Packed Bed Reactor (PBR) Plant Case Studies

Shoal Beach Subdivision – Aramoana, Hawke's Bay

Shoal Beach is a picturesque beach in the central Hawke's Bay, near Te Angiangi Marine Reserve.

The developers of the Shoal Beach Subdivision had a clear goal of what they wanted their development to achieve; they wanted to ensure that their development did not compromise the coastal environment. This was a success, with the development winning the **Hawke's Bay Environmental Awards** business category in 2004.

The focus of the project was very much on the environment and sustainability, and design of the wastewater treatment system mirrored this philosophy.

Figure 1. Shoal Beach, Aramoana – subdivision area.

In order to minimise adverse effects on the surrounding environment and coastal area, wastewater needed to be treated to a very high standard. It was important that the quality of effluent was not compromised in times of low, average or high flows. The view was also taken that as much as possible should be done to utilise the treated wastewater as a resource.

Innoflow Technologies NZ Ltd. (ITNZL) was able to produce a wastewater management solution that met with the developers high expectations, the council's strict requirements and the potential buyers environmental, economic, aesthetic and practical demands.

The wastewater from each household is stored in individual on-lot interceptor tanks fitted with Biotube® Effluent filters. This screened effluent is then delivered by gravity to a Recirculating Textile Packed Bed Reactor (rtPBR) treatment plant discharging to a planted area utilising dripline irrigation. An automatically controlled chlorine dosing disinfection system provided high quality recycled water back to each individual household for controlled reuse.

The following pages detail the system components and technical specifications. Also shown are the expected performance figures for this wastewater management system.

Table 1. Design Constraints

Constraint	Solution	Comment
Minimise visual impact of treatment and disposal system	Planting around treatment plant provides cover – dripline irrigation buried subsurface has no visual impact	The irrigation network has ensured good plant growth even in the dry summer months
Site close to Ocean and Marine Reserve	Ensure high level of treatment to mitigate possible contamination	
Limited water supply available	Install a recycle system to allow reuse of disinfected treated effluent for toilet flushing and irrigation Use a sectorised land treatment area, able to redirect water to dry areas for summer irrigation	Also further reduces environmental impacts
Seasonal Use	Use rtPBR process designed for very low loading and peak loading	The rtPBR process has a 100% turn-down ratio providing consistent performance under fluctuating loads
Remote location, limited onsite technical assistance	Use control system with telemetry and remote monitor/ management of plant operation	Allows immediate remote troubleshooting and control. This removes the need for an onsite technician

Figure 2. Photo showing the rtPBR treatment system bed.

Table 2. Treatment System Performance

Parameter	Required Value*	Expected Performance
BOD_5	15 mg/ltr	<10 mg/ltr
Suspended Solids	15 mg/ltr	<10 mg/ltr
Discharge Areal Loading	7 ltr/m^2/day maximum	4 ltr/m^2/day
Recycle Chlorine Residual	> 0.5 ppm	0.5 – 1 ppm

- *These figures are the set values in the resource consent for this project issued by the Hawke's Bay Regional Council*

The land application area has been split into a number of sectors. Recognising the valuable resource represented, the drip irrigation can be switched from one sector to another, providing excellent summer irrigation, even in times of drought.

Figure 3. Garden Irrigation

Figure 4. Control panel

The entire treatment system is controlled using an RTU remote/ monitor/ manage control panel. All pumps, controllers and meters are connected and controlled from this panel. This set up provides extra safety in the management of the system.

The new technology available has enabled more compact, high performance equipment to be used in this project. Furthermore, there are considerable cost savings in the on going maintenance of the treatment plant.

