GREAT DIVIDING RANGE WIND PUMPING SITES

"Wind Into Water"

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Abstract

The report proposes two new equipment designs for ground excavation and wind power capture. Each system offers more efficient ways of completing the respective tasks, and with possible international applications. A topical application for this equipment involves pumping water to a ridge top reservoir before releasing it to generate despatchable hydro power and/or water for irrigation. Using the wind to pump water from one of the several pondages in the Snowy Hydro Scheme back into a high level lake. Tasmania provides several sites where a similar process can occur. Specific applications might include pumping sea water into a lined cliff top reservoir before releasing it back into the sea to generate despatchable electricity. It is also feasible to revisit the Bradfield Scheme and use wind power to pump north Queensland river water to the west in a sequence that can be described as "electric siphoning".

1) Introduction:

Individual Consultants (ICs) member Evan Pryor proposed that it should be possible to use wind power captured at the crest of the Great Dividing Range (GDR) to raise water from east side rivers for discharge into west side catchments. Evan particularly focussed on the upper reaches of the Clarence River, as well as the Glen Innes regions of New South Wales and Queensland as possible suitable sites. Other ICs have also contributed, but particularly mechanical engineer John Robertson. The basic proposal envisages a more reliable water supply furnished to many of the ephemeral west side rivers as well as possibly generating more despatchable hydro electricity.

This review includes Victoria, NSW and Queensland, as possible GDR wind storage sites. A clear distinction is drawn between Pumped Storage and Wind Storage as discussed.[1]

Major Australian river systems include:

In reviewing the need for this project the following discussion is pertinent:

> *If we could go back to the early 90s period and just maintain our efficient coal fired power station fleet, with a serious discussion about introducing nuclear power generation, there is no doubt we would be much better off from a power cost view point.*
> *If the CSIRO and the Chief Scientist had been tasked with educating the public regarding Henry's Gas Law we may not now be dealing with a voting millennial population convinced that carbon dioxide is a pollutant - while they simultaneously breath it out.*
> *Unfortunately that train has well and truly left the station. Australia has signed various agreements which hamstring us significantly - costly to get out of in some cases, and politically as well as internationally embarrassing in the case of Paris.*
> *So where to from here? All we can do now, is make the best out of a very bad job.*
> *Australia has a unique situation in that we have the Great Dividing Range. On the east side - rainfall, and rivers. On the west side - water shortage, wide open plains, and large ephemeral river systems.*
> *We can use the wind, which is strongest on the ridge tops, to generate the power required to pump some water over the ridge. If we pump water to the top of the ridge we may as well generate electricity before releasing it to irrigate the west side. In this way we generate wind stored power when we need the power, as well as watering the hinterland.*
> *We may also be able to redirect the signed commercial agreements to some more practical use than cannibalising our remaining base load power suppliers through preferencing renewables over fossils.*
> *Still lots of work required to sort this thinking out, but a start has been made in proposing a more efficient wind turbine design at;*[2]

2) Methodology:

In a first cut review of possible sites, interactive maps from the Geoscience Australia are reviewed.[3] The crest of the GDR showed several regions where river beds on the east side of the range were less than 20km from river beds on the west side. These regions were selected on the basis that they probable indicated significant ground level variations which is an important engineering consideration in this proposal.

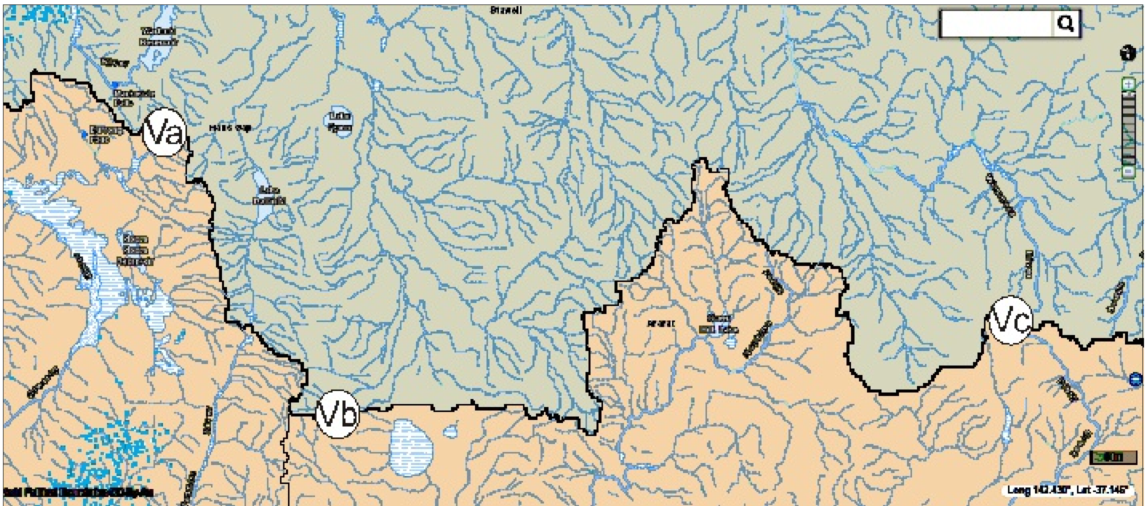
Information from Bureau of Meteorology shows past average wind speeds in Australia on a monthly basis with speeds of 15 kph frequently available at exposed locations.[4]

