PLANNING FOR SUSTAINABILITY, QLDC'S WASTEWATER STORY

Reuben Bouman, Evie Wallace (Beca), Trent Beckman-Cross, Calum Pringle (Queenstown Lakes District Council)

ABSTRACT (500 WORDS MAXIMUM)

Due to years of substantial growth, Queenstown Lakes District Council (QLDC) has been upgrading nearly all its wastewater treatment plants. At the same time QLDC has been developing the implementation of sustainability principles in its capital works projects. This paper outlines the methods QLDC have used to do this including Sustainability in Design (SustID) workshops. This paper will give practical examples of how these workshops were run and the initiatives developed and implemented. This process has been successfully applied to the upgrade projects for the Shotover WWTP in Queenstown and Pure WWTP in Wānaka. More recently it has also been used for the Hāwea to Pure wastewater pipeline.

The initiatives developed in the SustID workshops were categorised by ease of implementation, scale of impact, and ownership. The initiatives discussed cover a wide range of topics including greenhouse gas (GHG) emissions from construction materials and methods, GHG emissions from liquid and solids treatment processes (including a review of N_2O emission from sequencing batch reactors (SBRs)), waste minimisation (from a design and construction perspective), water reuse opportunities, tree planting within the project, and reuse of materials such as pond sludge onsite. Detailed carbon assessments were then used to help determine which sustainable design solutions should be implemented. For example, tapering of the concrete reactor walls to reduce the quantity of concrete and reinforcing steel, and high efficiency aeration blower and diffuser types.

This experience, along with work with other suppliers and stakeholders, has helped enable QLDC to develop sustainability KPIs for its Three Waters Panel, for both professional services and physical works. How these KPIs will impact and inform sustainability throughout both design and construction is also discussed in the paper.

As the Project Pure upgrade moves into the construction phase, a sustainability in construction workshop has been scheduled to discuss the protocols for waste management and carbon accounting. It is valuable for designers and constructors to work together with QLDC, to implement and build upon opportunities established in the design phase, and add additional construction related sustainability initiatives.

Another opportunity in doing these upgrades has been the chance to plan the space for future upgrades. This was particularly the case for the Shotover WWTP where the planned decommissioning of the ponds has created a large area for potential development with many parties interested in the use of the land. This

paper will detail the importance and collaborative method for developing these master plans, and how space for future sustainability initiatives has been incorporated.

KEYWORDS

Sustainability, wastewater, design, construction, greenhouse gas emissions

PRESENTER PROFILE

Reuben Bouman has 18 years of experience in the design of wastewater treatment systems. He is passionate about designing and delivering improved wastewater treatment for better community and environmental outcomes.

INTRODUCTION

For a significant period, the Queenstown Lakes District has experienced substantial growth in both the resident and visitor populations. See Figure 1 for data.

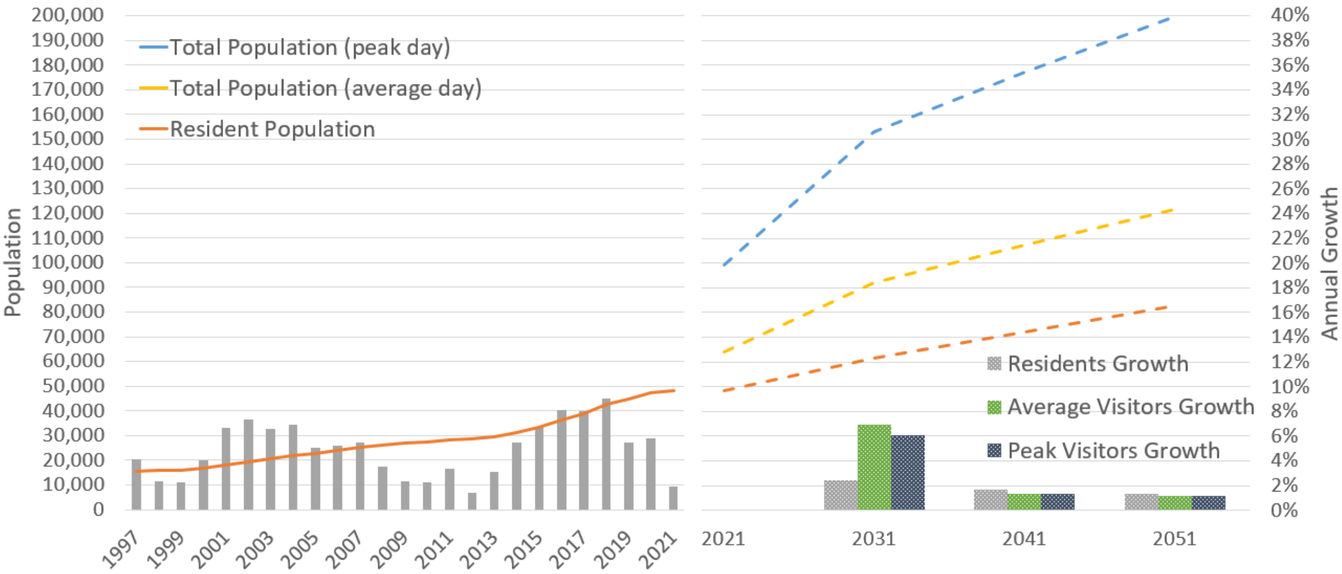

Figure 1: Historical and Forecast Population Growth for the Queenstown Lakes District

This has led to the need to upgrade much of its infrastructure. In terms of the Wastewater Treatment Plants (WWTPs), Table 1 shows the upgrades.

Table 1: Upgrades to QLDC WWTPs

WWTP	Upgrade
Shotover (Queenstown, including Arrowtown)	New CAS (Conventional Activated Sludge) plant (1xMLE reactor and clarifier) was built in 2013 to meet new consent conditions (existing ponds retained for part of the flow). Second MLE reactor clarifier to be built soon to meet demand from population growth
Pure (Wānaka, and Albert Town. Luggate connected in 2019)	New WWTP (2 x SBRs) was built in 2008, to meet new consent conditions. Third SBR is being built currently to meet demand from population growth
Hāwea	Temporary MBBR upgrade to existing pond based WWTP to meet consent conditions. Then the WWTP is to be decommissioned and wastewater pumped to Pure WWTP as consent is expiring.
Cardrona	New WWTP (2 x SBRs) built in 2021 to meet demand
Kingston	New WWTP (3 x SBRs) to be built in stages to meet development
Glenorchy	No upgrade

Since implementing the Climate Action Plan 2019-2022 (and the recent Climate and Diversy Plan 2022-2025), QLDC project managers and engineering staff have started requesting and implementing sustainable practices in these projects. This paper presents some of the methods, outcomes, and learning of doing this.

