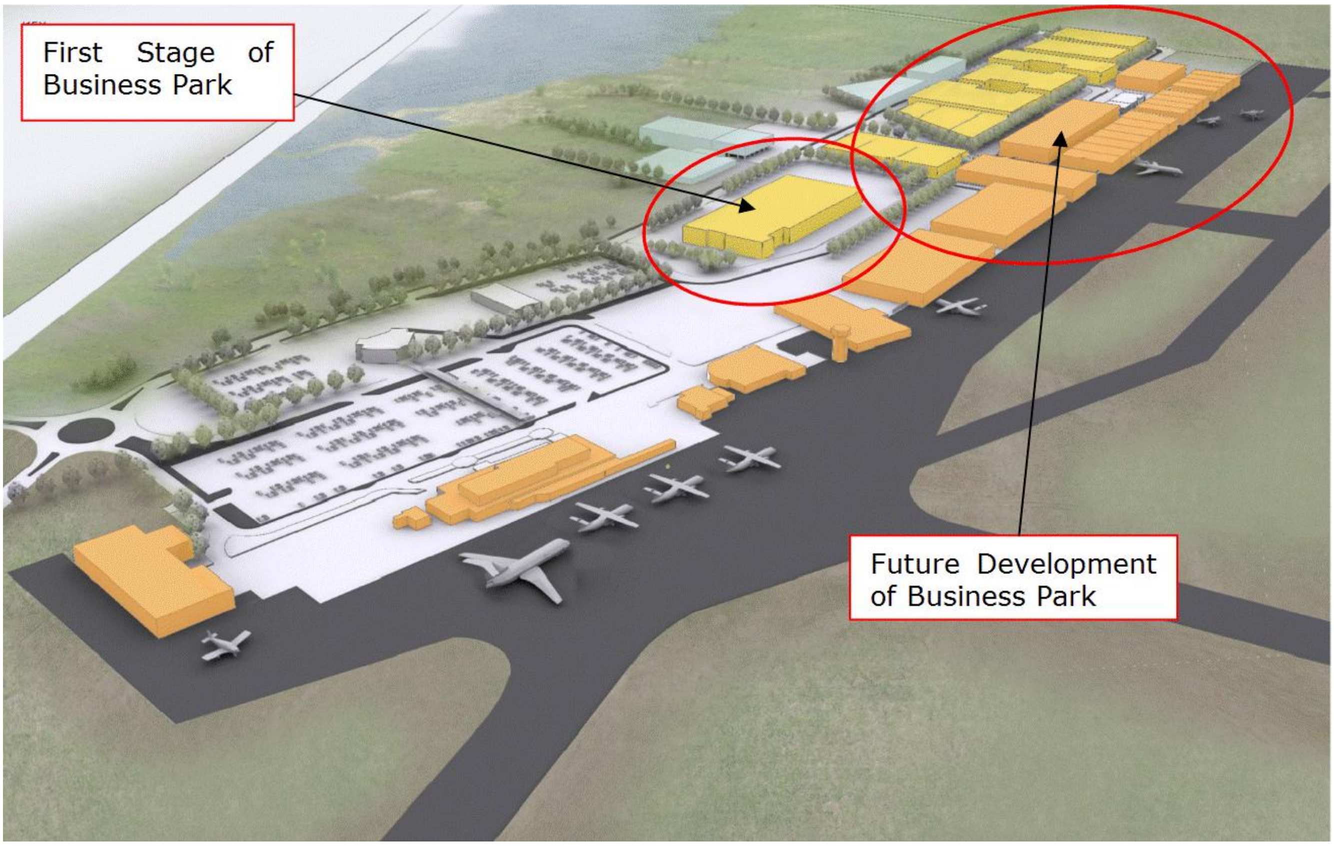

Figure 3: Business Park Development (figure prepared by Paris Magdalinos Architects)

Stage 3 – Preliminary design, resource consenting and building consents as necessary.

