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North Queensland regional power independence and a superb new water supply for Cairns

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ABSTRACT

We present hydrological and economic modeling of a dam 40 km south of Cairns at an altitude of 620 m. The key is a relatively large dam wall and a small but deep 40 GL lake in a catchment area that receives 6–10 m of precipitation annually (120–160 GL run off). This would secure all current and future water needs for Cairns. The lake would be coupled by a vertical shaft to a 250 MW (peak) hydro-power station 500 m below and inside the mountain. From there, a 6 km tunnel running east connects with the coastal dam service-tunnel and a 3 km tunnel running west takes the water back to the river below the falls. On average this would result in the release of 300 ML/d opening up opportunities for tourism, new industries, and irrigated farming of high yield crops. The tunnel offers the possibility of a new transport corridor from the Coast to Atherton on the central tablelands. The increased flows in the dry season could be important for the health of the river which is also a nursery-ground for the Great Barrier Reef. The CO_2 savings from reduced coal fire power needs are significant. Comparative analysis with all three local dams shows that the proposed lake is smaller and many times more useful per m^2. Importantly, this reliable hydro-power would allow considerable regional load-balancing of unreliable wind and solar power, representing a big step away from dependence on remotely provided power which is a key recommendation in the widely supported Tropical North Queensland – Sustainable Region Initiative.

Keywords: Cairns water supply; CO_2 reductions; Hydro power generation

1. Background

Hydro-electricity generation and dams have a long history in Far North Queensland. Capacity was estimated to be of the of the order of 400 MW in the 1950s by Nimmo [1] who discusses the potential of the Barron, Tully, Johnstone, Herbert and Burdekin Rivers, also mentioning Freshwater and Flaggy Creeks. It is likely that at the time the East Mulgrave catchment was thought to be too small and inaccessible as it is not discussed. We speculate that this is because it was not known at the time that total precipitation at the top exceeds 10 m in an average year [2].

The North Australian City of Cairns has currently two main sources of water with Behana Creek intake and Copperlode Dam finished in 1955 and 1976 respectively [3]. Some years ago it became clear that those sources would no longer be able to adequately serve Cairns' needs in the foreseeable future. Subsequently Cairns City Council's Water and Waste department and local consulting engineering firm GHD have been developing the Mulgrave Aquifer pumping project [4–6].

In looking for an alternative to the Aquifer pumping project we presented an intake, tunnel and power-station solution at CESE 2009 [7]. The author has a background

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in robotics and has been looking for an opportunity to develop mining and tunnelling applications from 2003 onwards leading to the alternative which is unlocked by a 6.5 km long tunnel from the coast about 50 km south of the Cairns CBD. The proposed tunnel is inclined at about 9% to access the East Mulgrave River at the back of Bellenden Ker Mountain at 620 m above sea level (Fig. 1). The tunnel emerges by the river where an intake funnels water into a pipe taking it to a small hydro power station at the lower, eastern portal. This would allow generating about 2 MW of base-load electricity, enough to power approximately 1500 homes. From the power station approx 30 km of pipelines guide the water to the existing reticulation. Most emphasis in the CESE 2009 paper was given to the precipitation model and the resulting stream-flow calculations which refuted [7] initial concerns about the small size of the catchment.

This paper (CESE 2010) presents the obvious extension, the hypothetical case where a dam is built at the intake site, simply referred to as Intake from here on. The green political movement argues that World Heritage Areas preclude the building of any infrastructure let alone a dam however the legislation contains an exception clause and those who dare look objectively at the cost-benefit analysis herein will be surprised indeed. Before we present the analysis we summarise the empirical data that has been gathered since the first paper was written.

2. Empirical data gathered at the crossing confirms stream-flow model

A 44 m wide causeway crosses the East Mulgrave River approximately 5 km downstream from the proposed site and approximately 300 m upstream from where the East Mulgrave River and the Mulgrave River join. The author has taken 14 manual measurements at the crossing over the course of 10 months from May 2009 to February 2010 [8]. Approximately 20 km downstream from the Crossing is a place called Fisheries where the first of two river gauging stations is located; the other is located at Peets Bridge. Since much historical data is available for Fisheries [9] it was thought interesting and relevant to empirically assess the range of the proportion of flow at the Crossing. Given that result we then estimate the proportion at Intake site by subtracting the estimated run-off from the extra catchment due to the 5 km of river between Intake and Crossing.