SUSTAINABILITY IN BUSINESS CASE ASSESSMENTS

Sustainability is first implemented at the business case stage where the greatest impact can be made (See Figure 2). This is where the key questions of building nothing or building less can be made. This has always been part of the business case process and is closely aligned to the value-for-money requirement of local authority investment. The addition of carbon accounting (i.e. a high-level comparison of capital and operational greenhouse gas emissions) is largely just another sustainability lens through which to view the options.

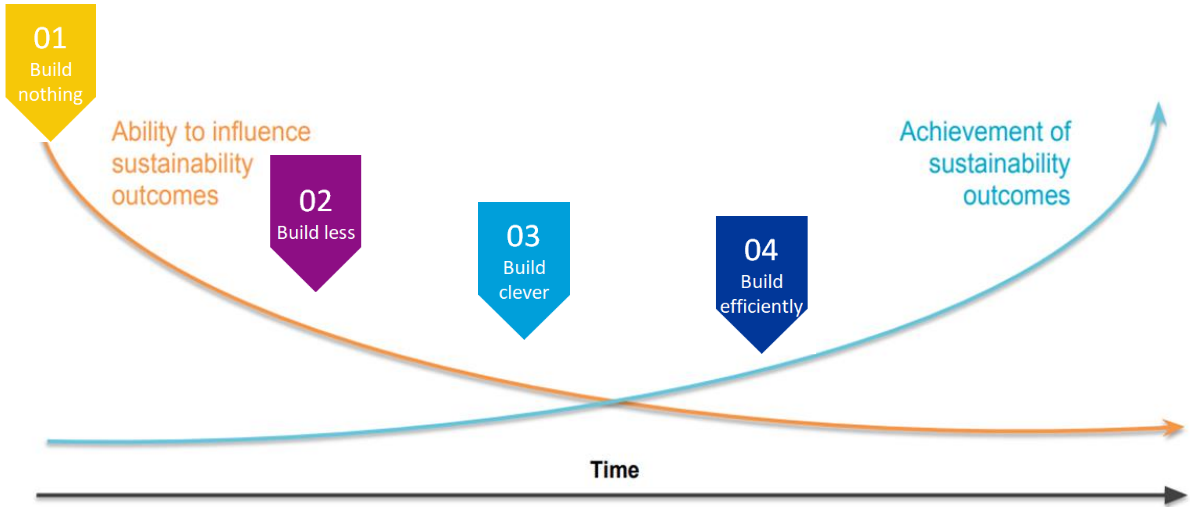

Figure 2: Sustainable outcomes in project lifecycle

Figure 3 shows the outcome of such an assessment. This is for the Hāwea wastewater business case where the options shortlisted options were:

- Option 1: New WWTP with irrigation
- Option 2: Upgraded WWTP with Rapid Infiltration Basins
- Option 3: Pump to Pure WWTP (two different routes)
- Option 4: Status Quo

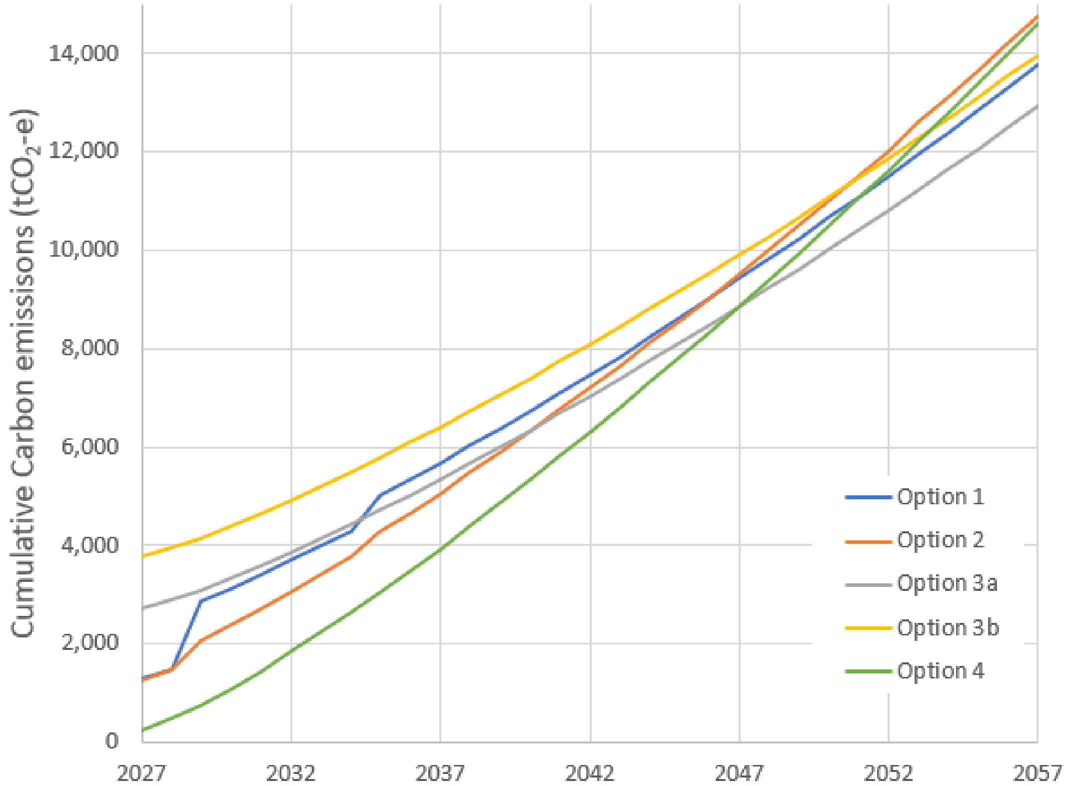

Figure 3: Hāwea wastewater Business Case carbon assessment of shortlisted options

SUSTAINABILITY IN DESIGN

HOW AND WHEN TO RUN A SUSTAINABILITY IN DESIGN WORKSHOP AND WHAT TO EXPECT

Once the business case and the associated high-level concept design has been approved, the next initiative in implementing sustainable design practice for QLDC projects has been the running of specific and standalone sustainability in design (SustID) workshops. These are initially run early in the design phase (e.g. at the start of concept design). This is capture initiative early when they have the greatest ability to positively impact the project, again see Figure 2. It also allows time for any initiatives highlighted in the workshop to be developed and incorporated into the design. A follow-up workshop at the start of detailed design has also been carried out and is recommended especially for large projects, where small design changes can have significant outcomes.