3) Victorian GDR Sites

Seventeen sites are identified as Va-Vq in Victoria as shown:

Victorian Wind Pump Sites

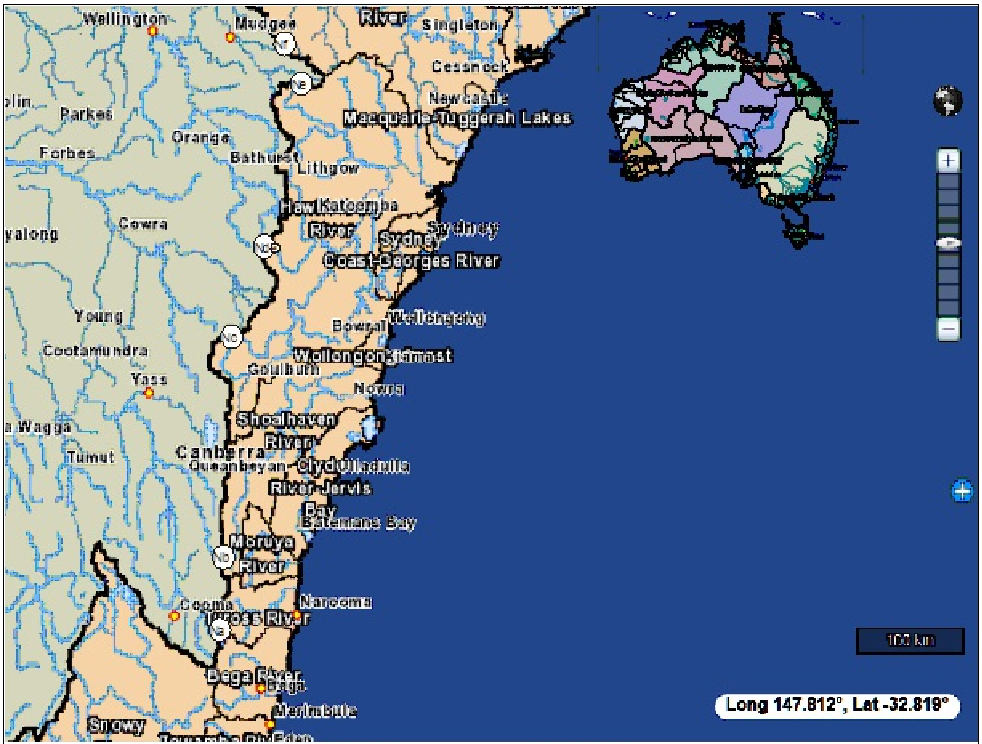
A more detailed map of the local areas for Va, Vb, and Vc is shown:



Victorian Wind Pump Sites Va - Vc

4) Southern New South Wales GDR Sites

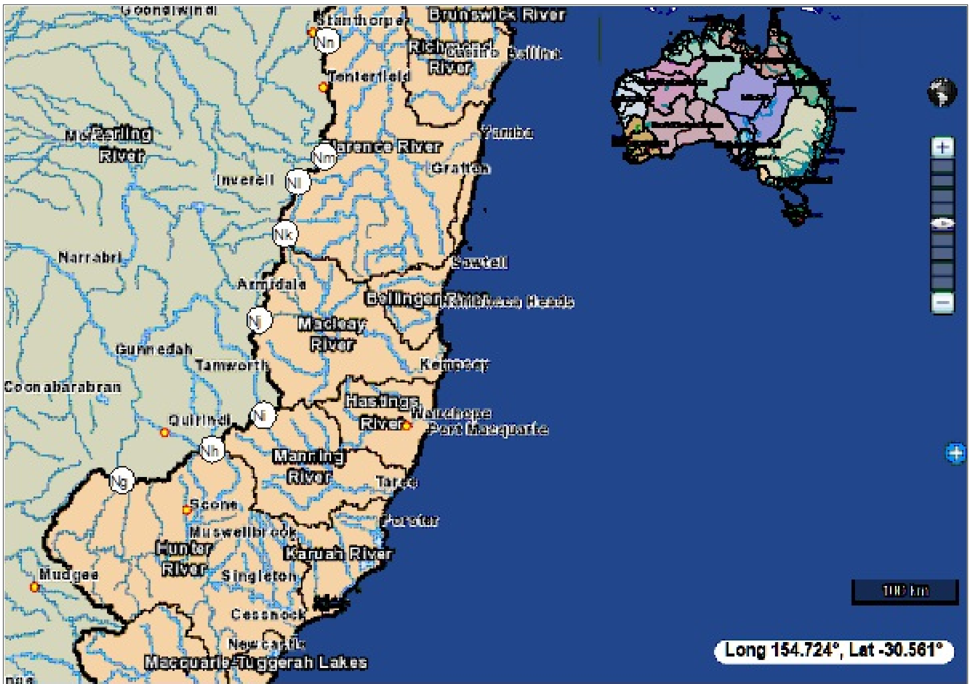
Six sites are identified as Na-Nf in Southern New South Wales as shown:



Southern New South Wales Wind Pump Sites

5) Northern New South Wales GDR Sites

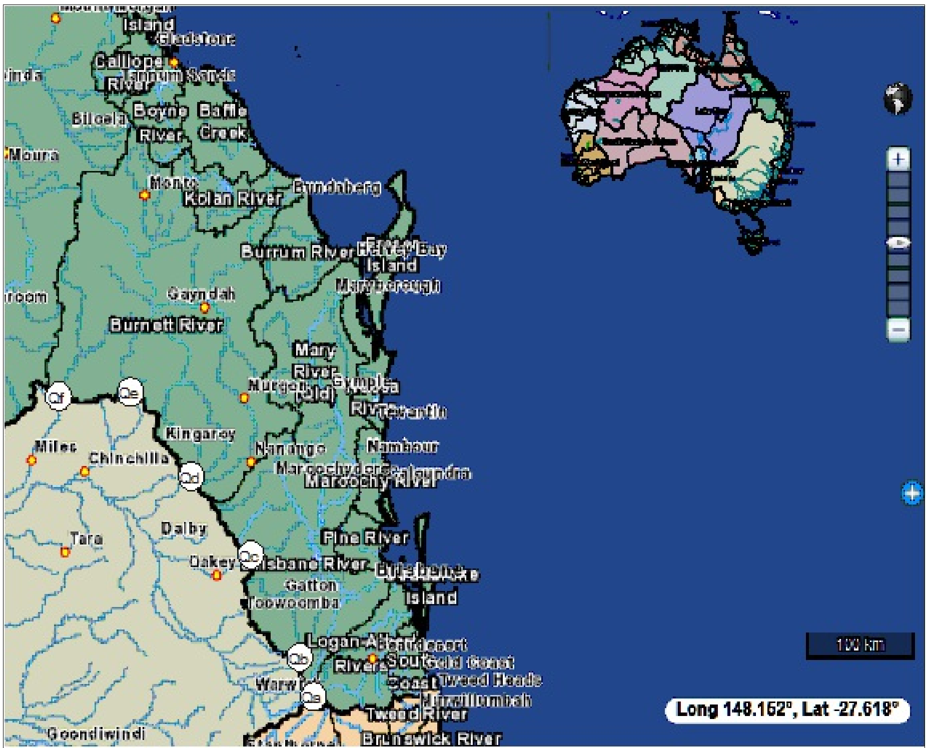
Eight sites are identified as Ng-Nn in Northern New South Wales as shown:



Northern New South Wales Wind Pump Sites

6) South Queensland GDR Sites

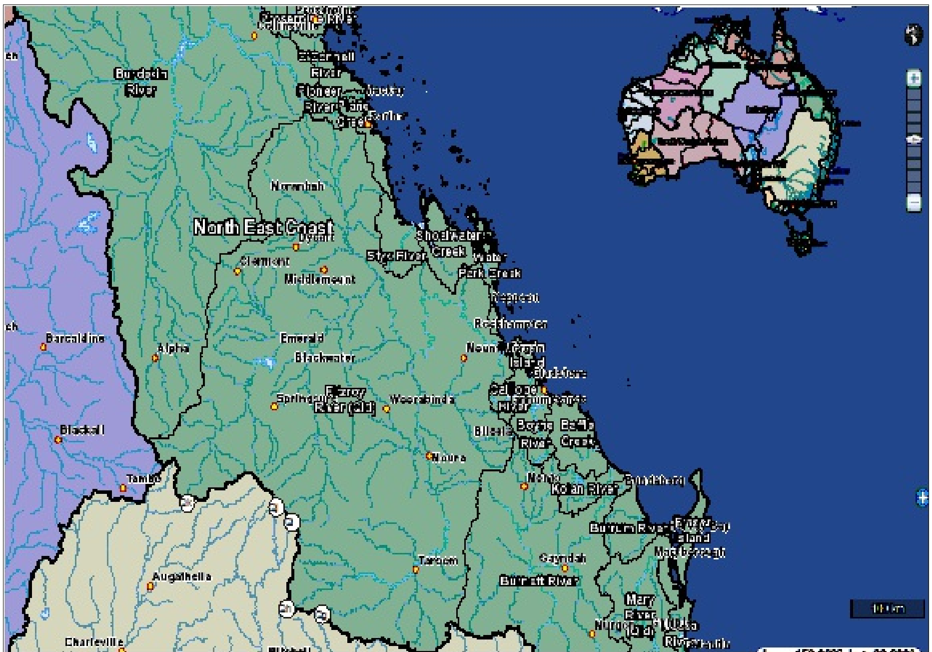
Six sites are identified as Qa-Qf in South Queensland as shown:



South Queensland GDR Wind Pump Sites

7) North Queensland GDR Sites

Five sites are identified as Qg-Qk in North Queensland as shown:



North Queensland GDR Wind Pump Sites

8) GDR Base Case Calculations

John Robertson's initial comment:

> *To get a handle on the numbers I have made several assumptions. That the uptake altitude on the East is 300 metres, the outlet on the west is at 500 m and that there are 7 x 3 MW ind turbines built on the ridge peak. There is a crossing of the range available at an altitude of 1,000 m. I have further assumed that the turbines reach an average of 50% of rated output. (This is about double the global norm and reflects the very favourable location at an assumed altitude of 1,200 m.)*
>
> *The average daily generation will be 240 MWhrs (taking the combined rated output to 20 MW). That will have to be produced at the turbines and transmitted by cable to pump(s) at the Eastern pick up. Assuming 100% efficiency and no friction loss in the up going pipe, the 240 MWhrs will pump about 1,200 tonnes (1.2 ML) up the 700 metres. When this water arrives at the low point on the West side (a fall of 500 m) it will be capable of generating 170 MWhrs. ~~*

Following several conversations and adjustments, a spreadsheet model of this proposed base case was developed as shown in Table 1:

Base Case Calculations			
Input			
	East Side Pump Height Estimate	m	700
	West Side Pump Height Estimate	m	500
	Peak Power Induction Turbine Capacity	MW	7
	Peak Power Induction Turbines	#	3
	SI (mks) Metric Value for g	m/s^2	9.8
	Turbine Derating Factor	%	50%
	Water Density	kg/m^3	1000
	Range Turbine Rated Output - favourable site location	%	95%
	Pipeline Efficiency	%	85%
	Murray-Darling Water Price	$/ML	$1,500
	Wholesale Electricity Price	$/MWh	$100
Output			
	Turbine Power	W	10,000,000
	Flow through the pipe	m^3/sec	1.24
	Flow through the pipe	L/sec	1239
	Flow through the pipe	ML/hr	4.46
	Power Generated (W) = Q x H x g x efficiency	W	5,160,714
	Power Generated	MWh	5.16

Table 1.

This simulation shows the situation where comparatively large pump height estimates are involved. If the pump heights are reduced, the volume of pumpable water is greatly increased while the power generated is also altered. In this way, design criteria for each site can be optimised.

For example, an east side pump height of 200m will increase the flow through the pipe from 4.46 to 15.61 ML/hr. The electricity generated for a west side pump height of 150m also increases from 5.16 to 5.42 MWh.

If water is not required on the west side, the pumped water can be returned to the east side for electricity generation purposes only. This option provides a 'water neutral' situation for times when water is scarce on both sides of the GDR.

9) GDR Base Case East Side Pumps

A suitable pumping system for the east side includes a set of positive displacement piston pumps. German designed Uraca pumps include a triple piston unit KD719. Pump supply prices are estimated from Chinese made units until quotes from Uraca become available.

The KD719 unit capabilities are as shown in Table 2.

A single pump is required to match the base case wind generating capacity, and pump heads. Pump operation can be adjusted to match the available wind strength and heads.

East Side Pump Calculations			
Input			
	KD719 Pump Pressure	bar	100
	KD719 Pump Capacity	L/min	200
	KD719 Pump Performance	kW	45
	KD719 Pump Mass	kG	380
	East Side Head	m	700
	Maximum Pump Efficiency	%	100%
	SI (mks) Metric Value for g	m/s^2	9.8
	F-1600 Triplex Piston Mud Pump	kG	18790
	F-1600 Triplex Piston Mud Pump	$	$67,568
Output			
	Required East Side Pump Volume	m^3/sec	1.24
	East Side Power Generated	kW	8.5
	East Side Pump Volume	L/min	20.7
	KD719 Pump Max Capacity	L/min	200
	Number of Pumps Installed	#	1
	P5-96 Pump Power Daily Consumption	MWhr	1.08
	Piston Pump Unit Price	$/kG	$3.60
	KD719 Pump Price	$	$1,366.45
	Pump Fleet Supply Cost	$	$1,366.45

Table 2.

