Sustainable Energy Development Office
Government of **Western Australia**

Study of Tidal Energy Technologies for Derby

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Executive Summary

Introduction

This study investigates tidal energy technologies and options to offset or replace the existing diesel generation facilities at Derby, Western Australia. The objectives of the study were:

- To assess the technical feasibility of developing a tidal power station and the likely environmental and social impact of such a development.
- To determine the economic viability of a tidal power development for the supply of power in the Derby region.
- To determine the preferred location and layout of the tidal power development.
- To evaluate the Turnkey and Build Own Operate (BOO) development options for the construction and operation of a tidal power development and advise on the scope of the tender process to deliver potentially feasible options.

The above objectives are covered in detail in this conceptual study. The findings of the study can be summarised as follows.

Study Limitations

Limitations of the current study are:

A. No detailed survey information is available and this limits the accuracy of the estimates of quantities and reservoir volumes;
B. No geotechnical investigation of the potential sites has been undertaken and the conditions may have a major impact on the civil construction costs;
C. No information is available on the sediment dynamics in the estuary. Sediment dynamics has significant environmental and technical implications to the project;
D. Only a preliminary assessment of the potential environmental effects has been undertaken to date.

Tidal Energy Technologies

Tidal technologies were investigated, including those under development and existing tidal plants. Information has been sought from documents on renewable energy, from the internet and from correspondence with technology developers worldwide. A reference list of documents, textbooks and internet sites has been included at the end of this report. Further information was requested from the tidal energy companies regarding many key issues including: costs, applicability, history of development/operating sites, O & M requirements and environmental impacts.

The main findings are:

1. Many tidal energy schemes have been investigated over the past 40 years but very few have actually been built, with very high capital cost and environmental impact the main deterrents.
2. Tidal barrage systems are technically feasible, utilising conventional low head hydro turbines and dams/barrages.
3. Tidal current schemes are primarily in the research and development phase with a few small prototypes being tested at present.
4. The tidal energy technology that is most appropriate for a small-medium scale (<10 MW) tidal plant at Derby is a tidal barrage scheme using conventional low-head hydro turbines.

Tidal Energy Generation

A series of tidal system simulation models was developed to determine the relative merits of different tidal power configurations and the available generation. Evaluation was carried out utilising five-minute simulation of a range of storage curves and tidal system capacities. At each time step the model assessed system load, available tidal power and storage.

The major limitations on tidal generation are posed by the storage volume and head (differential in level between tidal and pond levels) relationships and tidal characteristics of phase and amplitude. A tidal system poses additional limitations to the standard hydro system in that the available head does not increase with storage, it is determined by tidal amplitude, and the available storage and head are dictated by tidal phase.

The system modelling was carried out over a period of 1 year. The modelling was based on historical load patterns for the 2000/2001 financial year and assumes the tidal plant meets 100% of the load when there is sufficient tidal power generated (100% system penetration). The following tables summarise the findings of the system modelling.

Storage	Installed Capacity (MW)	% Utilisation	Total Generation (MWh)	Total Load Met (MWh)	Total Load Not Met (MWh)	Total Surplus Generation (MWh)
7.4 Mm^3 at 11.5m						
	15	13%	35,700	17,300	9,400	18,300
	12.5	16%	34,500	17,300	9,400	17,300
	10	**20%**	**31,400**	**17,300**	**9,400**	**14,000**
4.35 Mm^3 at 11.5m						
	10	16%	17,500	13,900	12,800	3,600
	7.5	21%	17,400	13,900	12,900	3,600
	5	**32%**	**17,100**	**14,000**	**12,600**	**3,100**
	2	**53%**	**9,500**	**9,300**	**17,400**	**200**
2.5 Mm^3 at 11.5m						
	7.5	21%	17,400	14,300	12,300	3,000
	5	**33%**	**16,700**	**14,300**	**12,400**	**2,300**
	2	**50%**	**8,700**	**8,600**	**18,000**	**80**
1.6 Mm^3 at 11.5m						
	7.5	11%	7,300	7,200	19,400	100
	5	16%	7,300	7,200	19,400	100
	2	**40%**	**7,000**	**7,000**	**19,700**	**20**
0.8 Mm^3 at 11.5m						
	2	21%	3,600	3,600	23,000	0
	1	**40%**	**3,445**	**3,445**	**23,236**	**0**

The main conclusions of the modelling are:

- The modelling showed that single basin tidal plants of 7.5 MW or more will have an uneconomic amount of surplus generation, leading to low utilisation of the plant.
- The optimum sized options in terms of maximising utilisation are of 1-5 MW.
- The small amount of surplus generation from these options will be absorbed by load growth
- For a single basin design, there are hours during the day when the tidal plant will not be generating power. These hours will change from day to day due to tidal cycles.
- The diesel generation system must be able to supply 100% of the load.

