Appendix C

Tillegra Mini Hydro Information Memorandum

Tillegra Dam Mini Hydro Information Memorandum

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Hunter Water Corporation

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Contents

Appendices

List of tables

List of figures

Executive summary

Overview

Hunter Water Corporation is proposing to construct a 450,000 ML water supply dam on the Williams River at Tillegra, approximately 12 km upstream of Dungog. The proposal includes a hydroelectric generator to take advantage of environmental flow releases from the reservoir. These flows are guaranteed as part of the licensing agreement for Tillegra Dam.

The dam proposed is of Concrete Faced Rockfill (CFRD) type. The hydroelectric generator proposed is of small scale mini hydro type. The mini hydro facility will be designed, installed and operated by an external operator.

The purpose of this Information Memorandum (IM) is to provide technical information to parties interested in designing, installing and operating the mini hydro facility. The IM is aimed to provide potential proponents with information allowing an assessment of the dam's power generating capacity. It is likely that the civil works necessary for the mini hydro will be constructed under the dam construction contract to designs prepared by the successful proponent. Generating plant would then be installed by the successful proponent.

The water balance

It is expected that the dam will take between 2 to 10 years to fill, which needs to be taken into account for any economic analysis.

Demand water releases affect the storage operation strategy for the dam and therefore have been studied in terms of two possible scenarios of 90 GL/year and 120 GL/year. These are projected future water supply demands based on historical water inflows of the wider lower Hunter Region scheme, which Tillegra Dam is part of.

Tillegra Dam's environmental releases are mainly made up of transparent and translucent releases and combined are capped at 62 ML/day, which are projected to be achieved 30% of the time. Environmental releases higher than this cap are projected to occur less than 1% of the time with peak discharge of 270 ML/day, contributed mainly by the release of water freshes which are intended to mimic the downstream river fluctuations. The water freshes will be released via the mini hydro's turbine or a Fixed Cone Dispersion (FCD) valve located in the same block as the turbine.

Environmental releases are deliberate water releases that occur most of the year. The only time that these are not required is when the dam is spilling and the volumes spilled meet the environmental release requirements. It is anticipated that if the spilled water is captured and released through the turbine instead of the spillway, flow duration at 62 ML/day can be increased from projected 30% of time to between 39% to 42% of the time, indicating potential additional energy generation.

Interface with the Dam

The mini hydro will be enclosed in a separate room within the valve block (powerhouse) which has separate access. A minimum floor area for the room of 25 m² is approximately the size to be made available and a pipe of diameter 800 mm branching from the main penstock has been assumed will supply the mini hydro. A minimum 50% overpressure is required to be designed into the pipe supplying the turbine to cater for water hammer pressure induced by a rapid shutdown. An intake screen will be required on the offtake pipe for runner protection.

The mini hydro will be interfaced to the local network owned and operated by Country Energy via the adjacent 11 kV line, with a current capacity of 1 MW. The interfacing point will be a pole mounted circuit breaker known as a Connection Point CB, which can be mounted on any of the 11 kV poles adjacent to the proposed dam site. The developer's substation shall have a generator CB and the protection system configured in accordance with Country Energy's "Co-generation Connection Guideline - CEK8012". It is anticipated that the power requirement at the dam site will exceed the current capacity of the existing line; hence upgrading of the line is necessary. It could well be that the upgraded capacity of the line will exceed the likely output of the mini-hydro and the work required to interface the mini-hydro to the Country Energy is minimal, however this is yet to be determined.

There may be an opportunity for generating additional power from water spillage resulting from a full dam especially during the flood season. Preliminary analysis shows that, with spills, the average water flow rates increase significantly to between 172 ML/day to 197 ML/day with flow duration of about 20% of the time. Channelling this excess water to the mini hydro, that would otherwise be spilled, maximises the potential power generation capacity. The key issue is to determine the proportion of spillage to capture and if a single or twin turbines are used to generate power. Twin turbines may achieve the highest efficiency but this needs to be justified by the increased costs of more expensive turbines and additional civil works and space. A single turbine is cheaper in cost but may operate at low efficiency since spillage only occurs when the dam is full which will take two to ten years to fill.

1 Introduction

Hunter Water Corporation (HWC) is seeking interested parties to design, install and operate a mini hydro facility for electricity generation,. The purpose of this Information Memorandum (IM) is to provide interested parties with information to assess this power generating opportunity.

While every effort has been made to ensure the accuracy of the information provided, it is the responsibility of the interested parties to verify that such is true. PB or HWC shall not be held liable for any information discrepancies in this document.

HWC is proposing to construct a 450,000 ML water supply dam on the Williams River at Tillegra, approximately 12 km upstream of Dungog. The dam is approximately 76 m high and has a length of 600 m.

The mini hydroelectric generator is to be part of the dam to take advantage of downstream water releases from the dam. The releases are due to the environmental requirement as part of the licensing agreement for Tillegra Dam, bulk transfer for Grahamstown Dam downstream, and spillage due to excess water inflows to the dam.

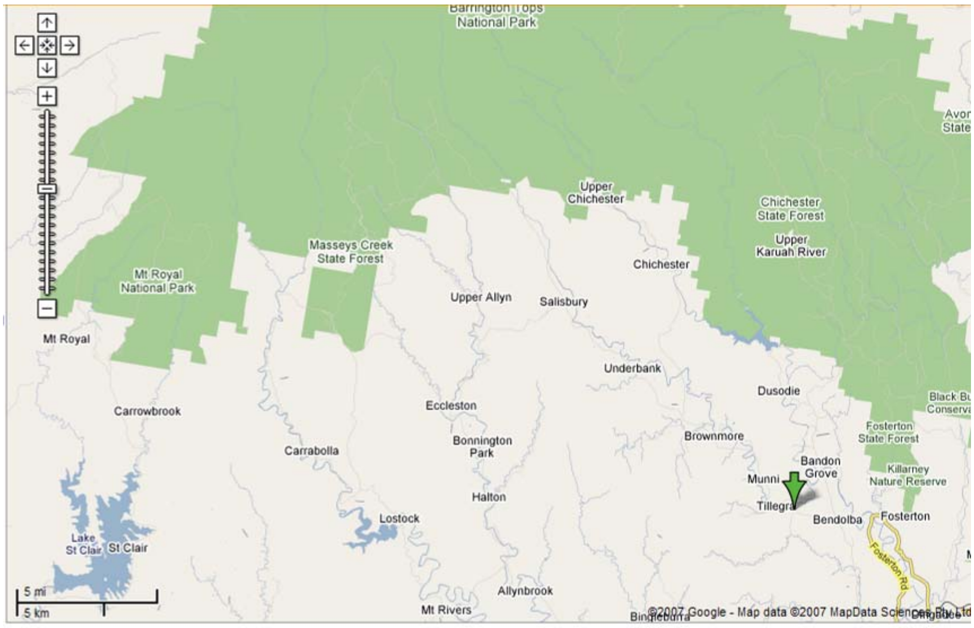
The dam is required to provide for future population growth and to provide additional system capacity for drought management in the lower Hunter Region. Under normal conditions, only the environmental releases, bulk transfers and flood spills will be released. In the case where emergency drought management is required, additional releases will occur from the dam through a Fixed Cone Dispersion (FCD) valve if the releases exceed the mini hydro capacity.

This document also considers the transmission and communications from the site.

2 Site parameters

2.1 Site location

The figure below shows the location of the dam and hydro station with respect to local geographic features. The green arrow indicates the approximate position of the dam.



2.2 Proposed site layout

A Concrete Faced Rockfill Dam (CFRD) type is proposed on the site. Details of the dam are covered in the Dam Type Options Study Report prepared by the NSW Department of Commerce.

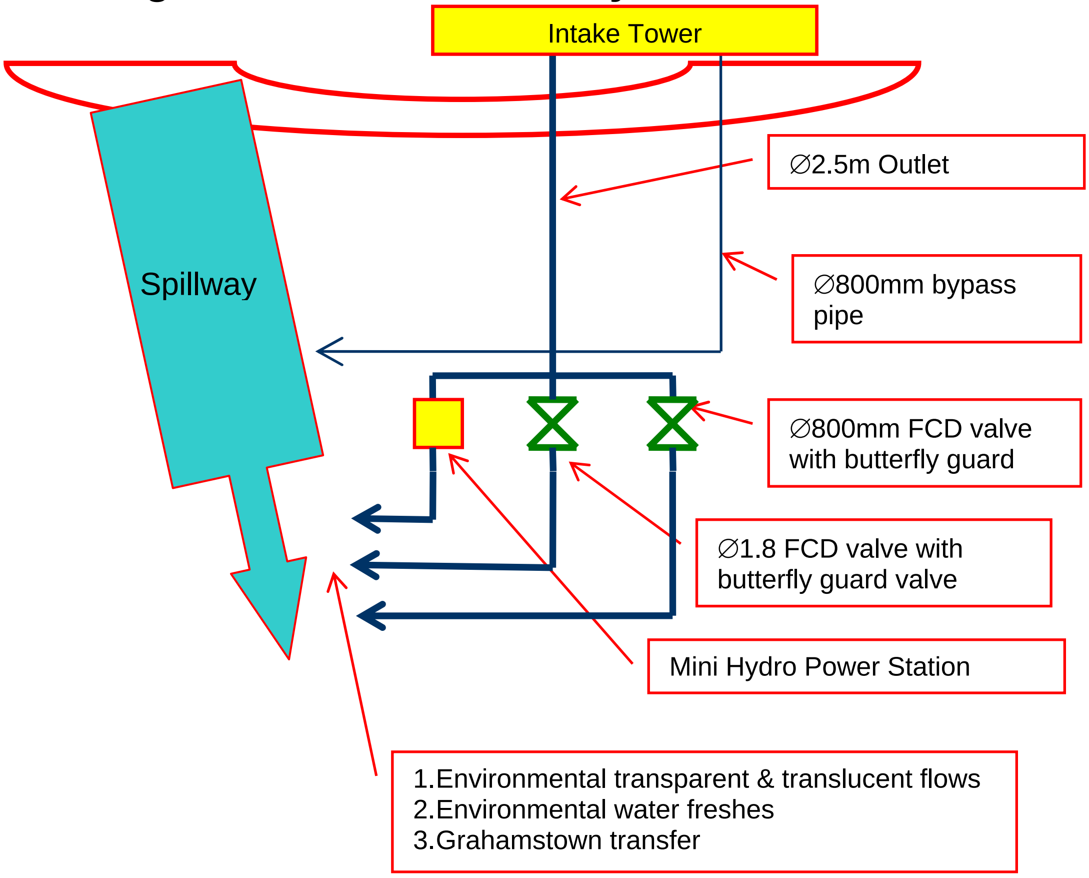
The layout is shown in the 5 drawings in Appendix A and consists of the following main elements:

- A 76 m high concrete faced rockfill embankment;
- A chute spillway on the right abutment, controlled by an ungated ogee crest and terminating in a flip bucket;
- A diversion tunnel with inlet and outlet channels on the right abutment;
- An outlet works constructed within the diversion tunnel and discharging into the spillway plunge pool;

2.3 Hydraulic schematic

The overall hydraulic schematic is shown below. The majority of the hydraulic elements are governed by requirements for operation of the dam irrespective of the mini hydro requirements.