A range of positive displacement pumps are available through various suppliers. Uraca pumps[5] have 2.58mW units capable of pumping up to 10,970 l/min against a head of 130 bar, or 405 l/min against a head of 360 bar. A FT powering such a unit will produce a variable current which is more suited to a DC motor drive. However, DC power from the FT would require the use of large heavy copper conductors which would also have to be buried. The preferable arrangement may be for an induction motor running asynchronously in the FT, producing AC current which can be supplied by overhead conductors to a solid state rectifier, before connecting to a DC pump motor. To cater for the high occasional power supply possible from the FT unit, more than one pump installation may have to be placed on standby.

10) GDR Base Case Pipe Calculations

Suitable delivery pipe construction is a steel pipe with rubber lining. The steel wall thickness is 16mm and the inside diameter is 200mm. This pipe configuration adds 24m of head resistance for each 5,000m of pipe. Pipe schedule as per Table 3.

The pipe selection is suitable for both the east side rising main and the west side Pelton generator supply. Pipe friction loss calculations are available at the National Pump & Energy site,[6] and Allowable Pipe Bursting Pressures are based on Barlow's Formula.[7]

Pipe Calculations			
Input			
	East Side Pipe Length	m	5000
	Rubber Lined Pipe Internal Diameter	mm	200
	Rubber Lined Pipe Wall Thickness	mm	16
	East Side Pipe Min Entry Pressure	bar	70
	West Side Pipe Length	m	3000
	Rubber Lined Pipe Internal Diameter	mm	200
	Rubber Lined Pipe Wall Thickness	mm	16
	East Side Pipe Min Entry Pressure	bar	50
	200mm Pipe Unit Weight	kg/m	73.3
Output			
	East Side Pipe Capacity	M3/HR	74.34
	East Side Friction Loss	m	24.04
	Pump Height Estimate	m	700
	Pump Height including friction	m	724.04
	Allowable Bursting Pressure	bar	192
	West Side Pipe Capacity	M3/HR	74.34
	West Side Friction Loss	m	9
	Pump Height Estimate	m	500
	Pump Height including friction	m	509
	Allowable Bursting Pressure	bar	192
	East Side Pipe Mass	t	366.5
	West Side Pipe Mass	t	219.9
	Alibaba Steel Pipe Price	A$/t	$933
	East Side Pipe Value	A$	$342,067
	West Side Pipe Value	A$	$215,240

Table 3.

11) GDR Base Case Dam Calculations

The Base Case assumes three dams are used:
East side dam collects feed water for the project.
Crest ridge dam receives water from the east side delivery pipe, and stores it as a head water supply.
West side dam collects water after it has passed through the Pelton wheel generator for possible irrigation use.

The design sizes for the three dams is shown in Table 4.

Dam Storages			
Input			
	East Side Volume Protection	Days	30
	Crest Volume Storage	Days	2
	West Side Storage	Days	5
	Unit Cost of Dam Excavation	$/m^3	$1.20
Output			
	East Side Dam Size	ML	3212
	East Side Dam Size	m^3	3,211,662
	Crest Dam Size	ML	214
	Crest Dam Size	m^3	214,111
	West Side Dam Size	ML	535
	West Side Dam Size	m^3	535,277
	Total Dam Volume	m^3	3,961,050
	Total Dam Excavation Cost	$	$4,753,259

Table 4.

It is proposed that the dams be excavated using custom sized Overburden Slusher equipment as illustrated in Figure 1. This new system is proposed by BOSMIN to improve Australian existing dam and maintenance efficiency, and is suitable for excavating new wind power potential power storages.[8]

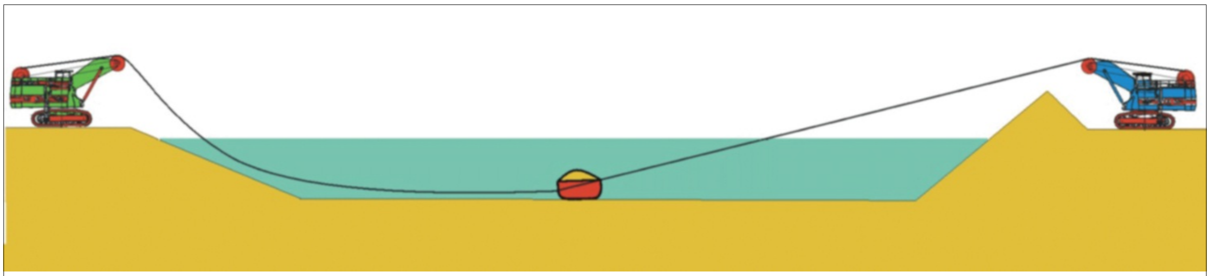


Figure 1.

