SNELLS BEACH WWTP: COLLABORATIVE WORKING FOR COST AND CARBON SAVINGS

Douglas Bale (Mott MacDonald Ltd) and Jacob Whitford (Watercare Services Ltd)

ABSTRACT (500 WORDS MAXIMUM)

The Snells Beach Wastewater Treatment Plant was designed as an Activated Sludge and Membrane Bio Reactor plant. Cost estimates from the mechanical and process design including construction identified that the project was unaffordable, and that action was required to bring the scheme back to within the project budget to allow it to proceed.

Watercare commissioned a value engineering exercise to review the design of the proposed Snells Beach Wastewater Treatment Plant with the goal of making substantial Capex savings.

The value engineering exercise involved a review of the historic design to identify opportunities for savings. The review also included a detailed review of construction methods for this scheme and adjacent works, to identify opportunities for efficiencies in construction. A process of collaborative working between the design team, the contractor and the client have led to estimated savings of $20 million on the project capital cost which have allowed the scheme to proceed. This paper will discuss the value engineering process and working practices adopted by the team which enabled the identification of such substantial savings.

While the value engineering exercise was focused on Capex savings, the embodied Carbon from the construction of the original plant design has been adopted as a baseline and the impact of design changes tracked. The paper will discuss the impacts of assessing CO2 emissions through design, how this can be used to drive sustainable decision making and how it can impact on cost.

The paper will also highlight the next steps for the scheme, as it moves from the value engineering phase into the detailed design and construction phases of the project delivery.

KEYWORDS

Procurement and project delivery, Wastewater treatment, Environmental Impacts of Water Industry Operations, Sustainability

PRESENTER PROFILE

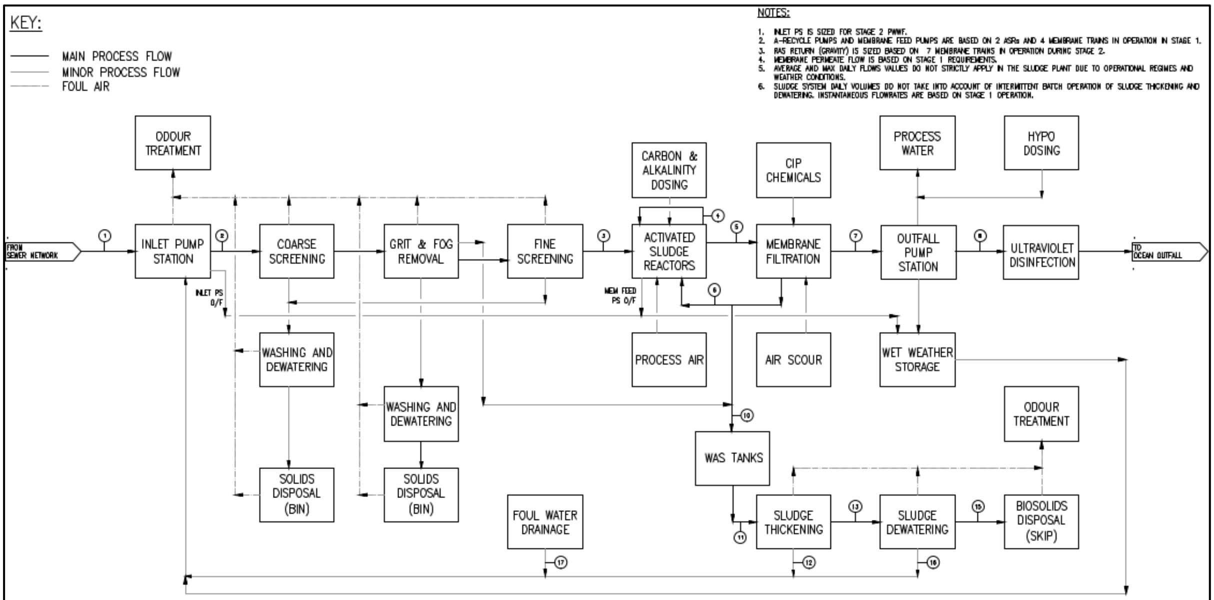
Douglas is a civil engineer with experience in the design and delivery of major water and wastewater projects in the UK and New Zealand. Douglas has managed the design for the Snells Beach Wastewater Treatment Plant through the value engineering process and into the detailed design phase.

1. INTRODUCTION

Snells Beach Wastewater Treatment Plant (WWTP) is a new plant which is to be constructed to meet new discharge consents and to cater for population growth for the Warkworth, Snells Beach and Algies Bay areas. The option of providing a single new treatment plant at Snells Beach with a transfer pipeline from Warkworth was selected as the preferred option in a 2016 study.

The plant was designed as an activated sludge and membrane bioreactor (MBR) process discharging to a new sea outfall pipeline. The solids treatment stream consists of thickening and dewatering by gravity belt thickeners and centrifuges, before the dewatered sludge is removed to landfill.

Figure 1: Process Flow Diagram



FLOW RATE SUMMARY

STREAMS	RAW WW	INLET PS	FEED TO ASR	A-RECYCLE	MEM. FEED	RAS RETURN	MEM. PRODUCTION	OUTFALL PS	WAS	GBT FEED Note 6	GBT FILTRATE Note 6	TWAS Note 6	SLUDGE CAKE Note 6	CENTRATE Note 6	FOUL WATER
NUMBER	1	2	3	4	5	6	7	8	10	11	12	13	15	16	17
STAGE 1 AVERAGE (m^3/d)	4842	5285	5285	16947	23980	19365	5073	5073	213	210	176	37	10	27	240
STAGE 1 PK MONTH (m^3/d)	6778.8	7310	7310	20336.4	33607	27110	7000	7000	310	310	253	57	15	38	240
STAGE 1 MAX DAILY (m^3/d) (WET WEATHER)	20590	21078	21078	61770	73917	53530	20818	20818	260 Note 5	260 Note 5	218 Note 5	42 Note 5	12	30	240
PEAK INSTANT FLOW (L/s)	429	460 Note 1	460	220 Note 2	800 Note 2	1112 Note 3	283 Note 4	340	6	15	13	3.3	0.8	2.2	-