Stage 4 – Confirmation of Design assumptions and risks.

Stage 5 - Detailed design and construction, with some detailed design elements completed during construction.

Stage 6 – On-going operation and maintenance. Confirmation of the overall Business Park and stormwater infrastructure approach is on hold pending further Business Park development.

Some important lessons were learnt during this process and are noted in Section 7.

4.2 SITE CONSTRAINTS

The Airport site has a number of constraints due to the nature of the land that was uplifted by the Hawkes Bay 1931 earthquake and then subsequently drained for agricultural use.

The ground at the Airport is very flat, with natural drainage generally by soakage into the sandy gravels and or ponding. There are natural wetland areas that have ponded water all year round, with other low-lying areas ponding during periods of high monthly rainfall in winter when the groundwater level rises to above the ground.

The Airport is located close to Hawke Bay, with the eastern edge of the site 200m from the sea and subject to significant tidal fluctuations in groundwater levels. Further to the west this fluctuation is less pronounced.

There is no gravity drainage from the Airport site beyond the Ahuriri basin area. Drainage relies on ponding, soakage to groundwater that fluctuates with tides and season, and on pumped drainage systems that discharge to the Ahuriri Estuary.

The airside area of the Airport is drained to the pump station whilst the land-side relies on storage and soakage with the constructed wetlands at the site and the DOC natural wetland. The DOC natural wetland has no gravity drainage outlet. It acts as a basin or sink, relying on the connection to groundwater with balancing of water levels over time. Critical storm events for this system are long duration rain events lasting several days when the ground is already saturated, with elevated groundwater levels.

4.3 TIME PRESSURES

There were significant time pressures for the planning, design and construction works required for the Business Park, due to the initial tenant's desired date to be operational on the site. This created a number of issues, especially with the design and consenting interfaces, the nature of the stormwater system and the site constraints. A number of aspects were advanced based on best assumptions or limited scope of investigations to allow the design and project decisions to be made.

The risks of not meeting project outcomes with this approach were significant, and generally these risks were not understood by all parties. It also limited the ability to make informed and integrated decisions for some design elements as there was not time to consider constraints to the desired detail and consider the various options.

4.4 INTERFACES

The project had a number of interfaces including:

- DOC for adjacent natural wetland and stormwater discharge
- NZTA for adjacent state highway
- Roading/services for integrating the stormwater design
- Individual developments within the Business Park for integrating the stormwater design
- Napier City Council (NCC) for building and planning consents.
- Iwi
- Landcorp Farm for wider drainage considerations
- HBRC for stormwater consenting

Whilst there is no local authority stormwater system to discharge to and the roading within the Airport and Business Park is owned and operated by the Airport Authority, there was still an important interface with NCC due to the need for building consents for individual developments and the Airports internal roading and services development.

As always, close liaison and consultation with key stakeholders was important in the development of the design and to achieve low-impact outcomes.

A key aspect of this design liaison involved ensuring that the design of building foundations and below ground services allowed for saturated ground conditions due to shallow groundwater and use of soakage stormwater systems on each site.

4.5 KEY UNCERTAINTIES

4.5.1 GROUNDWATER AND NATURAL WETLAND POND WATER LEVELS

Understanding the groundwater levels and any changes in the short and long term is key for the design of stormwater and drainage facilities relying on infiltration to areas with shallow groundwater. Aspects to be considered in a coastal system like this are:

- Typical and extreme tidal fluctuations in groundwater levels
- Influence of storm surge
- Future sea level rise
- Wider catchment influences

Part of the Airport site, specifically along the runway and the surrounding Landcorp farm has extensive drainage channels connected to a pump station that artificially controls groundwater levels. However the majority of the site is less influenced by the drainage system with groundwater levels seasonal, affected by tidal sea levels and rainfall over the previous weeks or months.

