SECTION 9 : WEIR GATES

9.1 INTRODUCTION

In general, the purpose of spillway gates is to release flood waters timeously from the impoundment in times of peak floods by opening the spillway gates, based on early warning information received from upstream residents or river flow gauging stations, thereby reducing the risk of extensive flooding downstream of the impoundment. The gates are generally operated by personnel stationed at the weir or dam.

In the case of the Popa Falls Hydro Power Project, the function of the gates is primarily to maintain a certain pre-defined maximum overflow depth, by automatic regulation of the gate opening process. As the water level rises above the maximum overflow level, the gates will open automatically, releasing water from the impoundment in order to maintain the maximum overflow level. This maximum overflow level has been set to limit the extent of flooding upstream of the weir.

The purpose of the gates is therefore to:

- maintain as high an operating water head as possible to maximize power generation,
- open under flood conditions to discharge flood waters,
- to provide sufficient waterway under the gates when open to prevent upstream flooding, and
- to fully open under peak flood conditions to rapidly draw down the water level and, if required, increase scouring velocities, to sluice/flush out the sediments that have accumulated in the basin (see Section **9)**.

9.2 DISCUSSION OF GATE ALTERNATIVES

Various types of gates have been considered, including the no-gate option. These are described in the following sections:

9.2.1 NO GATES

This is a fixed spillway section. Although it would require minimal maintenance, the backwater flood levels will result in extensive flooding. In addition, this type of spillway will not satisfy the requirements of sluicing sediments, if required..

9.2.2 ELECTRICALLY DRIVEN RADIAL GATES

Whilst these gates meet the performance requirements, they are considerably more expensive than the option chosen. In addition, maintenance on the gates and motors would be costly over the life of the power station. These gates do not open automatically and, apart from the fact that operating personnel would need to be stationed at the weir on a full-time basis, could be subject to operational failure during floods thereby causing upstream flooding.

9.2.3 AUTOMATIC SCOUR GATES

These gates meet the operational requirements and in addition open automatically to pass floods. However, the gates do not allow total unrestricted flow through the gate openings in the fully open position, which would be required for sluicing operations. The gates are made of steel, which require regular maintenance and are also more expensive than the preferred TOPS gates.

9.2.4 TOPS SPILLWAY GATES

These gates meet all the performance requirements and in addition, will open automatically to pass floodwaters and can be raised to well above the expected maximum flood level during sluicing operations if required. The gates will be constructed in concrete and therefore maintenance costs will be minimal. This option is also the most cost effective and has been adopted as the preferred gated system.

9.3 DESCRIPTION OF THE TOPS SPILLWAY GATES

The TOPS spillway gates are shown diagrammatically in **Figure B10-1** of **Appendix B** of **Volume 2** of this report

The TOPS gate comprises the following components:

- Closure face on the upstream side that seals off the gate against concrete piers.
- Ballast tank that contains water to balance the applied hydraulic forces on the gate to open or close as required.
- Inlet conduits that connect the ballast tank to the upstream water to fill the ballast tank with water. These inlets are protected from blockages by self-cleansing screens.
- Outlets that empty the ballast tank to open the gate. There are two outlets. The primary outlet is a gate valve connected to an electrically driven actuator with a manual override handwheel. A secondary outlet is a siphon that is self priming to empty the ballast tank.
- Pivot arms that connect the ballast tank and closure face to the trunnions mounted on the piers.
- Trunnions that allow the gate to rotate to open. They consist of a steel shaft with a non-lubricant bush. The trunnion is situated above the water level and is accessible for inspection.

- Seals that are hydraulically assisted with a ‘fluo-carbon insert’ contact surfaces for easy movement and durability.
- Seal plates that are built into the piers and sill to ensure adequate sealing against leakage.
- Manhole and step irons to provide access for inspections.

There will be twelve gates, each 9.75 m high and 10 m long.

9.4 OPERATION OF TOPS SPILLWAY GATES

9.4.1 NORMAL OPERATIONS

The operation of the TOPS gate is shown in **Figure B10-2** of **Appendix B** of **Volume 2.**

The water filled ballast tank provides a rotational force (moment in kNm) about the trunnion which exceeds the opening rotational force induced by the upstream water level, to keep the gate closed for all water levels up to 300 mm above the full supply level (FSL).

Water will overflow the gates to a depth of 300 mm before the gates will open. This is to accommodate smaller excess flows not passing through the turbines without the gates opening.