The winter of 2009 was exceptionally dry making it quite suitable for assessing the reliability of the proposed intake by empirical means. Illustrating this, the smallest measurement at Crossing was 74 ML/d on a day when at Fisheries 164 Ml were recorded [8]. The minimum recorded flow at Fisheries that winter was about 115 ML/d, with the historic minimum being 71.8 ML/d (17/12/2002) [9].

The collected data are presented in Fig. 2, representing the ratio Crossing/Fisheries. From this we estimate the ratio Intake/Fisheries which is more relevant for our purpose. Intake is located another 5 km upstream from Crossing, above the gorge and falls. In order to estimate that proportion we constructed a run-off model for the extra catchment area (approx. 10 km^2) much in the same way we constructed one for the intake catchment. No rainfall data is available for the 10 km^2 area in question therefore we had to use estimates. We used 6 m at Intake and 2 m for the lower regions with westerly orientations. The lower limit seems reasonable keeping in mind that average observed rainfall at Fisheries is only about 1.3 m/a and that open Eucalypt forest replaces rainforest only a few hundred meters west of Crossing. Using these numbers we estimate that the water at the proposed intake is 84.8% of water measured at the crossing. We acknowledge the relatively large error margins here but obtaining em-

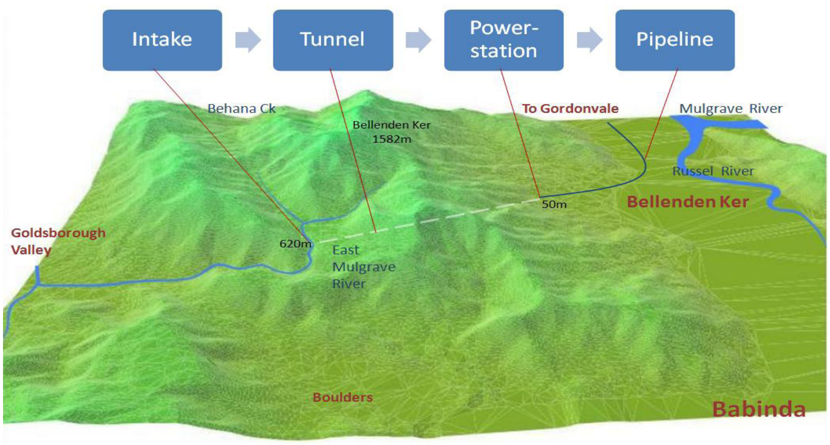

Fig. 1. The Intake, tunnel, power-station and 30 km pipeline to Cairns project as an alternative to pumping the aquifer (first presented at CESE 2009).

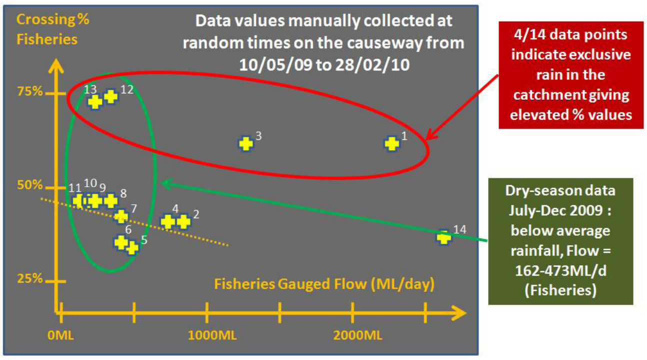

Fig. 2. Flow proportion of empirical data at Crossing (see text) when compared to gauged flow from 20 km downstream at Fisheries.

pirical data at Intake itself is nearly impossible without a tunnel or at least a helicopter.

Using the 14 empirical data we thereby calculate the range of the proportion of water at Intake compared to Fisheries as 29–63%. The lower limit of 29% was observed on July 5 after a long period of no rain anywhere, reflecting that the catchment at Intake (19 km^2) is only about 5% of the catchment at Fisheries (357 km^2). The mean of all 14 measurements is 42% which we use to calculate the average Oct daily flow at the proposed intake as 155 ML/d from the long term average gauged at Fisheries (370 ML/d). This independent estimate is very close to the middle of the range (113–196 ML/d) derived from the precipitation models [1].

