# REPORT

**Opuha Water Ltd**

**Opuha Downstream Weir Enhancement Mini hydroelectric generation opportunity**

Tonkin & Taylor

ENVIRONMENTAL AND ENGINEERING CONSULTANTS

# REPORT

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**Report prepared for:**

Opuha Water Ltd

**Report prepared by:**

Tonkin & Taylor Ltd

**Distribution:**

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# Executive summary

An opportunity exists to install a small generating plant at the Opuha Dam Downstream Weir (ODDW). Construction co-incident with that of the adjacent radial gate minimizes costs. In addition to the financial return obtained, a hydropower plant provides a key non-financial benefit in that OWL can be seen by both ECan and the public to use water efficiently by generating power where possible. The following table compares salient features of the three identified short listed generating plant options:

| **Plant vendor** | **Ossberger** | **Crosstech** | **Hydroworks** |
|---|---|---|---|
| Turbine type | Crossflow | Crossflow | Tubular Kaplan |
| Place of manufacture | Germany | Christchurch | Christchurch |
| Turbine complexity | Simple | Simple | Complex |
| Technology risk | Fully proven | Proven, but some upscaling required | Custom prototype gearbox (New Technology) |
| Project cost | $1,850,000 | $1,310,000 | $1,900,000 |
| Foreign Exchange | Yes | No | No |
| Generation | $165,000 (141%) | $117,000 pa (100%) | $184,000 (163%) |
| Financial return (IRR) | 8.1% | 8.3% | 8.6% |

The above financial returns are sensitive to assumptions regarding power price, project cost, plant reliability, and water flows. The above relative financial ranking is easily altered by unexpected problems resulting in lost generation and increased operational and maintenance costs. Hence proven and simple technology offers better generation certainty and we believe these benefits heavily influence the turbine decision given the relatively equal theoretical investment returns.

Consequently, provided that the financial return meets OWL's requirements, then this report recommends a crossflow turbine, either Ossberger or Crosstech depending on the relative importance attached to higher resource utilization and generation (Ossberger), versus local manufacture (Crosstech).

# 1 Introduction

## 1.1 Background

The proposed ODDW Enhancement involves construction of a new radial gate structure within the Closure Embankment near the true right hand side (looking downstream) of the existing structure. The proposed gate structure will require a slot to be excavated through the existing Closure Embankment. In order to construct the works, a coffer dam is necessary to isolate the construction site and to enable flows to be conveyed through the ODDW dam construction.

This proposal considers the opportunity to install a mini hydroelectric power station within the ODDW coincident with the gate structure works in order to take advantage of the coffer dam and excavation through the Closure Embankment. Depending on the generating plant option selected the proposed power station would have a peak capacity of around 300 or 450 kilo Watts, sufficient to service around 200 or 300 households respectively. The existing power station at the dam has a capacity of 7.5 MW, approximately 20 times greater than the hydroelectric power station proposed for the ODDW.

## 1.2 Scheme general arrangement

The proposed hydroelectric power station would involve the key following components:

i. A penstock passing through the Closure Embankment. The penstock inlet is screened and is located deep enough to mitigate vortex formation and air entrainment;

ii. A turbine and generator near the toe of the reformed Closure Embankment. The top of the concrete enclosure is set to mitigate flood risk. Because of limitations associated with the turbine operation, it is necessary to locate the turbine below finished ground level in the concrete structure. Limitations relate to hydraulic conditions (eg internal pressures) necessary for the turbine to function in the correct manner.

iii. A draft tube will discharge generation flows into a tail race adjacent to the proposed radial gates' stilling basin;

iv. Transformer and a new 11 kV overhead line approximately 800 m long from the proposed power station to the existing Allendale pumping station.

Appendix A overviews in more detail some specific parameters adopted for the analysis, and Appendix C presents general layout drawings.

In very broad terms the arrangement would be similar in concept to the layout at the main dam, that is, a pipe buried at the base of the embankment with a turbine below ground level near the downstream toe of the embankment.

## 1.3 Report contributors

This report is a collaborative effort between MTL, MECL and T&T, with responsibilities for mechanical, electrical and hydrology/civil respectively. MTL, MECL and T&T responsibilities under their respective engagement contracts are not altered or extended in any way by the collaborative nature of this report.

# 2 Key assumptions and risks

## 2.1 Water availability

Flow available to generate electricity at the ODDW is based on analysis of records from the water level recorder situated just below the existing ODDW. Data over the period January 2000 to May 2014 provided by Environmental Consultancy Services has been considered. Analysis of the opportunity is reliant on these flows being available in the future in order to generate electricity.

The data indicates that since about November 2011 there is considerably more water available within the range of flows that may be utilised for generation. At this stage it is not totally clear if this is a consequence of changes in scheme operation/regulation at the dam or to additional rain. It is suspected that the additional water available within the generation flow range capability is a consequence of refined scheme operation. If the data over the period November 2011 to May 2014 is representative of the future long term average than there will be more income from generation than predicted by the longer data set (refer following and note that cases for utilising both data sets over the period January 2000 to May 2014 and November 2011 to May 2014 have been considered in subsequent analysis). Table 1 below summarises flow duration characteristics or the time that two power station options may be able to operate at peak capacity.

**Table 1: Generation flow duration characteristics - Opuha Downstream Weir**

| Peak generation flow capacity Note 2 | Indicative time that the turbine may operate at peak installed capacity Note 1 | |
|---|---|---|
| | January 2000 to May 2014 | November 2011 to May 2014 |
| 5.2 $m^3/s$ | 63.5 % | 76.8 % |
| 7.0 $m^3/s$ | 48.7% | 62.1 % |

Note 1 Equivalent to the percentage of time that a flow is equalled or exceeded. Turbine may operate at reduced capacity at other times. Excludes shutdowns and the like.

Note2 Applicable at average pond level. At higher and lower pond levels then the peak generation flow capacity of the 5.2 $m^3/s$ power station option is increased to 5.7 $m^3/s$, and reduced to 4.9 $m^3/s$, respectively

## 2.2 Resource consent matters

### 2.2.1 Consent application

The project (proposed gate structure and hydro add on) require a suite of resource consents from Environment Canterbury (ECan) and McKenzie District Council.

Resource consents have been submitted to both councils and in each instance the applications are being processed on a Non-notified basis. This avoids cost and time delays associated with a hearing process. Affected party signoffs are complete with the exception of ECan river engineering. In the resource consent we have asked for a commencement period of 10 years should the hydro not be installed as the same time as the proposed weir gates.

### 2.2.2 Penstock intake screen

ECan have insisted that the proposed penstock intake is screened with a relatively fine bar screen in order to exclude emigrating adult eels. ECan have specified a maximum opening of 20 mm between bars and stated that the average screen velocity may not exceed 0.5 m/s. This is a relatively stringent obligation that results in additional constraints and poses potential operational complications associated with screen cleaning.

### 2.2.3 Elver passage

A new elver pass is required adjacent to the proposed power station as base flows will pass through the proposed power station. The existing elver pass will therefore be isolated for long periods of time. OWL will take this opportunity and endeavour to provide more effective elver passage past the proposed hydroelectric power station than presently occurs on the original structure.

## 2.3 Head and Overflow Embankment considerations

Following construction of the new power station the ODDW pond will be managed in order to maximise pond water level/head to operate the new power station. It is important to note that increasing the pond level too far would have an adverse effect on the much larger existing facility.

Accordingly, assessment of the proposed opportunity is based on a maximum pond level of 0.75 m below the crest of the existing ODDW concrete weir. Whilst this assumption is consistent with documentation from the time of the original construction a little uncertainty remains associated with the maximum water level available for generation. If this assumption is incorrect there may be a little less power available than anticipated by the analysis set out in this summary.