As the water level exceeds 300mm overflow over the gate, a discharge gate valve on the one side of the ballast tank will open to discharge water from the ballast tank at a rate exceeding the inflow. This loss of water from the ballast tank will reduce the closing rotational force on the trunnion to a level below the rotational force induced by the upstream water level, so that the gate will open outwards.

The discharge gate valve is controlled by an electrically driven actuator. Water level sensors will signal the actuator to open the discharge valve progressively as the water level rises and to close it down as the water level recedes. In this way, the upstream water level will remain constant within minor changes in the upstream water level.

All gates will be set to operate simultaneously so that there is an equal opening below the gates to assist with an even scouring effect across the waterway.

When the discharge valve is closed, the ballast tank will fill through the inlets to cause the gate to close to maintain the full supply level.

9.4.2 SLUICING AND FLUSHING OPERATIONS

If the sluicing option were to be pursued, the TOPS spillway gates will need to be lifted manually, with the help of hydraulic rams, to above the free water surface during sluicing operations, to sluice out sediment below the gates. Refer to **Figure B10-1** of **Appendix B** or details of the gate installation and hydraulic ram mechanism.

9.5 BACKUP FACILITIES

The TOPS spillway gate has a back-up facility to open a gate in the event that the primary opening mechanism of the gate valve fails. These include:

- A handwheel on the actuator to open the discharge valve manually. Provision is made for an operator to safely access the handwheel when the gate is open or closed.
- A siphon that will prime itself when the water level reaches about 600 mm over the gate. The siphon will draw down the water in the ballast tank to open the gate. When the water level in the ballast tank reaches the siphon inlet, the suction seal will break and the siphon will cease to discharge. The ballast tank will then fill through the inlets from the upstream water to close the gate.

9.6 MATERIALS AND CORROSION PROTECTION

The TOPS spillway gate is designed to have materials that require little or no maintenance. The following materials will consequently be used for the manufacture of the gates and associated equipment:

- The seal plates and seal clamping plates are in stainless steel grade 304L.
- Seal clamping bolts are stainless steel grade 304.
- The seals are natural rubber with PTFE (‘fluo-carbon’) inserts. The side seals are also protected on both the upstream and downstream sides with swipe seals to prevent damage to the seal from debris and the ultraviolet rays of sunlight.
- The closure face and ballast tank are constructed from hard, durable concrete with both steel and fibre reinforcement to minimise cracking and corrosion.
- The pivot arms are in mild steel with a good corrosion protection system of twin pack polyamine coating.
- The main heavy bolts connecting the pivot arm to the ballast tank will be galvanised and concrete encased in a plinth 400 mm high.
- The trunnion bracket is in mild steel suitably corrosion protected.
- The bearing shaft is mild steel with a stainless steel lining.
- The bush is Hi-lube Vesconite which is a hard, longwearing, non metallic and non lubricating bush.

9.7 STRUCTURAL CONSIDERATIONS

The TOPS spillway gate was modelled structurally using a plane frame analysis. The gate will be constructed in 50 MPa fibre reinforced concrete as a ribbed slab construction. The average slab thickness is 130 mm with ribs typically 400 mm deep by 250 mm wide at 1.5 m centres vertically and 1.6 m centres horizontally.

The maximum moments of 280 kNm can be accommodated in the ribs with reasonable amount of reinforcement. Maximum deflections in the ballast tank are expected to be in the order of 15 mm.

The gate will be analysed as a finite element model in detailed design, but the sizes indicated here are adequate to resist the applied forces.

The trunnion shaft diameter is expected to be in the region of 500 mm, and will be fitted with Hi-lube Vesconite bushes. The stress on the bearing will be kept to below 30% of its maximum stress to minimise long-term creep effects.

9.8 CONSTRUCTION METHOD

The metal items will be fabricated in a reputable steel workshop and will be subject to stringent quality assurance procedures. In addition, the following will be taken into consideration to simplify on-site construction.

- Two sets of purpose made shutters will be made for the 12 gates.
- The shutters will be made in 1.6 m lifts that can be manhandled or placed with a light crane.
- The concrete mix will be specially designed with additives to give a high strength, compact and durable concrete.
- Nylon fibres may be used in areas of higher stress to reduce cracking.
- Strict site control will be employed.

It is anticipated that it will take three weeks to construct one gate. After sufficient time for the concrete to cure and strengthen, the gate will be lifted with hydraulic jacks to the fully open position.