Tillegra Dam & Reservoir Hydraulic Schematic



3 Design criteria

3.1 Design data

Table 3-1 Scheme Parameters

Description	CFRD	Units
Spillway crest (Full Supply Level)	152.3	m AHD
Average lake level	153	m AHD
Spillway exit sill level	85	m AHD
Normal gross head	68	m AHD
PMF water level over spillway crest	158.9	m
Diversion tunnel diameter	5.8	m
Total tunnel and penstock length	330	m
Reservoir capacity	450,000	ML
Mini hydro offtake pipe diameter	800	mm
FCD valve maximum capacity	5200	ML/day
Regular environmental flow	62	ML/day
Design water transfer flow to Grahamstown	1670	ML/day

4 Hydraulic conditions

4.1 Operational requirements

The purpose of Tillegra Dam is to retain water during wet times so that there will be water available to supply the urban areas of the Lower Hunter and Central Coast in dry times in the form of emergency storage. Various dam operating approaches have been tested with the aim of developing an operating strategy that maximises the utility of the dam for town water supply in conjunction with the other Hunter Water sources and at the same time minimise the environmental and other impacts of the dam. The ultimate behaviour of the dam in terms of water level and down river flow will be a function of the operating strategy that is adopted.

Operational requirements of Tillegra Dam are set by the results of the environmental investigation studies and discussions between HWC and the Department of Water and Energy (DWE) based on flow data for a period of 76 years. These results are used as the basis to establish water releases required from the dam and are outlined below.

The DWE has indicated that when Tillegra Dam is built they will require Hunter Water to release water into the Williams River downstream of the dam for the purpose of maintaining river health and landholder water access rights. Further, they have indicated that the quantity of water to be released each day shall be a function of flow into the dam – i.e. the outflow from the dam shall be proportional to inflow. The actual function is likely to be fairly complex, with a bias to ensuring transparency between inflow and outflow when inflow is low, but allowing large floods to be largely captured in the dam.

It should be noted that the operational strategy developed to date does not include any allowance for hydro electric power generation, and depending on how it is configured, hydro operation has the potential to impact down river flow patterns. If hydro is simply used as an alternative mechanism for delivering the controlled releases that are described below it will make no difference, but if it is operated as an additional release, even during periods of spill, it will have an impact.

Proposed down river flows from the Tillegra dam can be divided into 3 broad categories:

1. Flow maintenance releases including transparent releases, translucent releases and 'freshes'
2. Spills
3. Bulk water transfers to Grahamstown Dam.

Flow maintenance releases

Flow maintenance releases are deliberate water releases delivered for the purpose of maintaining river health and ensuring that river water access by third parties will not be diminished by the presence of the new dam. These water releases generally occur when the dam is not spilling, though there will be times when the spill rate is inadequate, and will need to be supplemented with controlled flow maintenance releases.

Flow maintenance releases are in turn divided into 3 categories: transparent, translucent and 'freshes'.

1. Transparent and translucent environmental releases – Mandatory regular water releases for environmental flow maintenance. Rules for releases are outlined below:

   - **Transparent** releases are delivered at all times when there is a positive flow into the dam except possibly when the dam is spilling. The maximum size of transparent release has been set at the 90th%ile historic flow at the Tillegra Bridge streamflow gauge. It is 7.4ML/day. If the dam is spilling at a rate that is less than the nominal transparent release rate, then the rate of spill will be supplemented with deliberate releases to achieve the target dam outflow. If dam inflow is less than or equal to 7.4 ML/day, amount of release is equal to amount of inflow, i.e.,

     $$Q_{out} = \min(\text{inflow}, 7.4)$$

   - **Translucent** releases are delivered at all times when the rate of flow into the dam exceeds 7.4ML/day except some periods when the dam is spilling. Translucency is maintained for inflows of between 7.4ML/day and the 30th%ile historic flow at Tillegra Bridge, which is 100ML/day. If dam inflow is more than 7.4 ML/day but less than 100 ML/day, amount of release is 7.4 ML/day plus 60% of the difference between inflow and 7.4 ML/day, i.e.,

     $$Q_{out} = 7.4 + 0.6 * (\text{inflow} - 7.4)$$

   - **Translucent** releases: It is noted that while translucency is not maintained for inflows above 100ML/day, the translucent term is retained, but is set to a constant value relative to an inflow of 100ML/day. If dam inflow is equal to or more than 100 ML/day, amount of release is capped at 62 ML/day, i.e.,

     $$Q_{out} = 7.4 + 0.6 * (100 - 7.4)$$

2. Simulated environmental water freshes – Mandatory periodical water release to mimic natural water fluctuations in addition to transparent and translucent flows. The flow is triggered by HWC's prescribed specific environmental conditions and will occur at an average of 40-week interval with total volume of 234 ML at each release. Peak discharge rate is 270 ML/day.

3. Grahamstown transfer flow – Deliberate bulk water release required for Grahamstown Dam downstream, with a peak discharge of 1670 ML/day. Total release volume at each discharge is 4689 ML.

4. Dungog Water Treatment Works transfer flow – Deliberate water release to Dungog Water Treatment Works via the Chichester Trunk Gravity Main (CTGM) up to 135 ML/day. This is not a regular water release and will only take place is there is water quality issue at the treatment works. The release is not into the river.

5. Spillage – Uncontrolled water release when the dam has reached its spillway capacity through the spillway structure.

The term *environmental flow* will be used extensively in the remaining of this document. This term is defined as combined water release from transparent releases, translucent releases and simulated water freshes.

Water releases based on historical daily flow data over the period 1931 to 2006 have been modelled using two possible scenarios:

- A 90 GL/year demand, considered to be applicable to the year 2030
- A 120 GL/year demand, considered to be applicable to the year 2050

The above demand values are for the wider lower Hunter Region scheme, of which Tillegra Dam is one of the storage sites.

The results of the model form the main discussion of the remaining of this chapter.

It should be noted that the hydraulic model includes a 1 ML/day Tillegra Dam leakage allowance which is included in the calculation of the environmental flows and therefore the hydro flow rate is 1 ML/day less. Currently, there is no allowance in this flow modelling for operating fish passage facilities as there will be no such facilities.

It should also be noted that the dam operation strategy limits hydro electric generation from the controlled water releases only. There will be no additional water releases specifically for hydro generation.

4.2 Head Durations

Based on the proposed operating regimes and historical inflow based modelling, the head duration graph in Figure 4-1 has been derived based on the two scenarios. This shows the percentage of the time a certain reservoir water level can be anticipated.

From the graph it can be seen the operating range is approximately 9 m for water demand of 120 GL/year and 6 m for 90 GL/year. Both scenarios have an average Head Water Level (HWL) of approximately 153 m AHD.

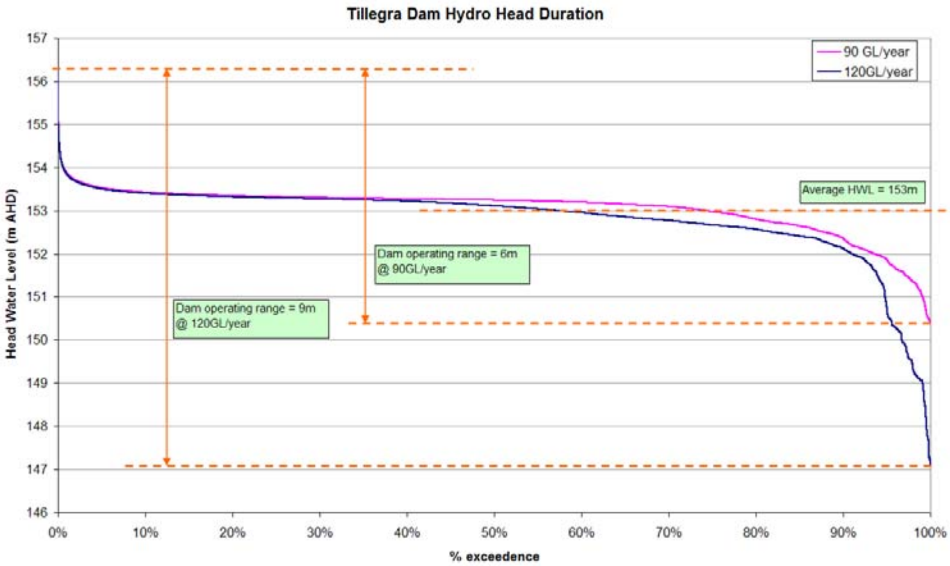


Figure 4-1 Head Duration Curves

4.3 Flow Durations

Duration curves of environmental maintenance releases have been prepared and illustrated in Figure 4-2 for both scenarios. Explanations of the plots are provided below. It should be pointed out that the curves are only for water released through the valve block (FCD valve or mini hydro).

Flow durations from environmental releases only for both scenarios, represented by the green and pink lines, are identical (the green line is overlapped by the pink line). Environmental releases of 62 ML/day are projected to occur about 30% of the time, implying inflows of more than 100 ML/day. From this point onwards, the releases are based on the rules outlined in Section 4.1 item 1 (i.e. transparent and translucent releases).

Again it should be noted that a 1 ML/day Tillegra Dam leakage allowance has been included in the calculation of the environmental flows, and therefore the hydro flow rate is 1 ML/day less than the environmental flow figures quoted.

Environmental releases will be delivered at all times except when the dam is spilling. If the spill rate is less than the required environmental release rate, it will be supplemented by deliberate release to achieve the required outflow.

If the spilled water is captured and released through the mini hydro, the environmental flow time through the turbine is projected to increase to 42% (purple line) and 39% (blue line) for water demand of 90 GL/year and 120 GL/year respectively. The implication of this is that there is a potential for more energy recoverable (energy equals area under the graph) if the spilled water is utilised by the mini hydro.

As shown on the curve, environmental water release in the form of water freshes occurs less than 1% of the time at a peak discharge of 270 ML/day.