One key aspect of the SustID workshop is engaging with a wide variety of contributors. QLDC workshops have benefited from having representatives across Property and Infrastructure inc. solid waste, operations, strategy and asset management, parks and open spaces.

The initial workshop is run as a facilitated brainstorming session where participants write a variety of sustainability initiatives on sticky notes (virtual or otherwise). Participants are then invited to discuss the initiatives they have come up with and combine notes where applicable. Other spin-off initiatives can be developed at this stage. The grouped initiatives are then placed on a board that is divided into a simple two-dimensional array or matrix based on the ease of implementation and the value of the initiative. See Figure 3 for a representation of this array and how it can guide implementation.

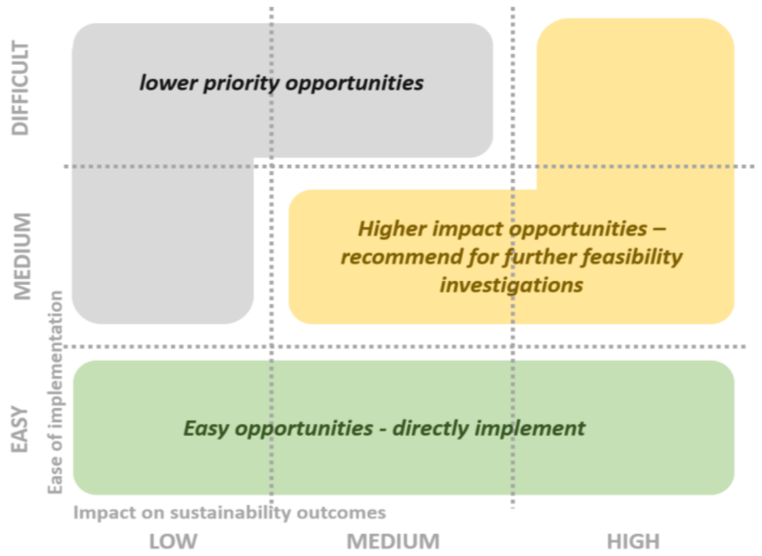

Figure 4: Sustainability in design workshop initiative matrix guide

Therefore, when placing an initiative on the board the team need to decide how easy it would be to implement and the size of the benefit. An example of this board from the Pure WWTP upgrade project is given in Figure 6. For this example, the notes were further categorised by colour to identify who can own and action the initiatives. Refer to Figure 5 for the key.

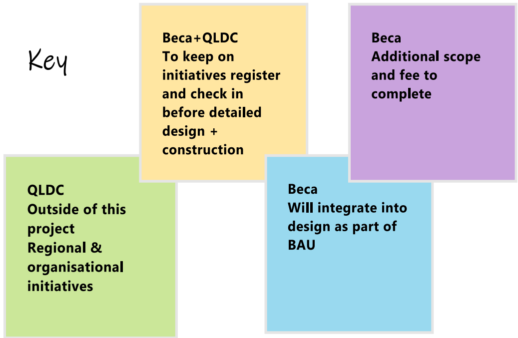

Figure 5: Key for the sustainability in design workshop initiative matrix for Pure WWTP Upgrade in Figure 4