9.9 INSPECTION AND MAINTENANCE

The TOPS spillway gates are accessible for full inspection. In its closed, but operating position, the external portions of the gate can be inspected underwater from upstream and downstream. The turbines in the adjacent gates should be turned off for this operation. The ballast tank can be accessed through a manhole. If necessary, underwater repairs can be affected with proprietary products.

The pivot arm and trunnion can also be inspected and recoated whilst the gate is closed. The top of the gate can be isolated by sandbagging on the upstream edge.

The gates can, however, be inspected and/or maintained when dry by placing stoplogs and lifting the gate clear of the water as shown in **Figure B10-3** of **Appendix B**.

A set of two 100 ton hydraulic jacks will be supplied for all gates as well as one set of stoplogs.

9.10 BUDGET COSTS

The estimated cost of constructing a TOPS spillway gate is N$900 000 per gate based on 10 or more gates being constructed. The price includes for one set of lifting jacks and one set of stoplogs for all gates. The price excludes VAT and contractors preliminary and general items which will be covered under the main contract.

9.11 FISH LADDERS

It is possible to accommodate fish ladders on TOPS gates by minor modifications to the gate. It would require a modified shape of the gate to include a 2 m wide separation between the upstream face and the ballast tank. This would accommodate two flights of ladders and a further two flights would need to be attached to the gate below the ballast tank. Each step, or box, would be approximately 0,75 m square and the water step would be in the order of 0,2 m in order for the velocity to remain below 1,5 m/sec, preferably 1,2 m/sec.

In the design of fish ladders it is necessary to take into consideration aspects such as

- Underflows as opposed to overflows, as some species don't jump.
- Protection against predatory birds.
- Adequate lighting.
- Rest pools within the ladder etc.
- Adequate size etc.

As an alternative to providing fish ladders on the TOPS gates, consideration should also be given to incorporating fish ladders in the concrete abutments of the weir. In addition, the need to provide ramps for crustaceans (e.g. crabs, etc.) should be investigated.

There is a whole science to fish ladders and it will therefore be necessary to research this topic thoroughly in the detailed feasibility study phase and to work closely together with a specialist on the subject, to ensure that the end product will work satisfactorily.

As an alternative to fish ladders, the potential of providing a fish bypass needs to be investigated. However, as water needs to flow down the bypass at all times, the channel will need to be cut down to, or close to, the riverbed level to ensure that fish are able to use the bypass throughout the year. The effect of this on the viability of the project will need to be determined.

A diagrammatic sketch of how fish ladders could be incorporated in the TOPS gates is given in **Figure B10-4** of **Appendix B** of **Volume 2**

9.12 EVALUATION OF PREFERRED GATE OPTION (TECHNICAL/FINANCIAL, SOCIAL, ENVIRONMENTAL)

The three weir gate options, together with the no gate option were evaluated in terms of their relative score against the desired criteria, as shown in **Table 9-1.**

Table 9-1 : Evaluation of Different Weir Gate Options

Criteria	No gates	Electrically driven radial gates	Automatic scour gates	TOPS spillway gates
TECHNICAL				
Minimise maintenance requirements	3	1	1	2
Maximise effectiveness of sediment removal	1	2	2	3
Minimise risk of failure	3	1	1	3
Sub-total (Rank)	**7**	**4**	**4**	**8**
FINANCIAL				
Minimise capital cost of installation	3	1	1	3
Minimise operating costs	3	1	1	3
Maximise electricity production	3	1	1	3
Sub-total (Rank)	**9**	**3**	**3**	**9**
ENVIRONMENTAL				
Minimise impact on the hydrograph	1	3	3	3
Minimise upstream flooding	1	2	2	3
Ability to incorporate a fish ladder/bypass	1	1	1	3
Sub-total (Rank)	**3**	**6**	**6**	**9**
SOCIAL				
Minimise upstream flooding of houses, buildings etc	1	2	2	3
Sub-total (Rank)	**1**	**2**	**2**	**3**
TOTAL (RANK)	**20**	**15**	**15**	**29**

Note: A score of 1 means that the objective is not, or poorly achieved, 2 = fair and a score of 3 means that the objective can be achieved. Criteria in red indicate fatal flaws.

Obviously the no gate option is the cheapest option requiring the least management and maintenance, however, it would result in unacceptable levels of flooding upstream during peak flow periods, which would have negative consequences for the local community and biophysical environment.

Of the three other options, the TOPS gates clearly have the advantage in terms of technical specifications and costs, in terms of capital expenditure and operating and maintenance costs. This design also has the least impact on the environment because the gates automatically respond to flood conditions, thereby reducing the risk of operational failure and upstream flooding.