# WHEN WATER RUNS UPHILL – A FLOOD CONTROL SCHEME THROUGH GROUNDWATER MANAGEMENT

***A Tonks***
***Cook Costello, 2 Norfolk Street, Whangarei 0110***

## ABSTRACT

Positioned next to Maungatapere Township in Northland, the residential subdivision Te Mara Estate has been developed with construction undertaken through the 2015/16 summer. The sites location within a basin with no defined outlet has seen the area frequently inundated following prolonged wet periods. Drainage to the neighbouring catchment was identified as the most feasible long term solution. The requirement for minimised total lifecycle cost, constraints such as covenanted bush areas, and the sites inherent soil and topographic attributes, culminated in a groundwater management scheme involving rain gardens and subsoil drainage, a 400m Ø200 syphon line primed by vacuum pump, and control system by PLC with remote groundwater monitoring stations. The design objectives and considerations, along with scheme construction, testing and operation are discussed.

### KEYWORDS

**Flood control, groundwater management, syphon, land development, allophanic volcanic soil**

### PRESENTER PROFILE

Adrian is a Civil & Environmental Engineer with a passion for all things water. In addition he manages an ITC department delivering Software as a Service products.

## SITE OVERVIEW

Te Mara Estate is an avocado orchard ten minutes' drive west of Whangarei, located in the township of Maungatapere. The 5.4ha property backs onto a primary school, in a countryside setting which has gentle topography making it an obvious candidate for residential development, were it not for the flooding. This paper discusses how the sites attributes were used to develop a hydrologically appropriate and cost feasible solution to address this hazard, along with the design process and construction experience.


*Figure 1: 2002 aerial image showing ponded surface water. A recent satellite image taken during construction*

The site resides within a larger 42ha basin catchment formed by a gently undulating basalt plane. The neighbouring property to the south of the site is the lowest point within the basin and is frequently inundated by standing water during winter months, with inundation extending into the Te Mara property periodically each year.

The property has residual volcanic soil which has excellent permeability due to its allophonic structure, with in-situ tests around 110mm/hr being a typical result in this soil type. However, the soil veneer is thin and while the weathered depth is variable the underlying low permeability rock is generally 1.5 – 2.5m below ground surface and floating boulders are common place.

With the exception of the eastern boundary adjoining State Highway 14 (SH14), the site is land locked from neighbouring catchments by surrounding properties. Lying between the developable area and SH14 is an existing QEII bush reserve. The ground elevation here is approximately 1m higher than the rest of the site forming a saddle separating the basin from the SH14/Maungatapere catchment to the north. Adjacent to the saddle, SH14 falls to the north with a ground elevation 7m lower than the site 220m to the north at the scheme outlet. The discharge location was chosen both for its elevation relative to the site and its position downstream of existing constrained reticulation infrastructure.

## CONCEPT DEVELOPMENT

While improving infiltration through the basalt rock was considered, the uncertainty of this approach along with the investigation cost and long term function precluded this as a feasible option. Another design concept inherited from the earlier plan change process sought to address the flood hazard by constructing a pond next to the QEII reserve and installing an outlet pipe by directional drilling. However, due to the prevalent rock at ground surface throughout the QEII reserve and the Trusts objection to drilling beneath or open trenching in this area, this concept also proved not viable. Additionally the pond would have removed two lots from the development and the ponding elevation would require the onsite effluent fields to be raised to achieve winter groundwater separation. From these constraints an early design concept evolved to use the soil void volume as storage in place of the pond and to pump to the SH14 catchment with a surface laid pipe through the bush reserve. With the relative ground elevations and limited lift height; if the stormwater rising main could be primed a syphon would be established and could potentially be used to reduce the pumping cost.

## HYDROLOGICAL ASSESSMENT

The ponded surface water is caused by groundwater daylighting at lower elevations within the basin, with ponding depths strongly influenced by the antecedent conditions. Severe ponding and flood waters entering the site occur with the coincidence of adverse groundwater conditions and extreme weather events.