The landside part of the Airport has constructed wetlands and drainage channels that have water in them all year round. These were expected to be representative of local groundwater levels in the surrounding ground. However during rain events the wetland, drains and formed ponding areas fill up above the general groundwater level due to the direct runoff from the Airport and surrounding development.

No groundwater level monitoring data at the site was available for designs. To refine the design assumptions groundwater level monitoring was installed for a short period at several locations, to check the catchments response to rain and tidal changes. Figure 4 provides a plot of data from this monitoring.

Rainfall occurred mainly in a 36 hour period between midday 19 March to late evening on the 20 March 2012. The loggers were installed at around 2pm on the 20 March 2012, after around 83mm rain had fallen in the previous 27 hours. An additional 22mm fell over the following 36 hours.

The response of the wetland pond water level to the rainfall event was minor with a maximum increase in level of only 40mm up to RL 10.43m. The wetland pond reached the maximum level around the time that the main rainfall ended in the early hours of 23 March 2012. Minimal tidal response was observed in the wetland pond level. It is therefore assumed there is limited direct connection of the pond to groundwater, with the base of the wetland pond sealed with fine material and isolated from tidal influences.

The groundwater response was greater with water levels elevated to RL10.65 or around 0.5m higher than the normal dry-weather tidally influenced range of 10.0 to 10.1m. These elevated levels dropped to near typical levels over a period of 3 days.