For completeness we also estimate the peak flow using the rational method $Q = CIA$. During prolonged rainfall events in the Australian Wet Tropics the runoff coefficient C has been estimated to exceed 0.90 at similar altitudes [10]. No rainfall intensity measurements are available for Bellenden Ker mountain but given it is the place with the most annual rainfall in Australia we use the highest observation for a one hour rainfall event in Queensland, 131 mm in Townsville [11]. The catchment area A is 1900 ha. Therefore $Q = 0.9{\times}0.131{\times}1900{\times}10000/3600 = 622.25$ m^3/s.

Having confirmed the estimate on available water at Intake we now present the modelling on a hypothetical dam.

3. The hypothetical dam project architecture

Some simple considerations set the main parameters for the hypothetical dam project, illustrated in Fig. 3a. Access is possible only via tunnel from the east and the water must be diverted for as short a distance as possible while maximising the height difference, therefore it must be diverted west. One engineering solution involves a 10 km long basis tunnel with a 500 m vertical shaft near the middle holding the penstock connecting the power station in the basis tunnel to the lake above, as shown in Fig. 3b. A closer 3D view is shown in Fig. 3c and Fig. 4 shows Split Rock Dam in NSW which is very similar in shape and size to the hypothetical dam.

4. Hydro electricity generation capacity

In order to model the performance of a lake and associated hydro-electricity production capacity an average stream-flow scenario was constructed in the following way: we used the gauged historical values at the Fisheries to calculate the average daily stream-flow for every month at the potential dam site. In doing so we were guided by the empirical data and constrained by the hydrology

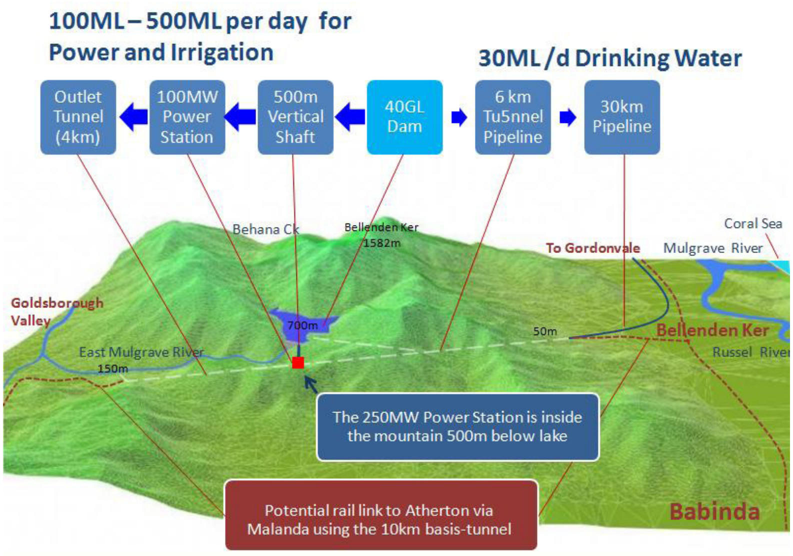

Fig. 3a. A 3D view of the dam hydro-project (looking north). The basis tunnel could also serve as a transport link to the Tablelands.