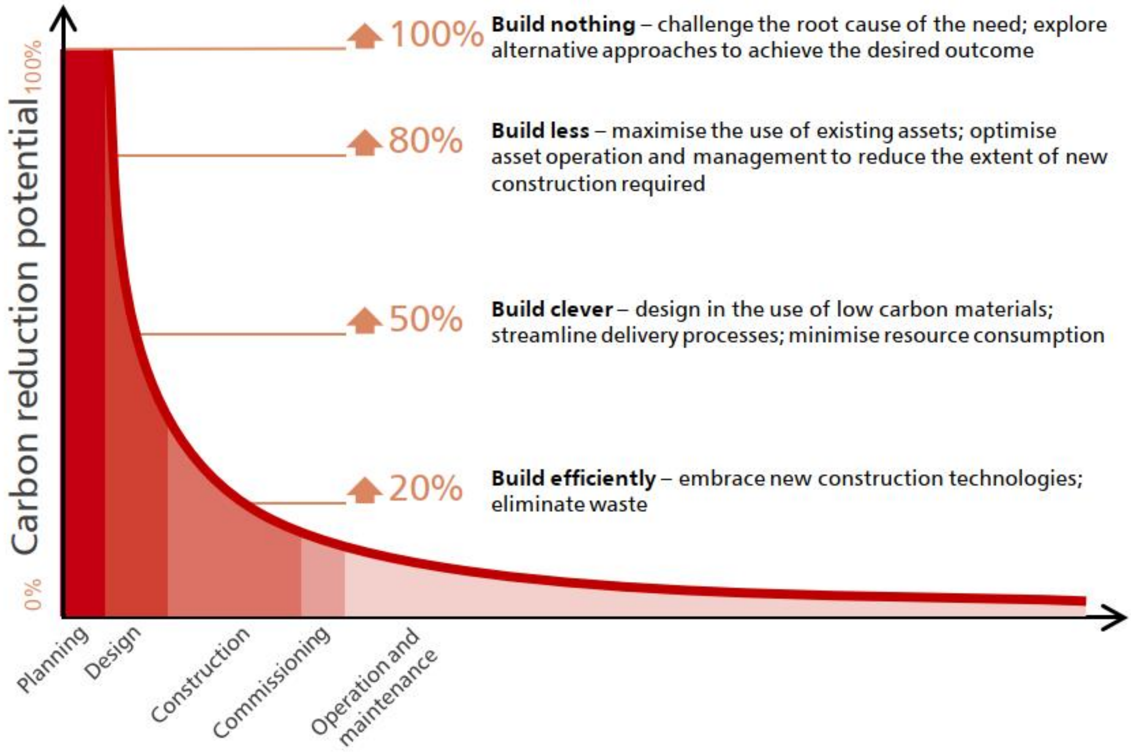
Following the development of the process and mechanical design, Watercare engaged Mott MacDonald as designer and Fletcher Construction Company to provide pricing and early contractor involvement (ECI) through Watercare's Enterprise Model. The first stage of the ECI identified that the capital cost of the scheme would substantially exceed the project budget. The decision was therefore taken to carry out a value engineering exercise in order to identify opportunities to make significant cost savings to bring the project cost estimate into line with the project budget.

2. DISCUSSION

2.1 COST SAVING HEIRARCHY

In order to identify cost savings for the project, the design team adopted an approach based on the carbon reduction curve shown in Figure 2.

Figure 2: Carbon reduction curve (Enzer et al (2013))



While this methodology was developed with the intention of reducing the capital carbon associated with infrastructure delivery, the principles apply to cost saving. Opportunities for savings in infrastructure projects can be categorized in a hierarchy as follows:

1. **Build nothing**: these opportunities are only available early in the project definition stage. At this stage the need must be robustly challenged, to ensure that the project is required and that new infrastructure is required to meet the need.
2. **Build less**: once the decision is taken that new infrastructure is required, build less opportunities are defined in the early development of a design solution. The project drivers and requirements must be clearly defined to identify solutions which meet the need efficiently, with the minimum new infrastructure. During these early stages, opportunities should be identified to maximise the use of existing assets, in order to reduce the new infrastructure required.
3. **Build clever**: Once a solution has been selected, explore the use of alternative materials in order to reduce costs.
4. **Build efficiently**: The solution is well defined at this stage and the focus is on selecting construction technologies and methods which are cost efficient.

It was clear from this hierarchy, that in taking the existing process and mechanical design, opportunities for savings would be limited predominantly to "Build clever" and "Build efficiently" solutions, as the design was well advanced and fixed.

In parallel with the value engineering review carried out by the design team. The ECI contractor also carried out a review, to identify potential savings by alternative or innovative construction methods. This not only looked at the Wastewater Treatment Plant Construction contract, but also considered associated contracts to upgrade the site access road and a package of early earthworks which was scheduled to be carried out in advance of the Wastewater Treatment Plant Construction.

2.2 OPPORTUNITY IDENTIFICATION

2.2.1 PROCESS DESIGN REVIEW

As shown in figure 2, the opportunities for cost savings diminish as a project progresses and the solution becomes more defined. The first stage of the value engineering process therefore involved a review of the process design.

By revisiting the process design, the intention was to unlock "Build less" opportunities, which would facilitate higher levels of cost savings than only "Build clever" and "Build efficiently" solutions.

As well as the process design, "Build less" opportunities could be accessed by challenging elements of the existing design philosophy, such as the consideration of reduced building footprints by challenging some of the project requirements and historic decisions with a Capex saving focus.