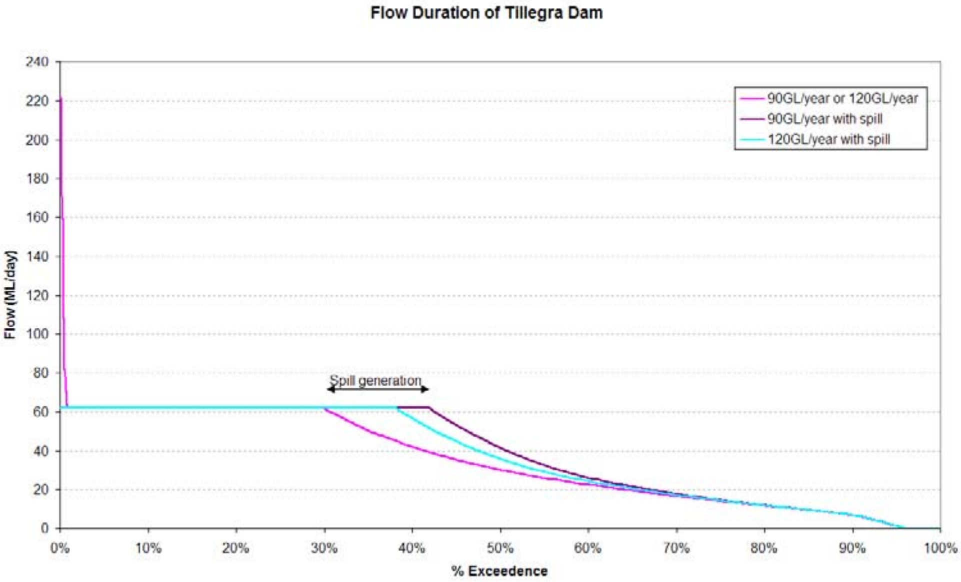


Figure 4-2 Tillegra dam flow duration curves

4.4 Transfer flows

Water is released to Grahamstown Dam downstream of Tillegra Dam. It is anticipated that the transfer will take place periodically with expected interval of 54 weeks, but up to of 4 discharges per year can occur. Flow durations for the transfer flow for each scenario have been prepared and are shown in Figure 4-3. It illustrates that transfer water releases occur less than 10% of the time.

Total transfer amount is 4689 ML per transfer with peak discharge of 1670 ML/day.

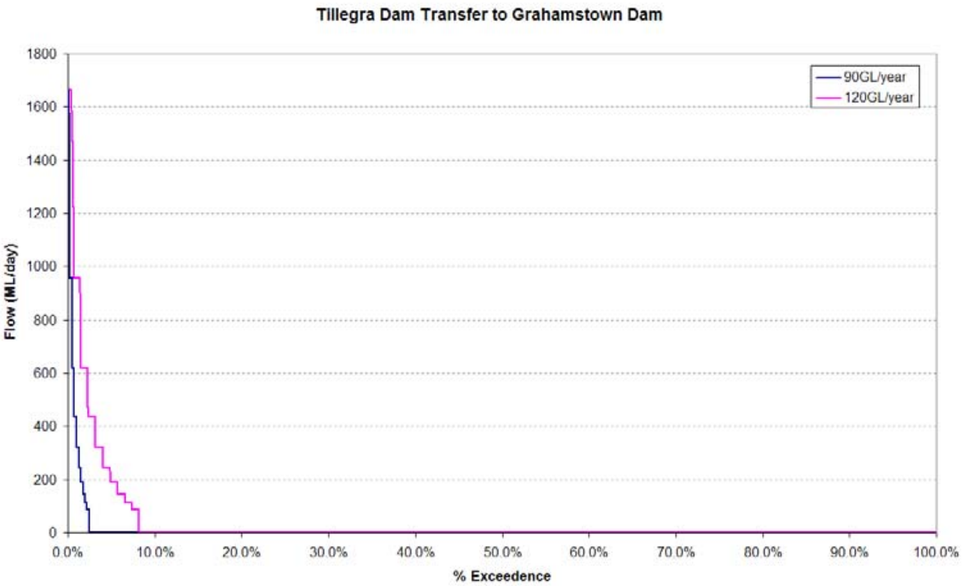


Figure 4-3 Water transfer flows

4.5 Head loss

Head loss from the lake intake to inlet of turbine is anticipated to be minimal. A head loss curve has been prepared and illustrated in Figure 4-4. For an environmental flow of 62 ML/day, the head loss is expected to be less than 1% of the total gross head. This is mainly contributed by the low friction coefficients of the lining materials used on the concrete tunnel and steel penstock through which the water flows from the inlet channel to the valve block as well as the short offtake pipe that connects the penstock to the mini hydro. It is also because the mini hydro is fed from the main waterways feeding the FCD Valves which are sized for much higher flows, thus flow velocities in the main waterways during times of generation are low.

The head loss curve in figure 4-4 has been prepared using information from drawing C361802-501 attached in Appendix A. Friction factors used were based on worst case scenario.

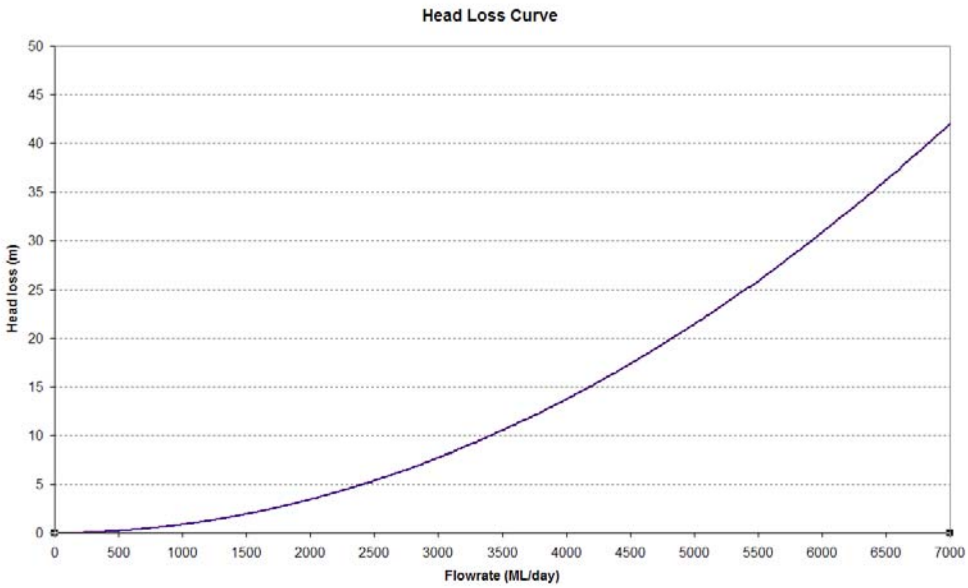


Figure 4-4 Head loss curve

4.6 Transients

In order to limit speed rise on the generator when it is inadvertently disconnected from the load due to faults such as line short circuits or disconnections, it is necessary to close the water flow to the turbine quickly. This results in a pressure rise in the upstream pipe. It should be noted that is only a problem on reaction turbines; impulse turbines can use deflectors to divert the flow from the turbine.

A minimum 50% overpressure should be designed into the pipe supplying the turbine to cater for water hammer pressure induced by a rapid shutdown of the turbine.

4.7 Tailwater curve

Tailwater curve influences the ground level of the powerhouse or valve block to be located at.

The elevation of the top of the valve block is set at Probable Maximum Flood (PMF) level for protection from flooding. Flooding risk is due to rapid rise of tailwater level when there is massive spill due to extreme rainfall.

Tailwater ratings determined from on site measurements and calculations are as shown in Figure 4-5. The curve at the measuring weir (red line) is the most appropriate for the powerhouse.

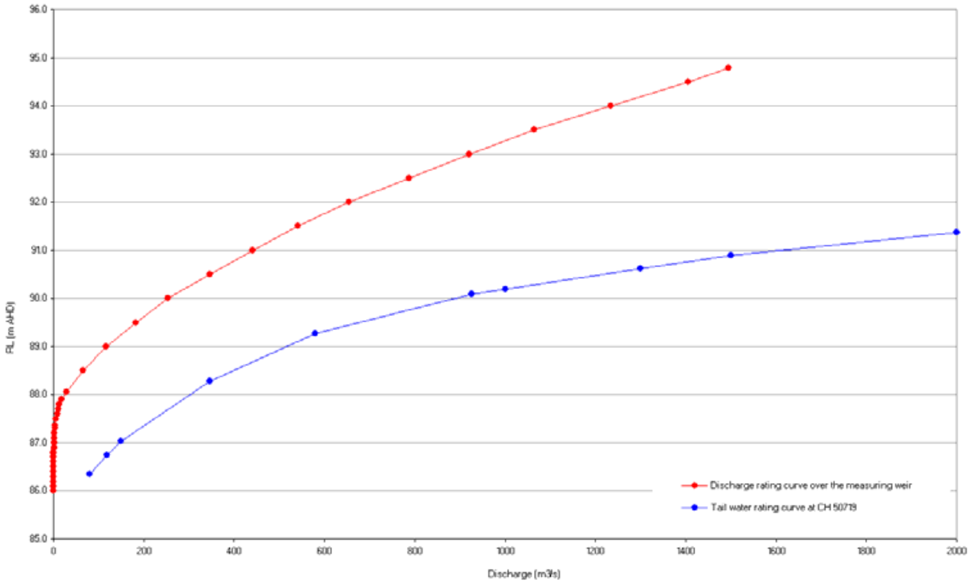


Figure 4-5 Tailwater ratings

Spillway flood routing design has been based on 36 hours Generalised Tropical Storm Method (GTSMR). This approach is critical for situations involving high outflow discharges such as spillway and for embankment and cofferdam overtopping. Flood data for the spillway design is summarised in Table 4-1. Flood routing data for the critical 36 hour GTSMR PMF is shown in Figure 4-6.

Table 4-1 Scheme Parameters

Flood	Crit Storm Duration	Peak Inflow	Peal Outflow	Max Storage Level
	hrs	m3/sec	m3/sec	AHD
AEP Floods	72	737.7	169.3	154.00
1 in 20	72	978.66	251.9	154.51
1 in 50	72	1096.2	286.1	154.70
1 in 100	36	1543.1	507.9	155.73
1 in 1,000	36	2051.5	748.6	156.65
1 in 10,000	36	2567.2	1,003.6	157.51
1 in 100,000	36	2890.4	1,166.0	158.01
1 in 500,000	36	3506.8	1,495.3	158.92
1 in 10,000,000				
Historical Flood		1,349.9	361.2	155.07
Apr-46	72	737.7	169.3	154.00

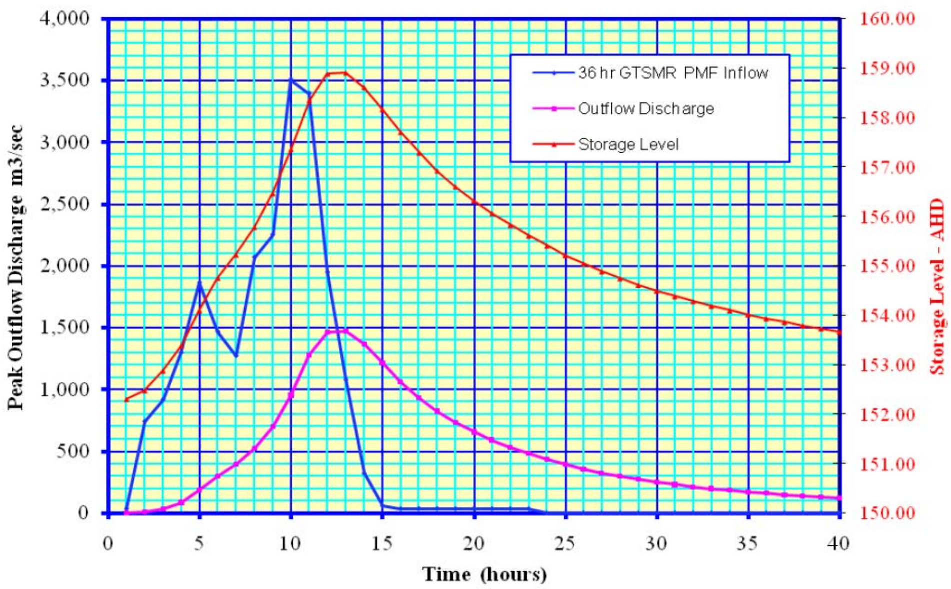


Figure 4-6 PMF water levels and flows

5 Generating plant

5.1 Guard valve

HWC will supply an isolating butterfly valve on the 800 mm diameter offtake pipe to which the mini hydro turbine(s) shall be connected. The valve will have lubrication free bearings so that no oil or grease will be in contact with the drinking water which will come from the Tillegra Dam reservoir.