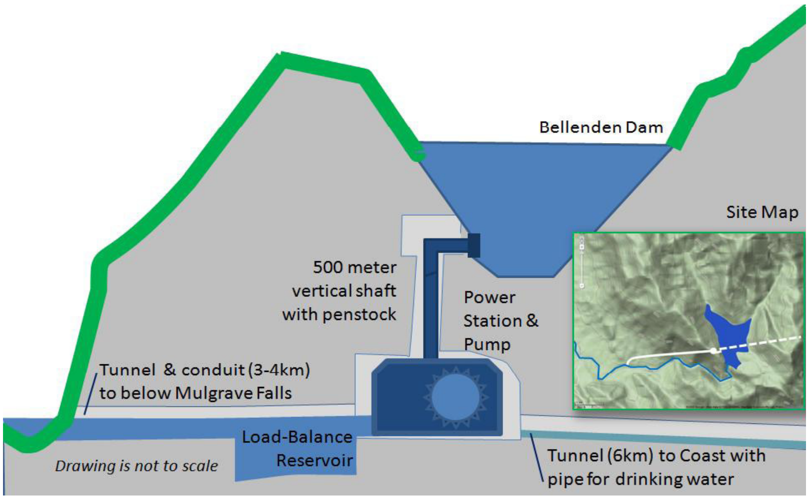

Fig. 3b. A sketch of the basic design. The basis tunnel allows access from the east and diverting water westwards, bypassing less than 4 km of river.

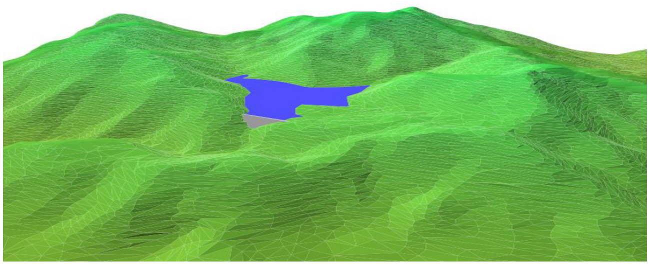

Fig. 3c. A closer look at the 3D model. For comparison, the highest peak is about 1600 m, the dam crest at about 700 m and the gorge is shown to about 150 m above sea level.

Fig. 4. The Split Rock rock fill dam in NSW is very similar in size and shape with a wall length of 469 m, a height of 66 m and a fill volume of 1.1 million m^3.

model based on precipitation values. A typical instantiation of the model is shown in Table 1. The gauged data are shown in column 9 and the proportion in column 1 is used to estimate the available water in column 2. To evaluate the validity we compare the October minimum and total annual flow to our estimates presented at CESE 2009 [7]. Both numbers are near the middle of that range. Some of the wet season proportions used in column 1 (0.17–0.31) are below the range obtained from the empirical data (0.29–0.63). That is because sampling was performed to estimate the flow in the dry season which is the time of concern. In accordance with our data the proportion in October and November is set to 42% and the total rainfall is 141 GL which is near the middle of the range (122–154 GL) [7].

In the particular model of the table below 325 ML/d are released in total and all of it is used for electricity generation, with 25 ML/d sent as drinking water to Cairns via the East portal and pipeline to Gordonvale. Columns 5–6 show the resulting increase or decrease in water stored; Column 7 shows the water that would remain in the approx. 3.5 km of river by-passed by the hydro-works and column 8 shows the flow at Fisheries with this hypothetical model. Column 10 is particularly relevant to the environmental impact discussion; it shows the relative decrease or increase in flows when compared to the current unregulated situation. Note the small decreases in the wet season compared to the significant increases in the dry season.

At the bottom of the table we calculate the resulting electricity production as the equivalent of about 20 MW base-load. To illustrate the scale of revenue we use a simple model where we produce 26 MW during the day and 13 MW at night. A more sophisticated model using four levels of demand and price including spot market sales has been constructed but is left out for simplicity as the price levels are estimates in any case, based on

Table 1
The hydrological model of a dam at Bellenden Ker. The equivalent of about 20 MW base-load power can be generated. Short term capacity is dependent on installed capacity. The units on the whole numbers are ML/d