Table 3. System Summary

System Component	Specification	Comment
Design Flow	60 m^3/day	48 m^3 discharge to ground – 12 m^3 recycled
Collection System	Septic Tank Effluent Gravity (STEG) onsite tanks feeding to effluent sewer	
Recirculation Tank Size	58 m^3	All underground
Recirculation Pump	4 x Multi-stage turbine (4")	At peak – 4.58 hours run time per day @ 0.750 kW per pump
Packed Bed Reactor Area	48 m^2	This process ensures NO odour production from the treatment plant
Treated Effluent Tank Size	58 m^3	All underground
Discharge Pump	1 x Multi-stage turbine (4")	At peak – 4 hours run time per day @ 0.75 kW per pump
Disinfection System	Continuous chlorine measurement and automatic control using the latest PID capable Dulcometer chlorine management system	Mixing and storage tank installed under control room shed. Controller connected to telemetry system
Land Treatment Area	14,000 m^2	Pressure compensating dripline irrigation to planted area

The focus on sustainability meant that design had to be tailormade to reduce environmental impacts as much as possible. With the use of interceptor tanks and effluent filters flowing to a *ProSTEP*™ reticulation system, all the houses were able to gravity feed to the treatment plant, even though the site was nearly completely flat. This reduced electricity requirements by a significant amount and reduced the environmental impact.

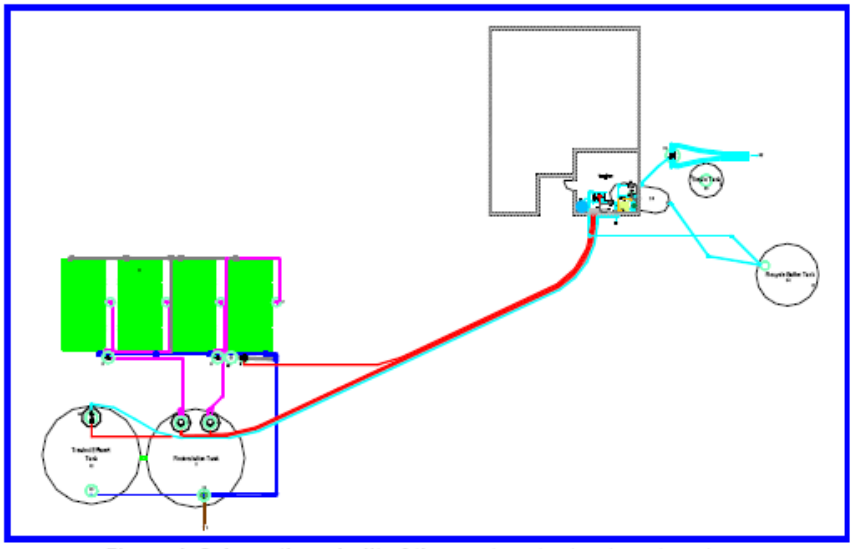

Figure 4. Schematic as built of the wastewater treatment system.

Jacks Point, Queenstown

Jack's Point is a 420ha resort-style development located 8km from the South Island town of Frankton, near Queenstown. The property sits between The Remarkables Mountain Range and Lake Wakatipu, and will ultimately be developed into ~5,000 lots. The development will comprise several medium density housing neighbourhoods, a village containing high-density apartment living, a number of large acreage lots and a golf course, all with a 95% open-space requirement. The water supply for Jack's Point is sourced from the adjacent lake and although the Queenstown municipal wastewater treatment plant is located nearby, capacity and cost issues dictated that a decentralised wastewater management system be specified.

Figure 1. The site at Jacks Point, Queenstown

The focus of the project was very much on the environment and sustainability, and design of the wastewater treatment system mirrored this philosophy.

Process Selection

Rather than provide approval for a particular wastewater technology or process, the Otago Regional Council (the licensing authority for the region) instead took an effects-based approach to the discharge consenting process. A requirement for post-development nutrient leaching from the entire development of significantly less than pre-development was specified, and was used in the wastewater selection process.

A resource consent for 844,000 litres per day, from seven different treatment and land dispersal sites, was granted, specifying the following:

- Collection of wastewater via a STEP/STEG Effluent Sewer, comprising on-lot *interceptor tanks* (pumped and gravity primary treatment tanks, fitted with effluent filters) and a watertight, small diameter pipe network.
- Treatment of wastewater via a Recirculating Packed Bed Reactor wastewater treatment plant
- Land dispersal of treated effluent via subsoil pressure compensating drip irrigation, to a maximum loading rate of 12mm per day

Tenders were called for the detailed design, supply, delivery, installation and on-going maintenance (for a minimum period of 5 years) for the first 2 neighbourhoods in the development. Innoflow were awarded the contracts, offering an Orenco® small diameter effluent sewer for the wastewater collection, and an Orenco AdvanTex® Textile Packed bed Reactor for the treatment system.