Determining design event reoccurrence intervals, and from these the volume of water that the scheme would need to shift, was a problem that did not fit well with traditional runoff methods. Approaches such the modified SCS method from ARC TP108 with a NRCS TR-55 Type 1A rainfall distribution, as per Whangarei District Council 2010 EES, were trialed however these produced unrealistic ponding volumes that were greatly overstated in comparison to historic events. This was due to importance of antecedent events and the effect of these on infiltration losses to ground. Eyewitness accounts of the June 2007 ponding event provided a reliable flood level and corresponded to a surface ponded volume of 9000m³. The June 2007 cyclone was preceded by an earlier cyclone in March 2007, an event that caused widespread damage throughout Northland although resulted in only minor ponding within the basin catchment. The Maungatapere daily rainfall records frequently recorded wet weather between March and June 2007, particularly leading up to June, and from inspection of these records along with residents accounts that ponding event was estimated by judgement at 10 year ARI. With no formal method to extrapolate this ponding reoccurrence interval to a 100 year plus climate change event a similar scaling as can be observed in the HIRDS rainfall depths was applied giving a ponding volume of 19,700m³.

With severe ponding associated with prolonged elevated groundwater and multi-day cyclonic weather events the maximum pumping was estimated at the 100yr ARI ponded volume pumped over four days, being 5000m³/day, or 57l/s. While these estimates are rough at best, during the process of developing the minimum floor levels further surveying fieldwork identified an alternate flow path to the north west of the site. While standing water surrounding dwellings would be unacceptable, the maximum possible flood height was determined independent of the ponding event probability from runoff for the TP108 method described above with the 100yr ARI plus climate change rainfall for the catchment applied the secondary flow path. A s106 process was completed to reduce the minimum freeboard requirement to 150mm above this height.

# INFRASTRUCTURE DESIGN

Conveyance of stormwater from the right of ways and individual lots was achieved in a 2 - 2.5m wide 700m long rain garden running through the subdivision. The rain garden discharges over a weir at the southern boundary in the location of an existing surface drain. The rain garden surface is 700mm below the sites average ground level and set 200mm below the downstream drain invert level, providing a treatment volume.

*Figure 2: Rain garden during construction showing subsoil, drainage aggregate, and blinding. Percolation testing of rain garden material build up.*

The alignment of the rain garden was determined to achieve the effluent field 15m horizontal setbacks and to pass through the lowest elevations across the site. The site topsoil was reused for the 0.5m deep rain garden media. These volcanic derived soils are relatively common in Northland with horticultural centers such as Maungatapere, Glenbervie and Kerikeri all sharing this soil type. Percolation testing of the rain garden build up including subsoil drainage aggregate, sand blinding and garden media were undertaken to measure hydraulic conductivity, TSS and settlement. Tests are run for 24 hours with intermediate measurements taken. Soil settlement of 15-18% determined from the percolation tests was managed during construction by installing the subsoil pipe, aggregate and blinding, followed by soil, as the trenching proceeded to allow time for consolidation before trimming to finished level prior to mulching and planting at the end of the program. Suspended solids within the discharged water are low with results <1 mg/l. The hydraulic conductivity is marginally higher than the in-situ percolation results with the two tubes testing 160 and 193mm/hr. The difference was due to the sand blinding with PAP7 substituted for the specified blinding grade, necessitated by procurement difficulty, producing the lower rate. These soils are frequently used in rain gardens within Northland and provide a lower cost alternative to engineered media in areas that they can be locally sourced.

Installed beneath the rain garden 2.4m below the average ground elevation, is a subsoil drain with the trench backfilled with washed grade 6 aggregate overlaid with a sand blinding layer. The result is a surface and groundwater management system within the same footprint, which from a construction perspective was efficient as the benching for the subsoil trench created the rain garden profile in the same operation. Maintenance lamp holes to the subsoil drain were formed with the lot connections for roof water runoff only, with runoff from paved areas discharging to the rain garden surface. The wet well is also located at the southern boundary with the 2 x Ø200 slotted subsoil drain pipe sized to convey the design pumping rate to this structure under the limited head available.