	1	2	3	4	5	6	7	8	9	10
ML/d	Propor-tion	Estimate flow at intake	Drink water	Total elec. use	Dam De-crease	Dam in-crease	Water left 3.5 km	Project flow at Fish'rs	Fish'rs current	% change
Jan	0.29	469	25	325	0	88	56	1504	1618	–7.02%
Feb	0.21	607	25	325	0	205	76	2661	2892	–7.99%
Mar	0.17	675	25	325	0	263	87	3682	3971	–7.27%
Apr	0.21	538	25	325	0	147	66	2392	2564	–6.72%
May	0.31	586	25	325	0	187	73	1677	1890	–11.26%
Jun	0.35	419	25	325	0	45	48	1125	1196	–5.90%
Jul	0.35	316	25	325	87	0	78	965	903	6.82%
Aug	0.41	287	25	325	111	0	73	787	701	12.26%
Sep	0.42	211	25	325	176	0	62	653	502	30.09%
Oct	0.42	157	25	325	222	0	54	570	373	52.84%
Nov	0.42	168	25	325	212	0	56	588	401	46.66%
Dec	0.41	268	25	325	128	0	70	756	653	15.72%
Totals		141050	9000	117000	28064	28166	23947			
Gain					102					
1/3 off peak		MW (12 h)		13.02	40	($/MWh)		2.28	$ M/y	
2/3 peak		MW (12 h)		26.05	70	($/MWh)		7.99	$ M/y	
								10.27	$ M/y	

Government projections. Short term generating capacity is dependent on installed capacity and it could be as high as 250 MW. This will require some storage facility between the power station and the river to release the water slowly across the whole day, or as required, rather than as one big gush following an hour of 250 MW generation.

From need arises opportunity. If there is a 500 ML storage facility accessible to the power station then on days with both sun and wind or any time with excess power one can pump water back up to the lake, as is done in many places around the world [12]. This is no doubt the most elegant way to store excess power for later use; by reusing hydro-electric generation facilities. The main additional equipment is pumps to reverse the flow in the penstock during periods of excess non-regulated renewable energy raising dam levels from below. The challenge is to build the infrastructure such that it is possible to go from power production phase to the power consumption phase with minimal if any lag. Around the world nearly all potential hydro-power schemes have been built and most were not designed with that dual use in mind posing a problem as far as balancing rapid fluctuations is concerned. This can be addressed in the design of any new hydro schemes [12].

The fastest way to address a demand peak is to redirect power from heating domestic water or similar robust process then slowly ramping up the available energy and re-engaging the water heaters. A move away from electrically heated water eventually may cause a problem for electricity companies but no doubt some other process could be used to consume excess power once all the water has been pumped up or the lake is already full. For example one could split H_2O into fuel and oxygen or make fertilizer.

For economic modelling we wish to know the resulting cost of electricity over the lifespan of the infrastructure. In order to estimate the cost we have made some very basic assumptions, namely that the total cost of construction is $350 M which is split into $150 M for providing water to Cairns and $200 M for hydro-electric power generation. We assume a 60 year life span which is very reasonable for water infrastructure and we that can borrow at 5%. The result[1] is about 5 cent/kWh which is comparable to coal fire production and much better than other green technologies. Table 2 lists the different production costs.

The entry in Table 2 assumes that the loan is paid back over 60 years. If the loan is paid pack quicker the cost per kWh may drop to as little as 3 cents (Table 3). Not only is this about 1/3 of the best case of wind generated electricity; unlike wind hydro can be regulated and hence used for load balancing, including storing excess energy.

[1] $/kWh = ($200 M/193 GWh/a) × 0.05 / (1 – 1.05^{-60}) = 0.0544

Table 2
Comparing power production costs (Typical Australian figures from various sources)

Proposed hydro	$0.05/kWh
Coal fire production costs	$0.04/kWh
Solar best case	$0.15/kWh
Wind best case	$0.09/kWh
Consumer pays (2009)	$0.11/kWh

Table 3
Electricity production costs for different loan durations

Loan duration (y)	Annual pay-back ($M)	Total pay-back ($M)	Annual est. profit ($M)	Cost kWh (cents)
60	10.6	636	3.6	5.4
45	11.3	506	2.9	4.4
30	13.0	390	1.2	3.4

Therefore the hypothetical dam would produce the most valuable type of power at the lowest cost.

5. Social benefits

5.1. Regional power independence

The Far North Queensland Region is very fortunate in having intense and reliable sunshine in the West and some of the most reliable trade-winds in the East along the coast. It has been recognized [12] that increased use of non-regulated renewables like wind and solar will lead to greater fluctuations in power being generated. In this context any additional hydro-power is very valuable as it can be used for load-balancing and serving peak-demand. Additionally wind and solar energy infrastructure is by nature more vulnerable to cyclones and terrorism. A suitable built rock-fill dam and underground power infrastructure are virtually indestructible.