The review of the process design confirmed that the selected process solution was appropriate to meet the discharge consent. The design appeared to be a robust solution, with well considered operability and robust redundancy. A number of areas were however identified which could yield substantial opportunities for savings

Table 1: Design opportunities longlist

Category	Option	Description	Potential Cost Savings	Potential Programme Savings	Complexity
Build nothing	No options	Do nothing options will not meet the project requirements	N/A	N/A	N/A
Build less	Flow balancing	Balancing of incoming wet weather flows to the works may reduce the required capacity of treatment process units. Potential to reduce sizes of structures and equipment throughout the WWTP.	High	Low	Medium
Build Less	Solids handling process	Opportunities to provide a rationalised solids handling process may provide significant cost savings.	High	Low	Medium
Build Less	Eliminate Primary Screening	Remove coarse screening treatment stage from inlet works, it may not be necessary based on influent and proposed process.	Medium	Medium	Low / Medium

Category	Option	Description	Potential Cost Savings	Potential Programme Savings	Complexity
Build Less	Remove chemical dosing	Proposed chemical dosing may not be required to achieve discharge consent. Remove acetic and alkalinity dosing and provide facility to install in future if required to achieve the discharge consent. Also consider build offsite packages for chemical dosing which is deemed necessary.	Medium	Medium	Low / Medium
Build Less	Eliminate sludge thickening	Other elements of the process on site may be capable of producing thickened sludge, without the requirement for independent sludge thickeners	Medium	Medium	Low / Medium
Build Less	Eliminate UV dosing	UV dosing may not be required to achieve discharge consent. Remove UV dosing and provide facility to install in future if required to achieve the discharge consent	Low	Low	Low
Build Less	Reduced building scope	Consider the scope requirements for the process and administration building and identify opportunities to reduce the scale of the buildings. Consider packaged equipment and locating equipment outside.	Medium	Low	Low
Build Clever	MBR Packaged Plants	MBR tanks can be provided as DfMA solution, reducing construction time on site.	Low	High	High
Build Clever	MBR on top of ASR	Packaged MBR tanks constructed on top of ASR tanks, (if no planning issues).	Low	Low	High
Build Clever	Gravitate from ASR to MBR	Adjust structural levels to allow gravity flow between ASR and MBR to remove interim pumping between processes.	Low	Low	Medium / High
Build Clever	Packaged Inlet works	Consider provision of inlet works as packaged solution with stainless steel tanks instead of in situ reinforced concrete construction	Medium	High	Low
Build Clever	Inlet PS construction method	Consider provision of the inlet pumping station as a circular shaft instead of a rectangular structure. This provides opportunities for efficiencies in construction, particularly in the temporary works for the pumping station excavation.	Medium	Medium	Medium

At a high level the options were provided with a comment on potential cost savings, programme savings and the complexity to incorporate them into the design.

2.2.2 CONSTRUCTION OPPORTUNITIES

As noted above, the Contractor also completed a review of the project for cost saving opportunities. A key point to note, is that to identify efficiencies, the contractor considered a wider programme of works for efficiencies. By considering the early earthworks, adjacent road upgrades and wastewater treatment plant as a common programme of works, the Contractor was able to identify several areas for significant efficiencies.

Several of the opportunities identified by the Contractor aligned with items raised in the design review, however several unique opportunities were raised:

1. Utilise an existing commercial building or warehouse in Warkworth as a site office hub to mitigate traffic delays through Hill Street intersection and provide an area where plant can be fabricated off site to be fully ready for efficient installation on site.
2. Provide continuity from enabling works through to delivery of the main treatment plant construction contract to avoid mobilizing to site twice.
3. Minimise removal of fill from site through landscaping and re-use of materials as far as practicable. This could be supported by delivering the treatment plant earthworks in parallel with adjacent access road upgrades.
4. Consider raising both the ASR and MBR tanks above finished ground level to reduce earthworks and temporary works in construction
5. Consider ground improvement or piled foundations instead of preloading to mitigate poor ground conditions, reduce risk and improve efficiency in construction
6. Adjacent access road works involve installation of new large culverts, consider providing culverts as PE to allow prefabricated internal features and quick installation

The options identified in the design and construction review were presented in a workshop with the design team, Watercare, their operations team and the Contractor to review the feasibility of the options. The discussions covered technical feasibility, operational impacts and constructability.

From these discussions, the options were categorized as follows:

1. Shortlisted for further development prior to progressing the main works contract
2. To be considered during delivery of the main works contract
3. Not to be progressed

The shortlist for further development, then defined the scope of works for a specific value engineering contract.

2.3 VALUE ENGINEERING INVESTIGATIONS

As noted above, the shortlisted options were then progressed to a more detailed level of investigation to identify their feasibility, this stage involved development of concept designs for the opportunities which were costed by the Contractor.

2.3.1 PEAK FLOW BALANCING

During the more detailed review of the treatment plant capacity a discrepancy was identified in the design capacity of the plant. The inlet pumping station and inlet works were all sized to pass the peak instantaneous flow of approximately 7.5 times the average daily flow (ADF). The MBR plant had however had its capacity reduced to the maximum daily flow (MDF) of approximately 4.3xADF. While this limited the opportunity to further reduce the capacity of the plant, it identified a key issue in the design which required rectification. In order to manage the reduced MBR capacity, an operational overflow upstream of the biological treatment process would be required. This overflow could therefore be located in the following locations:

1. The inlet pumping station
2. Downstream of the inlet works

Locating the overflow in the inlet pumping station would provide the opportunity to reduce the size of the inlet pumps, coarse screening, grit removal and fine screening. Reduction in the size of the inlet works would represent a significant opportunity, however an undersized inlet works would be a large operational risk. This therefore required a more detailed understanding of the incoming flows to assess the level of this risk.