6 Site layout and civil works

6.1 Geotechnical

There are no geotechnical issues associated with the civil works of the mini hydro plant as all works will be within the valve block structure.

6.2 Intake screening

In order to avoid the small gaps between turbine blades being blocked during operation, screening is required to ensure debris such as leaves, branches, plastic bags and fish do not enter the turbine.

The screening provided by trashracks on the intake tower is sized for protection to the waterway and FCDVs but is considered too coarse for a mini hydro. Therefore, a separate and finer screening needs to be provided. It is anticipated that this screen will be installed within the 800 mm offtake pipe that supplies to the mini hydro. The screen will be provided and maintained by the operator of the mini hydro.

6.3 Penstock

The supply of water to the mini hydro is anticipated to be an offtake pipe leading from the main outlet penstock. The pipe will have a diameter of 800 mm, but a smaller pipe might be adequate. This pipework is to be designed and installed by HWC to the outside face of the powerhouse.

The penstock pipe will need to be rated for up to 150% of the design head to cater for overpressure.

6.4 Powerhouse

Given the requirements for the valve block for normal operation of the dam, the valve room (powerhouse) will be watertight. The mini hydro will be located within a separate room with separate entrance adjacent to the valve block.

HWC will build the room to house the mini hydro under the dam construction contract to the design prepared by the operator which shall include:

- Access requirements for the mini hydro components
- An oil interception system including sump and sump pumps

The design shall exclude the following:

- The nomination of the general location of the mini hydro pit
- The design of the outlet channel from the mini hydro pit

The mini hydro and any other associated installations are to be provided by the operator following the completion of the main contract works.

Floor area for the mini hydro room is estimated to be about 25 m^2, excluding storage and workshop. It should be noted that this area is based on the assumption that power will be generated from a single turbine with water releases capped at 62 ML/day.

The valve block is to be located on the right bank side of the dam structure.

6.5 Tailrace

The tailrace channel for the outlet of the water discharged from the mini hydro will be combined with FCD valve and spillway discharge.

6.6 Transmission conduits

Transmission conduits will be provided by NSW Department of Commerce under the spillway.

7 Control and operation

7.1 Control and monitoring

HWC's valve block control system for Tillegra Dam will include flow monitoring, water level measurements, valve/gate positions, rainfall monitoring, etc. Signals will feed back to HWC's control system.

The interface of the mini hydro's control system to HWC's system shall be provided by the mini hydro operator.

7.1.1 Inflow transmission

HWC will have an inflow transmission system in place that records water inflow into the lake. This is required to dispatch water flow to the mini hydro.

7.1.2 Lake level transmitter

HWC will have a transmitter installed to monitor the lake level. This may not have any direct contribution to the mini hydro power generation, but it is useful for information logging and informs the operator when water is spilling from the dam.

7.1.3 Tripping signal

In the event of the mini hydro tripping, a signal must be given to the Fixed Cone Dispersion Valve (FCDV) to initiate operation to ensure continuous flow of environmental water releases. It will be the responsibility of the mini hydro operator to provide such signal connection to the HWC valve block control system.

7.1.4 Flowmeter

The mini hydro operator shall install a flowmeter device at the inlet pipe to provide readings of the water flow rates. The readings will be used to verify that the operator has met its environmental obligations to HWC. Signal from the flowmeter must be provided to HWC's valve block control system.

7.1.5 Interfacing

HWC will provide the interfacing between the mini hydro and HWC's control. The interface will have a water discharge set point programmed into it to allow excess water to the mini hydro to be diverted to the FCDV for release.

7.2 Operations and maintenance

Operations and maintenance of the mini hydro will be the full responsibility of the mini hydro operator. A proper and competent operations and maintenance philosophy must be documented and agreed upon with HWC, ensuring that any operations and maintenance activities will not cause any undesirable environmental impacts. Issues to consider include:

- Oil leakage prevention
- Oil spill control
- Oil and any other waste disposal
- Water temperature
- Water quality
- Bypass arrangements in the event of malfunction or trip
- Any other issues specified in HWC's water licensing agreement

8 Transmission

8.1 Transmission company

The local transmission company is Country Energy.

Preliminary enquiries have been made to Country Energy, regarding aspects such as voltage level, point of closest existing poles and issues relating to the supply of electrical power to the dam site during its construction.

The following information is provided for proponents to assess the work required to interface the mini-hydro to the CE network.

8.2 Transmission network schematic

The existing 11kV rural distribution feeder which services the general area surrounding the proposed Tillegra dam, is known to Country Energy as the Chichester / Salisbury feeder, "DGG6607". It carries a distributed rural load which peaks at around 1MVA, and has a minimum loading of about 250kVA.

The backbone of this feeder is lightly constructed of "Apple" conductor (6/1/3.00 - ACSR) which is sufficient for the loadings which it has historically encountered. There are no voltage regulators on the line, and none are currently needed.

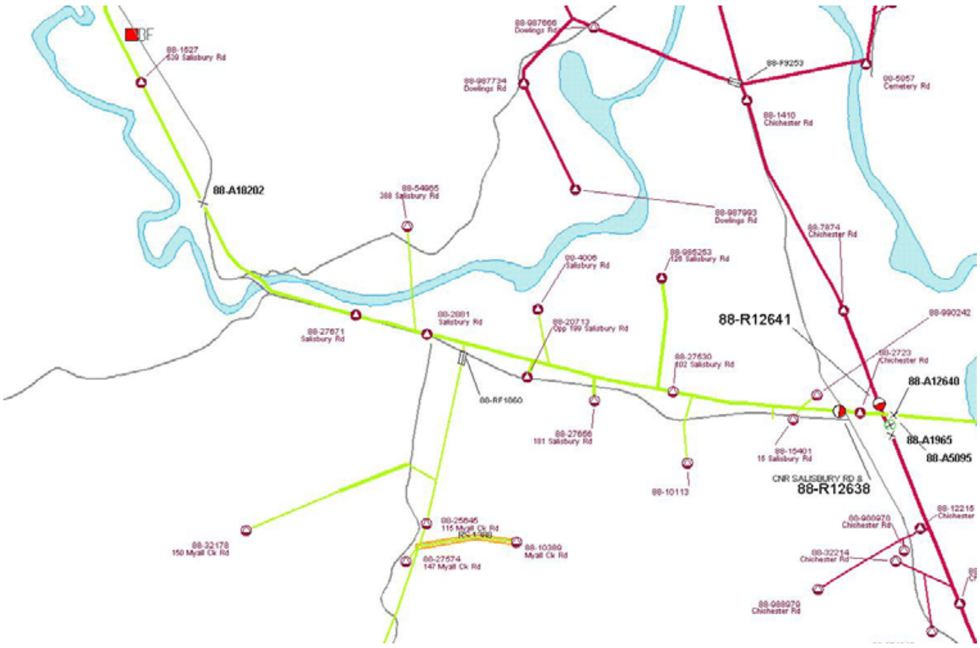


Figure 8-1 General overview of local distribution network [source: Country Energy]

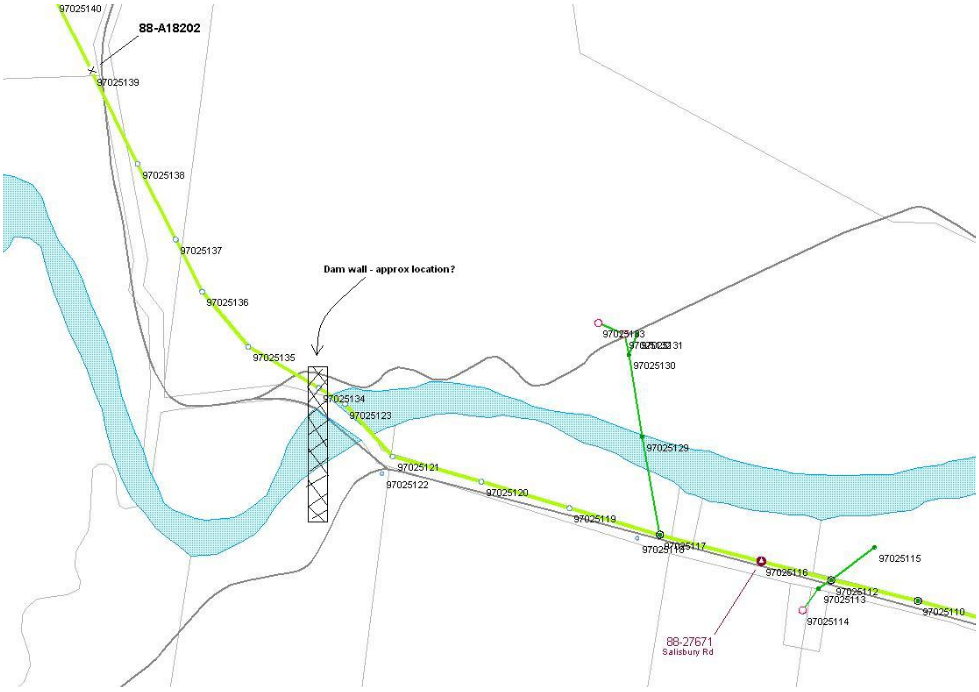


Figure 8-2 Local distribution network within the vicinity of the dam

8.3 Connection point

It is anticipated that power will be transmitted along the Salisbury Road 11 kV circuit known as the Chichester/Salisbury feeder and according to Country Energy it has a capacity of approximately 1MW.

Depending on the output capacity of the mini-hydro, the developer shall carry out a comprehensive network study to identify the maximum voltage swings Country Energy customers might experience in the worst-case scenarios. One of these is when the network load is at a minimum, e.g. 250kVA, and the generator output is at a maximum, and if the generator suddenly drops off line due to a fault.