In order to maximise the generation potential, the pond will be run as high as possible without compromising the efficiency of the existing power station and as required to attenuate flow releases to the river. With a consistently higher pond level there may be a slight increase in maintenance work on the fusible Overflow Embankment.

## 2.4 Rock level

Based on levels provided to T&T and limitations inherent with the turbines, the base of the draft tube is expected to be below rock level. A modest amount of rock excavation is required based on the rock head level inferred from ground penetrating radar information obtained during site investigations.

## 2.5 Power station configuration and noise

The power station would comprise a concrete structure substantially buried near the base of the closure embankment. Subject to the particular turbine adopted, the structure would be about 6 m by 6 m in plan. Concrete would extend to a little above existing ground level in order to provide flood protection to electrical and mechanical equipment. A light weight roof would be provided to protect against the weather and vandals. The roof would be designed to be able to be lifted off by hiab or excavator in order remove key pieces of plant for maintenance.

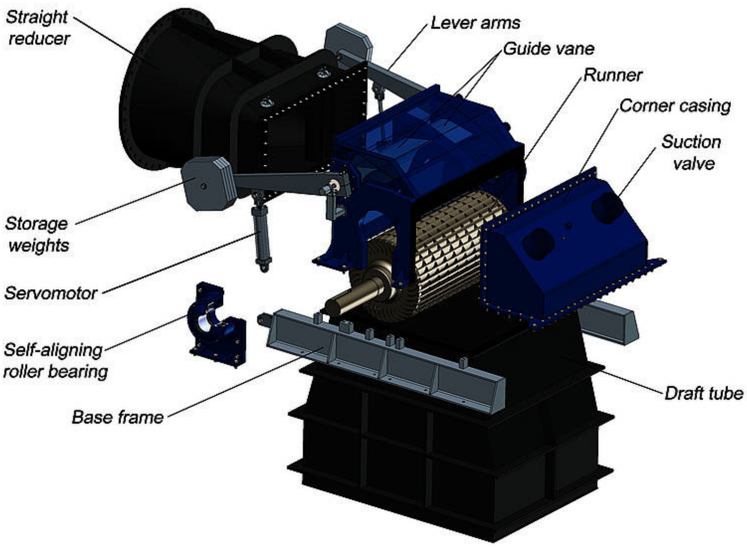
Plant noise has been reviewed with the potential generating plant vendors, and it appears not necessary for the power station to incorporate special provision for noise attenuation. Noise limitations will be included in the plant purchase contract.

## 2.6 Turbine

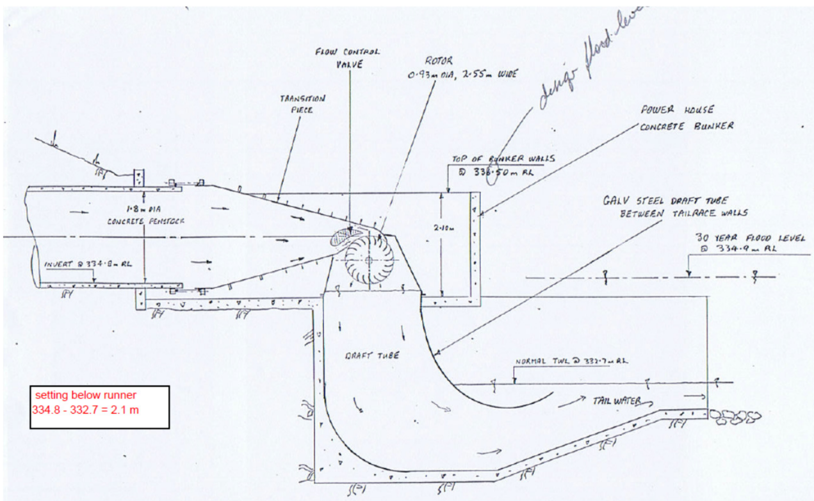
### 2.6.1 Crossflow turbine (Ossberger and Crosstech)

Two vendors, Ossberger (Germany) and Crosstech (Christchurch), offer crossflow type turbines. The turbine comprises a horizontal rotor with blades, inside a casing at slightly sub-atmospheric pressure, as shown below. An external, free-standing, off-the-shelf, gearbox connects the turbine to the generator.

Two Ossberger units have been installed in New Zealand, one at Aniwhenua Dam, Rangitaiki River, in the late 1970s, and one on Fereday Island, Rakaia River, in 2007. Both units have operated without problem. Crosstech have installed several units in Canterbury over the last 10 years without problem.




*Ossberger turbine*




*Crosstech turbine*

This type of turbine is simple, reliable, and easily maintained. The gearbox is easily accessed and replaced. The Ossberger turbine is a fully proven design, whereas the Crosstech turbine is a scale-up from previous installations, but otherwise is not innovative. The plant from both vendor's is very similar, the major differences being as follows:

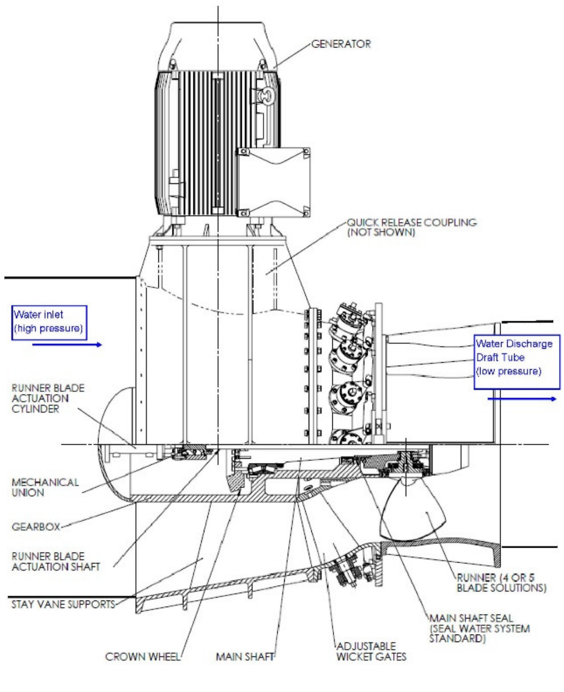
1. Ossberger have a machined water inlet control valve, split 66%/33% into two flow control sections. This provides significantly higher energy conversion efficiency over the operating flow range, and thus greater generation, than Crosstech offer;
2. Ossberger are able to offer a 7 $m^3/s$ turbine, whereas Crosstech's maximum flow is 5.3 $m^3/s$. Ossberger's higher flow capacity also provides significantly greater generation than Crossflow. Nonetheless, Crosstech 's capacity is a significant scale up from their previous experience;
3. Crosstech offer six to seven months delivery. A similar ex-works delivery is expected from Ossberger, with the addition however of shipping time from Bavaria, which delays the commencement of generation compared with Crosstech;
4. Ossberger has an Euro Foreign Exchange risk.

### 2.6.2 Tubular Kaplan Turbine (Hydroworks)

Hydroworks (Christchurch) offer a tubular, Kaplan type turbine. This turbine is similar to a ship's controllable pitch propeller, but operating in reverse - power is extracted from the water, rather than input into the water. The water flow through the turbine is controlled by controllable pitch vanes mounted in the turbine case. A hub located within the turbine waterway contains rotating, controllable pitch, blades, to extract power from the water. The hub also contains a gearbox to transmit power from the hub shaft to the generator located outside the turbine case. Space and shape in the hub is highly constrained. Consequently, the gearbox is not a standard off-the-shelf unit, but is a prototype unique, custom design by Hydroworks with gear wheels purchased from an established gearbox manufacturer.