12) GDR Base Case Pelton Wheel Generator

Several medium sized wheel generators are available which are suitable for the Base Case application as shown in Table 5 with calculations based from The Renewable Energy Website.[9]

Pelton Wheel Generator			
Input			
	Gravity constant	m/sec^2	9.81
	Generator System Efficiency	%	85%
	Pelton Wheel Generator Unit Pri	$/MW	$30,405
Output			
	West Side Water Head	m	500
	Available Water Volume (Q)	l/sec	1,239
	Power Generated	kW	5,166
	Power Generated Daily	kWh/day	123,984
	Power Generated Daily	mW/day	124
	Pelton Wheel Generator Cost	$	$156,914

Table 5.

13) Wind Turbine Systems

The efficiency of the wind turbine is a critical part of any discussion on harvesting wind energy. The modern wind generator includes a very large set of rotating blades connected to a generator and operating under the limitation identified by German Physicist Albert Betz in 1919 and known as Betz's Law.[10]

Betz' law teaches us that air coming into the rotor gives up velocity and hence energy when impacting the rotor blades. This causes air exiting the rotor to slow down and thereby build up back pressure behind the rotor blades. Increasing amounts of energy can be progressively extracted from the incoming stream until a limit of 59% of the available energy is extracted. At that time the build up of back pressure behind the blades prohibits any further capture of energy from the wind stream.

Other limitations to the modern wind generator are identified to include:

1. The wind mill is a large highly stressed structure with generating capacity limited by the size of blades that can be used.
2. They cannot operate in high winds and are shut down. "Nordex 2.5MW unit operates between 4 & 25 mps, 14-90 kph". Gusty wind conditions may also cause shut down. This occurs because of asymmetric loadings on blades, and a requirement to keep blade tips operating below sonic velocities. For this reason, they can be shut down for 65-70% of the time.[11]
3. Cold weather leads to icing on the blades which can be hazardous in a number of ways.
4. At low wind speeds WT are 100% ineffective requiring an alternate (or stored) power supply be always on standby for power critical applications.
5. Keeping the blades below sonic velocity often leads to a requirement for one or more gearbox drives, although some installations exist where customised multi-pole generators are direct coupled to a WT and operate in phase synchronisation with the reticulated grid supply.
6. Large Wind Turbines have mechanical controls to ensure they always 'point' correctly. These can be problematic.
7. Foundation costs (particularly at off shore installations) are high and about the same price regardless of WT size. This aspect favours a more productive unit, if available.
8. A moving blade light shadow associated with WT operation is a significant consideration at some locations and has precluded the siting of other units.
9. Noise levels are generally very low, but at rural and coastal siting of many WT installations, noise is cited as having significant impact due to the incessant, throbbing, low pitched tone. This is particularly noticeable at low wind speeds when natural noise levels are not present. Recent consideration of ultra sonic noise impact suggests the hollow turbine support tube, in association with the rotating blade causes the tube to hum like an organ pipe, at very low frequencies.[12]

A solution to these limitations is suggested by BOSMIN referred to as a Fuselage Turbine (FT).[13] The proposed turbine consists of a diffuser attachment to reduce back pressure on the fan blades, and a nozzle feature in front of the fan blades to funnel more high speed air into the fan system. The nozzle design is particularly significant because it features a 'perforated' nozzle which effectively draws additional air from outside the nozzle into the fan blades. A schematic design of the proposed construction is shown in Figure 2.

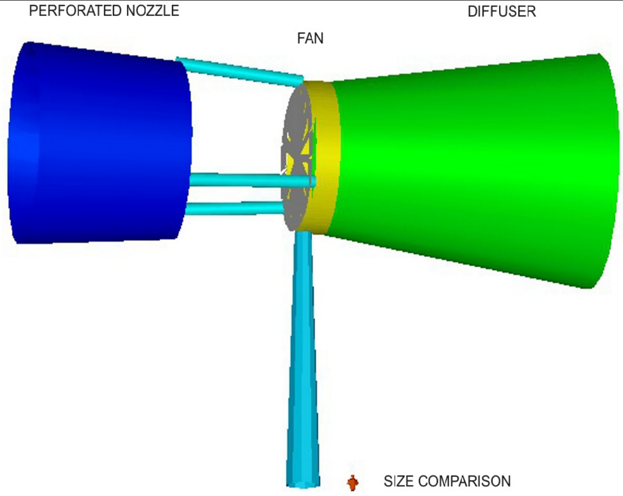


Figure 2.

A 3 MW Wind Turbine typically has a rated wind speed of 15mps (54kph), with a rotor diameter of 90m.

A 3MW Fuselage Turbine has a comparable nozzle diameter of 38.5m, with an overall length of the nozzle, fan and diffuser of 110.4m. A single fan is mounted in the fan housing, with an outer diameter of 28m. The outer fan blade speed reaches an acceptable 0.81 Mach speed, ensuring FT noise is not too high. Refer Table 6.