To assess the risk associated with a reduced capacity inlet works, it was necessary to re-visit the plant design basis, population growth data and regional rainfall data. This would allow the design flows to be validated, and to assess the likelihood of overflow events in various design scenarios.

It was agreed that the population growth forecasts for the project remained valid. This removed a potential variable from the assessment of the flow data which allowed for a more efficient review.

Influent flow data from the existing Warkworth and Snells Beach WWTPs were reviewed in conjunction with rainfall data obtained from the NIWA Climate Database to gain an understanding of the impact of rainfall events on the flows at the existing treatment plants. A direct correlation was established for both catchments between rainfall and flows recorded.

These existing, measured flows were extrapolated based on the growth rate projections which had been evaluated in the original design basis. This gave new estimates for the total flows at each stage of the design horizon. These new flows were used to review the volume and frequency of overflow events based on two treatment plant capacities 3xADF (reduced capacity) and 4.3xADF (4.3ADF capacity to align with the MBR plant). The outcome of this exercise was presented in the Table 1.

Table 2: Estimated number and duration of overflow flow events from 2025-2035

Flow to Treatment	2025								2030								2035							
	3.0x ADF				4.3x ADF				3.0x ADF				4.3x ADF				3.0x ADF				4.3x ADF			
m³/hr	> 605 < 1,240	Overflow (m³)			> 868 < 1,240	Overflow (m³)			> 605 < 1,410	Overflow (m³)			> 868 < 1,410	Overflow (m³)			> 605 < 1,576	Overflow (m³)			> 868 < 1,576	Overflow (m³)		
Duration (hrs)	No.	Max	Ave	Min	No.	Max	Ave	Min	No.	Max	Ave		No.	Max	Ave	Min	No.	Max	Ave	Min	No.	Max	Ave	Min
1	7	65	25	2	2	315	294	273	13	115	50	4	4	345	302	276	9	172	64	5	6	182	90	40
2	7	293	123	30	2	889	831	774	6	468	191	77	2	718	638	558	7	643	225	25	6	394	148	30
3	1	112	112	112	2	1,227	1,087	948	1	404	404	404	2	1,447	1,229	1,011	4	362	255	118	1	1,001	1,001	1,001
4	9	1,381	530	114	3	1,640	1,476	1,381	4	777	636	407	2	1,824	1,566	1,308	2	1,110	900	690	2	1,219	934	649
5	2	817	528	239	1	2,644	2,644	2,644	5	1,265	757	444	4	3,305	2,524	2,152	3	1,713	1,037	267	1	629	629	629
6	1	1,079	1,079	1,079	2	2,634	2,500	2,366	1	645	645	645	1	3,365	3,365	3,365	3	1,096	916	559	1	2,714	2,714	2,714
7	1	2,793	2,793	2,793	0	#N/A	#N/A	#N/A	2	3,613	2,042	472	2	3,363	3,165	2,968	2	1,182	1,182	1,182	2	2,566	2,225	1,884
8	2	2,843	2,005	1,168	2	3,800	3,770	3,740	2	3,739	2,212	685	0	#N/A	#N/A	#N/A	2	1,263	1,132	1,001	3	2,363	1,429	463
9	1	2,033	2,033	2,033	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	2	5,125	5,074	5,022	1	4,502	4,502	4,502	1	3,755	3,755	3,755
10	2	3,933	3,148	2,363	0	#N/A	#N/A	#N/A	4	5,097	3,436	1,873	0	#N/A	#N/A	#N/A	3	6,261	5,126	4,419	0	#N/A	#N/A	#N/A
11	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	1	2,935	2,935	2,935	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
12	1	4,475	4,475	4,475	0	#N/A	#N/A	#N/A	1	5,844	5,844	5,844	0	#N/A	#N/A	#N/A	2	7,213	5,815	4,418	2	4,065	3,657	3,249
13	1	3,891	3,891	3,891	0	#N/A	#N/A	#N/A	1	2,126	2,126	2,126	0	#N/A	#N/A	#N/A	2	2,912	2,417	1,922	0	#N/A	#N/A	#N/A
14	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
15	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	1	5,361	5,361	5,361	0	#N/A	#N/A	#N/A	1	6,869	6,869	6,869	0	#N/A	#N/A	#N/A
16	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	1	3,219	3,219	3,219	0	#N/A	#N/A	#N/A
17	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	1	4,661	4,661	4,661	0	#N/A	#N/A	#N/A
18	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
19	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
20	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
21	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
22	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
23	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
24	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A
≥ 25	1	4,366	4,366	4,366	0	#N/A	#N/A	#N/A	1	6,899	6,899	6,899	0	#N/A	#N/A	#N/A	1	9,473	9,473	9,473	0	#N/A	#N/A	#N/A
Total No. Events	36				14				43				19				44				25			
No. Events per year	18				7				21.5				9.5				22				12.5			
Max duration (hrs)	>25				8				>25				9				>25				12			

Both cases showed a significant number of overflow events per year. The decision was taken that the number of overflows for both cases would be excessive for unscreened sewage. The decision was therefore taken to maintain the inlet pumping station and inlet works capacity at the peak instantaneous flow of 7.5ADF and include the works operational overflow downstream of the inlet works.

While the opportunity to reduce the capacity of the works appears to have already bene incorporated in the MBR plant design, the principles should be considered in the definition and design of WWTPs. Wet weather flows should be carefully considered in the sizing of treatment plants. The sizing of equipment for peak flows which are heavily influenced by rainfall can have a significant impact on both capital and operational costs of a scheme. While in this case the storage of unscreened wet weather flows was not considered to be appropriate, a purpose built storm storage facility can be designed with measures to prevent odour release and facilitate washdown after use.