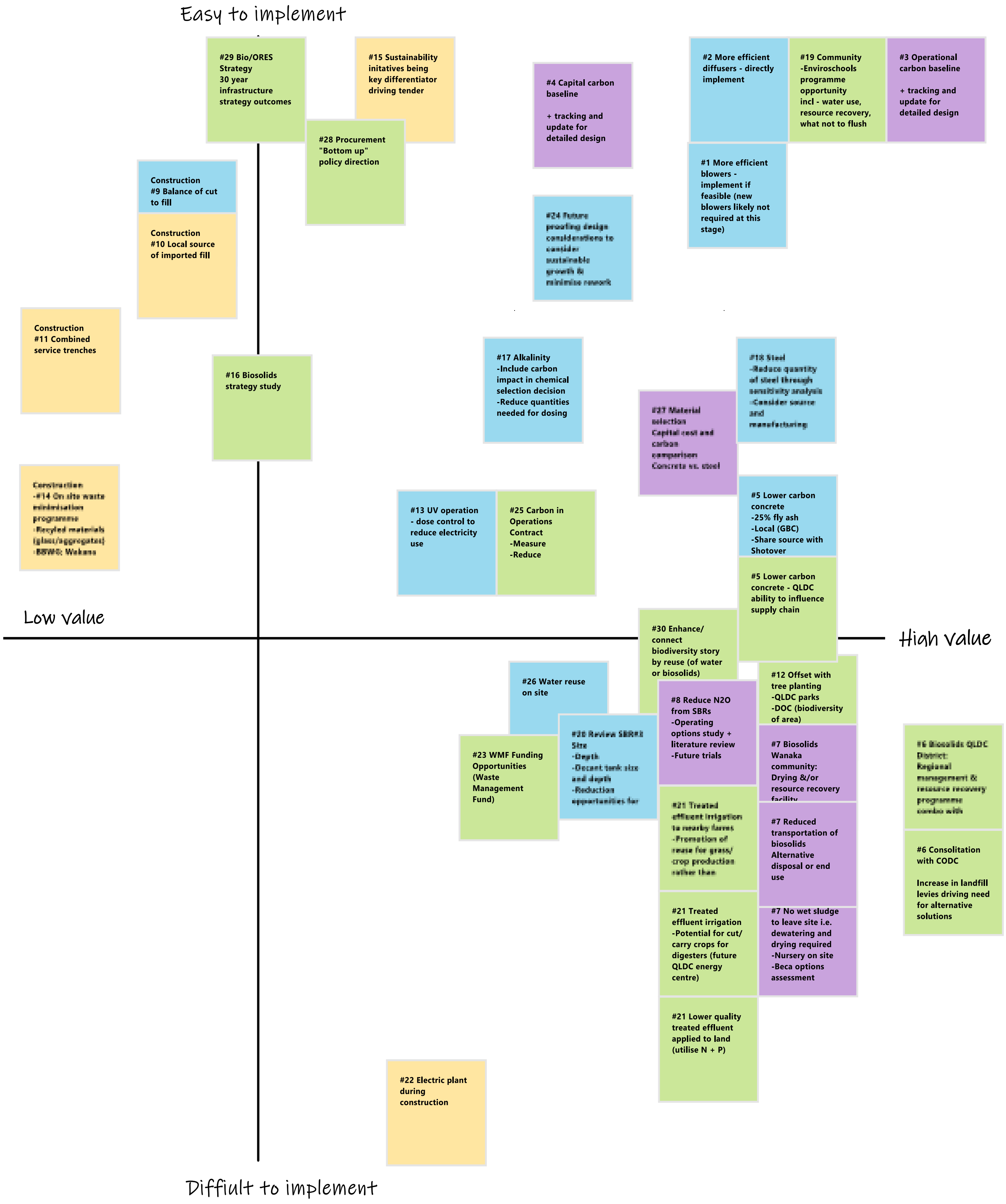

Figure 6: Sustainability in design workshop initiative matrix for Pure WWTP Upgrade

Finally, after the workshop, the initiatives are placed in a register where they can be tracked and managed through the project.

Idea	Capital Cost	Capital Carbon	Operational Cost	Operational Carbon	Indicative savings and benefits	Indicative costs and limitations	Fee Range (indicative)	Programme (indicative)
Turbo Blowers for Air Supply to MLE: Install more energy efficient Turbo blowers instead of Tri-Lobe blowers for addition of air to MLE	↑	--	↓	↓	Energy efficiency Low noise generation Easy to install Beca has experience specifying for other clients - reduce redesign cost	Capital costs per 75kW Motor Blower: □Turbo - $61,600/unit □Tri-Lobe – $30,000/unit Limitations: Will lead to loss of common spares - 2 different blower types until stage 1 blowers are replaced Unknown maintenance costs.	<$5k	No impact if confirmed before start of procurement
Lower carbon concrete Use of lower carbon pre-cast and ready mix (RM) concrete options	?	↓	--	--	Engage with local cement suppliers Guaranteed performance		No impact	No impact

Figure 7: Sample initiatives register

This process for the Sustainability in Design workshop can be summarised in the flow diagram in Figure *8*.

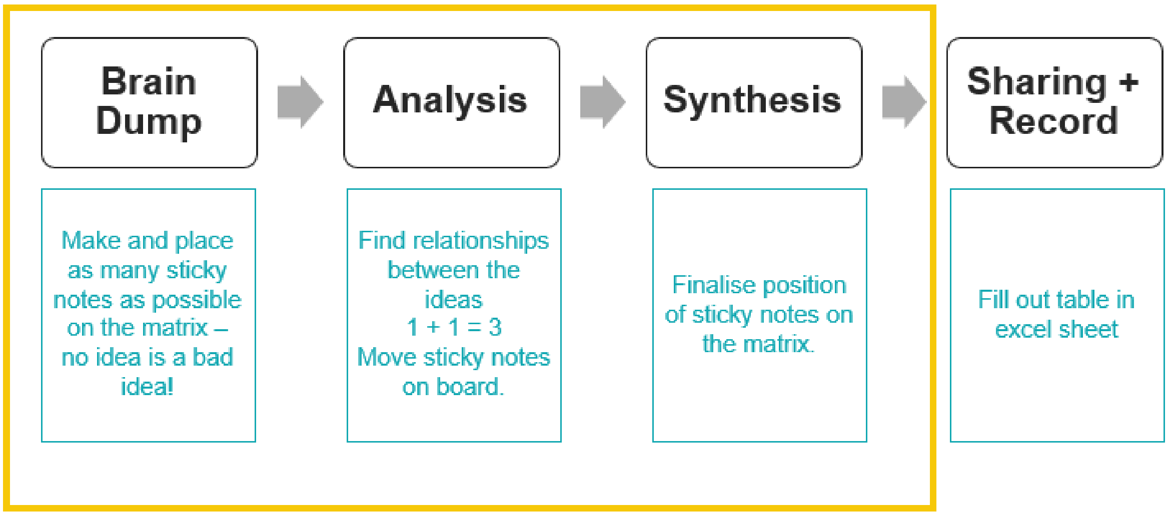

Figure 8: Flow diagram for a Sustainability in Design workshop

SUSTAINABILITY IN DESIGN INITIATIVES

To start understanding the embodied carbon associated with its infrastructure capital projects and to track the SustID initiative, capital (or embodied) carbon estimates were undertaken at the concept and detailed design stages. With the changes for the Shotover WWTP shown in Figure *9*. An as-built embodied carbon calculation will be undertaken upon completion of construction.