The physical connection point for the generator is likely to be a new substation, located as close as possible to the hydro generator. In reality, with site restrictions, this separation might have to be as much as 50 or 100m or so; but every effort should be made by the developer to keep the substation close to the generator. The type and the design of the substation shall be the developer's responsibility, however they shall ensure the protection system complies with Country Energy's requirements.

A relatively short section of 11kV overhead line or underground cable would need to be extended from one of the existing adjacent 11kV poles — 97025121, 97025123, or 9702513.

The developer shall be responsible for all costs associated with extending the HV to the substation, installing the substation, connecting the low voltage cabling between the substation and the generator, and installing all metering and generator protection equipment.

At the anticipated interconnection of the installation, there would usually be a LV isolation circuit breaker installed at the substation, where Country Energy would take over responsibility for all assets on the supply side of that isolation point. The Developer would retain responsibility for the low voltage cables and protection equipment (and generator) on the "load" side of that switch.

It is anticipated that the construction power will be drawn from the Country Energy’s network via the adjacent 11 kV line. The construction power requirement is likely to be higher than the current capacity of this line; therefore it will have to be upgraded. If the line capacity exceeds the likely output capacity of the mini hydro, no line upgrade will be required.

However the existing lines will undoubtedly need to be reconfigured for the construction of the dam, so there is the option for sharing some of the common costs with HWC, such as the cost of network studies, reconfiguration of conductors etc. which will be have to be negotiated.

8.4 Connection agreement

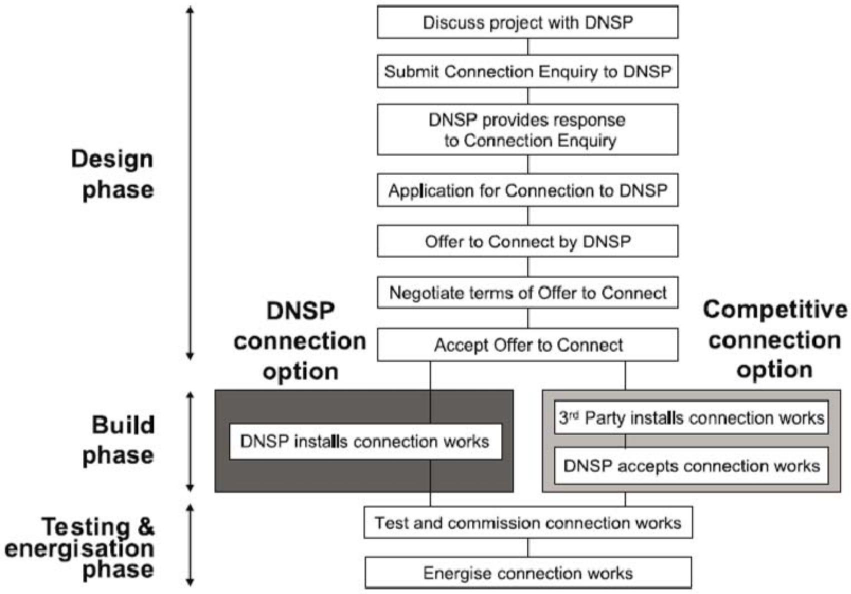
The developer shall negotiate a connection agreement with Country Energy to allow the plant to connect to the local distribution network. Hunter Water will participate in such negotiations on the request of the developer.

Issues that may be addressed in a typical connection contract could include:

- Equipment required to be purchased and installed to protect the system being connected to,
- Insurance covering liabilities arising from operation and interconnection of the mini hydro facility with the utility system,
- Phase, current, frequency, voltage and delivery location,
- Termination procedures,
- Reasonable inspection provisions,
- Interruption provisions.

8.5 Connection process

A new generation scheme may require investment in new plant on DNSP (distribution network service provider) infrastructure. Figure 9-1 indicates the normal steps undertaken to connect a new scheme.



Taken from "Technical Guide for Connection of Renewable Generators to the Local Electricity Network" by BCSE

Figure 8-3 Typical flowchart for the connection process

Dialogue with the DNSP has begun and that information is summarised in this document. Upon confirming the final output the developer shall submit a formal connection enquiry to the DNSP. This maybe done in conjunction with HWC as the enquiry shall be to initially obtain power for construction and later connection of the mini-hydro.

Formal application for connection should be carried out once planning permission is granted and financial go ahead for the project is given, although environmental constraints may mean this process needs to be brought forward to ensure line routes and other works are suitable.

Country Energy advises that the connection shall conform to their "Co-Generation Protection Guidelines CEK8012." The Developer shall be responsible for the supply, setting and maintenance of equipment for the protection of the generation equipment according to this document.

8.6 Protection and isolation requirements

The table below indicates the standard protection requirements for plant connected to a distribution network. The mini-hydro falls in the category of permanent parallel operation – LV generating plant, with the protection requirement determined by the final power output selected.

Table 8-1 Protection requirements

Protection required for DNSP network	Permanent parallel operation					Short term test parallel			
	HV generating plant		LV generating plant			HV generating plant	LV generating plant		
	No export	Export	Small <150kVA	**Medium 150-250kVA**	Large >250kVA	No export	Small <150kVA	**Medium 150-250kVA**	Large >250kVA
Under/over Voltage & frequency	●	●	●	●	●	●	●	●	●
Loss of mains/phase	●	●	●	●	●				
Overcurrent	●	●	●	●	●	●	●	●	●
Sensitive Earth fault	●	●	●	●	●	●	●	●	●
Earth fault	●	●		●	●	●		●	●
Reverse power	●	●			●				
Directional overcurrent	●	●			●				
Neutral Voltage displacement	●	●	●	●	●	●	●	●	●

Notes:
**Indicates required protection.*
Reverse power or Loss of mains protection may be required if the generator is not asynchronous.
Neutral Voltage displacement protection may not be required if reverse power relays are present or if the generator is connected to an underground system with adequate phase to earth protection systems.

Taken from "Technical Guide for Connection of Renewable Generators to the Local Electricity Network" by BCSE

Country Energy has advised no special 11kV isolation point is likely to be required. It will be satisfactory for Country Energy isolation purposes at this site, for a low voltage circuit breaker to be made. This will be referred to as the "Connection Point Circuit Breaker" (CPCB). There is some flexibility as to how this might be achieved. The main thing is it needs to be a current sensing circuit breaker (i.e. not just an isolator) and it must be readily accessible to Country Energy at all times. It also needs to be secure against unwanted access or interference by non-authorised people. It could simply comprise of a locked box on the sub pole.

A separate circuit breaker called the "Generator Circuit Breaker"(GCB) will be required in addition to the "Connection Point Circuit Breaker". This generator circuit breaker shall be installed between the CPCB and the generating unit and controlled by a protection module containing (as advised by Country Energy):

- Overcurrent protection
- Under Frequency protection
- Over Frequency protection
- Over voltage protection
- Undervoltage protection
- Loss of Supply to Protection Module

The GCB shall be suitably rated for the service voltage, maximum load current and to interrupt the perspective asymmetrical fault current.

It is not considered necessary in this instance to have the following facilities (as advised by Country Energy):

- Earth Fault protection
- Rate of Change of Frequency protection
- Vector Surge protection
- Neutral Voltage Displacement protection

It should be noted that these protection requirements differ a little from the requirements of Table 8-1.

The developer shall also submit a "Protection Analysis Report" and "Protection Maintenance Plan" for the generator, when submitting the connection application to Country Energy.

The Protection Analysis Report should detail (as a minimum):

- Protection operation for faults in the portion of the Country Energy network directly fed from the Generating Plan
- Protection operation and grading with upstream Country Energy protection for faults occurring on the Generator side of the Connection Point CB
- Provide maximum and minimum connection point fault levels and positive, negative and zero-sequence source impedances of the generating plant
- Ensure that protection systems can prevent islanding from occurring within the specified time.

The Protection Maintenance Plan should detail:

- Frequency of Protection Maintenance
- Records of Protection Maintenance and relay testing
- Storage of Protection settings records
- Storage of Protection setting reports.

9 Construction of powerhouse

As covered in Section 6.4, construction of the mini hydro room will be under the Tillegra Dam construction contract to designs prepared by the mini hydro operator. All other installations are to be provided by the operator following the completion of the main contract works.

10 Environmental considerations

The mini hydro will be required to cover certain aspects of the environmental considerations, as described below.

10.1 Oil interception

An oil interception system must be operating in the mini hydro station sump to ensure that oil is not discharged into the station tailrace. The mini hydro operator must determine the likelihood of oil spill occurring and select the appropriate oil interception system.

The mini hydro operator must provide relevant documents, calculations or evidences that the oil interception system selected meets the required criteria set by HWC.

10.2 Monitoring

Monitoring is not required for the mini hydro but will be provided by HWC at the intake tower and outlet channel.

11 Capture of spillway flows – maximum potential capacity

Spillage occurs when there is an excess water inflow into the dam when the storage is full. Some of the excess water could be discharged through the mini hydro to maximise energy capacity. It should be noted that spillage only occurs when the dam is full, which initially will take an estimated two to ten years for first fill.

There are likely to be two options for installing this maximum capacity; either install the full capacity in one unit, or install a small turbine operating continuously for environmental flow duties and a separate larger turbine to generate intermittently from the flows that would otherwise pass over the spillway. As the reservoir will take two to ten years to first fill, the larger capacity turbine could be installed at a later stage since there will not be any spillage until the dam is full. The justification for installing two machines should be investigated by the mini hydro developer as this would increase the capital cost of the turbine(s), and affect the size and cost of the downstream infrastructure (control, switchgear, transformers) and also more civil works to provide larger room for the turbines, thereby also increasing the capital cost.

The advantage of providing two units is that the smaller unit can be dedicated to generate from only the environmental flows, and therefore its efficiency will be optimum. The environmental flows are continuous, resulting in a firm base load, which is an optimum operating regime for a turbine.

However, an advantage of providing a single larger unit is that this unit could easily accommodate an increased level of environmental flow, either continuously or as intermittent bursts, such as the transparent, translucent and freshes releases. A single turbine requires only one tapping from the 800 mm diameter pipe in the valve block, whereas two separate turbines would each require tappings and would take up a much larger floor area. The likely key disadvantage from a larger single unit is that during times when only environmental flows are passed, which could be 40% to 50% of the time (and 100% of the time for the first two to ten years), it will operate at a very low efficiency.

11.1 Net flow duration

Flow duration curves for all net flow releases excluding Grahamstown transfer and leakage have been prepared in Figure 11-1. As before, the curves have been prepared and considered for the two scenarios of 90 GL/year and 120 GL/year.

For the 90 GL/year scenario, about 35% of the time the flow exceeds 62 ML/day (purple line). The total average net flow is 197 ML/day. For the 120 GL/year scenario, about 27% of the time the flow exceeds 62 ML/day and the total average net flow is 172 ML/day. Both scenarios demonstrate the vast amount of water spillage that can possibly be captured to maximise energy output.