2.3.2 SLUDGE STRATEGY

The original design included a mechanical dewatering system which consisted of:

- 600m³ Waste Activated Sludge (WAS) Tank (complete with mixer pumps and thickener feed pumps)
- Duty / Standby Gravity Belt Thickeners (sized for future flows)
- Duty / Standby Centrifuges (sized for future flows)
- Duty / Standby Conveyors associated with the centrifuges
- Polymer dosing systems
- Dewatering building
- Self levelling sludge cake bins

While this design provided a robust solution for solids handling it was a high cost solution. The requirements for sludge disposal from the new site are understood to be a sludge cake with a minimum solids content of 18-20%.

On this basis, a number of options were reviewed to minimize the sludge handling infrastructure:

1. Repurpose existing ponds as WAS storage
2. Repurpose existing ponds as drying beds
3. Dewater sludge in a single stage by centrifuge

Options 1 and 2 involved repurposing elements of the existing Snells WWTP process in order to store sludge. The option for utilization of the pond as WAS storage would require sectioning off a small section of the existing pond to utilize for storage. This would however require covers to capture odours and prevent rain ingress. The stored WAS would require mixing and this would still involve the construction of the mechanical dewatering system.

Re-purposing of the existing pond as a drying bed would remove the WAS tank, the dewatering building and all of the mechanical dewatering equipment. Although this option would require capital works to convert the existing pond, it would still represent the minimum Capex option, with substantial savings when compared with the costs associated with the mechanical dewatering system. It was however noted, that while this is the minimum Capex option, it would have increased perational costs involved in desludging of the drying beds.

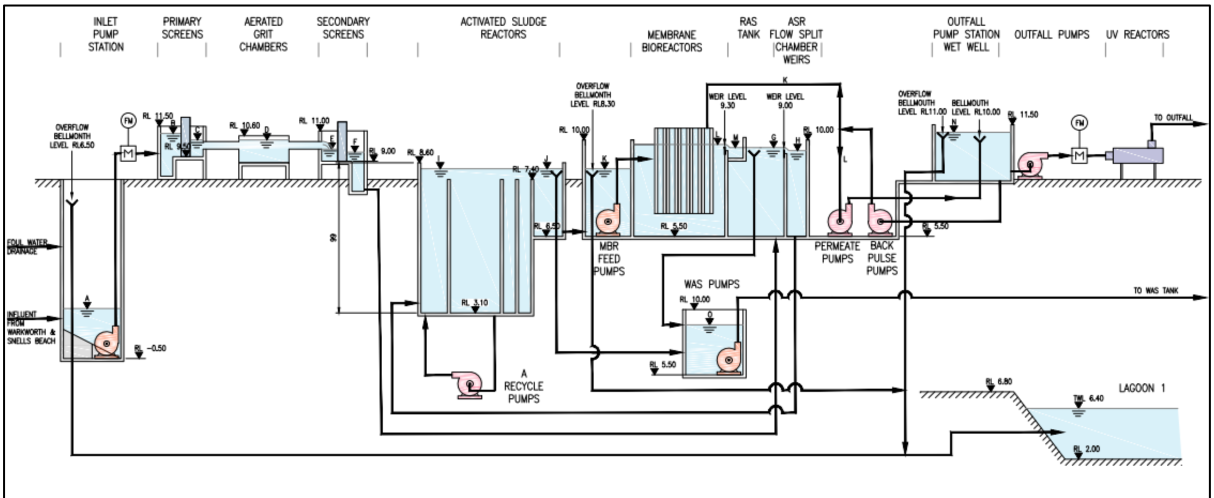
Through liaison with suppliers, it was identified that there are a number of products available which could dewater WAS from 1% solids (Estimated solids content of WAS from MBR) to the 18-20% required for disposal from site. This option would still include WAS storage and a building to house the dewatering equipment.

The sludge drying beds were therefore selected as the preferred option, due to the Capex driver of the project. It should however be noted that if evaluated on a whole life basis, an alternative option would be preferred. This selection is currently under review as it is felt that further consideration of the whole life cost and construction programme may drive the decision to a reduced scope mechanical dewatering solution.

2.3.3 REVISED HYDRAULIC PROFILE

Opportunities were identified from both a design and construction perspective associated with modifications to the works hydraulic profile. In having both the design and ECI team working together it has been possible to address constructability concerns concurrently with the design development.

Figure 3: Original Design Hydraulic Profile



LOCATION	DESCRIPTION	STAGE 1 ADF			STAGE 1 MWWF		
		Flow (L/s)	BWL (m)	TWL (m)	Flow (L/s)	BWL (m)	TWL (m)
A	INLET WET WELL	56	0.40	2.00	430	0.40	2.00
B	COARSE SCREEN INLET CHANNEL	56	10.42		430	10.90	
C	COARSE SCREEN OUTLET CHANNEL	56	10.22		430	10.70	
D	AERATED GRIT TANKS	56	9.95		430	10.45	
E	FINE SCREEN INLET CHANNEL	56	9.36		430	10.15	
F	FINE SCREEN OUTLET CHANNEL	56	9.13		430	9.94	
G	RAS TANK (RAS PLUS INFLUENT FLOW RATE)	224	9.12		800	9.28	
H	ASR FLOW SPLIT OUTLET CHAMBERS (FLOW RATE PER ASR)	112	7.66	8.11	400	8.35	8.70
I	ASR ANOXIC ZONE 1 (FLOW RATE PER ASR)	195	7.62	8.10	483	7.90	8.20
J	ASR OUTLET CHANNEL OUTLET	224	7.41	8.10	800	7.60	8.17
K	MBR FEED PUMP CHANNEL (FLOW RATE PER MBR)	112	7.40	8.10	200	7.40	8.00
L	MBR TANK (PERMEATE FLOW RATE PER MBR)	28	9.37		108	9.37	
M	RAS CHANNEL (FLOW PER MBR)	84	9.12		93	9.31	
N	OUTFALL PUMP STATION WET WELL (OUTFALL PUMP FLOW RATE)	56	8.00	11.00	340	8.00	11.00
O	WAS WET WELL	6	6.50	9.12	6	6.50	9.28

The construction team noted that the depth of the ASR and MBR structures would require extensive temporary works in poor ground conditions. Reduction in the depths of these structures would result in reduced risk and costs during construction.