Environmental Assessment

There are several significant environmental constraints to the development of tidal power options in the Derby area. The majority of issues relate to changes in the tidal flow patterns in the immediate vicinity of the plant, resulting in altered geomorphological processes, disturbance of riparian communities and potential changes in water quality.

Of greatest concern is the potential for excessive sedimentation of the channels upstream and downstream of the plant and hence the need for ongoing dredging. It is likely that mangrove ecosystems will be modified or destroyed, with losses upstream and possible expansion downstream.

There is a high risk of acid sulphate soils being present, which could lead to corrosion issues with infrastructure, water quality problems and fish kills. Corrosion from seawater, abrasion erosion from silt and sand and biofouling are all major concerns. Preliminary discussions with the Kimberley Land Council did not identify any significant aboriginal heritage issues.

It is concluded that there are three broad sites in the immediate vicinity of Derby for which there do not appear to be overwhelming environmental constraints and therefore should be assessed in terms of technical and economic feasibility for tidal power development. These sites are Airport Creek and various locations along Doctors Creek, particularly the western branch. In addition, it should be noted that there appears to be significant potential for tidal power development in the Buccaneer Archipelago with less environmental impact for much greater available power – the tradeoff being poor existing access and long transmission requirements.

While the environmental assessment did not identify any issues that would preclude tidal power development, proper management of environmental issues could impose significant economic constraints.

Development Options

Three development options were identified around the Derby area – tidal barrages at Airport and Doctors Creek, and the construction of a new reservoir. The installed capacity of the tidal plants investigated range from 1 MW to 5 MW. Multiple basin designs for small systems were not viable due to greatly increased barrage lengths, and therefore no preliminary cost estimates were made.

Conceptual designs and cost estimates were made for the four most economic options based on following assumptions:

- The powerhouse structure would consist of mass concrete foundations to resist buoyancy, and be supported by driven piles to prevent subsidence, rotation and lateral displacement. The walls would be heavily reinforced and the roof would consist of removeable panels.
- Construction of the access road would most likely be achieved by displacement of the upper level of tidal mud with rock.
- Slope and bed protection will be required for protection against erosion.
- Low head bulb or Kaplan turbines would be used, and the warm, saline environment may limit the options significantly.
- The power station will require both upstream and downstream bulkheads, inlet and outlet gates to seal off turbines during maintenance periods, and radial sluice bypass gates.
- Spinning reserve and demand peaks will be major factors in meeting performance standards.
- To maintain a speed and frequency, either a governor or controllable load will be required. A hydrogen production cell could be used for energy storage, or pumping and heating loads.

- Conventional high voltage transmission lines can be used, with an expansion of the existing SCADA system to incorporate the new plant.

Preliminary cost estimates were made for the four most promising options. The cost per kW ranged from $6,770 to $12,800. Capital costs ranged from $12.8 million to $33.9 million for 1 MW and 5 MW options respectively. Capital costs had high fixed components, resulting in larger plants being more cost effective. The cost estimates are very approximate, as they were based on very limited information.

Economic Analysis

The most cost effective option was found to be a 5 MW tidal plant at Doctors Creek with a 2.5 Mm^3 volume of water storage. The proposed development can be constructed for an estimated capital cost of $33.9 million and is expected to generate approximately 16.7 GWh of energy annually including a surplus generation of 2.3 GWh. The tidal plant would meet 50% of the annual demand, with the existing diesel generators meeting the remaining load.

The cost of unsubsidized tidal energy was estimated at $0.41/kWh.

Including the cost of diesel generation, the discounted weighted average tariff for this option was estimated at $0.30/kWh given a 50% capital cost grant of $16.9 million and a nominal discount rate of 15%.

The project is very sensitive to variations in diesel fuel costs, installed capital cost, the grant received, power output and the discount rate used (and therefore inflation).

Social Issues

Tidal power development at Derby is likely to be positive for the social and economic climate of Derby and the greater Kimberley region. There is a high level of support within the township for such development and although the issues need to be investigated in more detail, there do not appear to be any significant social constraints on tidal power development for the township of Derby.