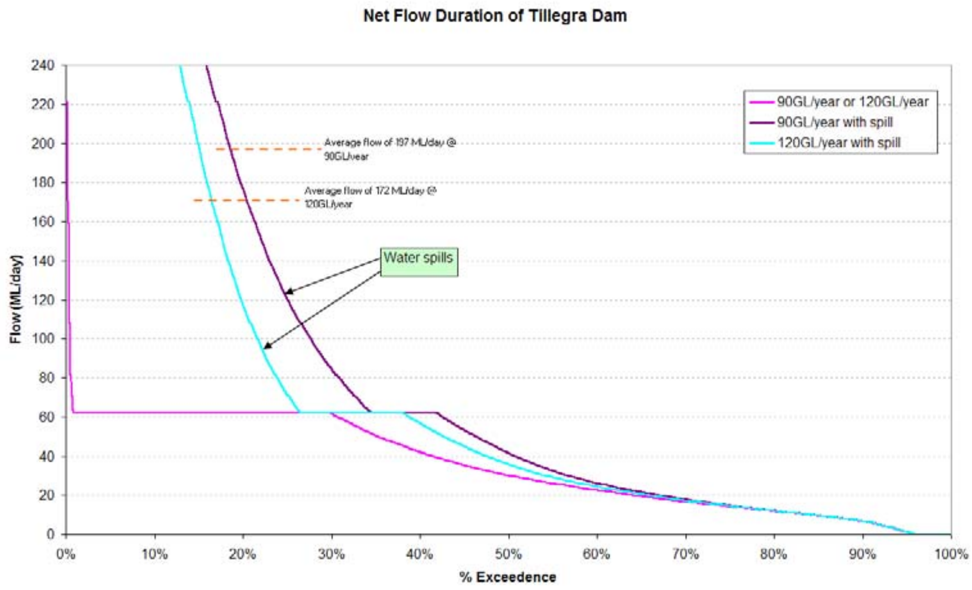


Figure 11-1 Duration of net flow releases (capture of all flood flows)

11.2 Incorporating a larger machine

A larger machine, given its larger capacity, will necessarily be heavier and physically larger. The larger machine would still be housed within the valve block in a separate room with separate access, however the dimensions of the room would need to be increased. At this stage a floor area of 35 m² to 50 m² is recommended depending on whether a single larger unit or double units option is adopted. These do not include storage and workshop areas.

A larger machine also means deeper submergence if a reaction type of turbine is used. This means a locally deepened internal floor and outlet pit to achieve the required submergence to prevent cavitation.

It is anticipated that the larger machine would require no alterations upstream of the penstock pipe tapping, other than the branch penstock being of a larger diameter and an additional tapping if the two machines option is selected. The capture of some of the flows for generation, that would otherwise be discharged over the spillway, means that these flows will instead pass through the intake structure.

As the machine is of larger electrical capacity, it is likely to be a synchronous generator, with a frequency governor, and will require a more comprehensive protection suite.

The effect of increased power output capacity on the transmission lines needs to be discussed with Country Energy. If necessary, a transmission lines study needs to be pursued to come to meaningful conclusions.

If the generator is to generate at 11kV, it can be directly connected to the local electrical grid, and therefore a setup transformer will not be required.

11.3 Assumptions and cautionary note

Whereas the preceding sections deal with potential energy capacity from environmental flow releases, for which the flow is guaranteed as part of the licensing agreement for Tillegra Dam, this section addresses the potential maximum capacity that could be possibly installed. However, this additional capacity depends entirely on the magnitude and duration of outflows from the reservoir, which in turn is governed by the magnitude of flows into the reservoir and the operational rules for maintaining water levels in the reservoir.

11.4 Summary of key issues

In summary, the decision for single or twin turbines needs to be assessed with regard to the following key points:

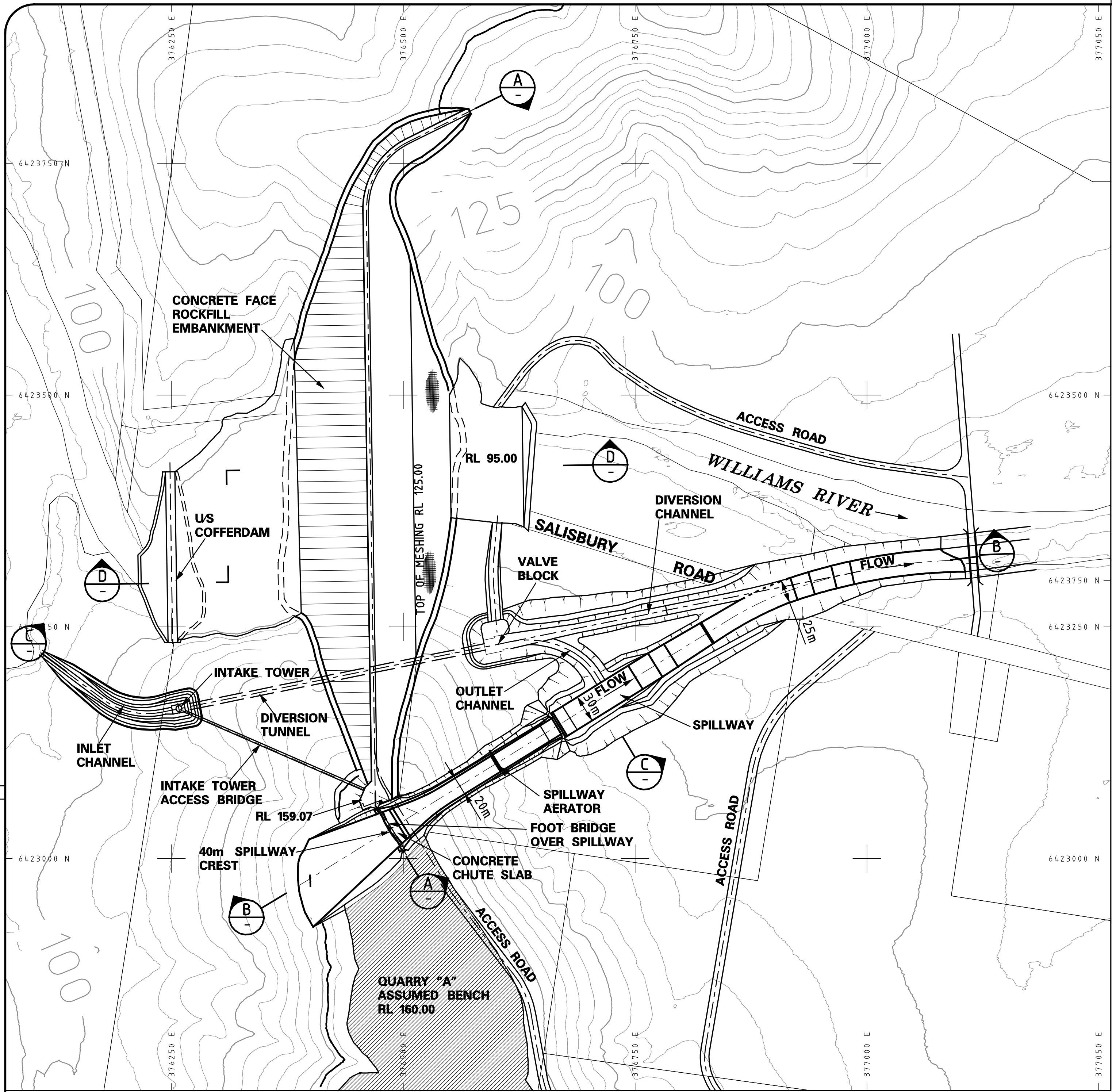
- Efficiency of the larger machine to run at low (environmental) flows
- Ability of the larger machine to operate over the entire flow range
- Economics of total installation.

12 Defined Terms

AHD	Above Height Datum
CFRD	Concrete Faced Rockfill Dam
DNSP	Distributed Network Service Provider
FCD	Fixed Cone Dispersion (Valve)
GTSMR	Generalized Tropical Storm Method
HV	High Voltage
LV	Low Voltage

Appendix A

Drawings



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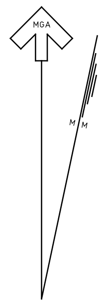
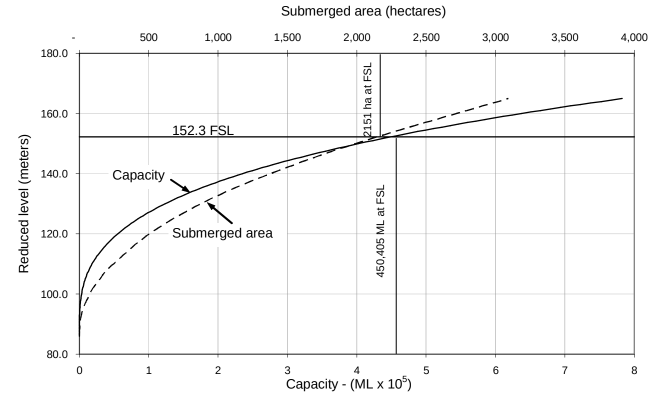
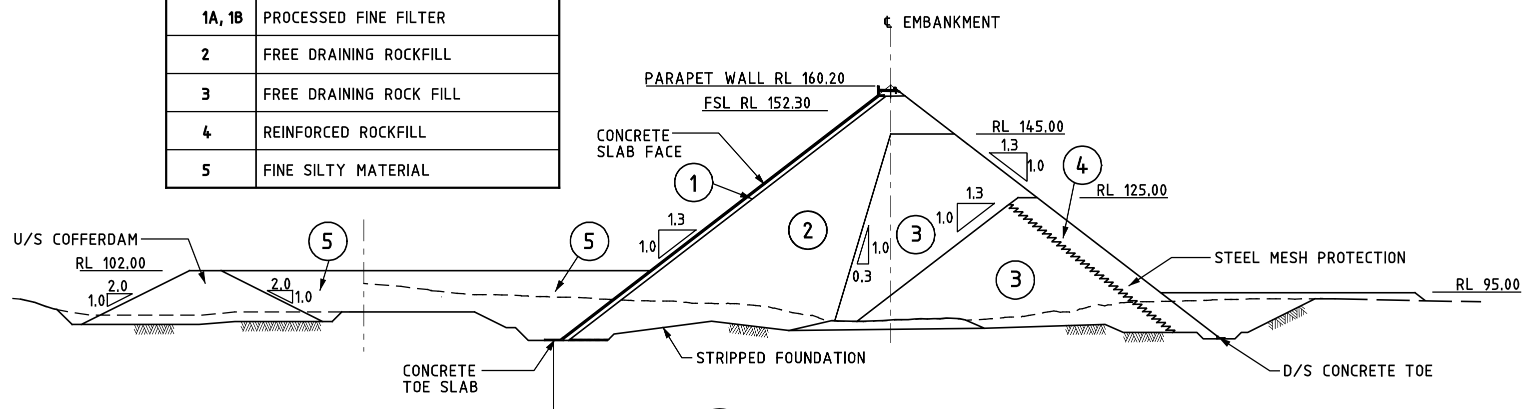