Cairns already has a 70 MW power station at Barron Gorge. However it takes several hours for water released at Tinnaroo Dam to reach the weir and power station, imposing additional parameters on its use. None the less, together with the hypothetical dam at Intake the combined on-demand electricity generation could exceed 300 MW which would be enough to run all FNQ emergency services and provide basic power needs for lights and appliances to everyone. In another scenario the hypothetical dam could provide 120 MW continuous power for about 20 days making it a very reliable backup to wind and solar.

5.2. A superb Cairns water source

The intake proposed at CESE 2009 is itself a very good water source with plenty of top quality water available for 9–11 months of the year. What makes the dam a superb source is that it is available all year and quantity is limited by pipeline capacity only.

5.2.1. Battery based all-wheel drive train?

Li-ion battery technology has rapidly advanced over the last years; not only have these batteries excellent power and energy to weight ratios, recent advances has produced prototypes that can be fully recharged in as little as a minute thanks to 3D cathode and anode surface technologies. Already several entirely electric buses are operating around the world.

We propose light rail where each carriage, the weight of a bus, is driven on all wheels by electric engines and battery packs. This allows recovering all braking energy and importantly should increase the incline that such a train can climb or descend significantly. Li could become a key Cairns diversification element if value adding can be handled locally [13].

5.3. A light rail transport corridor to the central tablelands

Potentially this project unlocks the solution on how to best increase transport capacity from the coast to the tablelands. This proposal not only increases traffic volume, it does so as a geographic alternative helping to distribute people and decreasing average trip length, further resulting in environmental benefits. Besides passenger carriages, special light rail carts could be constructed to carry about 2–3 cars each.

Thanks to the potential of Li-ion batteries and all-wheel drive trains one ought to be able to greatly reduce the extra tunnels required to extend a light rail system from the west portal near Crossing via Malanda to Atherton on the tablelands. The situation of the west portal is clever in that it is very near the watershed between the Russel and Mulgrave Rivers minimising the size of the largest bridge required on this potential transport corridor.

5.4. Tourism diversification

Some believe water will be the gold or oil of the future and this in itself may increasingly attract tourists to the region. A dam would allow rafting and water activities on the lower Mulgrave in the same way hydro-electricity has unlocked reliable Tully rafting opportunities.

A rail link to Atherton would open up a rail circle Cairns – Gordonvale – Bellenden Ker – Goldsborough Valley – Yungaburra – Atherton – Mareeba – Kuranda – Cairns. This would represent a significant new eco-tourism option with the potential to lure many previous visitors back to Cairns for a repeat holiday. With ever more expensive petroleum, rail will become more important again and if the all-wheel battery light rail is the first in the world it will be an attraction in itself and a contribution to combating climate change in the form of technology development, back to smaller and slower.

5.5. Cairns public transport

Cairns' cane rail corridors are a unique opportunity for a light-rail system to be implemented and this system could be integrated with the Bellenden-Ker to Atherton line. Further, the tunnel excavations would produce large amounts of quality rock that can be used for building elevated sections for flood-proofing of new light rail corridors, such as one directly into the city from Edmonton and Gordonvale via East Trinity or Admiralty Island. With suitable large parking spaces in walking distance from the train stations this should help ease traffic loads along the existing southern corridor lowering the need for its expansion.

In theory the on-demand electricity afforded by the hydro project would allow smooth and fast charging of trains while they are at the stations. For example this may require delivering 2 MW of power for three minutes, something that is not easily accomplished by the general grid but load balance is aided greatly by any nearby on-demand hydro-electric power station, as discussed above.

5.6. Irrigation and other water dependent industries

Climate change has brought increased uncertainty to farming and most rainfall models predict a decrease for the Far North Queensland region in the dry season [14]. The historical minimum of the Mulgrave River at Peets Bridge is 72 ML [9] so an ability to release 300 ML/d for irrigation and extra environmental flows is very attractive. This would give much confidence to the landholders, including the most important regional industry besides tourism, sugar cane, at a time of climate uncertainty. It also allows considering more protein rich and more `thirsty' crops such as rice to be cultivated where suitable soils are located.