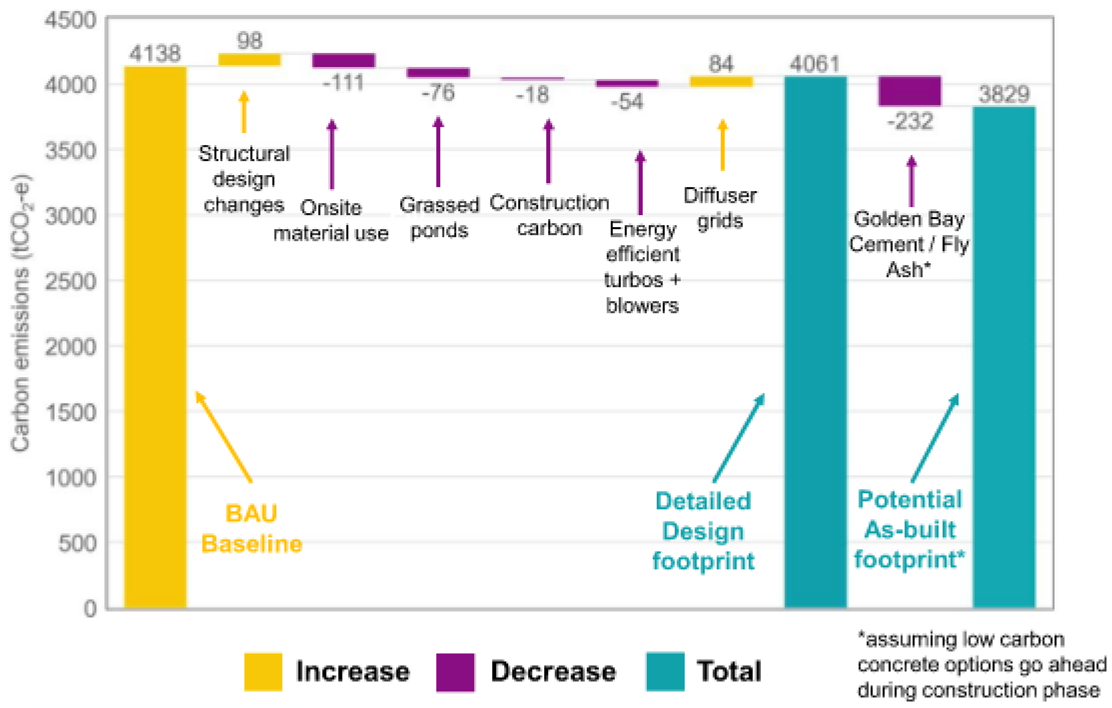

Figure 9: Embodied carbon assessments example for Shotover WWTP upgrade

Some of the initiates that targeted reducing embodied carbon through the design process were:

- Review clarifier structure and launder material
- Reuse of Biosolids from Pond de-sludging for onsite landscaping
- Tapering of concrete walls
- Lower carbon concrete
- Waste minimisation
- Tender evaluation criteria

Some of these initaitives are discussed futher below.

Initiates that targeted reducing operational carbon included:

- Reduce nitrous oxide (N_2O) emissions from the reactors including,
  - Ammonia-Based DO control in MLE reactor
  - Promote simultaneous nitrification and denitrification (SND) in MLE reactor
  - Alternative operating parameters such as DO setpoints, cycle time (for SBR)
- UV disinfection set point reduction
- High efficiency blowers
- High efficiency aeration diffusers
- Chemical options alternatives

Other initiates that regularly came up but were outside the scope of the projects:

- Wastewater heat recovery
- Local Energy Centre (PST) and biosolids re-use

Clarifier structure and launder material

The concept for Clarifier 2 to be built as part of the Shotover Stage 3 upgrade was to replicate Clarifier 1 which is a 35m diameter concrete structure with a stainless steel launder. Changing to a steel clarifier was not carried forward for detailed assessment due to the perceived limitations of:

- The constructability of steel tanks becomes difficult for larger structures, >20 mØ
- The current clarifier mechanism is driving from the wall, and hence a different mechanism would be required.
- The clarifier has a long design life and would benefit from the more permanent concrete construction.

During preliminary design, an assessment was made as to whether to install a stainless-steel launder on Clarifier 2, as used for Clarifier 1 or to change to a concrete launder. The considered capital cost, carbon impact and operational and maintenance factors. The stainless-steel option was selected due to no significant difference from a carbon perspective, the ability to clean the stainless-steel launder more easily and the likely lower capital cost of the stainless-steel option.

Lower Carbon Concrete

Lower carbon concrete is a capital carbon reduction opportunity for Project Shotover Stage 3. Supplementary cementitious materials (SCMs) in the concrete mix (such as one of 8% microsilica or 30% fly ash) are required from a structural durability perspective, and they offset a portion of the cement content which equates to a carbon saving compared to if SCMs were not used. However, there are opportunities within and beyond this to achieve lower carbon mixes. Golden Bay Cement (GBC) is locally sourced within New Zealand and therefore has a lower associated carbon impact compared to imported cement.

High efficiency blower and diffusers

NPV and whole of life carbon assessment were carried out for turbo blowers and panel diffusers for the Shotover WWTP upgrade. The results are summarised in Table 2. This led to the selection of the more efficient aeration blowers and diffusers for this upgrade and the Pure WWTP upgrade.

Table 2: Summary of assessment of efficient aeration blowers and diffusers for the Shotover WWTP Upgrade.

Assessment	Net Present Value	Whole of Life Carbon	Approx. Payback
More efficient blowers BAU: Tri-lobe roots blowers Alternative: Turbo blowers	↓ $0.7M Turbo blowers have a high capital cost but offer a 30% yearly power saving	↓ 1,200 tCO_2-e Turbo blowers have lower operational and whole of life carbon	3 years
More efficient diffusers BAU: Tube diffusers Alternative: Panel diffusers	↓ $0.4M Panel diffusers have a 50% higher capital cost but offer a 21% yearly power saving	↓ 650 tCO_2-e Panel diffusers have a lower capital and operational carbon, with a longer engineered life	7 years
Blowers and diffusers combined	↓ $1.0M	↓ 1,800 tCO_2-e	5 years

<u>UV disinfection operation</u>

A review was carried out of the current setpoints for the two WWTP UV system, Shotover and Pure, with the view to determine if operational cost and carbon savings could be made.

Shotover UV already uses Dose Pace control (meaning that at times of lower flow and/or higher UVT, a reduced input power and in turn electricity associated operational carbon), but was having a significant change to in the feed (30% of the UV feed was pond effluent and would be changed to clarifier effluent, which better UVT) and effluent requirement reduced to 10 cfu/100mL E. coli. The net effect was following commissioning of Stage 3, to reduce the UV setpoint to from 24 to 23 mJ/cm² . Then carry out additional testing of the UV influent and effluent, and review with Xylem for possible further reduction to 22 mJ/cm².

Pure UV does not use Dose Pace control and the existing unit would require reasonable investment to convert with a payback in excess of 20 years for a small (6 to 10 tCO2-e/yr) carbon saving. Thus this was deferred until the existing units 14yrs old are replaced.

Reduce nitrous oxide (N_2O) emissions from the reactors

- Ammonia-Based Aeration Control (ABAC) in MLE reactors to promote simultaneous nitrification and denitrification (SNdD) at Shotover WWTP

Power savings could be achieved by promoting some nitrate shunt or SNdN. This could be facilitated with the investment in an ammonia analyser for ABAC or changes to the control using the business as usual (BAU) dissolved oxygen (DO) analysers.

Extensive biological mechanistic modelling to determine the potential benefits of Ammonia-Based Aeration Control (ABAC). The assessment concluded that using BAU DO control (rather than ammonia-based control) at lower DO setpoints appears to be the simplest method of promoting nitrate shunt or SNdN and gaining power savings. This initiative obviously carries some compliance risk, but has no capital cost and is one which can be retreated from if it proves unreliable or unstable. Additionally, the modelled N_2O emissions increased slightly offsetting any emissions savings from reduced power consumption.