The design also noted that the MBR design included a pumped feed. This would result in double pumping of the full treatment flow through the works, as it has already been lifted by the inlet pumping station. The decision was therefore taken to aim to reduce the depth of the structures in parallel with facilitating gravity flows from the ASR through the MBR. In order to do this in a single stage of pumping it would be necessary to raise the level of the inlet works above ground level.

The alternative approach to provide gravity flow from the ASR to the MBR, would be to maintain the inlet works level and to provide an interstage pumping station between the inlet works and the ASR. While this would provide the maximum degree of flexibility in the levels of the ASR and MBR tanks, it would result in high ongoing opex costs of two stage pumping of the full flow to treatment, in addition to the capex costs of a second large pumping station. For this reason it was considered that the preferred option for modifying the hydraulic profile would be to raise the inlet works.

Raising of the inlet works would involve increasing the head pumped by the inlet pumping station, however this was considered to be preferable to an additional pumping station.

2.3.4 PACKAGED INLET WORKS

In parallel with the review of the levels of the inlet works, the supply chain were engaged to discuss the feasibility of providing the inlet works as a packaged solution with stainless steel tanks instead of in-situ reinforced concrete structures.

For an inlet works at ground level, this represents a significant opportunity as inlet works are typically a reasonably complex in situ concrete structure which is both time consuming and costly to construct. The construction of in-situ concrete inlet works also presents challenges in terms of construction tolerances, screens, penstock rebates and stoplog rebates are all typical requirements within inlet works channels which add complexity and risk during construction. This packaged solution is feasible for a plant the scale of the Snells WWTP.

The provision of a prefabricated stainless steel inlet works as part of a package supplied by the screen supplier, minimizes the risk during construction and also provides a solution which can be constructed rapidly on site.

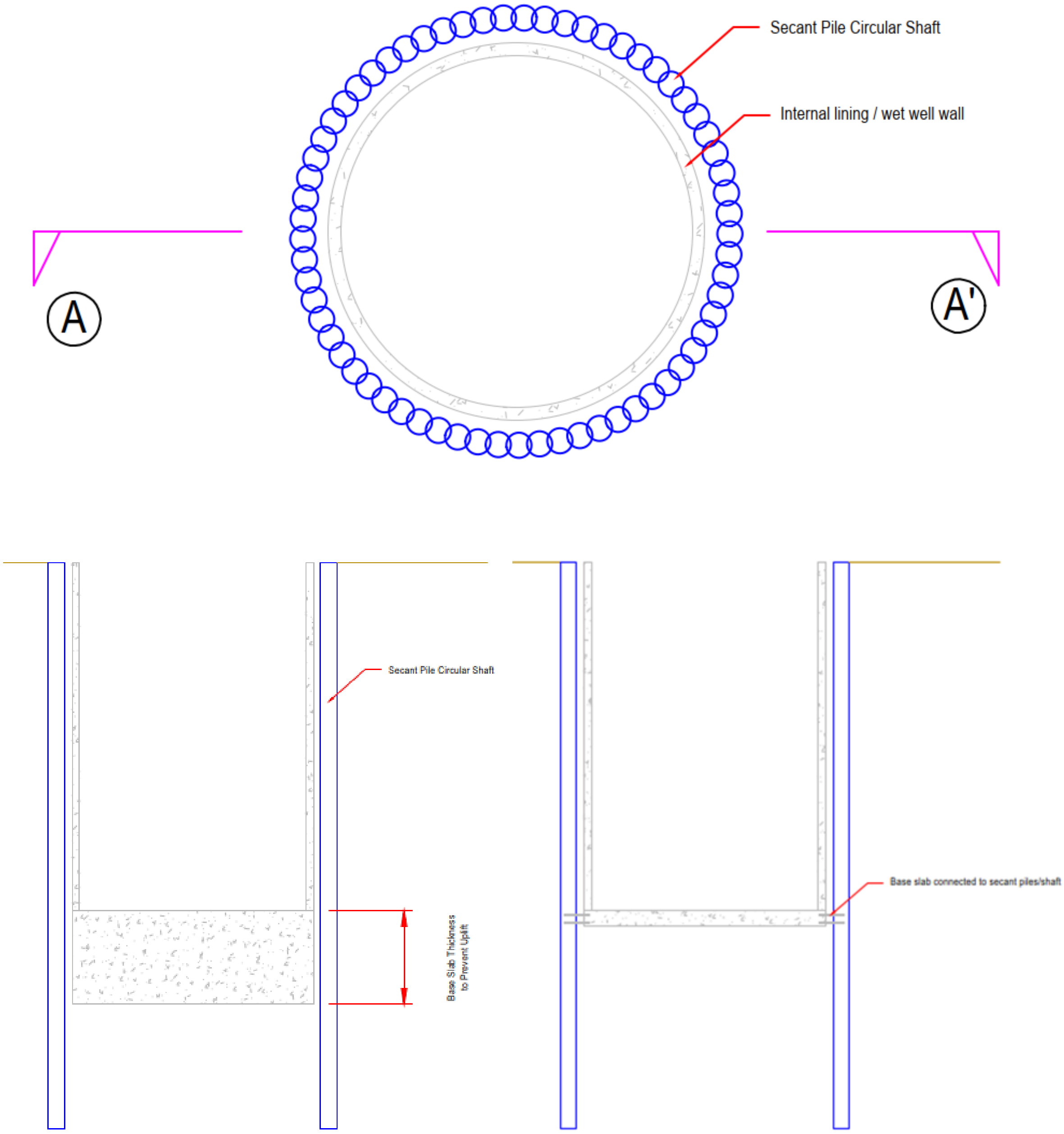
The decision to raise the inlet works further amplifies the benefits associated with stainless steel tanks, as the weight of the structure to be supported is significantly reduced. Stainless steel tanks can be supported on simple braced steelwork frames which are quick to construct with relatively low risk.