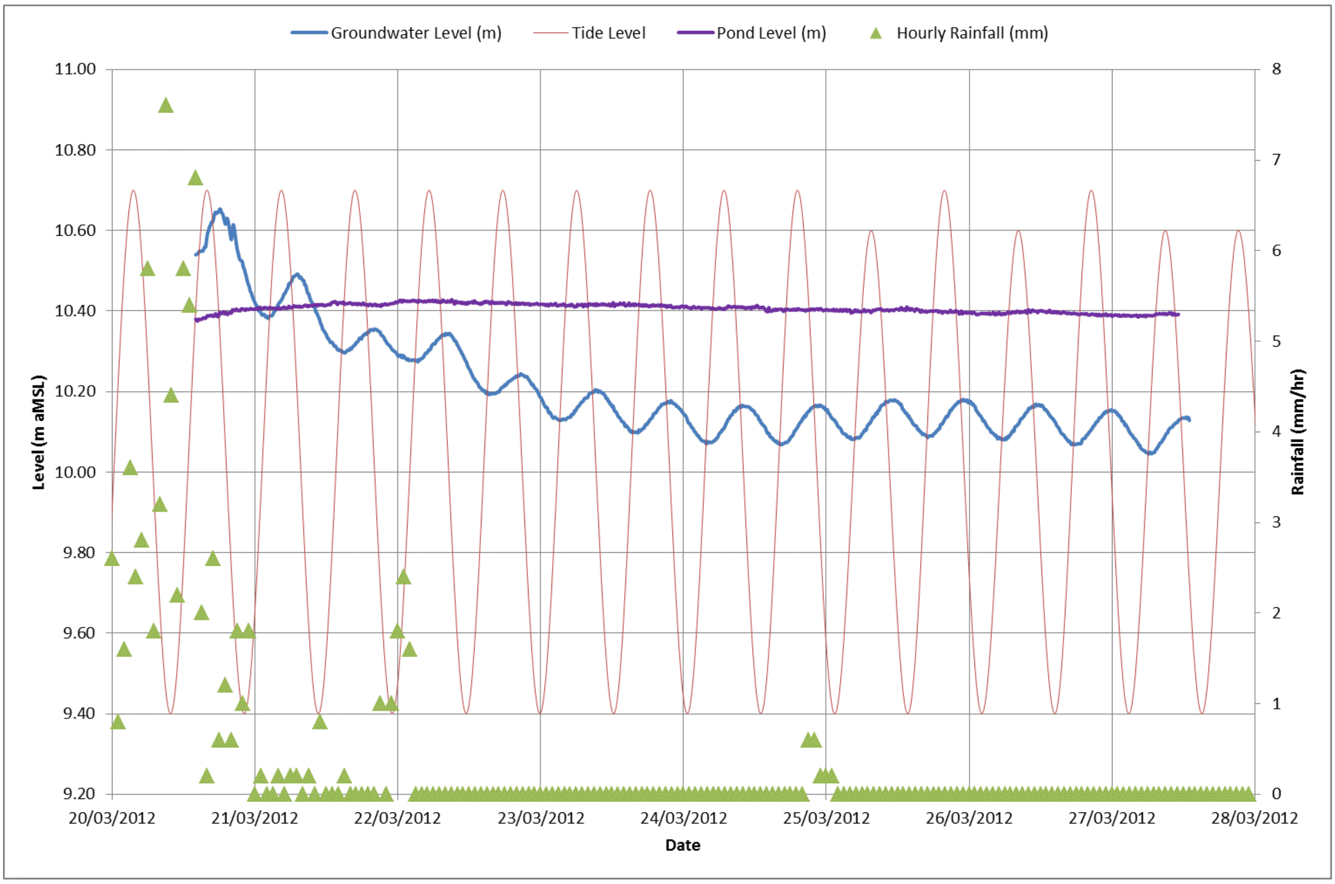

Figure 4: Groundwater Level Monitoring

The groundwater level response of around 500mm rise equates to around 5 times the 100mm of rainfall depth. This is greater than expected, with soil porosity of 25% to 30% would equate to around 3 to 4 times rainfall depth. This may be due to lower porosity or to the additional discharge of stormwater runoff to ground from the adjacent Airport buildings in the vicinity of where the monitoring point was installed.

Typical tidal groundwater response of 100mm variation to around 1.3m variation in sea level is less than 10%. This is a reasonable amount but indicates a significant amount of buffering in considering larger tide cycles (King Tides) that occur periodically. Storm surge is not considered to be an issue with the buffering and protection provided by the higher elevation land along Westshore between the Airport and the sea.

Future sea level rise is expected to have a direct and corresponding effect on groundwater levels at the site. Considering a 0.5m rise over the next 100 years the groundwater level would rise by 0.5m to an average level of RL 10.6m. The effect on the natural wetland pond level is expected to be less, with the normal natural wetland pond level expected to rise to a similar level to the surrounding groundwater.

4.5.2 INFILTRATION & SOAKAGE RATES

Geotechnical investigations within the Business Park site were carried out to better understand the soils and ground conditions. Existing soil and geological maps for the site indicate the site is underlain by generally silty to sandy gravels, from the historic estuarine environment. This was supported by the project specific geotechnical investigations and assessments. However the gravels are interbedded with dense thin silty sand and sandy silt layers with occasional clay layers.

The gravel layers themselves have high permeability and infiltration capacity but this would be limited in some areas of the site due to the thin layers of finer materials interbedded with them.

Soil infiltration rates and hydraulic conductivity for groundwater at the site remain an uncertainty for performance of the system, especially for later stages of the development that will require further investigation and assessment with adaptation in approach as necessary.

Based on the information available the designs progressed on the basis of generally very low infiltration and soakage rates, conservative ponding volumes, extents and critical storm durations.

4.5.3 WIDER AHURIRI BASIN PONDING

The Airport site is within the wider Ahuriri basin with no positive gravity outlet and relies on groundwater soakage and pumping systems to control groundwater and surface water levels in the open drains. A significant rainfall event in April 2011 caused widespread ponding as shown in Photograph 1 below. The ponding elevation within the Landcorp farm is around 0m above mean sea level (aMSL), compared to a ponding level of around 0.5m aMSL for the landside area, due to the different operating basis of the Landcorp drainage and pump system to the Airport pumping system.

The ponding areas within the landside and airside areas of the Airport are separate, with higher ground including Watchman Road preventing the ponding areas connecting. However if ponding levels were high enough then the ponding area for the wider basin or airside part of the Airport could join with the landside ponding areas forming one larger ponding area.