Figure 2. On lot STEP tank

Design Detail

Peak Wastewater Flow (N1 & N5)	268,000 litres per day
Wastewater Collection Process	An Orenco Effluent Sewer, comprising on-lot primary treatment tanks and a small diameter collection network
Wastewater Treatment Process	An Orenco AdvanTex® Textile Packed Bed Reactor
Reuse Method(s)	Subsoil pressure compensating drip irrigation @ 12mm per day
Design Effluent Quality	BOD_5 - <10 mg/l TSS - <10 mg/l TN <20 mg/l
Capital Costs	$8,000 per lot (STEP collection) $6,000 per lot (treatment and dispersal)
Operation and Maintenance Costs	$150,000 over 5 years

Figure 3. Treatment System

Key Performance Factors

The system, which utilises Orenco's AdvanTex® Textile Packed Bed Reactor technology, has been designed to achieve an effluent quality of better than 10:10:20 for Biological Oxygen Demand, Total Suspended Solids and Total Nitrogen respectively, and has been able to achieve post-development Total N leached value of 75% of the calculated pre-development value. This has been adopted as the resource consent condition for Total Nitrogen.

Aesthetics and visual impact are key factors at Jack's Point, given the development's setting. The low-profile, below-ground Orenco® wastewater treatment plant, with only green lids visible at ground level, well exceeded the expectations of the developers and other parties involved. The treatment plant for Neighbourhood Five is situated in a field adjacent to the main highway, yet cannot be seen from the road. The system requires only quarterly maintenance visits for the main treatment plant, and annual visits for the on-lot interceptor tanks. The treatment plant for the first two neighbourhoods has been supplied and installed for less than $6,000 per lot.

The process and design outcomes at the Jack's Point development demonstrate that properly designed and specified decentralised wastewater management systems can be successfully implemented for small to medium communities, with better environmental outcomes than other uses for the site. DWM systems need not be obtrusive on the surrounds, and in fact can enhance the environment by providing consistent, high-quality effluent for local reuse such as irrigation.

Waipatiki Beach – MoH Sewer Subsidy Scheme

Waipatiki Beach is a small, seaside community on the east coast of New Zealand's North Island. Prior to the development of the new subdivision, the community comprised 42 existing holiday homes, as well as a small camping ground. The new subdivision has added another 30 lots to the community. Waipatiki Beach has a permanent population of only 1 person, but during the summer the population swells. The settlement has been hampered by septic tank and on-site drain field failure for many years. With the possibility of another 30, poorly-designed and operated on-site systems from the new the development, the Hastings District Council decided to implement a wastewater scheme, combining the existing and new residences. The collection system and treatment plant was partially funded under the MoH Sewer Subsidy Scheme.

Figure 1. – AdvanTex® Treatment System and Control Shed

Using the set criteria Innoflow Technologies NZ Ltd (ITNZL) produced a wastewater management solution that met with the developers and the Hastings District Council's high expectations and strict requirements and the potential buyers economic aesthetic and practical demands.

The land application area was placed in an existing managed pine forest, creating a low visual impact, no odours and enhanced growth of the trees which will be harvested in future years and used for making wood products.

Process Selection

The Hastings District Council, in conjunction with the developer of the new site, decided to undertake an options assessment and run tenders for the wastewater services before a resource consent was sought for the discharge. The assessment was completed and based on the council's past knowledge a Design & Construct specification was prepared calling for a traditional approach; a conventional gravity sewer and pump station to an aerated lagoon to be located 2.2km from the settlement.

The D&C tender allowed for non-conforming bids, and Innoflow offered an Orenco® effluent sewer collection system and AdvanTex® textile packed bed reactor. The project was awarded to Innoflow, principally on a capital and operational cost basis.