Ultimately it was concluded not to invest in an ammonia analyser for ABAC control as it shows no real advantage over the BAU, and the BAU CO control was retained until onsite N2O emissions can be carried out.

It was noted that there were difficulties in being able to accurately model the ABAC scenarios.

- Alternative operating parameters such as DO setpoints, cycle time (for SBR)

An operational carbon estimate was carried out for the baseline carbon emissions associated with operation of the Pure WWTP (2019/20 baseline year), and the largest contributor was estimated to be nitrous oxide (N_2O) emissions from the secondary treatment process. This is typical for most centralised aerobic WWTPs, but N_2O emissions do have a high associated uncertainty and are difficult to estimate and measure accurately. Therefore, a more detailed assessment was carried out on possible/likely N_2O emissions, with a focus on Project Pure but with outcomes and recommendations that can apply across QLDC’s WWTPs.

A review of the emission factor for N2O emissions highlighted the variability, as shown in Figure *10*.

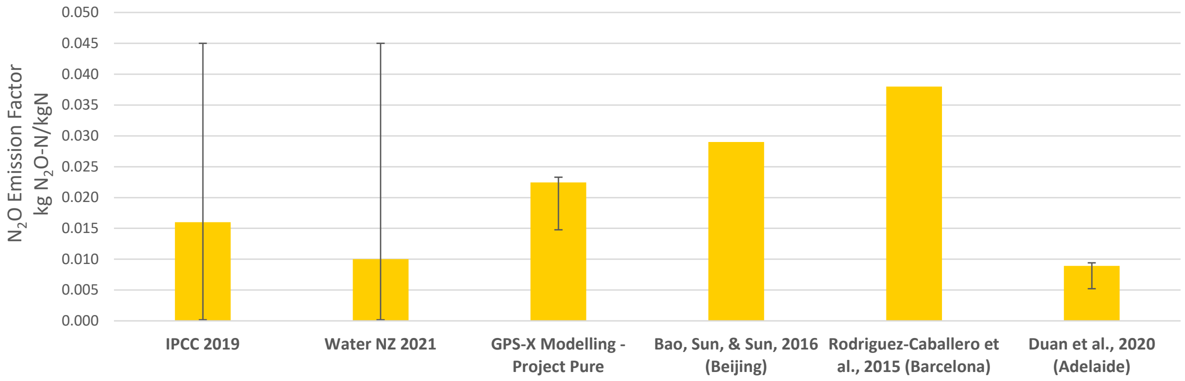

Figure 10: Range of N2O Emission Factors (Including Default Factors, GPS-X Model for Project Pure, and other SBR Plants in Literature)

A recent international case study from South Australia Water (Duan et al., 2020) provides context on the process and cost for on-site measurement of emissions. Cost for equipment & testing is in the order of $115k, and they achieved N2O reductions in an Adelaide SBR plant in the order of 35% through operational changes without compromising treatment performance. This was achieved through operating at low DO (0.5mg/l), encouraging simultaneous nitrification and denitrification (SNdD). This was also confirmed by biological mechanistic modelling of the Pure WWTP process. Note that this is in contrast to the findings for the continuous MLE process as reported above. Figure *11* shows the modelled N_2O emissions at changing DO setpoint. Note the effluent BOD (Biochemical Oxygen Demand) does worsen at the low DO setpoint, indicating that the aerobic sequences may need to be extended.

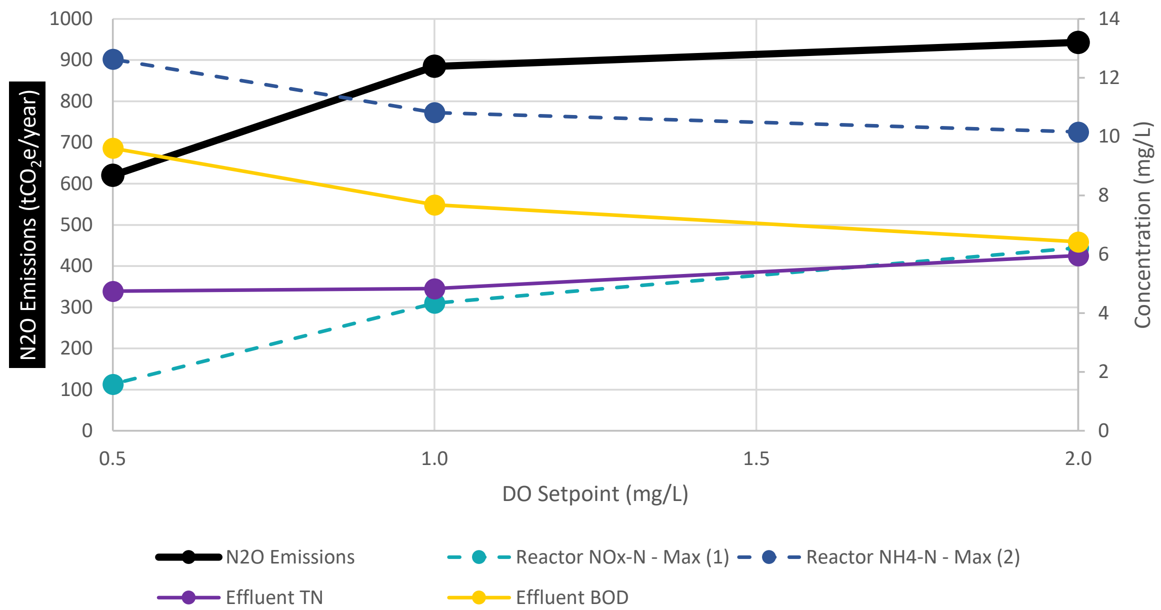

Figure 11: Modelled GPS-X Emissions for Project Pure (2025) at a changing DO Setpoint

SUSTAINABILITY IN CONTRACTS

While the design phase can identify a number of sustainability opportunities and integrate these into the design, there is significant cross-over into the construction phase in terms of realising many of these opportunities. Additionally, some opportunities are specific to just the construction phase. Therefore, sustainability needs to be integrated into the construction contract at the tender stage.

SPECIFICATIONS

The following two key sections were integrated into a number of the QLDC construction contracts (and the results in practice are discussed further in the next section of the paper):

Waste Management

The Contractor must develop a waste management plan under the BRANZ Resource Efficiency in the Building and Related Industry (REBRI) methodology to manage waste throughout the works. The Contractor shall report on progress against this on a monthly basis, including the different waste streams, where these are going and alternatives for disposal.