The site overlies a mapped aquifer and with the scheme ultimately discharging to surface water, the objective was to manage only problematic elevated groundwater with the natural infiltration within the basin the primary means of disposal. With stormwater concentrated in the rain garden and subsoil system, this objective was achieved by controlling the pump from the water level in two remote monitoring wells, rather than by the water level in the wet well itself. In addition to resolving the flooding issue the scheme is also required to maintain the effluent field 600mm minimum vertical separation to ground water. The remote monitoring wells are located between the effluent fields and the rain garden with the pump on level set at 0.9m below the average ground level with the draw down curve extending to the disposal fields to achieve the minimum vertical separation.

The rising main from wet well to outlet is 400m long, with a maximum lift of 4.3m and an elevation difference between the inlet and lower outlet of 4.7m. The rising main was sized to minimise the pump capital and running cost with Ø200 being the selected size. Despite the early intentions to create a syphon by priming the line with the pump flow it was not possible to achieve sufficient velocity to purge the line without reducing the rising main diameter and incurring a marked increase in pump cost. The wet well pump also had the cost implication of reticulating 3-Phase power to the final stage of the development, well ahead of when it would be required for that part of the subdivision. Alternate pumping options were investigated and instead of situating a pump within the wet well the constructed design uses a vacuum pump situated at the rising main apex, a location 5m within the boundary with SH14.

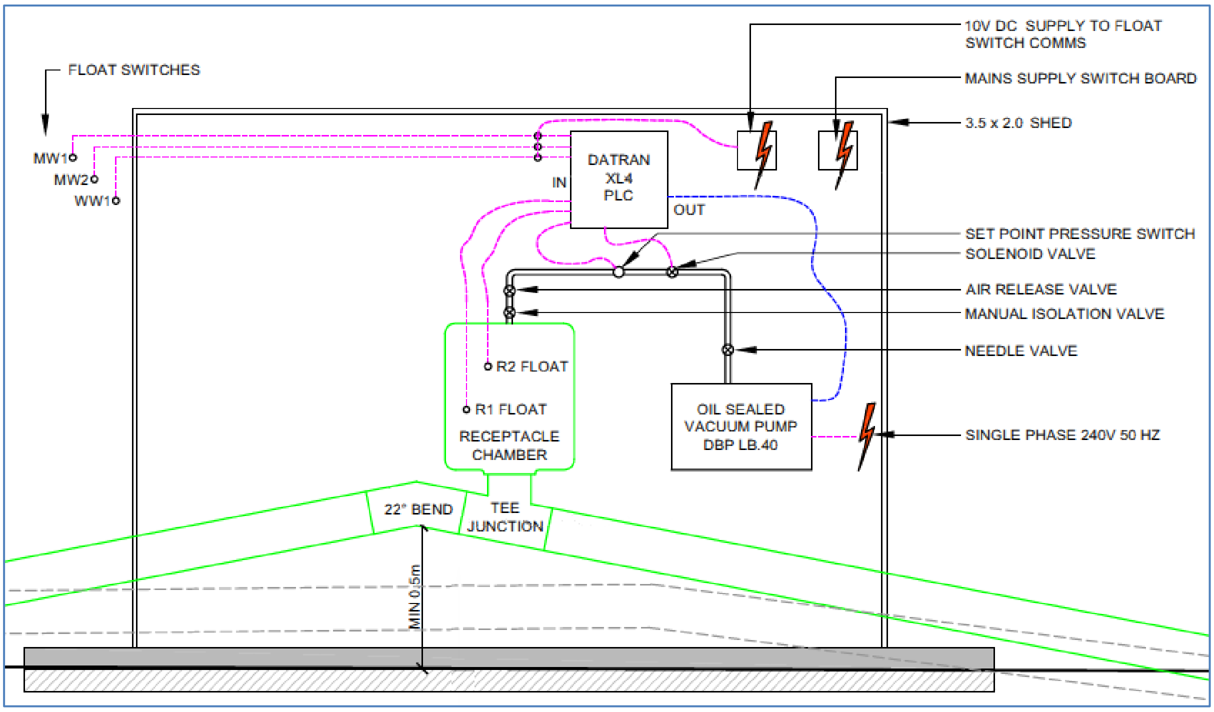

*Figure 3: Vacuum pump station schematic.*

The vacuum pump purges air from the line drawing water up from the wet well. The outlet is closed during the early stages of the priming with a submerged non-return valve located in the outlet manhole. The standing water in the outlet manhole assists in sealing the non-return valve and prevents air entering the line and breaking the syphon during its operation. Above the standing water level a vertical slot in the outlet manhole discharges to the roadside table drain and during operation serves as a means to gauge the discharge flow rate.