Photograph 1: Ahuriri Basin & Airport Ponding – 28 April 2011 (3 to 4pm)

A mass balance approach with conservative assumptions on parameters was used to determine if the wider Ahuriri Basin needed to be considered for the Airport Business Park development within the landside catchment. Reference to other designs, and design parameters used for drainage works within the wider basins area was made. The main design basis and assumptions included:

- Entire basin and upstream catchment area contributing with full runoff beyond infiltration rate allowed for.
- Infiltration rates of only 1/5 of those in other assessments (0.5mm/hr instead of 2.5mm/hr) to allow for uncertainty in groundwater flow rates.
- Ponding volumes calculated from LiDAR reduced by 20% to allow for inaccuracies in LiDAR
- Considering long duration rain events of up to 28 days
- Entire contributing catchment treated as a basin with no outlet and no pumped discharge in operation. This is a conservative worst case scenario assuming that a major power failure during a storm event prevents a pumped stormwater discharge from the whole basin for a significant period.

The calculated net volumes were modeled over the entire Ahuriri basin using 12D software to identify the potential extent and depth of flooding. From this modeling, and assumptions made, the critical storm duration was estimated at 7 days, with a net volume of just over 5.5 million cubic metres. Various base water levels within the Ahuriri basin were considered and confirmed that the landside area even in extreme events would be separate from the wider Ahuriri basin ponding extents.

4.5.4 SEPARATION FROM THE AHURIRI ESTUARY

The Ahuriri estuary, along the main outfall channel, has stop banking along the edge with the Ahuriri basin to provide separation. It also provides separation from the adjacent hill catchment that drains to the estuary. However there is uncertainty on the level of protection provided and the integrity of this stop bank. This uncertainty includes how much protection is provided from storm surge, climate change or future mean sea level rise.

4.6 CONFIRMING OBJECTIVES AND DESIGN STANDARDS

The key objectives identified and confirmed were:

- Low impact approach where economic
- Improve the stormwater system servicing existing landside development
- Improve site amenity and landscaping. Meet discharge consents requirements
- Comply with minimum standards
- Minimise costs
- Avoid filling, raising land significantly, with minimum development height.

These ultimately formed the basis for informing design decisions for the stormwater system.

Key national and local design standards and guidelines for the stormwater system were:

- Napier City Council Code of Practice for Subdivision and Land Development, April 2002 (NCC Code of Practice)
- Hawkes Bay Waterway Guidelines Stormwater Management, May 2009 (HBWG)NZ
- New Zealand Building Code E1 Surface Water
- NZ WERF On-Site Stormwater Guidelines

A 2% AEP design standard was selected for the secondary conveyance and ponding systems and preventing ponding within the Business Park access roads up to a 10% AEP standard in accordance with the NCC Code of Practice. A 400mm freeboard to minimum building floor levels was selected. NCC Code of Practice does not specify a freeboard height so was based on NZS4404:2010 of 300mm to underside of floor slab for industrial buildings, allowing for 100mm thick slab.

4.7 OPTIONS

The options for servicing the Business Park were limited by the constraints, objectives and design standards chosen. Initial implementation was on the basis of limited on-site treatment and storage facilities.

The stormwater conveyance options considered piped and open drain systems with provision of storage/soakage facilities to attenuate short duration high intensity events and reduce the size of conveyance required. Discharge was either to the landside system or connecting through to the airside pumped drainage system. Offset storage and/or pumping upgrades were required to mitigate the additional runoff volumes from the Business Park. Low impact measures were considered to minimise any volume increases and associated upgrades.