Eliminating the gearbox, effectively means the FT can operate in any wind conditions, significantly improving the quantity of power generated.

Under suitable atmospheric conditions, water spray injected into the air stream can increase the density of the feed air. This increases the FT capacity to 4.0MW from this unit.

While the overall length of the unit is large, the nozzle and diffuser units act as counter balances, and can be centrally supported with a mast protruding above the fan housing. Guy wires from the mast to either end of the FT support the structure, and the rear guy wire provides a useful mounting point for a wind pointing sail.

	Fuselage Turbines		
Inputs		**Units**	**FT#1**
	Nozzle Entrance Wind Velocity	kph	53.9
	Air Density	kg/m^3	1.225
	Model Raw Inlet Velocity - v1	mps	3.13
	Model Accelerated Inlet Velocity - v2	mps	4.17
	Turbine Efficiency	%	100%
	Generator Efficiency	%	100%
	Gearbox Efficiency	%	100%
	Nozzle D1 to Turbine Diameter Ratio	factor	1.373
	Nozzle d1 to Turbine Diameter Ratio	factor	1.144
	Nozzle Sail Length to Turbine Diameter Ratio	factor	1.146
	Diffuser d2 to Turbine Diameter Ratio	factor	1.481
	Diffuser Length to Turbine Diameter Ratio	factor	1.954
	Nozzle Length to CL Turbine Diameter Ratio	factor	2.197
	Diffuser Length to CL Turbine Diameter Ratio	factor	1.739
Outputs			
	Wet Assist ? Y=1	###	
	Model Accelerated Inlet Velocity - v3	mps	4.42
	Nozzle-Diffuser Velocity Scaling Factor	factor	1.33
	Nozzle Entrance Wind Velocity	mps	15.0
	Turbine Intake Velocity	mps	19.9
	Generator Poles	###	32
	Synchronous Speed	RPM	188
	Gearbox Ratio	###	1
	Max Turbine Diameter	**m**	**28.0**
	Min Turbine Diameter	m	0.2
	Turbine Annulus Area	m^2	617
	System Efficiency	%	100%
	Nozzle Inlet Area	m^2	1164
	Nozzle Inlet Diameter	m	38.5
	Combined Nozzle Inlet Diameter	**m**	**38.5**
	Nozzle Outlet Area	m^2	808
	Unit Nozzle Outlet Diameter	m	32.1
	Unit Nozzle Sail Length	m	32.1
	Unit Diffuser Length	m	54.8
	Diffuser Outlet Area	m^2	1355
	Unit Diffuser Outlet Diameter	m	41.5
	Unit Nozzle Length	m	61.6
	Unit Diffuser Length	m	48.8
	Unit Overall Length	m	110.4
	Combined Overall Length	m	110.4
	Multiple Turbine-Generator Units	###	1
	Fuselage Diameter Fill Factor	###	
	Unit Power Factor	W/m^2	4,861
	0.5 x Rho x V^3 x A x Eff / 1000	kW	3,001
	Fuselage Turbine Rated Power	MW	3.0

Table 6.

14) Base Case Operating Expenses and Income

Income from the wind pumping operation has two possible sources.

1) From water released into the Murray-Darling basin for sustainability purposes.
2) Electricity generated from releasing water from the crest storage dam.

Expenses include routine maintenance and major repairs as detailed:[14]

Routine Maintenance

To ensure the wind farm operates in a safe and reliable manner, it would require regular inspection and maintenance on an 'as needs' basis. This would generally be carried out using standard light vehicles.

In addition, regular scheduled maintenance is required, generally at 3, 6 and 12 monthly intervals. As a guide, each turbine requires approximately 7 days of maintenance per year. This does not require the use of major equipment, and could be carried out in a normal utility or small truck and would not require any additional works or infrastructure.

Major Repairs

It is possible that major unexpected or unscheduled equipment failures could take place during the life of the wind farm. While wind turbines and electrical components are designed for a 20 - 30 year life, failures can occur, for example due to lightning strike.

Most repairs can be carried out in a similar manner to routine maintenance, with some exceptions:

Replacement of wind turbine blades, if necessary, would require bringing new blades to the affected turbine and installation of these blades using large cranes. The requirements are similar to the construction phase, and the access tracks established for construction would be used.

Replacement of wind turbine generators or gearboxes may require a crane and low loader truck to access the wind farm.

Replacement of substation transformers would require a low loader truck to access the site.

We assume two people are assigned full time for these duties.

These incomes and expenses are estimated in Table 7.