Figure 2. – The Orenco® Effluent Sewer was laid in the road reserve

Design Detail

Peak Wastewater Flow	76,000 litres per day
Wastewater Collection Process	An Orenco® Effluent Sewer, comprising on-lot primary treatment tanks and a small diameter effluent sewer
Wastewater Treatment Process	An Orenco AdvanTex® Textile Packed Bed Reactor
Reuse Method(s)	Subsoil pressure compensating drip irrigation @ 5mm per day
Design Effluent Quality	BOD_5 - <10 mg/l TSS - <10 mg/l TN <20 mg/l
Capital Costs	$725,000.00 for the full collection, treatment and reuse scheme
Operation and Maintenance Costs	$68,000 over 5 years

Key Performance Factors

The effluent sewer collection system and AdvanTex® Textile Packed Reactor treatment plant was supplied and installed at Waipatiki for 76 equivalent lots, and for a capital cost of $725,000, some $300,000 less than the nearest conventional bid. The solution provides 10:10 (BOD:TSS) effluent for local irrigation of a nearby young pine forest, rather than taking the wastewater more than 2 kilometres way for treatment.

The treatment system is maintained on a 3-monthly basis, with the on-lot STEP tanks inspected annually. The overall footprint of the packed bed reactor is less than 80m^2, and the low-profile finish of the entire system has little visual impact on the site. The watertight 50mm diameter effluent sewer has meant the treatment plant has only been sized for peak dry weather flows from the homes, and not for wet weather situations, which are now kept out of the pipe network.

Waipatiki presents good evidence for the viability of DWM township retrofits, and indicates that these can bring benefits of both costs, and beneficial local reuse to settlements where historically wastewater has created problems. Rather than prevent future development, local authorities can use it as an opportunity to improve services in establishing communities, and share the associated costs of such improvement with the developer.

Figure 3. Land Application Area

Submerged Aeration Filtration (SAF) Plant Case Studies

The **Motutere Wastewater Treatment Plant** presented below was commissioned in June 2007. This system includes septic tank effluent discharging to a two stage SAF plant with Lamella Clarifier discharging to a carbon bed prior to final land disposal.

PROJECT DETAILS		WORK CATEGORY AND PHASES
Name of Project	Motutere WWTP	Submerged Aerated Filter (SAF) design with a Carbon Bed for Nitrogen Removal for peak day flow of 150m³/d.
Client	Taupo District Council	
Contact Details	Kevin Sears (07 376 0899)	Camping Ground contains high influent nitrogen loads.
Type of Project	Wastewater Treatment Plant Upgrade	
Duration	2 Years	Land disposal of wastewater.
Value	$750,000	Plant design from feasibility stage, process selection, disposal system design, construction observation and commissioning.
Effluent Quality (mg/L)	05/03/08: TN=7.01, TSS=5.3, BOD_5=8.68 02/04/08: TN=9.7, TSS=2.8, BOD_5=10.41 07/05/08: TN=11.86, TSS=5.2	
Resource Consent Limits	• Discharge of up to 200kg of TN/hectare/year.	

The **Mangakino Wastewater Treatment Plant** presented below was commissioned in December 2007. This system includes parallel single stage SAF modules followed by a conventional Clarifier. This plant is designed to be converted to an MBR plant in the future with very little alteration to the plant configuration.

PROJECT DETAILS		WORK CATEGORY AND PHASES
Name of Project **Client** **Contact Details** **Type of Project** **Duration** **Value**	Mangakino WWTP Taupo District Council Greg Hadley (07 376 0899) Wastewater Treatment Plant Upgrade 1 Year $1,500,000	Small community wastewater treatment plant for peak day flow of 600m³/d. Required high level of treatment for land disposal system. Plant design from feasibility stage, process selection, disposal system design, construction observation and commissioning.
Effluent Quality (mg/L) **Resource Consent Limits**	05/03/08: TN=24.73, TSS=6.3, BODs=6.44 07/05/08: TN=17.29, TSS=4.4 21/05/08: TN=27.99 • None in terms of nutrient limits	

The **Arthur's Pass Public Toilets Wastewater Treatment Plant** was commissioned in July 2007. It consists of a septic tank discharging into two SAF reactors in series, followed by a clarifier and then a UV disinfection system. Disposal to land is by soakage trench land application. A photo of this plant is unavailable at this stage. The system was installed in beside the toilets and the railway line and has been installed completely underground, except for the control shed which is visually unobtrusive. This is an extremely sensitive environment for both visual effects and potential odour.