While there are a wide range of stormwater treatment devices and methods available, constructed wetlands for the Airport site were selected because of the following reasons:

- The restrictions imposed by the very flat slopes on use of devices which require significant driving head (i.e. artificial filter systems)
- Any devices considered should have a low start-up cost and minimal ongoing maintenance costs
- Availability of space on site
- Recognition that constructed wetlands provide one of the most robust treatment solutions available
- In keeping and adding to the site amenity once planting matured
- Shallow groundwater all year round allows for constructed wetland areas to remain wet all-year round, even with the relatively small stormwater catchments at the site.

Increased wetland area and risk of bird strike, or additional bird control measures at the site were not significant, given the large wetland and estuary areas around the site.

4.8 APPROACH CHOSEN

To avoid major earthworks and reduce costs the development elevation was limited to existing Airport development levels. This limited the hydraulic fall available for the stormwater system, requiring an integrated approach with larger open drains for primary stormwater conveyance, soakage and partial treatment prior to the use of banded bathymetric wetlands. Each component and transition was sized and shaped to minimise headloss at peak design flow.

Integration of the drains, landscaping and road levels was required to achieve the 10 year design standard for the road, with secondary flows along the roads and overflows from the main stormwater drain direct to the DOC natural wetland pond. Incorporation of on-site storage within the site car-parking for individual developments with an overflow for extreme events to the wider ponding area provided for long duration storm events. Pipework for drainage of individual sites is generally submerged, due to water levels in the main conveyance drains, relative to pipework.

The works have been staged with provision for later stages of the Business Park able to be accommodated either in the land-side stormwater conveyance and treatment system, or provision of separate systems to the DOC natural wetland or alternatively to the airside system and pumped to the Estuary. This allows flexibility in the layout and type of future development within the Business Park.

For areas beyond the initial Business Park stormwater system, a standard soakage design incorporating storage was developed for roof stormwater. This makes use of a shallow soakage trench, to be above groundwater level, located within a grass berm adjacent to buildings. The design allows for future connection to the wider stormwater system when developed.

Figure 5 below shows layout arrangements for the banded wetlands installed for the Business Park and existing Airport terminal, car-parking and associated buildings and facilities.

A number of aspects of the overall stormwater system have been deferred for future consideration and confirmation as the Business Park develops. At present (early 2014) less than 20% of the Business Park has been developed. These items include:

- Future development of the proposed Business Park and distributed discharge locations of the remaining stages of the Business Park to the DOC wetland and/or to the existing airside pumped drainage system.
- DOC wetland storage capacity taking into account sea level rise and its effect on groundwater levels and developing details for adaptive options.
- Limiting stormwater runoff by diverting roof stormwater runoff into underground or above ground soakage areas at each individual site.