The Contractor shall also provide an as-built Schedule of Quantities at the end of the construction period, reporting on:

- Quantity and type of materials used
- Source of materials (e.g. shipped from China to Dunedin, road freight from Dunedin to the project site)
- Fuel use associated with construction.

The Contractor shall also include mobile plant fuel use in the as-built Schedule of Quantities, to be recorded monthly and task based where practical (e.g. litres of fuel associated with excavation, or litres of fuel associated with concrete pumps for major concrete works. Material supplier and supply location shall also be included for all mechanical items and bulk civil materials (such as all pipework, concrete, and imported fill if used).

Sustainability

In addition to the waste management and materials reporting requirements above, the Contractor is encouraged to demonstrate how they have considered sustainability for the project. The following are additional sustainability initiatives that will be considered favourably during tender evaluation (note that the Contractor is also encouraged to detail any other sustainability initiatives they propose):

- Local hiring of staff and sub-contractors (including for small aspects of the project for example hiring of a local firewood supplier to remove trees and sell as firewood in the local market)

- Use of local (New Zealand) cement, i.e. Golden Bay Cement rather than imported cement, as due to the reduced transport emissions, it has a lower associated embodied carbon.
- Waste minimization, sorting and recycling initiatives
- Re-use of pond sludge or other contaminated material within the site for landscaping bunds where possible (note needs to be in line with consent), rather than trucking and disposing to landfill
- Opportunity to import clean fill from other nearby construction sites at time of works. Coordination through the Principal with other project sites required.
- Opportunity to use recycled construction materials, as appropriate, on site for construction activities such as filling and road bases e.g, crushed roading, concrete, pavement materials.

PANEL CONTRACTS

'The process of incorporating sustainability initiatives within the Shotover and Pure design and construction works has, in part, helped enable QLDC to develop sustainability KPIs for its three waters panel, for both professional services and physical works. These measures sit within the existing Environmental ‘key result area’ on the panel.

QLDC released the following draft KPIs, and has discussed and refined them in a series of workshops with members of the panel (Beca, Stantec, Fulton Hogan, Downer and HEB).

Professional Services:

- Demonstrate that the design considers climate hazards and vulnerabilities throughout the project lifecycle (design, build, operate, decommission).
- Demonstrate the design protects and enhances biodiversity and ecology.
- Demonstrate the design reduces Scope 1, 2 and/or 3 carbon.

Physical Works:

- Number of Environmental Product Declaration products (EPDs) used in construction. NOTE: Constructor may also demonstrate efforts to have common construction materials registered as EPD to achieve this KPI.
- Number of construction waste generating streams reported on and effective initiatives to reduce these demonstrated per bundle.
- Number of fossil fuel reliant construction activities which are either eliminated or reduced through the constructor’s methodology.

Further refinement is likely following trial of the KPIs on a number of projects.

SUSTAINABILITY IN CONSTRUCTION

Once Project Pure entered construction, a Contractor led sustainability in construction workshop was held to discuss the protocols for waste minimisation and carbon accounting for the project. The workshop was held during the site establishment phase of the Contract and enabled QLDC to emphasise the importance of the sustainability initiatives identified during design. The workshop also enabled the Principal and the Designer to foster a collaborative approach to sustainability in construction with the Contractor.

The outcome of the workshop is that Contractor, Designer, and QLDC all agreed to a method of waste minimisation reporting and carbon accounting that provides the data required while still being practical to implement alongside the typical construction management requirements of a complex construction project. Ongoing reporting and review are required to ensure the methods are appropriate and provide QLDC with the data needed to contribute to organisational sustainability objectives.

Waste minimisation

Waste minimisation is critical to reducing the emissions footprint of a project. The REBRI methodology was adopted as a minimum level of reporting for the Project Pure Contract. However, the template form of reporting is better suited to vertical construction projects. Therefore, QLDC and the Designer collaborated with the Contractor to agree on a reporting format better suited to civil construction projects. Nonetheless, the requirement for waste minimisation reporting has encouraged the adoption of several initiatives on the project to date that are suited to wider adoption in the industry.

Firstly, the temporary nature of construction projects means that site office facilities are established for the term of the Contract. The furniture and fittings are typically sent to landfill at the end of the project and the Contractor repeats the same exercise on the next project. This example of waste generation is easily avoided and increases the Preliminary and General costs of a Contract. The Contractor on Project Pure has fitted out their site offices using second hand office furniture from a local second-hand store and plan to return the furniture to the store at the end of the project.

Secondly, the Contract Specification typically requires the use of imported aggregate for use as engineered backfill. However, geotechnical investigations can be used to understand the potential to reuse in situ material in place of imported material as backfill. The Designer identified an opportunity to reuse a proportion of in situ material excavated for the SBR and Decant Tank construction material as backfill. The Contractor has implemented on site crushing and screening to produce material suitable for use as engineered fill and pipe bedding material. The remaining excess fill will be used to construct new on-site bunds. This approach significantly reduces the emissions associated with the import and export material for the project.

In isolation, the examples listed are relatively minor examples of sustainability in construction. However, the cumulative project and industry effect can be significant and may provide a cost and methodology competitive advantage for Contractors when bidding for Contracts.

As built carbon reporting

As described earlier in this paper, the capital and operational carbon estimates were completed during the concept design of the upgrade. The capital estimate was intended for use as a baseline against actual as-built carbon reporting from the Contractor. QLDC and its Designer defined the data required from the Contractor but worked collaboratively to agree the format and scope of reporting.

The first round of data is due to be reported in early August and all parties expect to further refine the data reported and the method of reporting. The data reported will enable the Designer to validate the assumed emissions from typical construction activities. This will improve the accuracy of estimating the emissions generated during construction and where to focus efforts during design to provide the best opportunity to reduce the capital carbon footprint for future projects.