ZONE	MATERIAL
1	CRUSHED ROCK FILL
1A, 1B	PROCESSED FINE FILTER
2	FREE DRAINING ROCKFILL
3	FREE DRAINING ROCK FILL
4	REINFORCED ROCKFILL
5	FINE SILTY MATERIAL



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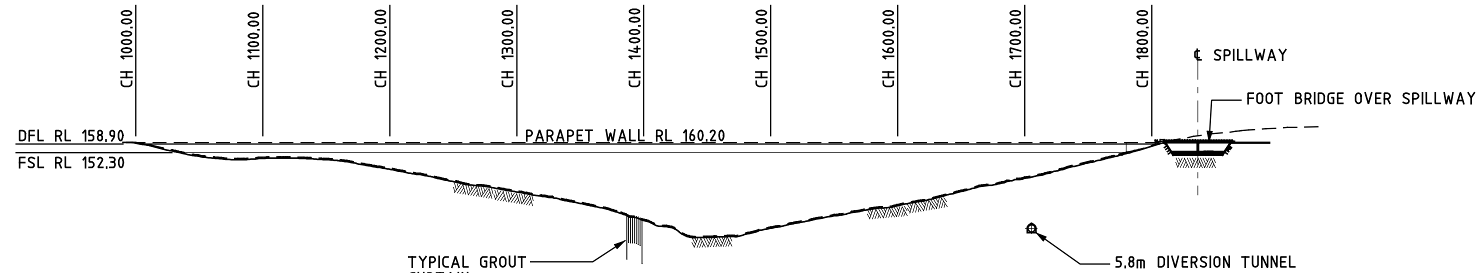

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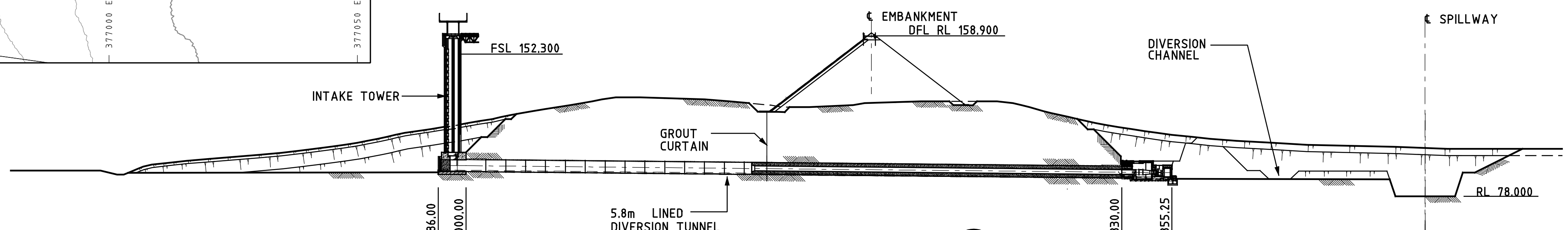

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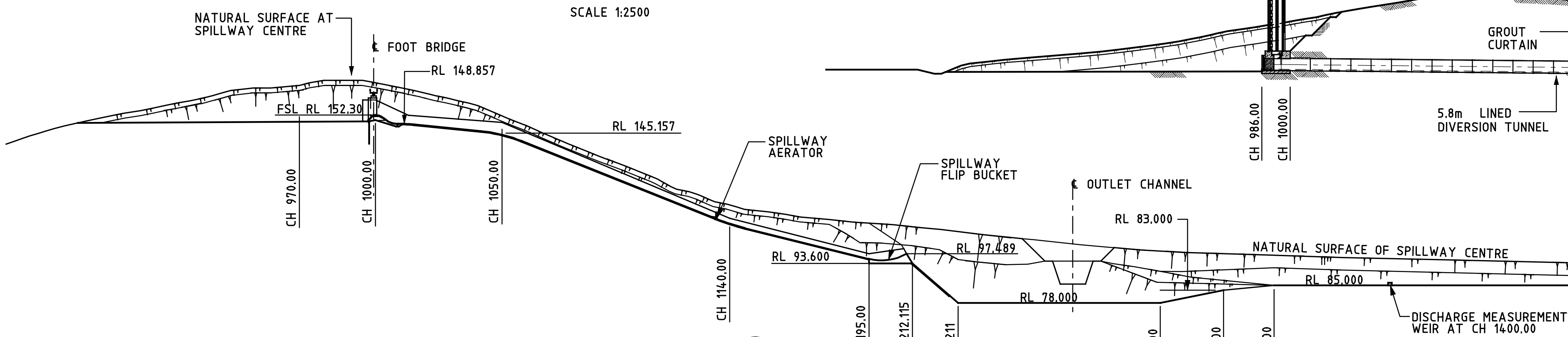

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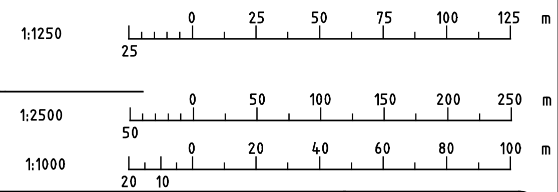

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TILLEGRA DAM
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GENERAL ARRANGEMENT

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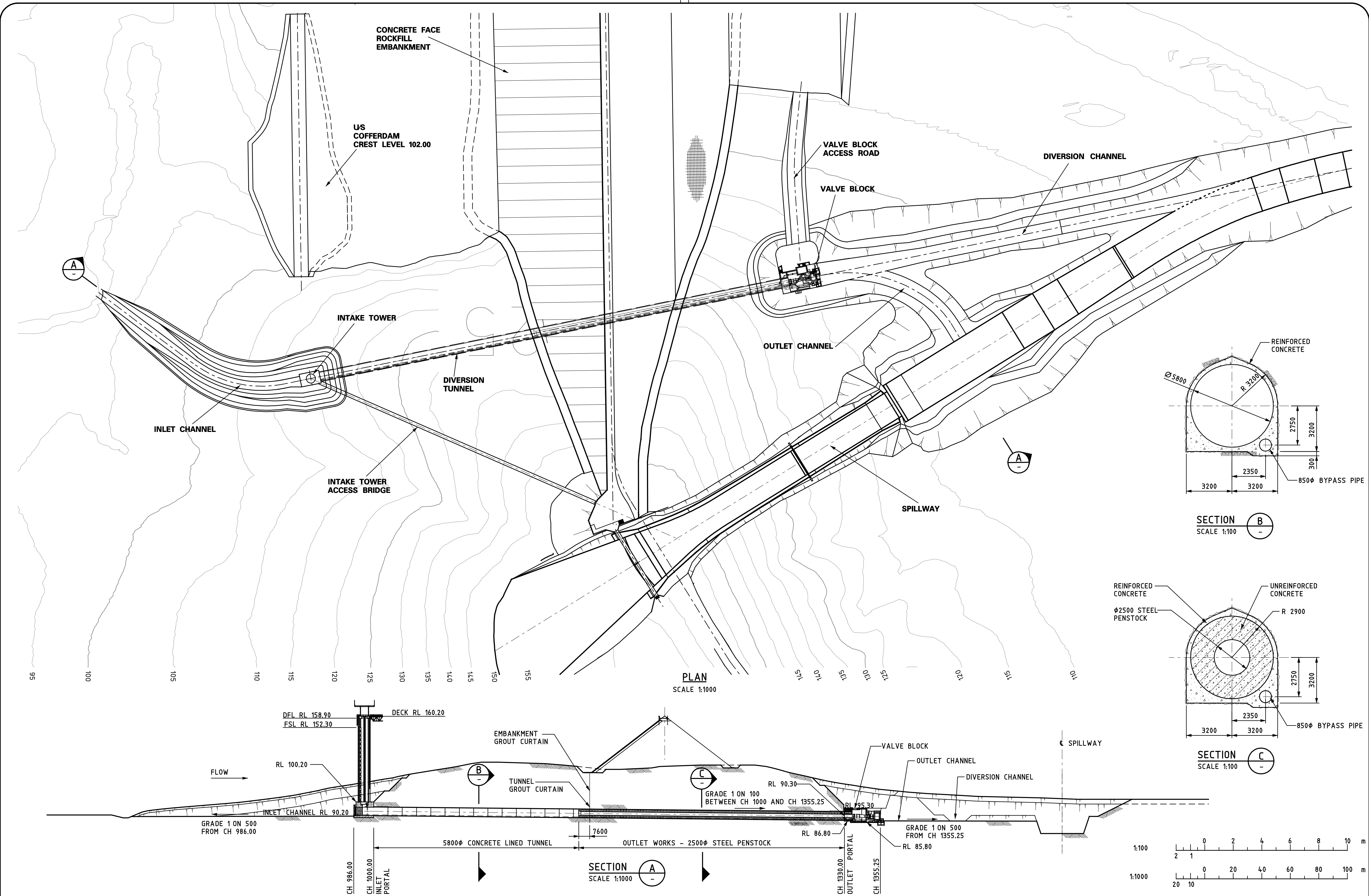

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OUTLET WORKS ARRANGEMENT
Sheet 1 of 2