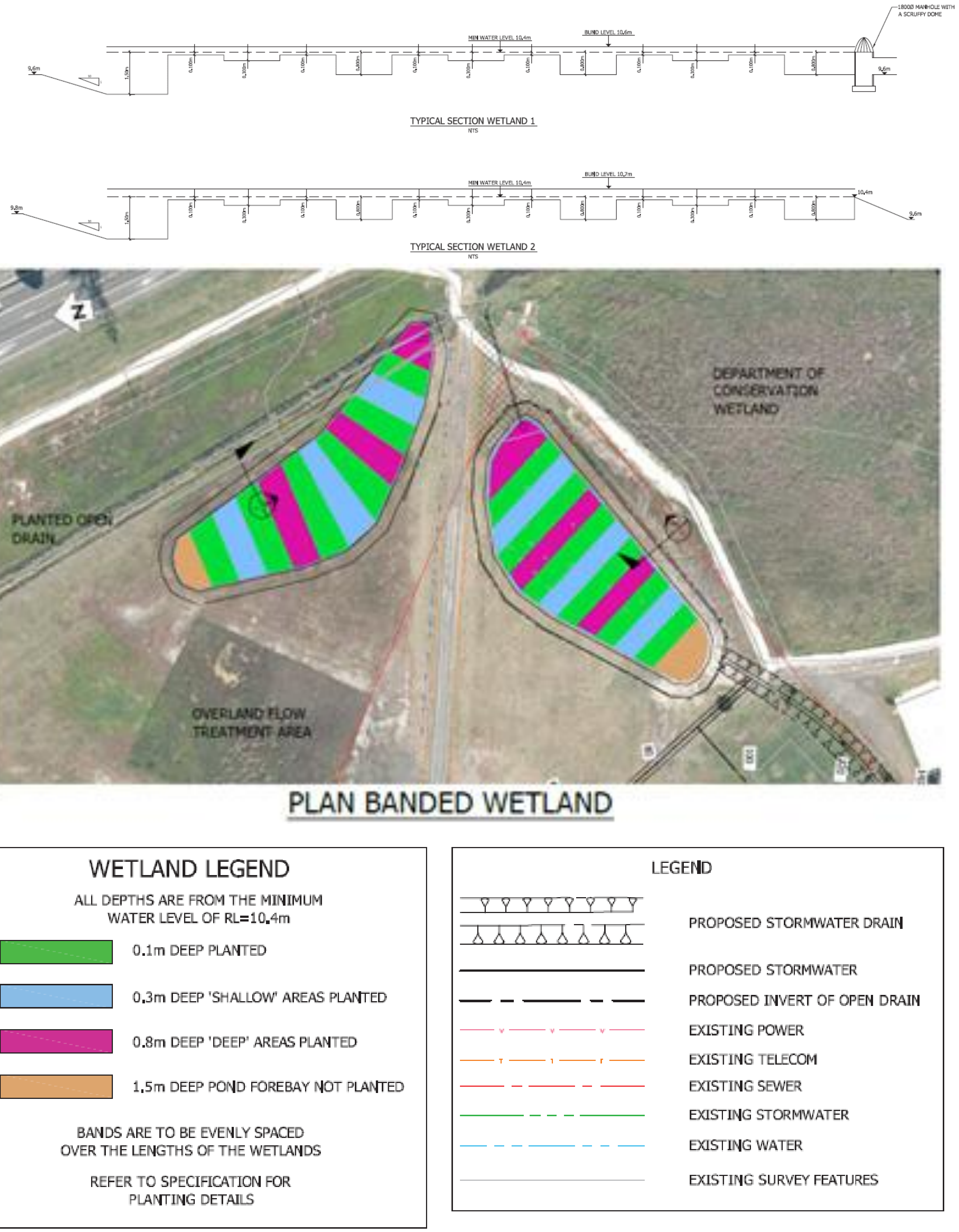

Figure 5: Banded Bathymetric Wetlands

5 CONSTRUCTION AND STAGING

The works were constructed as part of the wider Business Park access roads and water services infrastructure installed between September and December 2012. These included formation of the banded wetlands, main drainage channels and road culverts to allow for future development and extension of the Business Park.

The wetland and drainage channel construction required excavation of the existing ponding area and other parts of the site below groundwater level as shown in Photograph 3 below. The nature of the gravel soils at the site meant that dewatering would be difficult, but also unnecessary with excavation and shaping works able to be carried out in the wet. Fine material suspended with the excavations was able to be settled without discharge beyond the immediate working environment.

Photograph 3: Banded Wetland and Drainage Channel under Construction

The main construction issues related to staging of the Business Park with existing buildings and services that were planned to be demolished but not able to be at the time of the works, due to operational constraints. This required some workarounds in the construction, including temporary piping of open drains, or installing narrower channels for the initial works, with upgrade required during future stage construction. Other issues included encountering, by excavation, unmapped services within the site.

A key element of the design to achieve effective performance, is the establishment of planting within the wetlands and drainage channels. Planting within the wetland required temporary pumping to lower the groundwater level and also work was scheduled during lower tide periods. Planting was carried out in Spring of 2012. The subsequent 2012/13 summer was particularly dry, with drought conditions proving difficult for plants to establish, and most of the plants along the drains and perimeter of the wetlands died off. Also plants within the deeper bands of the wetland have not established well. Because of this planting establishment is continuing and expected to take several years to be effectively completed. Trialing of alternative species at the site within the deeper banded areas of the wetlands is proposed.