2.3.5 INLET PUMP STATION

While the original design proposed a rectangular wet well structure for the inlet pumping station, this was considered to have high temporary works costs for the construction. A circular shaft was considered to be a more effective approach as this would be constructed using a secant pile wall as the temporary works. The secant piles would be constructed quickly and reduce the construction risks associated with the shaft excavation.

A deep shaft will generally require a thick concrete base plug to provide additional weight resistance against buoyancy due to groundwater. Due to the close working relationship between the design and construction teams, an opportunity was identified to utilize the weight of the secant piles to resist buoyancy. In traditional secant pile shaft construction, the piles would be utilized only to provide temporary support to the excavation and to prevent groundwater ingress to the excavation. The permanent works would then be constructed within the secant piles forming a monolithic structure rather than two independent structures.

Figure 4: Typical shaft design (left) vs. proposed solution (right)



SECTION A-A'

SECTION A-A'

Coordinating the permanent and temporary works design will allow the weight of the secant piles to be tied into the permanent shaft structure, which will remove the need for an excessively thick base plug. This is estimated to remove approximately 380m^3 of concrete, which would have an equivalent carbon footprint of 300tCO_2e.

The delivery of this opportunity is made possible through the close collaborative working of the design and construction teams. The approach which will be taken is for the design team to carry out the design of the permanent shaft including the secant piles. This will then be shared with the temporary works designer to review the secant pile design to ensure that the piles are suitable for the temporary works requirements.

2.3.6 GROUND IMPROVEMENT STRATEGY

The site for the new treatment plant has poor ground conditions. Some areas of the site have been filled extensively with undocumented fill which overlies a thick layer of settlement prone soils.

The original design included an extensive programme of excavation and removal of uncontrolled fill and unsuitable material, replacing with improved fill. Followed by an extended period of preloading to induce settlements. The preloading period would create an extended period where works on the WWTP site would be unable to progress, the Contractor would therefore be required to demobilize from site, then remobilize at the commencement of the main contract works. In order to facilitate a continuous programme of work, it was necessary to review alternative ground improvement methods which would remove the preloading period.

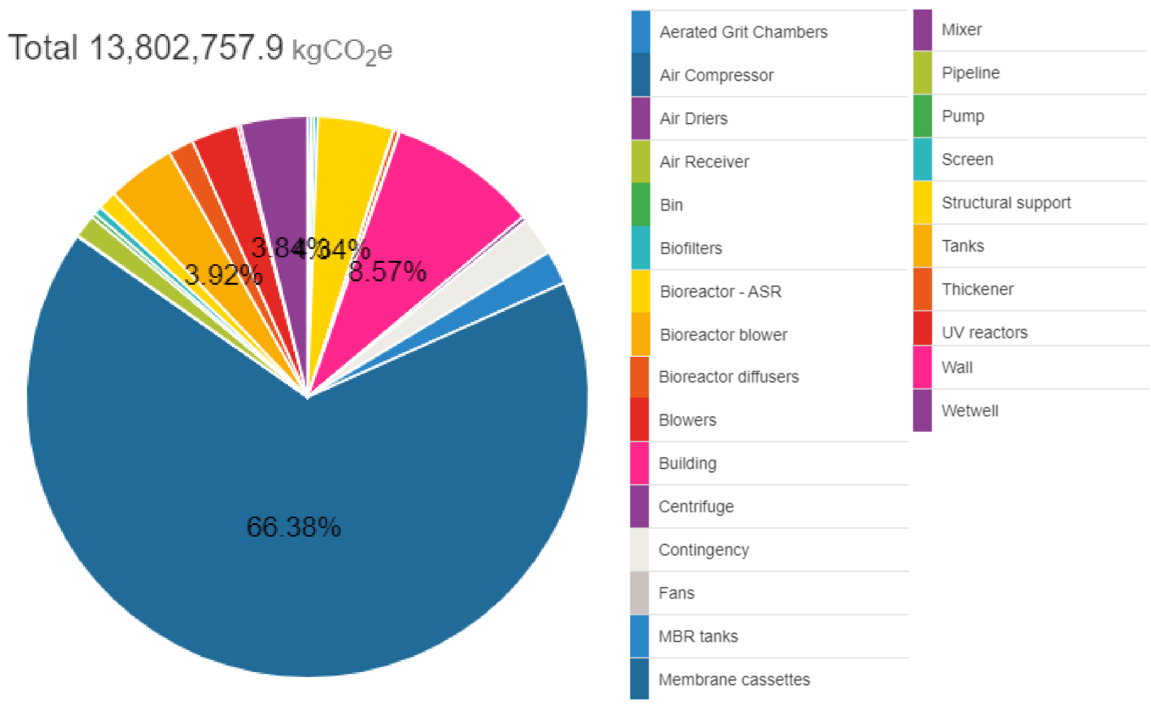
Several options to remove the need for preloading were identified and collaboration between the design team and the ECI contractor has been key in developing an effective project solution. The most applicable options were identified as cement stabilization of the soils (either by in-situ or ex-situ mixing) or an extensive regime of undercutting, removal of unsuitable materials and replacement with imported, compacted gravel. Cement stabilization of the existing soils will minimize the quantity of materials to be removed and imported to site. This will substantially reduce vehicle movements required during the enabling works.