The inlet wet well invert is a meter deeper than the subsoil drain and 3.4m below the average ground level. Depending on the wet well water level the syphon discharge flow rate ranges from 39 – 55l/s. The design flow rate for the extreme event flood protection far exceeds the inflow required for the groundwater draw down. In normal circumstances and without regulation the syphon would cycle through priming, sudden evacuation of the subsoil drainage, and syphon breaking within a minimal period, limiting the peripheral groundwater response. This issue is resolved by a float operated sluice gate on the rising main inlet within the wet well, with discharge reduced by the gate as the water level falls below the subsoil drain invert.

Theoretically were the syphon system perfectly sealed it would only require priming once and thereafter the majority of water entering the subsoil system would discharge via the scheme rather than infiltrating to ground. However the design objective is utilise the scheme only for the discharge of excess groundwater, with infiltration to ground the preferred means of drainage to maintain the natural hydrological cycle. While it is unlikely for the system to remain primed over prolonged idle periods a small orifice in the sluice gate ensures the syphon is broken outside of the groundwater management periods.

The vacuum pumps on/off is coordinated by a PLC with GPRS for alarm text messaging. Due to the pump sheds location within heavy bush, communication by telemetry could not be used and the monitoring and wet well float switches are wired directly to a relay at the PLC. A 60l chamber is located at the apex with high and low water level float switches providing a buffer to maintain the syphon and a means to evacuate air should it find its way in during operation. The single phase 1kW vacuum pump displaces 11l/s and the time to fully prime the line is 40 minutes, with partially primed flow commencing after 30 minutes from the point that the water column head downstream of the apex exceeds the lift height. In event of the high water level float switch failing an Air Release Valve provides a line of defence to prevent water reaching the pump and a pressure switch detects this event, which via the PLC shuts the pump off. The long term operation of the vacuum pump is compromised if moisture accumulates in the oil seal. While the pump is capable of purging moisture during operation a warm up and warm down phase gives the pump a period to do this with air drawn from a needle valve with the pump isolated from the chamber by the normally closed solenoid valve. The needle valve also provides a means to break the vacuum and reopen the Air Release Valve prior to retrying the run logic. A data logger, manual run switch, isolation valve for maintenance and commissioning, fault lights and float switch status lights complete the system. Independent of the system is three water level divers located in the monitoring and wet wells.

SMS alarm messages are sent for a range of scenarios including unexpected pump stop during run phase, elevated groundwater but insufficient water in wet well to prime the line, excessive pump run duration or cycling, unexpected float sensing within the receptacle chamber, and unexpected mains power outage. The system messages and retries up to five times. On successful run after fault or restoration of mains power a message is also sent. With alarm messaging and the logic to detect abnormal operation, the system has been designed to run on failure of the float switch with the high water level indicated by an open circuit. The systems redundancy is primarily provided by the soil void volume above the managed water level and ground surface, and the control logic can be bypassed by the manual override in the event emergency pumping is required.

Long periods without use present a risk to the scheme and are managed by the system being running manually monthly by a residence association member. In event of a fault during normal operation the fault and float switch status lights assist in diagnosing whether the problem can be resolved by the first responders or whether further technical assistance is required. The logging of system state and run, as well as the water level diver data, are downloaded to laptop for in depth analysis in the event this is required and is also done annually as part of the system operation review.

# CONCLUSIONS

The soils and topography were two of the sites attribute that enabled a resilient low operating cost solution to the flood hazard. By using the reticulation element and the soils void volume to store and buffer stormwater in place of a pond the hydrological cycle was less affected by the development by prioritizing infiltration to ground and the subdivision lot yield was 10% higher. The technical aspects of the scheme construction were coordinated with the pump supplier, a plumber / fitter turner, electronics contractor and PLC programmer. While seemingly complex as a whole the individual aspects were simple within each of the specialist disciplines and working with a group with relevant experience in their own fields was a key factor in the delivery.