Hydroworks have previously installed six of this type of turbine, three for Watercare Services near Auckland, and three on Fereday Island, near Christchurch. The former experienced several significant problems, whereas the later have performed well. All these turbines have a belt drive from the hub to the generator. As noted above, an innovative gearbox is proposed for Opuha, in place of the belt drive, to reduce noise and maintenance.


*A Hydroworks turbine generator installed on Fereday Island, Rakaia River*




**INRACE TURBINE ASSEMBLY PLAN VIEW**

*Hydroworks turbine generator proposed for Opuha*

The Hydroworks turbine offers significantly higher power conversion efficiencies than the Ossberger turbine, whose efficiency is significantly higher than that of the Crosstech turbine. However, compared with a crossflow turbine from Ossberger or Crosstech, Hydroworks' tubular Kaplan turbine is mechanically complex, and this complexity is located within a hub within the waterway, with restricted space and access for maintenance. In addition Hydroworks' proposed unit has a prototype, unique, custom design gearbox, whereas the crossflow turbines utilize proven well established design.

Hydroworks offer one year delivery, which delays the commencement of generation compared with Crosstech and Ossberger.

Similar plant by Turab (Sweden), Toshiba (Japan) and Tamar (Australia) was also investigated, but is not proposed, as it is significantly more expensive.

### 2.6.3 Screw Turbine (Andritz)

The Archimedies screw turbine type was considered for Opuha, but is not suited to the large pond level variation that occurs at Opuha.

### 2.6.4 Discussion

The Ossberger, Crosstech and Hydroworks turbines may be compared in the following ways:

1. A simple, easily maintained, turbine (Crosstech and Ossberger), versus a complex, but more efficient, turbine with innovative aspects (Hydroworks);
2. A higher turbine flow capacity that utilizes more of the available flow resource and thus generates more electricity (Ossberger and Hydroworks), versus a smaller turbine generating less electricity (Crosstech);
3. Local turbine manufacture (Crosstech and Hydroworks), versus foreign manufacture (Ossberger).

No vendor offers (1) a simple, easily maintained turbine, with (2) a high flow and generation capacity, and (3) local manufacture. Vendor selection must discard one of these three attributes.

The proposed generating plant power income is relatively small compared with potential operational and maintenance costs. It is of the utmost importance to the financial return calculated below that the plant does not require significant management, operational and /or maintenance resources. Whilst the relative financial ranking of Ossberger (lowest), Crosstech (middle) and Hydroworks (highest) is important, this ranking is easily destroyed by unexpected problems resulting in lost generation and increased operational and maintenance costs. Hence proven and simply technology offers better generation certainty and we believe these benefits heavily influence the turbine decision given the relatively equal theoretical investment returns. Consequently this report recommends a crossflow turbine, either Ossberger or Crosstech depending on the relative importance attached to higher resource utilization (Ossberger) versus local manufacture (Crosstech).

## 2.7 Turbine maintenance isolation

The south arm of the ODDW is significantly shallower than the main section within the old river bed. It is possible to lower the pond level and pass flows up to 16.25 m3/s, equivalent to the main power station peak capacity, via the existing radial gate whilst maintaining the pond level below the intake to the proposed power station. However, this arrangement does not de-water the turbine during a significant flood.

As described above, the Hydroworks turbine has innovative and mechanically complex equipment located within the hub in the turbine’s waterway. Hub inspection and maintenance is a substantial, time consuming, undertaking. The turbine’s flow control vanes’ location does not isolate the hub from the pond. Moreover, the vanes are also complex, potentially requiring maintenance themselves. Thus an inlet gate at the penstock inlet is provided to allow turbine vane and hub inspection and maintenance without alteration to pond operation.

An inlet gate is not provided for the crossflow turbine option. The turbine rotor can be fully inspected through casing hatches by closing the turbine inlet flow control valve, without alteration to the pond level. The turbine rotor can be quickly removed for maintenance by temporarily draining the south arm of the ODDW if leakage through the valve is excessive/inconvenient. Once the rotor is removed the casing can be replaced, and the pond returned to normal service with the turbine inlet valve closed, whilst the rotor is repaired. Leakage through the inlet valve will be contained by the casing and directed to the turbine draft tube. In the unlikely event that maintenance of the inlet valve itself is required, it appears best timed when there is a low flooding risk, and emergency re-instatement of the valve allowed for.

Note 1: Turbine emergency shutdown is provided by a brake, and an automatic turbine isolation gate is not provided.

Note 2: The south arm of the ODDW is also drained for inlet screen cleaning. It is understood that this will be required infrequently.

## 2.8 Electrical

Induction generators are offered, which are a standard electric motor operating in reverse. The power factor correction equipment required for this type of generator is included. The electrical system comprises a switchboard, 440/11,000 transformer, and 750 m of 11 kV overhead line connecting to Alpine Energy’s existing network. The line is no different from that commonly found throughout New Zealand rural electrical networks.

*Power factor correction equipment at Fereday Island*

Alpine Energy has confirmed that their network can accommodate receive the hydropower plant's maximum power output without the need to update the lines.

## 2.9 Control system/SCADA

A simple type of PLC is provided. The control system (SCADA) system would link into the existing system at the powerhouse.

## 2.10 Staging

It is possible to stage the project. As a minimum, stage one would involve construction of the penstock whilst the radial gate works are undertaken. This will enable reinstatement of the closure embankment. A temporary bulk head, or permanent inlet gate as required for the Hydroworks plant option, would be necessary to seal the penstock if construction of the power station is delayed. A subsequent stage 2 would involve construction of the remainder of the works and would require the pond to be lowered for a period if the permanent inlet gate was not installed.

This scenario would involve significant additional expense in order to install the penstock and no return would be generated until the scheme was operational at some future date.

The resource consent notes that OWL wish to retain the right to stage the project for a period of up to 10 years.

## 2.11 Procurement

Civil works would be undertaken at the same time as the radial gates civil works, as an extension of the radial gates civil works contract.

Procurement of Ossberger generating plant is relatively simple and straight forward, as the unit is of entirely standardized, 'production run' manufacture. Price quotations are obtainable from Ossberger's pro-former quotation form on their web site. The experience on Fereday Island was that very little additional correspondence was required. Installation would be by local skilled plant tradesmen, and is straight forward. Crosstech and Hydroworks plant would be procured, installed and commissioned under a custom contract specifying performance, noise, reliability etc. The contract for Hydroworks plant would be significantly more detailed and complex than that for Crosstech.

# 3 Cost estimate

## 3.1 Construction cost estimate

Appendix B presents the cost estimate.

### 3.1.1 Civil works

Preliminary estimates of the capital cost for construction of the civil works extra over those required for the proposed radial gate structure works have been carried out based on the preliminary design presented in this report. It should be appreciated that these estimates may be updated following the confirmation from ECan of resource consent conditions and the detailed design stage.

Estimated June 2014 construction rates were selected for items, and a base cost estimate built up. Note that estimated construction rates have been benchmarked against local contractor input. Percentages were allowed for contingency (20%) and contractor's preliminary and general (12%).

The estimate for civil works does not include any of the following costs which would be additional to the reported estimates (this list may not be comprehensive):

- Enhancement or modification of the existing Overflow Embankment in the event that this is necessary;
- Allowance additional to that specifically stated above for rock excavation
- Resource consenting;
- Environmental mitigation aside from the intake screen and elver pass described above;
- Financing;
- Insurance;
- Developer related costs;
- Construction cost variations due to high demand, for example as may relate to the Christchurch rebuild.

### 3.1.2 Mechanical and electrical

Adjustments have been made for the differing scopes of the prices obtained from Crosstech, Hydroworks and Ossberger's.