Besides irrigation and aquaculture farming a range of other industries require a reliable water supply such as textiles, paper and other manufacturing. One of them is the Mulgrave Sugar Mill which due to low water levels in the Mulgrave had to construct ponds for their cooling requirements during the crushing season. It is predicted that water shortages is likely to impede economic growth [15] with some industries forced to shut down or move due to the increased cost of water. In this global environment a local dam that can guarantee water would make it possible to attract those industries which are forced to adapt. This would help to diversify the regional economy which is what political leaders are calling for to reduce dependency on tourism [16].

Water can be used to add value to products and on that basis different uses are valued vastly different, with mining and manufacturing about double that for power production, which is seen as more valuable than drinking water, which in turn is more valuable than irrigation farming [15]. Within irrigation faming, horticulture is much more valuable than cotton or rice[2] in terms of product value per ML water used [15].

6. Environmental impact discussion

6.1. Dam impact — comparison with existing dams

We propose a quantified environmental cost–benefit analysis, namely the amount of rainforest destroyed per unit of water usage, comparing the existing three local dams, Copperlode, Tinnaroo and Koombooloomba with the hypothetical case. The existing three lakes have been constructed on the Tablelands which have resulted in lake shapes illustrated by Copperlode dam in Fig. 5.

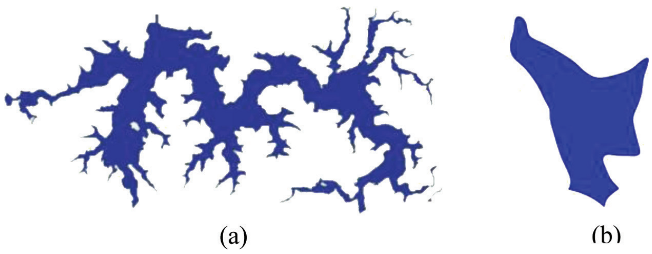

Fig. 5. (a) The shape of a shallow tableland dam (Copperlode) and (b) the shape of a deep dam in a mountain-canyon (Bellenden).

The analytical comparison is summarised in Table 4. To assess the relative environmental cost versus the benefit we form the ratio of flooded forest area over usage in GL. For simplicity we treat electricity and drinking water as equal in this respect and irrigation/industrial as 1/5 as important. In so doing we are valuing drinking water as the cost of additional water which for many cities means desalination as opposed to the historic value of drinking water which is much smaller [15]. We divide Tinaroo's electricity contribution by two as it only has half the hydraulic head. The results are conclusive as can be seen from the table-row labeled "Impact". The relative environmental cost of the hypothetical lake is over six times smaller than the next best, Koombooloomba.

While extreme precipitation obviously leads to better use of flooded areas it is not obvious that extreme precipitation increases biodiversity. Bio-diversity of Australian tropical rainforest is dominated by soil fertility [17]. Granite results in poor acidic soils [18]. Herwitz

[2] One proposal for water savings is to replace Cotton with Hemp and to move Rice production to North Australia where water is available seasonally at a much smaller environmental cost compared to that in the Murray–Darling basin.

Table 4
An environmental cost-benefit analysis for three regional dams and the hypothetical dam for the East Mulgrave River

	Bellenden	Copperlode	Tinaroo	Coom'ba
Storage GL	40#	45	407	205
Drinking GL	15	40	0	0
Electricity GL	95	0	72	170^
Irrig./Ind. GL	60	0	205	60^
Base-load MW/h	20	0	15	50^
Ave depth m	25#	15	13	12
Surface Area ha	120#	332	3360	1550
Dam height m	60#	45	43	40
Dam length m	300#	121	512	500#
Impact: Ha/GL	0.7#	8.3	13.9	4.6^
Economy: GL/Dam	0.16	0.23	0.17	0.45
Precipitation/a	6–12m	3–4m	1–2 m(Kairi)	2–4m

Estimate within 15%; ^ Estimate within 30%

researched the ecology at 1000 m on Bellenden Ker and he had the following to say in regard to this matter: "Bellenden Ker is an intrusive igneous granite formation. ... The geochemistry of the Mount Bellenden Ker granite may partly account for the low nutrient content of the soil" [19].