PROJECT DETAILS		WORK CATEGORY AND PHASES
Name of Project **Client** **Contact Details** **Type of Project** **Duration** **Value**	Arthur's Pass WWTP Selwyn District Council Rob Allen (03 344 0262) New Wastewater Treatment Plant 1 Year Unknown	Plant is to treat water from new public toilets at the Arthur's Pass village and DOC facilities Required UV treatment and treatment must be that of an aerated system or of equivalent quality to be discharged to a soakage trench land application system. Plant design from feasibility stage, process selection, disposal system design, construction observation and commissioning.
Effluent Quality (mg/L) **Resource Consent Limits**	03/04/08: BOD_5=44, TSS=33, FC=50cfu/100mL • None in terms of nutrient limits	Commissioning sample (early and expected to be far superior to this now)

The **Cape Kidnappers Wastewater Treatment Plant** presented below was installed around September 2007 with a design flow of 20m^3/d. To cater for any potential odour issues, the plant is buried completely underground. Discharge for the plant is by irrigation.

PROJECT DETAILS		WORK CATEGORY AND PHASES
Name of Project **Client** **Contact Details** **Type of Project** **Duration** **Value**	Cape Kidnappers Lodge WWTP Private Owner Niki Johnstone (09 571 0091) New Wastewater Treatment Plant 1 Year Unknown	Plant is to treat water from a luxury resort and has a design flow of 20m^3/day Odour mitigation very important – plant was completely buried underground. Discharge is by irrigation. Plant design from feasibility stage, process selection, disposal system design, construction observation and commissioning.
Effluent Quality (mg/L) **Resource Consent Limits**	Unknown • BOD: 20 mg/L • TSS: 20 mg/L	No sampling as private owner

The **Mangawhai Heads Development Wastewater Treatment Plant** presented below was commissioned in late 2004 to treat a design flow of 60m^3/d. The plant consists of a septic tank and SAF reactors. Due to aesthetics being an important issue in the subdivision, the plant is buried completely underground.

PROJECT DETAILS		WORK CATEGORY AND PHASES
Name of Project **Client** **Contact Details** **Type of Project** **Duration** **Value**	Mangawhai Heads WWTP Private Owner Niki Johnstone (09 571 0091) New Wastewater Treatment Plant 1 Year Unknown	Plant is to treat water from an 80 lot subdivision and has a design flow of 60m³/day Plant is completely buried for aesthetic reasons in the subdivision Plant design from feasibility stage, process selection, disposal system design, construction observation and commissioning.
Effluent Quality (mg/L) **Resource Consent Limits**	Unknown • BOD: 15 mg/L • TSS: 15 mg/L	Private owner

Sequencing Bed Reactor (SBR) Plant Case Studies

BP Of New Zealand Limited
Albany, Auckland

Contact

Motor Services Centre Wastewater Treatment Plants
Consultant – URS Corporation Limited
Reference: Mr Graham Chapman – URS Corporation Limited

Description

To design and build a 60m³ per day SBR Wastewater Treatment Plants for the Motor Service Centre. Whilst the hydraulic loadings are relatively small the anticipated BOD loading of 2000 mg / litre are very high which meant a treatment plant of approximately 960 PE was necessary to handle these high loadings.

The Wastewater Treatment Plant consisted of influent pumping wells and emergency storage tanks located some distance from the actual treatment site. The influent is pumped to the plant and is screened prior to entering the Reactor.

The Reactor is fitted with Rehau fine bubble diffusers and the air to supply these diffusers is from duty/standby rotary lobe blowers. A single submersible pump is used to provide the RAS/WAS duties by way of automated changeover valves.

The treated effluent is decanted via a floating decanter to a sand filter (single pass) then to the treated effluent storage tank. From the storage tank the effluent is pumped to the extensive underground disposal system. Please refer to Page 62 for a typical effluent analysis from this treatment plant.

Value
$675,000

Construction Period
February 2004 – June 2004 - Completed on time and within budget.