PLANNING FOR A SUSTAINABLE FUTURE

Another opportunity in doing these upgrades has been the chance to plan the space for future upgrades. This was particularly the case for the Shotover WWTP where the planned decommissioning of the ponds has created a large area for potential development with many parties interested in the use of the land. By engaging broadly across the council including Parks and Solid Waste departments a whole of council masterplan was able to be established with space reserved for future sustainability-driven initiates or projects. Projects included:

- Future (long-term) expansion of the wastewater plant
- Opportunity for future solids proceeding.
  For Shotover, this included a centralised energy centre processing sludge from Shotover and other WWTPs in the region and other organic waste such as garden and/or kitchen (green) waste. Also producing a re-useable biosolids.
  For Pure, is allowed space for solar drying
- A Municipal Recycling Facility (MRF) for Shotover
- Future potential reuse facilities.
  For Shotover, this was to allow for tertiary filtration and a reservoir to enable irrigation of a nearby golf course
  For Pure, this was to allow for a pump station to pump the treated wastewater to nearby farmland.

Sample outputs for Shotover are shown in Figure 12 and Figure 13.

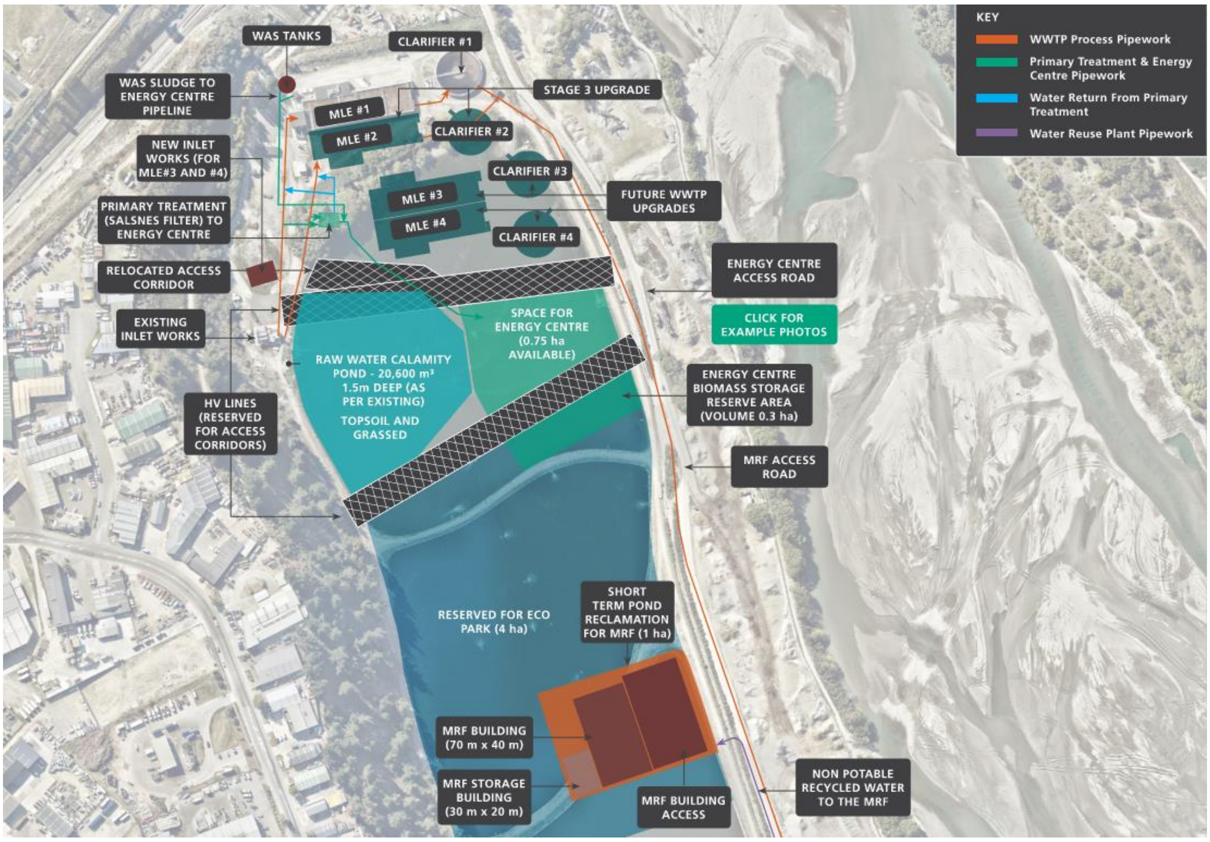

Figure 12: Shotover WWTP Masterplan map 1

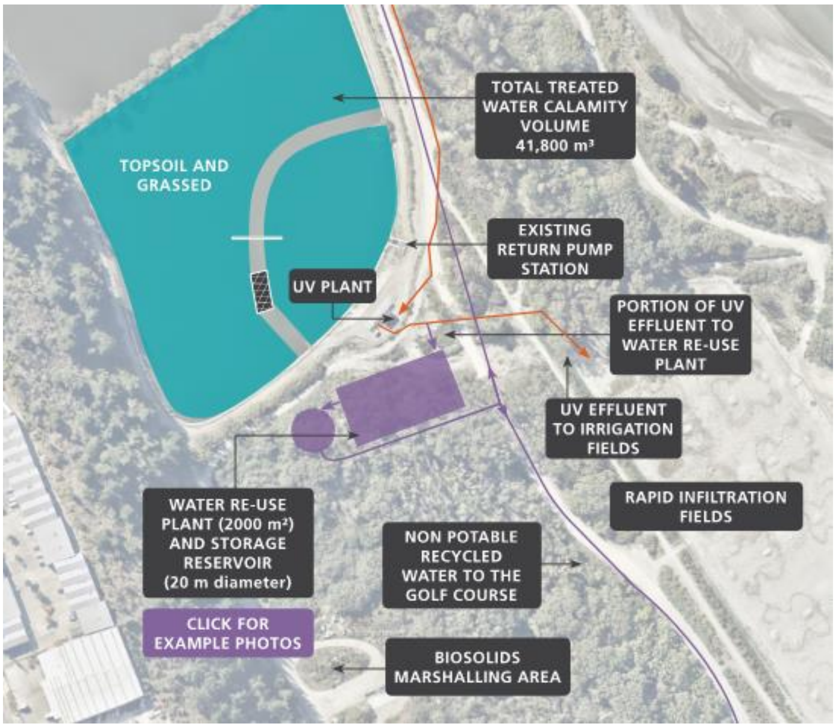

Figure 13: Shotover WWTP Masterplan map 2

CONCLUSIONS

Through deliberate action, QLDC have incorporated sustainability principles into the design and construction of several of its recent wastewater projects. A number of tools such as sustainably in design and sustainably in construction workshops have been developed along the way as well as enhancing sustainability in its panel contracts and master planning.

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