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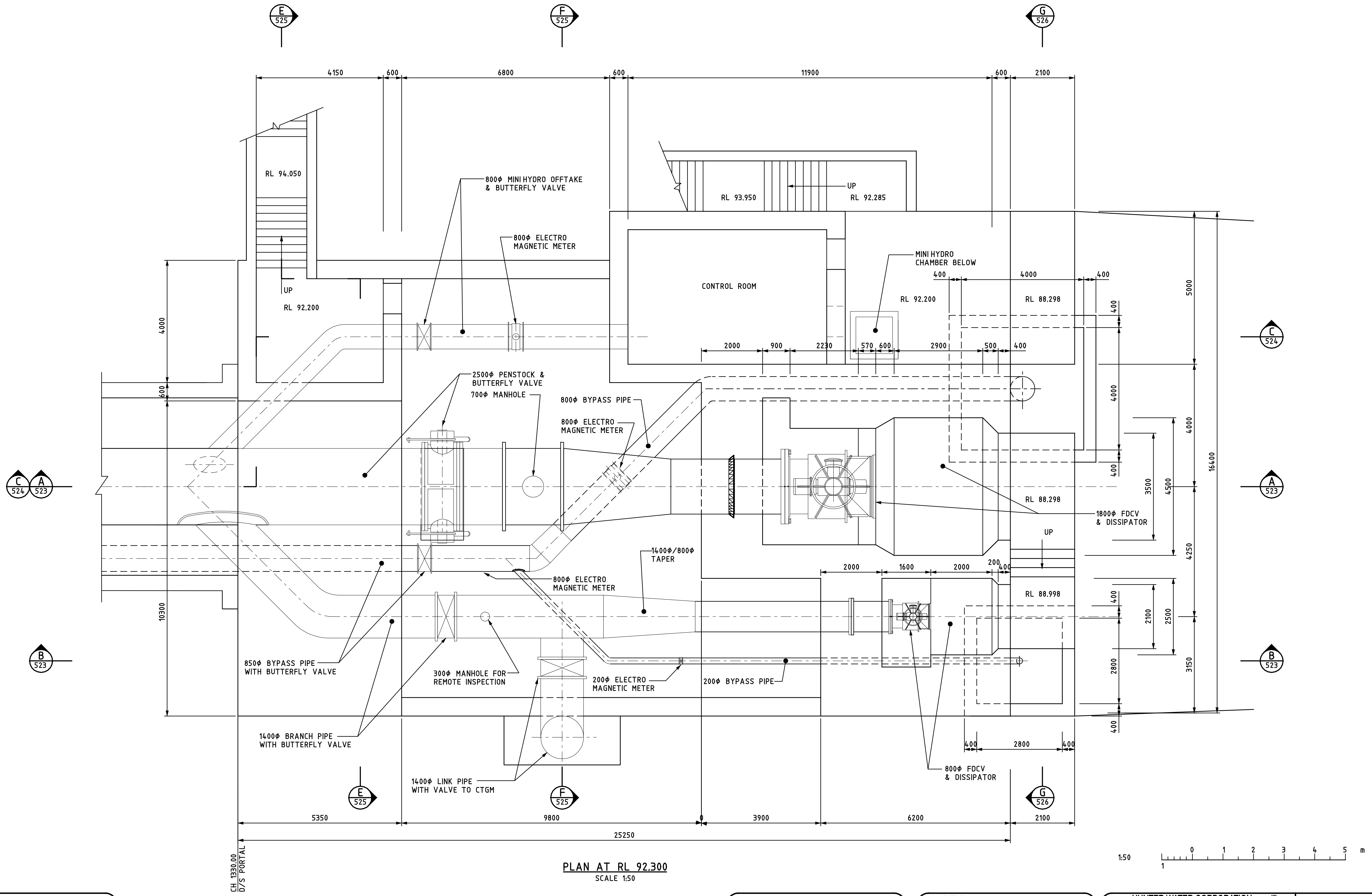

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OUTLET WORKS VALVE BLOCK
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Sheet 2 of 6

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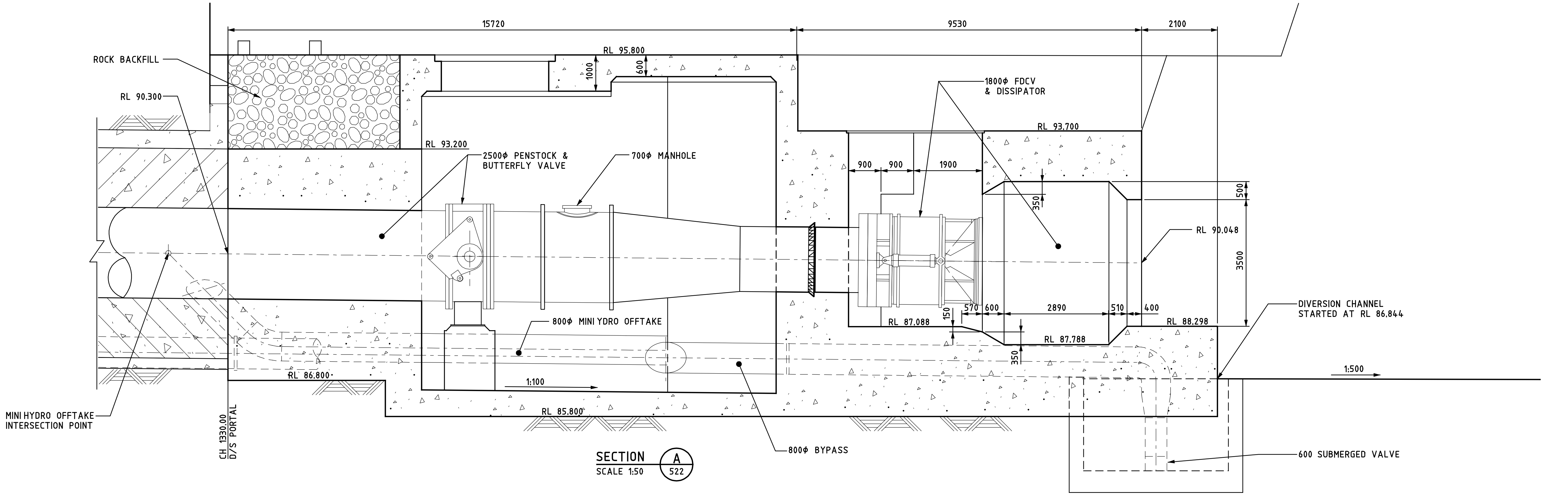

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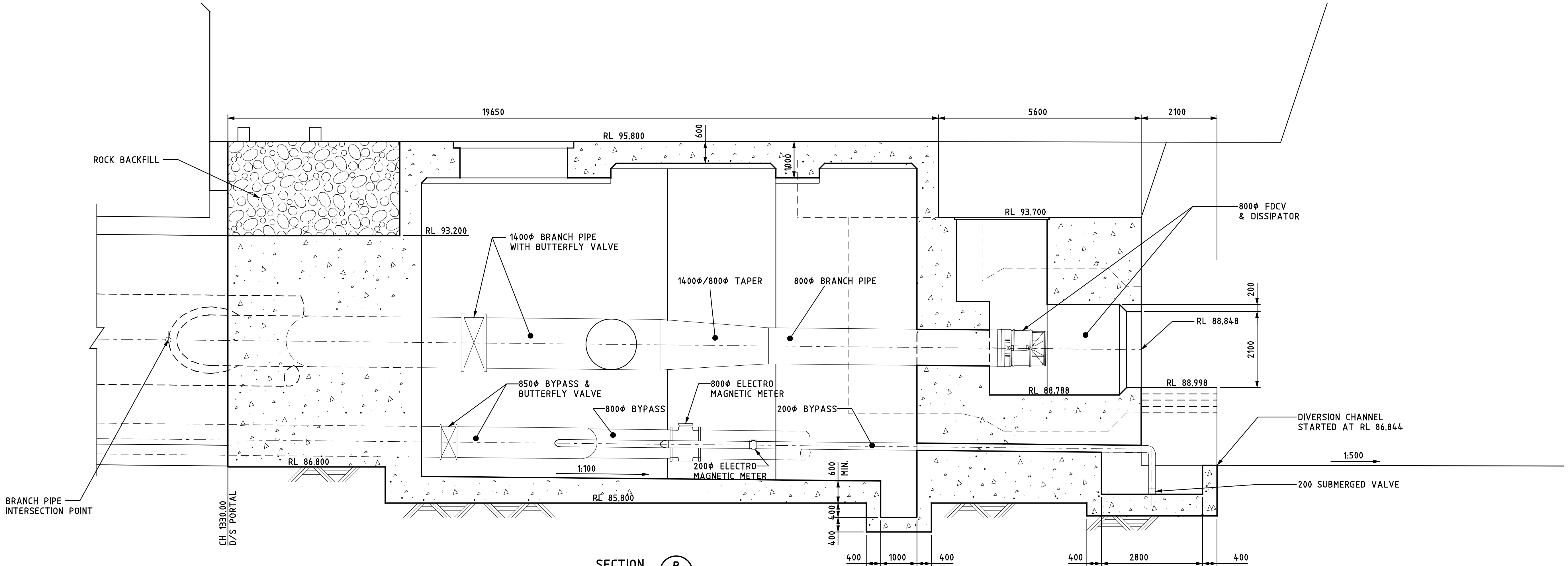

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OUTLET WORKS VALVE BLOCK
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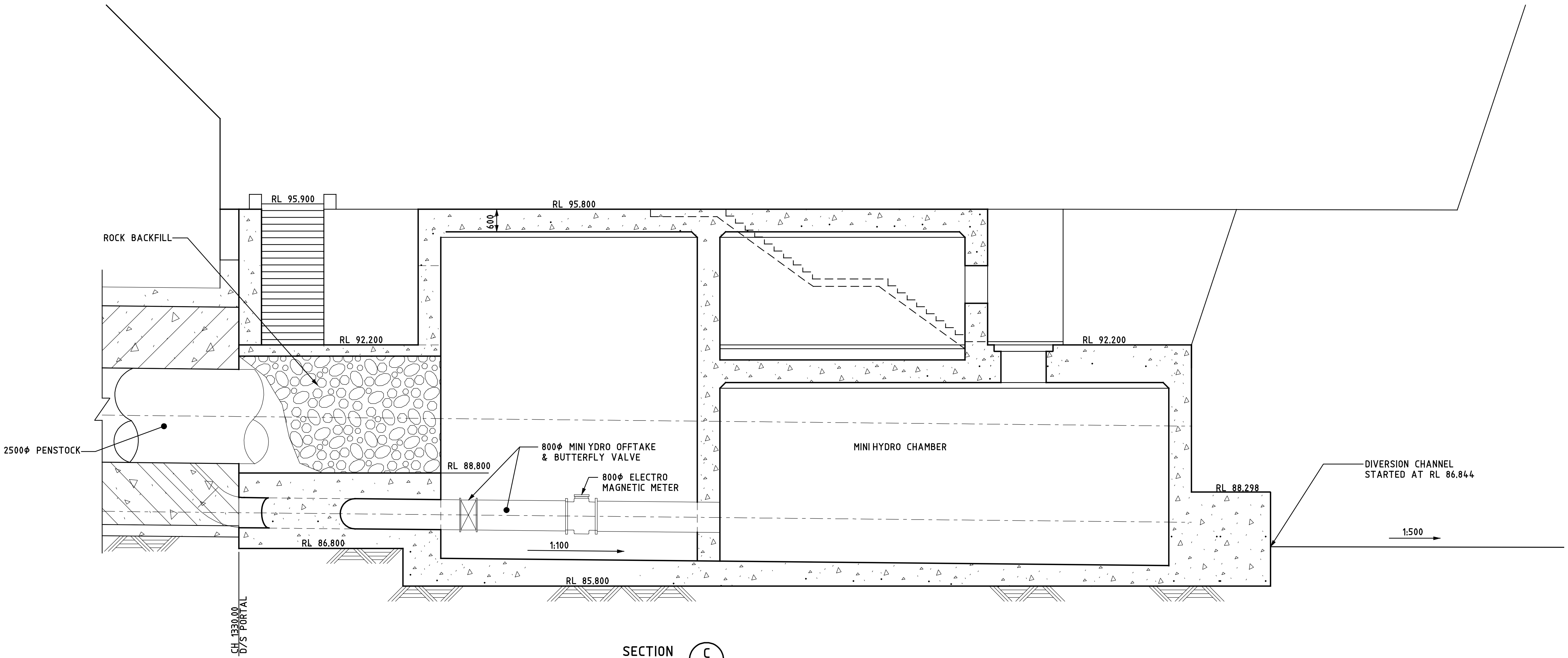

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