Engineering and commissioning costs, in addition to those allowed by the plant vendors, are allowed as follows:

| | **Ossberger** | **Crosstech** | **Hydroworks** |
|---|---|---|---|
| Engineering | 10% | 10% | 15% |
| Commissioning | 7.5% | 5% | 7.5% |

The higher percentages for Hydroworks are intended to mitigate risks associated with this plant's higher complexity and prototype innovation. The higher percentages for Ossberger commissioning, compared with Crosstech's, reflects the absence of this from Ossberger's scope. (Noting that Ossberger's plant cost is also higher, thus this percentage is applied to a higher base.)

## 3.2 Financial analysis

The following table summarizes the financial comparison of the three vendors presented in Appendix B:

| | | Crossflow Turbine | | | Tubular Kaplan Turbine | |
|---|---|---|---|---|---|---|
| | | Ossberger | Crosstech | | Hydroworks | |
| | | Base Case | Base Case | | Base Case | |
| **TECHNICAL PARAMETERS** | | | | | | |
| **Flow @ net head** | **$m^3/s$** | **7** | **5.3** | | **7** | |
| Plant outages | | 5% | 5% | | 5% | |
| Loss due to variable pond level | | 2% | 2% | | 0% | |
| Minimum Flow | | 10% | 20% | | 20% | |
| | | | | | | |
| Power | kW | 342 | 232 | | 387 | |
| Generation | kWh pa | 2,146,141 | 1,520,393 | | 2,472,425 | |
| | | | | | | |
| **FINANCIAL PARAMETERS** | | | | | | |
| **Value of power** | **c/kWh** | **8.0** | **8.0** | | **8.0** | |
| Generation | $ pa | $ 172,000 | $ 122,000 | | $ 198,000 | |
| O&M costs | $ pa | $ (7,000) | $ (5,000) | | $ (14,000) | |
| **Total Income** | **$ pa** | **$ 165,000** | **$ 117,000** | | **$ 184,000** | |
| | | | | | | |
| **Total cost** | | **$ (1,850,000)** | **$ (1,310,000)** | | **$ (1,900,000)** | |
| | | | | | | |
| Major refurbishment cost in yr 20 | | $ 100,000 | $ 70,000 | | $ 150,000 | |
| Generation in the first year | | 75% | 100% | | 50% | |
| | | | | | | |
| **IRR (35 yrs operation)** | | **8.1%** | **8.3%** | | **8.6%** | |
| Payback period | yrs | 11.2 | 11.2 | | 10.3 | |

The above base case power price of 8 c/kWh is a preliminary figure, and should be subject to OWL's review and independent reassessment.

The following table summarizes the effect on the above financial returns for Crosstech and Hydroworks for changes to various parameters (Ossberger is not presented as their cost and income is located in between the other two vendors):

| **IRR** | **Crosstech** | **Hydroworks** |
|---|---|---|
| Lower power price (6.5 c/kWh) | 6.3% | 6.7% |
| Higher power price (8.5 c/kWh) | 8.9% | 9.3% |
| Higher project cost (+5%) | 7.8% | 8.2% |
| Higher outages and O&M costs | Low risk | 8.4% |
| Higher flows (as from Nov11) | 9.6% | 10.0% |

# 4 Conclusions & recommendations

This report presents the feasibility of installation of a small generating plant at the Opuha Dam Downstream Weir (ODDW). The cheapest option is to install the hydro generating plant while the proposed construction of two radial gates and stilling basin.

With installation of the hydro generating plant there is a key non-financial benefit in that OWL can be seen by both ECan and the public that the water is being used efficiently by OWL at all times and generating power.

Several power plant options were investigated with three options being discussed in more detail in this report. The following table compares features of the three identified short listed generating plants

| **Plant vendor** | **Ossberger** | **Crosstech** | **Hydroworks** |
|---|---|---|---|
| Turbine type | Crossflow | Crossflow | Tubular Kaplan |
| Place of manufacture | Germany | Christchurch | Christchurch |
| Turbine complexity | Simple | Simple | Complex |
| Technology risk | Fully proven | Proven, but some upscaling required | Custom prototype gearbox (New Technology) |
| Project cost | $1,850,000 | $1,310,000 | $1,900,000 |
| Foreign Exchange | Yes | No | No |
| Generation | $165,000 (141%) | $117,000 pa (100%) | $184,000 (163%) |
| Financial return (IRR) | 8.1% | 8.3% | 8.6% |

More detailed analysis is in Appendix B. The above financial returns are modest and are sensitive to power price. With the returns being modest all of the plant options are very sensitive to unexpected problems with the plant. Should the plant be out of operation there is loss of generation, increase maintenance costs an increase OWL management time in sorting the problems.

The advice from Pioneer generation, who themselves operate a number of small hydroelectric plants was “keep it simple and keep to your core business”. Therefore proven and simple technology offers better long term certainly. With simple plant, local engineering workshops will be able to service the plant which will help to minimise down time and loss of generation.

With the key non-financial benefit of OWL being seen to using water efficiently by generating power from the residual flow and should the financial returns meet OWL investment return threshold, then the recommendation is a crossflow turbine. Either Ossberger or Crosstech turbines are recommended. Either unit have a New Zealand local proven history and are a low maintenance plant.

# 5 Applicability

This report has been prepared for the benefit of Opuha Water Limited (OWL) with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Mechanical Technology (MTL) have been engaged separately by OWL and have assessed the mechanical and electrical components of this project.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

| Report prepared by: | Authorised for Tonkin & Taylor Ltd by: |
|---|---|
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TGM

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# Appendix A: Preliminary design parameters

# Appendix A: Preliminary design parameters

Ossberger parameters are similar to Hydroworks

| **Parameter** | **Crosstech Engineering Crossflow turbine** | **Hydroworks Climate Defender tubular turbine** |
|---|---|---|
| Turbine type | Cross flow | Tubular Kaplan |
| Generator and electrical transmission arrangements | 415 V induction generator, step-up transformer and new 11 kV overhead line to nearest Alpine Power connection point | 415 V induction generator, step-up transformer and new 11 kV overhead line to nearest Alpine Power connection point |
| Maximum generation flow at maximum net head (equivalent to 340.0 m RL pond water level) and corresponding maximum flow rate. | 5.7 $m^3/s$@ 7.6 m net head | 7.0 $m^3/s$ @ 7.4 m net head |
| Electrical output at maximum net head and corresponding maximum flow rate above. | 285 kW | 450 kW |
| Maximum generation flow at average head (equivalent to 339.00 m RL pond water level – pond level equalled or exceeded 50 % of the time 7 Nov. 2011 to 15 May 2014 based on TrustPower data) | 5.3 $m^3/s$@ 6.6 m net head | 7.0 $m^3/s$ @ 6.4 m net head |
| Electrical output at average net head and corresponding maximum flow rate above. | 230 kW | 385 kW |
| Maximum generation flow at minimum head (equivalent to 338.20 m RL pond water level) | 4.9 $m^3/s$@ 5.8 m net head | 7.0 $m^3/s$ @ 5.6 m net head |
| Electrical output at xx m net head (equivalent to 338.20 m RL pond water level and maximum flow rate above) | 190 kW | 340 kW |
| Annual output | 1.52 GWh pa | 2.47 GWh pa |
| Annual generation income based on 8 c/kWh | $122,000 | $198,000 |
| **Upstream and downstream water levels adopted for generation assessment** | | |
| Upper bound pond water level adopted for purposes of generation assessment. | 340.0 m RL (0.75 m below the crest of the existing ogee weir at 340.75 m RL) {TBC confirmed/agreed by all}. Based on likely maximum level to avoid a reduction of generation from the existing power station. | |
| Lower bound pond water level adopted for purposes of generation assessment. | 338.20 m RL. Based on altered pond operation to avoid low pond levels (Note: level duration data over the period 7 November 2011 to 15 May 2014 shows levels up to 1.4 m lower for 16 % of the time. | |
| Tail water level | 332.10 m RL | 332.23 m RL |
| Maximum total head based on above water levels | 7.9 m | 7.77 m |