In addition to the reduced vehicle movements, the ground improvement through soil stabilization has been identified to provide a significant opportunity for construction efficiencies. Stabilization of the soils will reduce the need for temporary works during minor excavation works for construction and provide a good quality working platform throughout the construction programme. Due to the various benefits highlighted, ground improvement by cement stabilization has been selected as the preferred option for the project.

2.4 CARBON BASELINE

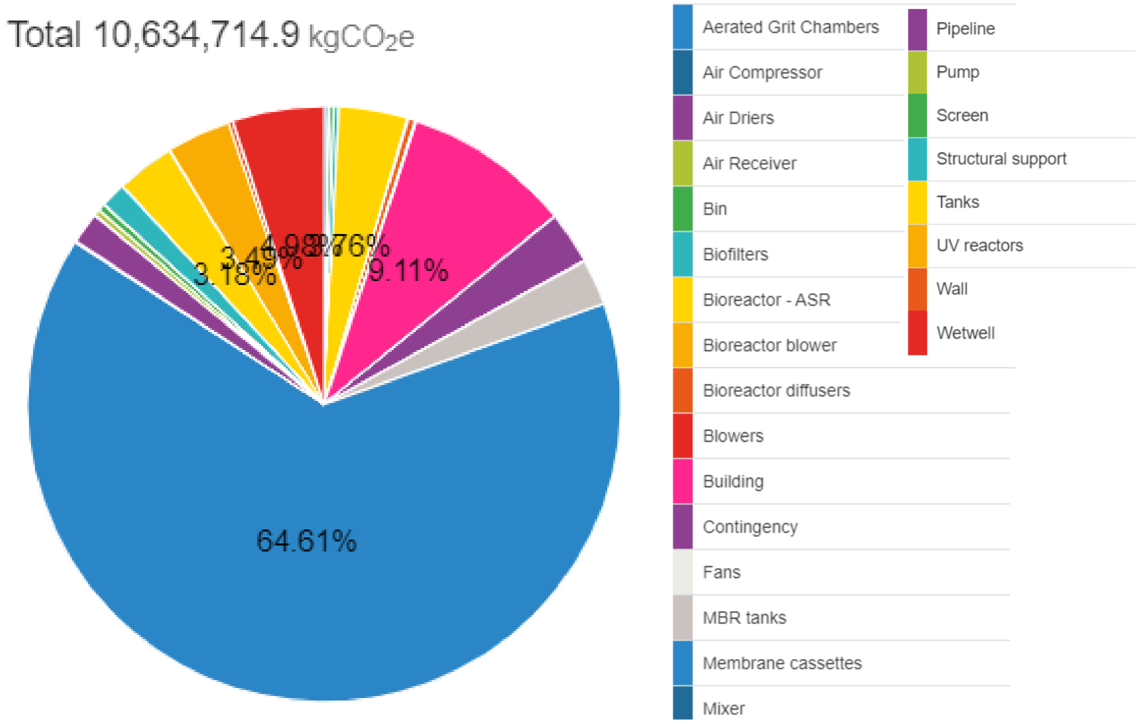
The embodied carbon content for the project scheme has been modelled using the Moata carbon portal before and after the changes adopted from the value engineering process. The cumulative impact of the value engineering changes implemented so far have resulted in approximately 20% reduction in the embodied Carbon of the scheme.

Figure 5: Estimated embodied carbon before value engineering



Total 13,802,757.9 $kgCO_2e$
3.84%
3.92%
8.57%
66.38%
Aerated Grit Chambers
Air Compressor
Air Driers
Air Receiver
Bin
Biofilters
Bioreactor - ASR
Bioreactor blower
Bioreactor diffusers
Blowers
Building
Centrifuge
Contingency
Fans
MBR tanks
Membrane cassettes
Mixer
Pipeline
Pump
Screen
Structural support
Tanks
Thickener
UV reactors
Wall
Wetwell

Figure 6: Estimated embodied carbon after value engineering



The embodied carbon of the scheme is being monitored as the scheme develops and is taken into consideration in project decision making. An example of this has been the selection of timber post and panel retaining walls across the site, instead of a concrete post and panel system. The timber retaining walls are estimated to provide a carbon sequestering effect which has not been factored into the current embodied carbon estimates.

2.5 CURRENT STATUS AND NEXT STEPS

The savings identified through this value engineering process totaled approximately $20M; over 20% of the original construction cost estimate. The savings identified were sufficient to bring the project cost estimate within the clients budget and allow the project to proceed.

The project is currently progressing into detailed design and construction delivery. As well as the ongoing Capex drivers the project is also being targeted for accelerated construction.

The detailed design is progressing with a continuing high level of collaboration between the Contractor, Designer and Client. Team members from all parties are co-locating to share information and progress key project decisions in a timely manner. The collaborative approach continues to be facilitated by the Watercare Enterprise Model which has allowed the Contractor to be fully engaged to support the design from an early stage.

3. CONCLUSIONS

The value engineering works on this project were highly effective in identifying opportunities for cost savings. It has only been possible to achieve this level of cost saving through the close collaboration between the design team, the Contractor and the Client.

From a process perspective it is key to note that definition of the required design flows, wet weather influence and project staging are key factors. Design flows heavily influenced by wet weather can require a high level of Capex investment for equipment which will infrequently be used. This equipment may require ongoing maintenance throughout the design life, regardless of the frequency which it is used.

As already noted, the largest opportunities for cost and embodied carbon savings are in the early stages of project inception and delivery. In order to achieve the maximum value from all parties, obtaining inputs from both designers and Contractors in the project inception early design stage is key. Early inputs from the Contractor can reduce the risk of design rework as constructability can be fully considered throughout the design development. Early engagement with the supply chain can also assist in the identification of opportunities through their knowledge of specific products and the applications.

REFERENCES

Enzer, M., Manidaki M., Radford J., Ellis T. (2013) '*Infrastructure Carbon Review',* HM Treasury, London, 11.