Photos 4 and 5 below show the completed banded wetland and conveyance drain following wet-weather in July 2013.

Photograph 4: Banded Wetland in Wet Weather (July 2013)

6 OUTCOMES AND REQUIREMENTS

Key outcomes, requirements and status of the Business Park:

- Low cost, limited hard infrastructure, improved amenity stormwater system with generally low environmental impacts. Actual performance of the treatment systems is unproven to date with wetlands and drain planting still to be effectively established.
- Stormwater conveyance requires flat grades, submerged pipes or open channels.
- The overall site relies on disposal to groundwater / wetlands that disperse stormwater by soakage or lateral drainage to the wider groundwater and coast/estuary.
- Sensitive receiving environment with stormwater treatment, site management and spill response critical to the effective operation of the system.

Photograph 5: Open Drain (Planting still to develop) in Wet Weather (July 2013)

- Wider Business Park development to have distributed discharge locations and/or a connection to airside stormwater system through overflow or pumped system for extreme rainfall events.
- Current stormwater consent is limited to only small part of proposed Business Park with any further significant development requiring a new or revised consent.
- Inert roofing materials have been required for all buildings within the Business Park (i.e. ColourSteel, ColourCote) or alternative roof material or coating that will avoid release of metal contaminants with runoff.
- Roof water to be discharged directly to ground soakage with a component of storage to allow for peak high intensity rainfall, and overflow to the wider stormwater system for extreme events.
- The preferred primary treatment method for yard and car parking areas is through planted banded wetlands for both on individual tenant's sites and for the wider communal treatment system.
- Certain industry and commercial activities will be high risk sites (from a contaminant generating perspective) and require a site specific stormwater management plan.
- Hazardous substances and non-inert materials require specific storage arrangements with covered storage areas and drains to sewer, not stormwater.
- A spill response plan and methods is required for each site.

7 CONCLUSIONS

A number of lessons learnt and key conclusions from the project are noted below.

- It is important to know, from available information or specific investigation the wider site context, constraints and interfaces for effective low impact stormwater outcomes as an individual site generally can't be assessed in isolation.

- Proving the performance or nature of a particular site compared to installing the most practicable treatment or management option needs to be considered. Especially when the uncertainties in monitoring outcomes and the cost of the monitoring are considered.

- Investigations to prove or have a high certainty in design parameters may have a high cost when limited existing investigation information is available. Engineering judgement on assumptions or appropriate conservative parameters is needed when cost and time limitations are considered for the desired outcomes.

- Developing design solutions in parallel to strategic planning has a much higher risk. This is not always easy to address with private development when there is not a desire to advance expenditure prior to committing to implementing works. This leads to a more reactive design process with changes needed. Especially when non-standard designs are required.

- Client management of risks, risk tolerance and understanding of risks is important for long-term outcomes to be achieved. Often clients do not understand the nature of the risks. Some elements may be deferred to be resolved later, but could be forgotten and lead to failures at a later date.

- Establishing planting within a site, especially with shallow groundwater and rapidly draining gravels is difficult and careful selection of species, installation methods and monitoring during establishment are critical. The difficulty of this was underestimated for this project, and means overall outcomes have not been achieved to date. Establishing plants is expected to continue for several years. Photo 6 shows the limited wetland plant establishment as at February 2014.

- Getting buy-in to action pro-actively and in a planned manner the operation and maintenance of new assets, especially if of a different types to that currently maintained on an existing site is important and can take time. This may include works procured on term contract or adding to existing site operation and maintenance work. Generally this aspect is more important for low impact type of solutions with greater maintenance need compared to hard engineered solutions where limited maintenance is required.

Photograph 6: Business Park and Banded Wetland (February 2014)

ACKNOWLEDGEMENTS

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