| | | |
|---|---|---|
| Minimum total head based on above water levels | 6.10 m | 5.97 m |
| Penstock and screen arrangement | | |
| Forebay invert level | 334.5 m RL | 334.5 m RL |
| Screen arrangement | 20 mm maximum clear aperture between bars together with maximum average velocity 0.5 m/s as advised by ECan in order to accommodate emigrating male eels. | |
| Penstock invert level | 334.8 m RL | 334.8 m RL |
| Penstock submergence at minimum operating level to soffit of penstock | 1.74 m | 1.60 m |
| Penstock | 1.66 m internal diameter welded polyethylene pipe approximately 31.4 m long | 1.80 m internal diameter welded polyethylene pipe approximately 32.2 m long |
| Penstock and turbine isolation | Lower pond below to dewater penstock and utilise turbine control valve to prevent machine pit flooding in the event of flood occurring whilst runner casing removed. | Close penstock inlet gate |
| Power station & draft tube | | |
| Turbine speed | 117 rpm | 330 rpm |
| Generator speed | 1500 rpm | 1500 rpm |
| Maximum turbine efficiency | 75% | 93% |
| Turbine runner | 0.93 m dia x 2.55 long | 1.2 m dia |
| Turbine rotor material | Painted mild steel | Martensitic stainless steel |
| Maximum overspeed (control failure) | 210 rpm | 925 rpm |
| Finished floor level | 333.70 mRL | 332.43 m RL |
| Finished wall level to accommodate d/s flooding | 336.3 m RL | 336.5 m RL |
| Draft tube arrangement | Galvanised duct supplied by Crosstech | Concrete duct to formwork supplied by Hydroworks |
| Draft tube outlet invert level | 329.7 m RL | 330.1 m RL |
| Maintenance access & lifting provisions | Removable roof and mobile lifting hoist | Removable roof and mobile lifting hoist |
| Plant room provision | Not required, control panels incorporated into power station. | Not required, control panels incorporated into power station. |