As an aside to environmental cost it is interesting to assess the relative economic cost, see the row labeled "Economy" in the table below. We form the ratio of GL water use per annum to wall size. The hypothetical lake is the least economic but not by much, although this does not include the necessary tunnel just to get there. All values in the row labeled "Impact" are approximate however the clear differences where present are very significant.

6.2. Impact on the 3–4 km of river by-passed

In times when the lake is not full and the spill-way is dry the falls and gorge part of the river will receive significantly less water. However if water is guaranteed approximately 50% above the historic minimum (estimated at 20–30 ML) then that part of the river is buffered against extreme dry spells also. The riparian zone of that short river section is very small or non-existent where the water runs straight across bedrock in the East Mulgrave gorge. In particular it can be said that no aquifers will be affected by this by-pass.

6.3. Impact on the river below the west portal

The impact on the river below the west portal at Fisheries is such that the water quantity is reduced up to about 10% during the wet season however it can be increased by over 200% in very dry times, with 50% the expected average value of extra flows. Therefore it can be argued that the impact on the river is positive as environmental damage can be halted or reversed due to extra dry-season flows.

6.4. Global impacts

The CO_2 saving from hydro-electricity alone is equivalent to taking about 50,000 cars off the road permanently (280,000 t). Green technologies developed as part of the project such as the Li-ion light rail may help save greenhouse emissions worldwide.

Fig. 6 shows the respective green-house gas footprint of various electricity production types [20]. Hydro is listed as the most effective in combating global warming. The data includes emissions from construction of the required infrastructure. It is recognized that this requires the thorough removal of vegetation prior to completion of the dam.

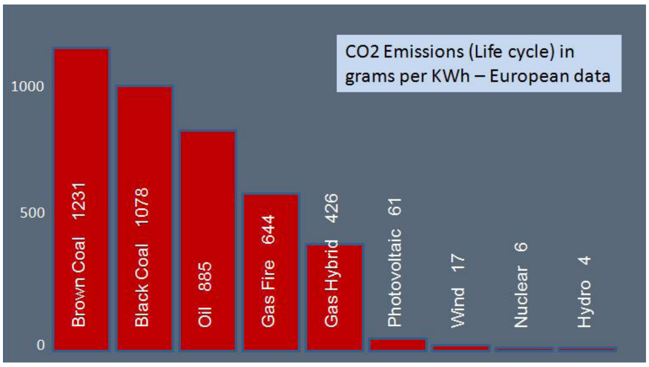

Fig. 6. Comparing CO_2 emissions of different types of electricity production.

7. Conclusions

The proposed dam has many direct and potential indirect social benefits such as locally produced hydropower, CO_2 savings, drinking water, irrigation, economic diversification, new tourism attractions and a new transport corridor. The economic viability is attractive based on power and water sales alone although much more modeling remains to be done with regards to costing.

Environmentally the hypothetical dam at Intake would achieve by far the best usage per m^2 of flooded rainforest compared to any existing dams thanks to extreme rainfall and multiple use of impounded water. Additionally most of the Mulgrave River and its aquifers would benefit from increased environmental flows in the dry season.

The loss of approximately 120 ha of rainforest is an obvious negative environmental impact, the size of the area is significant and it is pristine forest on relatively slight slopes also containing 2–3 km of creeks. No ordinary project could justify such destruction.

However lakes provide micro-climate refugia mitigating global warming by increasing local humidity and moderating temperatures by up to several degrees [21]. This is especially relevant during prolonged dry-spells which climate models predict will occur more frequently [14]. Therefore a lake may actually help to save some species of plants and animals from the effects of global warming and the associated new habitats may increase bio-diversity. Supporting this argument are reports where temperature increases have been linked to the disappearance of lakes [22].

No doubt current political thinking does not favor any new dams no matter how useful and small the affected area is. The case is made even more difficult by the argument that the wettest part of the wet tropics should be protected the most. In contrary! The wettest part is actually the most environmentally friendly to build a dam in. As a final argument, the social benefits from the dam would help guarantee the resources to implement the best environmental protection for all of the wet tropics.

Acknowledgements

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