Mana Island Resort
Fiji

Contact

New Greenfield site Wastewater Treatment Plant (2004)
Mr Robert Hazelman

Description

Reaman Industries Ltd was commissioned to construct a new 450 m3/day SEBAS® SBR for the Resort. This was due to the imminent collapse of the existing wastewater treatment plant tanks and to add to the capacity of the plant to handle additional Resort accommodation now and in the future.

The SEBAS® SBR Tank was purpose designed by a registered Civil Engineer and constructed by Pacific Pools Fiji under the supervision of the Resort's Chief Engineer. The SBR Reactor was fitted out with manual influent screens, submersible influent pumps and the Rehau fine bubble diffusers and the air supply is generated from rotary lobe blowers.

The floating decanter is a proprietory decanter designed for this project. The treated effluent is pumped to the effluent screen filters before discharging to the storage lagoon adjacent. From the irrigation lagoon the effluent is irrigated to the Resort's lawns and gardens

Was/Ras pump provide the return activated sludge and the wasting sludge processes.

The complete system is run automatically through a PLC with an operator interface panel. This enables low operator assistance and ensures the integrity of the entire process. To ensure that fault diagnostics can be achieved easily if required, the process can be viewed through a "dial up" modem.

During the commissioning phase extensive staff training was undertaken. The site is visited regularly under a preventative maintenance regime to ensure that equipment can operate efficiently under the extreme Fijian climate. The process is operating correctly and the Operators are fluent with the process and controls.

This plant achieves BODs and TSS loading less than 10 mg/l plus nutrient level reduction.

Value

$300 000 – Process, Design and Mechanical only.

CASS™ - Cyclic Activated Sludge System

Location: Wick WWTP, Scotland

Client: North of Scotland Water Authority

Type: Municipal Wastewater Treatment Facility

Value: £4.6 M **Date:** Commissioned 18th December 2003

Project Description:

The project comprises the design, construction and commissioning of a new 13,500 PE (8,000 residential and 5,500 industrial/distillery/airport) wastewater treatment plant for the town of Wick. It replaces the previous direct discharge of screened sewage to the sea outfall, and will comply with UWWTD legislative requirements. The plant is built on an exposed scenic headland with many environmentally sensitive issues.

Features of the project include preliminary treatment with 6mm bi-directional screening and grit removal, pumping, primary tank (to generate primary sludge to assist sludge dewatering) two circular CASS™ SBR process basins (with fine bubble aeration grids), sludge storage, sludge dewatering to 22% cake, odour control bio-filter, and fully automated plant controls (telemetry, PLC / MCC control).

Design Flow:	0.65 MGD (2462 m^3/d) average, 3.9 MGD (14,774 m^3/d) peak
Influent Conditions:	BOD 250 mg/L, SS 250 mg/L, TKN 50 mg/L, NH_3N 30 mg/L, P 5 mg/L
Effluent Limits:	BOD 25 mg/L, COD 125 mg/L UWWTD standards.

CASS™ - Cyclic Activated Sludge System

Location: Muir of Ord, Scotland

Client: North of Scotland Water Authority

Type: Municipal Wastewater Treatment Facility

Value: £1.0M Lump Sum Turnkey Contract

Date: Commissioned May 2001

Project Description:

The project comprises the design, construction, procurement and commissioning of a new 6,300 p.e. wastewater treatment plant for the town of Muir of Ord to meet European UWWTD and Bathing Water / Bathing Beach legislation. The project will provide increased environmental quality to the Moray Firth and local bathing beaches.

Features of the project include a new Inlet pumping station and preliminary treatment with 6mm screening and grit removal, storm tank, two 16 m diameter CASS™ SBR process basins (with removable aeration grids), sludge thickening and storage, and fully automated plant controls (telemetry, PLC / MCC control).

Design Flow:	1.1 MGD (4163 m^3/d)
Influent Conditions:	BOD 88 mg/L, SS 102 mg/L, TKN 17 mg/L, NH_3N 11 mg/L, P 3 mg/L
Effluent Limits:	BOD 20 mg/L, TSS 30 mg/L as 95%ile spot samples.