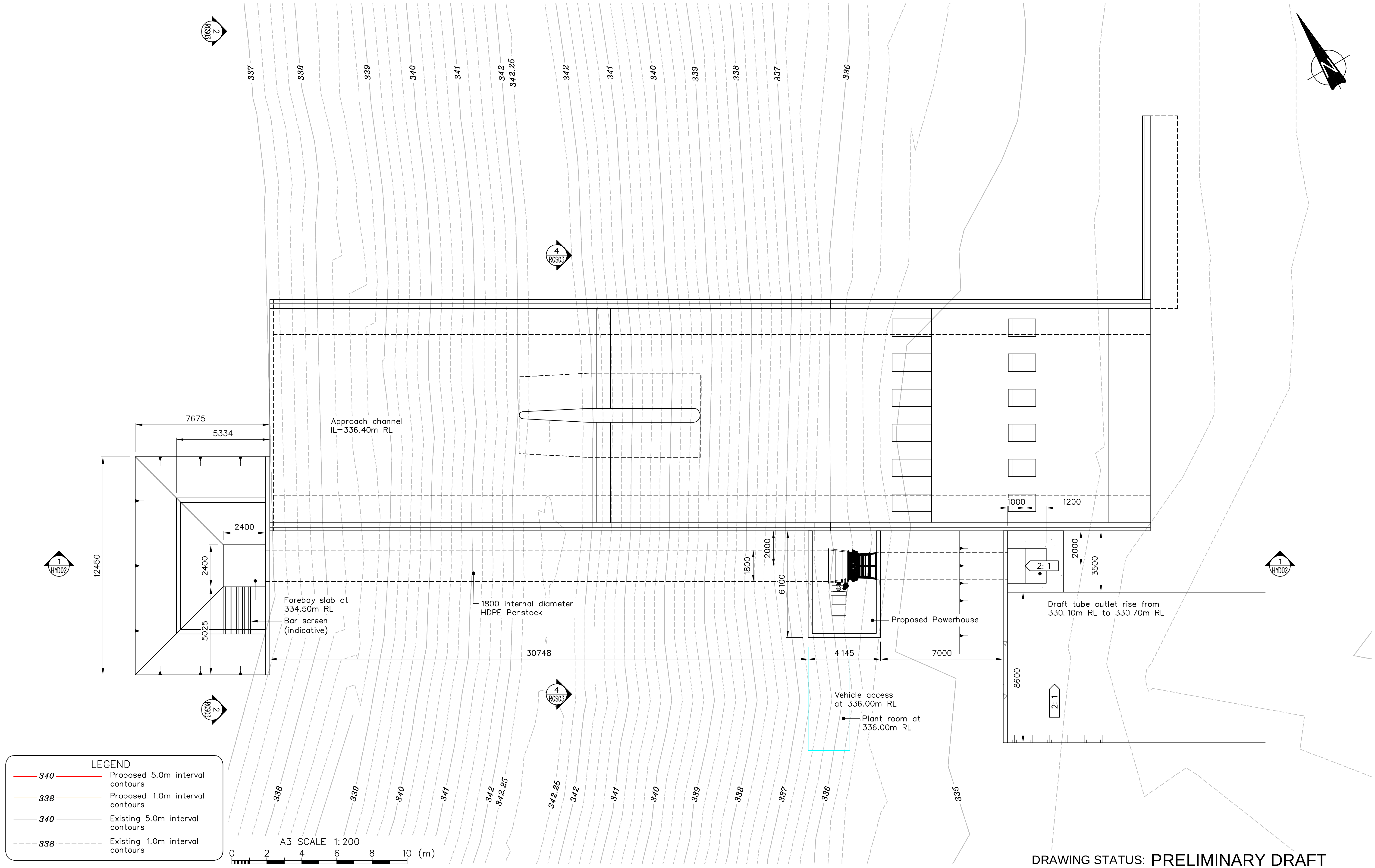
# Appendix B: Cost estimate

# Appendix B: Cost Estimate

| | | Crossflow Turbine | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ossberger | Crosstech | | | | | | |
| | | Base Case | Base Case | Lower Power Price | Higher Power Price | Higher Cost | Higher Flows (from Nov11) | Operating Range Max Head | Min Head |
| TECHNICAL PARAMETERS | | | | | | | | | |
| **Flow @ net head** | **$m^3/s$** | **7** | **5.3** | **5.3** | **5.3** | **5.3** | **5.3** | **5.7** | **4.9** |
| Average net head | m | 6.31 | 6.60 | 6.60 | 6.60 | 6.60 | 6.60 | 7.60 | 5.80 |
| Penstock diameter | m | 2.1 | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 | 1.72 | 1.59 |
| Penstock velocity | m/s | 2.00 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 |
| | | | | | | | | | |
| Plant outages | | 5% | 5% | 5% | 5% | 5% | 5% | | |
| Loss due to variable pond level | | 2% | 2% | 2% | 2% | 2% | 2% | | |
| Minimum Flow | | 10% | 20% | 20% | 20% | 20% | 20% | | |
| | | | | | | | | | |
| Power | kW | 342 | 232 | 232 | 232 | 232 | 232 | 286 | 188 |
| Generation | kWh pa | 2,146,141 | 1,520,393 | 1,520,393 | 1,520,393 | 1,520,393 | 1,719,236 | | |
| Plant factor | | 72% | 75% | 75% | 75% | 75% | 85% | | |
| | | | | | | | | | |
| FINANCIAL PARAMETERS | | | | | | | | | |
| **Value of power** | **c/kWh** | **8.0** | **8.0** | **6.5** | **8.5** | **8.0** | **8.0** | | |
| Generation | $ pa | $ 172,000 | $ 122,000 | $ 99,000 | $ 129,000 | $ 122,000 | $ 138,000 | | |
| O&M costs | | 4% | 4% | 4% | 4% | 4% | 4% | | |
| O&M costs | $ pa | $ (7,000) | $ (5,000) | $ (4,000) | $ (5,000) | $ (5,000) | $ (6,000) | | |
| **Total Income** | **$ pa** | **$ 165,000** | **$ 117,000** | **$ 95,000** | **$ 124,000** | **$ 117,000** | **$ 132,000** | | |
| | | | | | | | | | |
| Civil cost | | $ (302,000) | $ (275,000) | $ (275,000) | $ (275,000) | 105% | $ (275,000) | | |
| Civil P&G (15%) | | $ (55,000) | $ (50,000) | $ (50,000) | $ (50,000) | 105% | $ (50,000) | | |
| Civil contingency (20%) | | $ (61,000) | $ (55,000) | $ (55,000) | $ (55,000) | 105% | $ (55,000) | | |
| Intake gate and screen | | $ (19,000) | $ (19,000) | $ (19,000) | $ (19,000) | 105% | $ (19,000) | | |
| TG, incl draft tube | | $ (735,000) | $ (460,000) | $ (460,000) | $ (460,000) | 105% | $ (460,000) | | |
| Elec & control | | $ (263,000) | $ (186,000) | $ (186,000) | $ (186,000) | 105% | $ (186,000) | | |
| E&M Commissioning (varies) | | $ (82,000) | $ (49,000) | $ (49,000) | $ (49,000) | 105% | $ (49,000) | | |
| E&M Contingency (15%) | | $ (165,000) | $ (107,000) | $ (107,000) | $ (107,000) | 105% | $ (107,000) | | |
| Engineering (varies) | | $ (167,000) | $ (105,000) | $ (105,000) | $ (105,000) | 105% | $ (105,000) | | |
| **Total cost** | | **$ (1,850,000)** | **$ (1,310,000)** | **$ (1,306,000)** | **$ (1,306,000)** | **$ (1,375,500)** | **$ (1,306,000)** | | |
| | | | | | | | | | |
| Major refurbishment cost in yr 20 | | $ 100,000 | $ 70,000 | $ 70,000 | $ 70,000 | $ 70,000 | $ 70,000 | | |
| Generation in the first year | | 75% | 100% | 100% | 100% | 100% | 100% | | |
| | | | | | | | | | |
| **IRR (35 yrs operation)** | | **8.1%** | **8.3%** | **6.3%** | **8.9%** | **7.8%** | **9.6%** | | |
| Payback period | yrs | 11.2 | 11.2 | 13.7 | 10.5 | 11.8 | 9.9 | | |

| | | Tubular Kaplan Turbine | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hydroworks | | | | | | | |
| | | Base Case | Lower Power Price | Higher Power Price | Higher Cost | Higher Outages First 3.5 Yrs | Higher Flows (from Nov11) | Operating Range Max Head | Min Head |
| TECHNICAL PARAMETERS | | | | | | | | | |
| **Flow @ net head** | **$m^3/s$** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** |
| Average net head | m | 6.37 | 6.37 | 6.37 | 6.37 | 6.37 | 6.37 | 7.37 | 5.57 |
| Penstock diameter | m | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.91 |
| Penstock velocity | m/s | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.45 |
| | | | | | | | | | |
| Plant outages | | 5% | 5% | 5% | 5% | 10% | 5% | | |
| Loss due to variable pond level | | 0% | 0% | 0% | 0% | 0% | 0% | | |
| Minimum Flow | | 20% | 20% | 20% | 20% | 20% | 20% | | |
| | | | | | | | | | |
| Power | kW | 387 | 387 | 387 | 387 | 387 | 387 | 448 | 339 |
| Generation | kWh pa | 2,472,425 | 2,472,425 | 2,472,425 | 2,472,425 | 2,342,298 | 2,797,240 | | |
| Plant factor | | 73% | 73% | 73% | 73% | 69% | 83% | | |
| | | | | | | | | | |
| FINANCIAL PARAMETERS | | | | | | | | | |
| **Value of power** | **c/kWh** | **8.0** | **6.5** | **8.5** | **8.0** | **8.0** | **8.0** | | |
| Generation | $ pa | $ 198,000 | $ 161,000 | $ 210,000 | $ 198,000 | $ 187,000 | $ 224,000 | | |
| O&M costs | | 7% | 7% | 7% | 7% | 10% | 7% | | |
| O&M costs | $ pa | $ (14,000) | $ (11,000) | $ (15,000) | $ (14,000) | $ (19,000) | $ (16,000) | | |
| **Total Income** | **$ pa** | **$ 184,000** | **$ 150,000** | **$ 195,000** | **$ 184,000** | **$ 168,000** | **$ 208,000** | | |
| | | | | | | | | | |
| Civil cost | | $ (306,000) | $ (306,000) | $ (306,000) | 105% | $ (306,000) | $ (306,000) | | |
| Civil P&G (15%) | | $ (55,000) | $ (55,000) | $ (55,000) | 105% | $ (55,000) | $ (55,000) | | |
| Civil contingency (20%) | | $ (62,000) | $ (62,000) | $ (62,000) | 105% | $ (62,000) | $ (62,000) | | |
| Intake gate and screen | | $ (69,000) | $ (69,000) | $ (69,000) | 105% | $ (69,000) | $ (69,000) | | |
| TG, incl draft tube | | $ (755,000) | $ (755,000) | $ (755,000) | 105% | $ (755,000) | $ (755,000) | | |
| Elec & control | | $ (199,000) | $ (199,000) | $ (199,000) | 105% | $ (199,000) | $ (199,000) | | |
| E&M Commissioning (varies) | | $ (77,000) | $ (77,000) | $ (77,000) | 105% | $ (77,000) | $ (77,000) | | |
| E&M Contingency (15%) | | $ (165,000) | $ (165,000) | $ (165,000) | 105% | $ (165,000) | $ (165,000) | | |
| Engineering (varies) | | $ (205,000) | $ (205,000) | $ (205,000) | 105% | $ (205,000) | $ (205,000) | | |
| **Total cost** | | **$ (1,900,000)** | **$ (1,893,000)** | **$ (1,893,000)** | **$ (1,995,000)** | **$ (1,893,000)** | **$ (1,893,000)** | | |
| | | | | | | | | | |
| Major refurbishment cost in yr 20 | | $ 150,000 | $ 150,000 | $ 150,000 | $ 150,000 | $ 150,000 | $ 150,000 | | |
| Generation in the first year | | 50% | 50% | 50% | 50% | 50% | 50% | | |
| | | | | | | | | | |
| **IRR (35 yrs operation)** | | **8.6%** | **6.7%** | **9.3%** | **8.2%** | **8.4%** | **10.0%** | | |
| Payback period | yrs | 10.3 | 12.6 | 9.7 | 10.8 | 11.3 | 9.1 | | |

# Appendix C: Scheme figures




DRAWING STATUS: PRELIMINARY DRAFT

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| DRAWN : | NSW | Jun. 14 |
| DESIGN CHECKED : | | |
| DRAFTING CHECKED : | | |
| CADFILE : \\51137.018–HYD01.dwg | | |
| APPROVED : | | |

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| REVISION | DESCRIPTION | BY | DATE |
|---|---|---|---|
| 0 | First Issue | | |

NOTES :

1. All dimensions are in millimetres unless noted otherwise.

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CLIENT, PROJECT
OPUHA WATER LIMITED
OPUHA DAM

TITLE
DOWN STREAM WEIR ENHANCEMENT
Hydro Electric Works General Arrangement Plan

| SCALES (AT A3 SIZE) | DWG. No. | REV. |
|---|---|---|
| 1: 200 | 51137.018–HYD01 | 0 |

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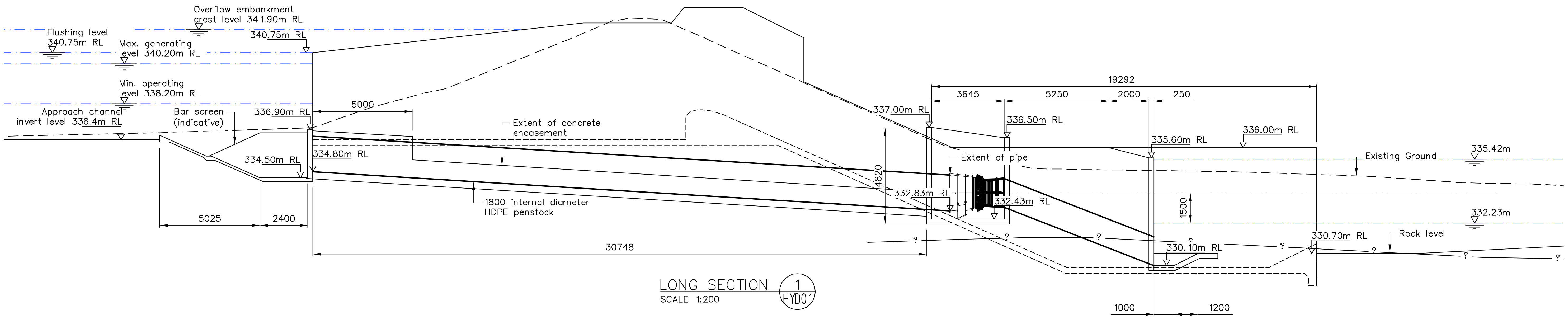


LEGEND

| | |
|---|---|
| — — — — — — | Existing Ground profile |
| —— ? ———— | Existing Rock profile |

A3 SCALE 1:200

0 2 4 6 8 10 (m)

DRAWING STATUS: PRELIMINARY DRAFT

| | | | |
|---|---|---|---|
| 0 | First Issue | | |
| REVISION DESCRIPTION | | BY | DATE |

| | | |
|---|---|---|
| DESIGNED : | TGM | Jun. 14 |
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| DESIGN CHECKED : | | |
| DRAFTING CHECKED : | | |
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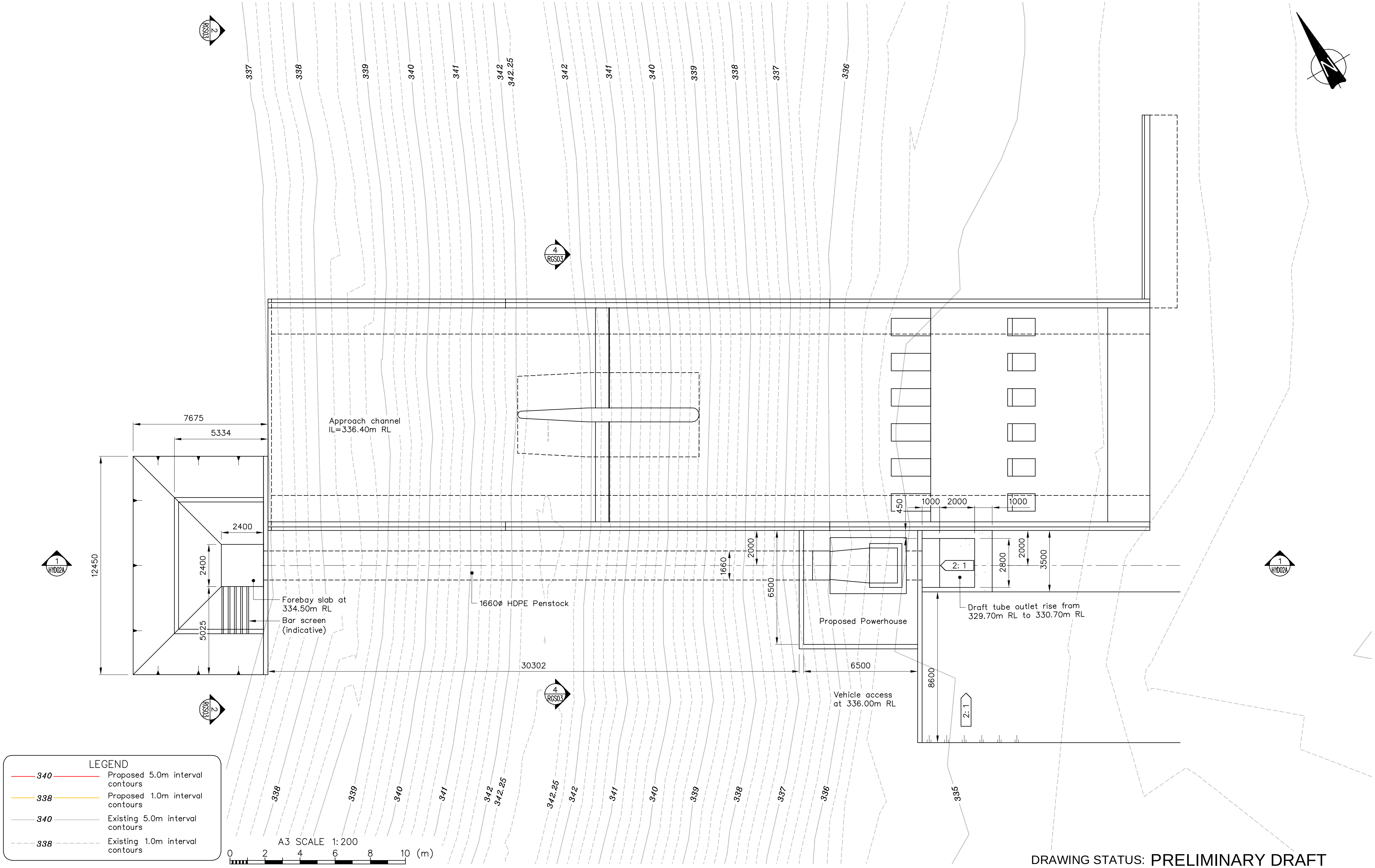
CLIENT, PROJECT
OPUHA WATER LIMITED
OPUHA DAM

TITLE
DOWN STREAM WEIR ENHANCEMENT
Penstock Long Section

| SCALES (AT A3 SIZE) | DWG. No. | REV. |
|---|---|---|
| AS SHOWN | 51137.018–HYD02 | 0 |




DRAWING STATUS: PRELIMINARY DRAFT

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| REVISION DESCRIPTION | BY | DATE |

| | | |
|---|---|---|
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| DRAWN : | NSW | Jun. 14 |
| DESIGN CHECKED : | | |
| DRAFTING CHECKED : | | |
| CADFILE : \\51137.018–HYD01.dwg | | |

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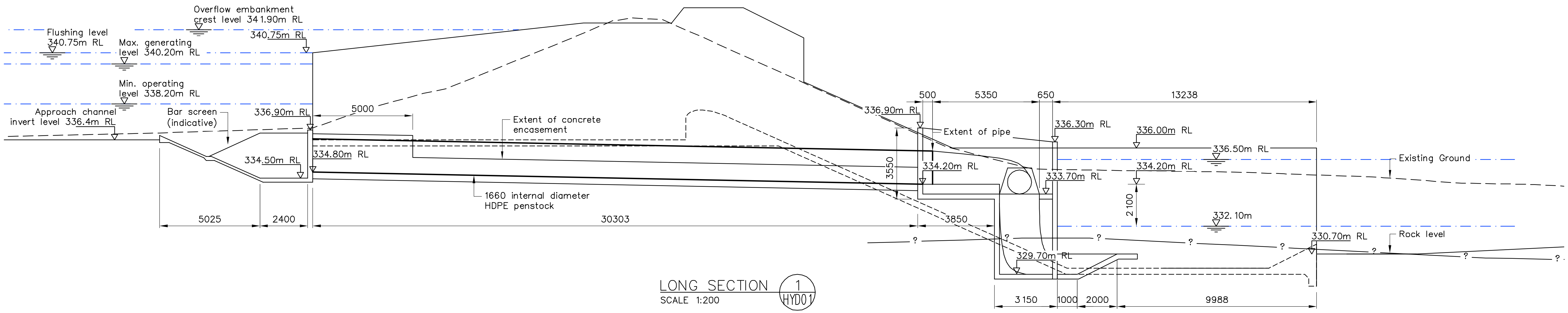
OPUHA WATER LIMITED
OPUHA DAM

TITLE
DOWN STREAM WEIR ENHANCEMENT
Hydro Electric Works General Arrangement Plan

SCALES (AT A3 SIZE) 1: 200
DWG. No. 51137.018–HYD01A
REV. 0




LONG SECTION 1 HYD01
SCALE 1:200

LEGEND

| | |
|---|---|
| — — — — — — | Existing Ground profile |
| —— ? ———— | Existing Rock profile |

A3 SCALE 1:200
0 2 4 6 8 10 (m)

DRAWING STATUS: PRELIMINARY DRAFT

| REVISION | DESCRIPTION | BY | DATE |
|---|---|---|---|
| 0 | First Issue | | |

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DRAWN : NSW Jun. 14
DESIGN CHECKED :
DRAFTING CHECKED :
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TITLE
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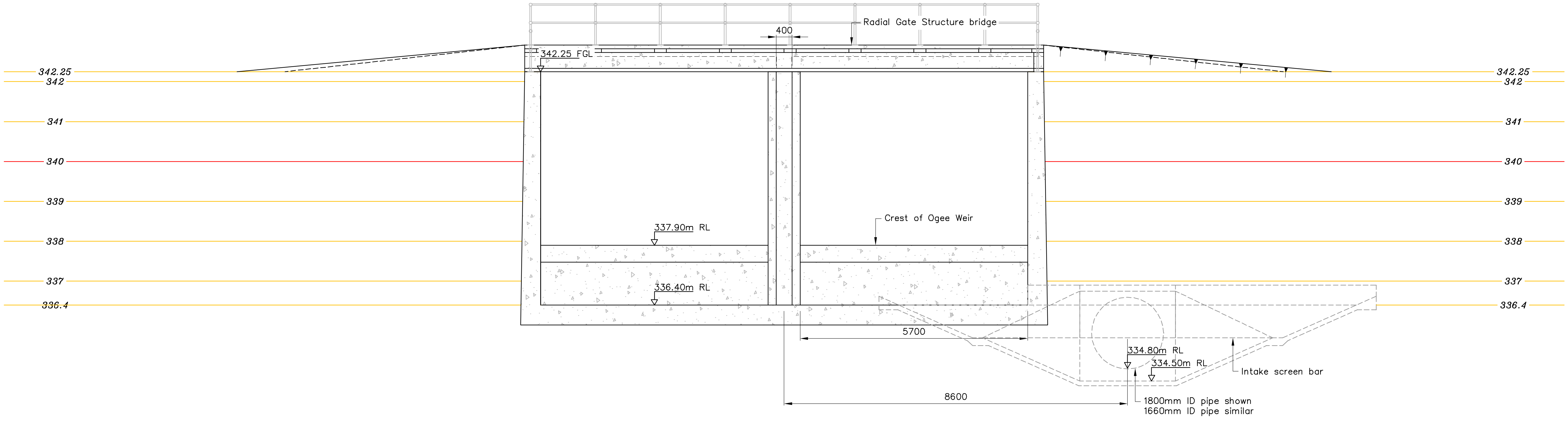
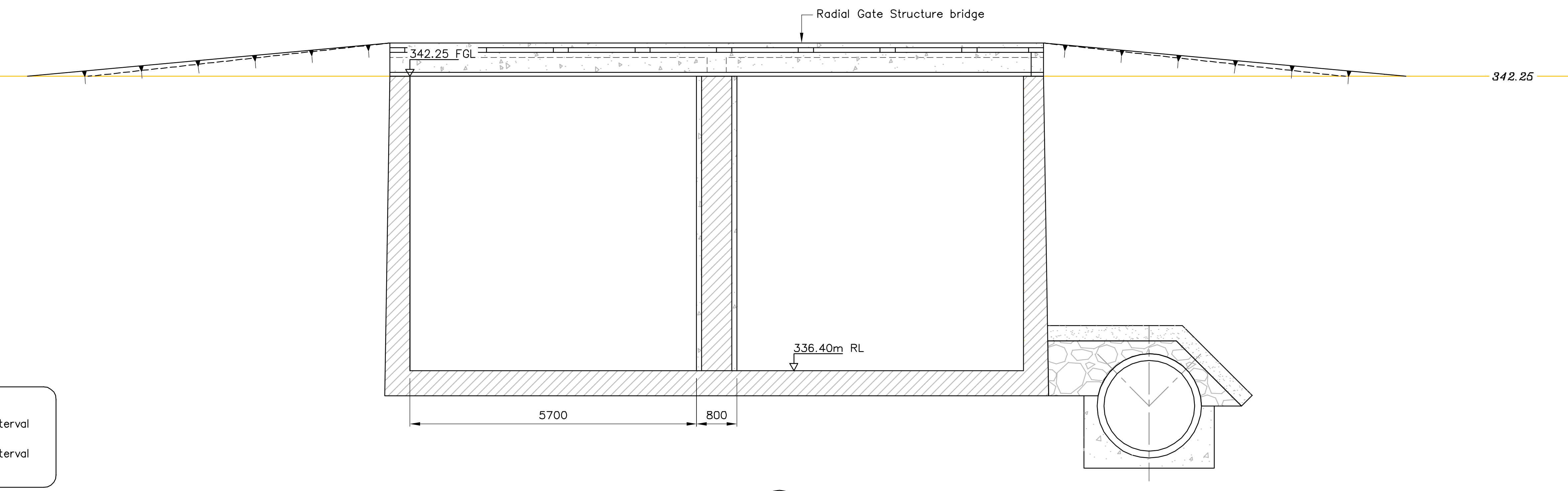
SCALES (AT A3 SIZE) AS SHOWN
DWG. No. 51137.018-HYD02A
REV. 0




ELEVATION 2 RGS01 APPROACH CHANNEL
SCALE 1:100




SECTION 4 RGS01
SCALE 1:100

LEGEND

| | |
|---|---|
| 340 | Proposed 5.0m interval contours |
| 338 | Proposed 1.0m interval contours |

A3 SCALE 1: 100
0 1 2 3 4 5 (m)

DRAWING STATUS: PRELIMINARY DRAFT

| REVISION | DESCRIPTION | BY | DATE |
|---|---|---|---|
| 1 | Second Issue | | |
| 0 | First Issue | TGM | Apr. 14 |

| | | |
|---|---|---|
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| DRAWN : | NSW | Jun. 14 |
| DESIGN CHECKED : | | |
| DRAFTING CHECKED : | | |
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OPUHA WATER LIMITED
OPUHA DAM

TITLE
DOWN STREAM WEIR ENHANCEMENT
Approach Channel Elevation

SCALES (AT A3 SIZE) 1: 100
DWG. No. 51137.018–RGS03
REV. 1

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