Base Case Income and Expenses			
Input			
	Murray-Darling Water Price	$/ML	$1,500
	Wholesale Electricity Price	$/MWh	$100
	Turbine Effective Operating Time	hr/year	6000
	Maintenance Personel	#	2
	Annual Cost of Maintenance Personel	$pa	$150,000
Output			
	Flow through the pipe	ML/hr	4.46
	Power Generated	MWh	5.16
	Delivered Water Value	$/hr	$6,690.96
	Delivered Electricity Value	$/hr	$516.07
	Maintenance Cost	$pa	$300,000
	Annual Net Income	$pa	$42,942,201
	Annual Net Income	$m	$42.94
	Sustainable Capital Cost	$m	$429.42

Table 7.

15) Base Case Capital Expenses

Capital costs are estimated from pro rate size information for dam construction, wind turbine, rubber lined pipes, and Pelton wheel generators. Local area electricity distribution is estimated as being equal to pipe supply cost.

An installation, cost estimated to add 200%, to the supply cost, is included to cover the laying pipe, power reticulation, site works, and equipment development costs as shown in Table 8.

Base Case CAPEX			
Input			
	Wind Turbine Unit Cost	$/MW	$866,667
	Rubber Lined Steel Pipe	$/l	$811
	Installation Cost Assumed Portion of CAPEX	%	200%
Output			
	Installed Wind Turbine Capacity	MW	21
	Turbine Fleet Cost	$	$18,200,000
	East Side Pipe Cost	$	$4,054,054
	West Side Pipe Cost	$	$2,432,432
	East Side Pump Cost	$	$1,366
	Local Area Electricity Reticulation Cost	$	$6,486,486
	Pelton Wheel Generator Cost	$	$156,914
	Total Dam Excavation Cost	$	$2,826,262
	Total Dam Equipment Cost	$	$28,262,624
	Project Installation Cost Estimate	$	$68,315,031
	Total	$m	$130.7
	Capital Cost per Unit of Capacity	$/MWh	24.13

Table 8.

The capital cost per unit of capacity calculates to $24.13/MWh, which compares with existing coal and wind power: [15]

> *"In 2017, the marginal cost of generating power from an existing coal station is less than $40/MWh, while wind power is $60-70/MWh"*

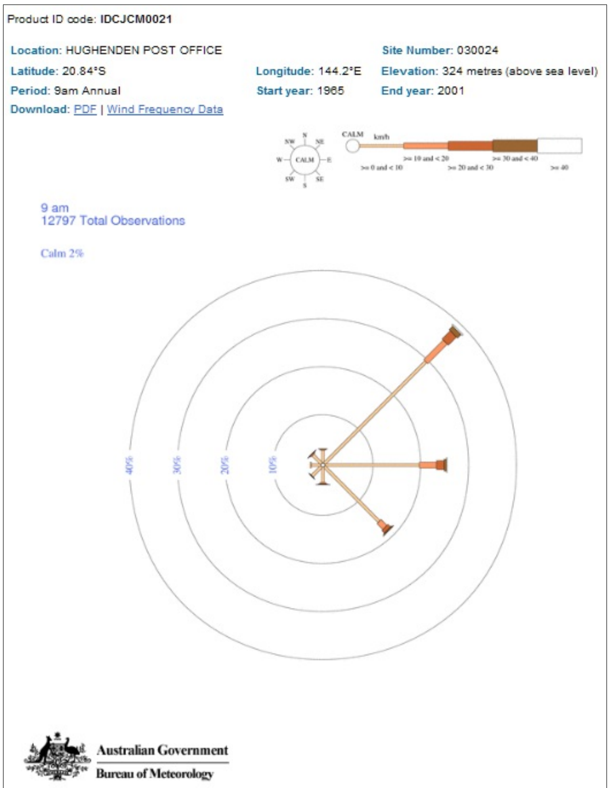


Figure 3.

This improvement is mainly due to the better FT design characteristic which enables the FT to operate through the full range of wind speed conditions. Figure 3 shows wind conditions recorded at Hughendon, Queensland where calm is noted as 2%. The rest of the time wind is blowing at between 0 and 40 kph. Table 1 assumes only 50% of the time energy is collected. However FT units operate through the full range of wind speeds, unlike conventional WT units.

The noted improvement may be partly due to too optimistic performance assumptions, under estimation of capital and operating costs, or over estimation of project income from RED scheme.[16] These factors highlight the need for rigorous field testing and costing review of these new technologies.

No allowance is made for land access, or connection to regional transmission lines.

The national implication of the "Wind Into Water" proposal suggests it may be suitable for support under Future Fund investments,[17] with the Aussie designed reservoir maintenance and wind turbine technologies having possible international applications.

16) Snowy Mountain Hydro Wind Storage Project 3.0

A critical point is to distinguish between pumped storage and wind storage. Unfortunately, pumped storage does little more than cannibalise our base load power supplies, but it does shave off some of the peak power costs while averaging up overall electricity prices. The more pumped storage we install the worse power prices will become. Snowy 2.0 will add to the average cost of supply - as illustrated in the SMA document and reproduced in Figure 4.[18]

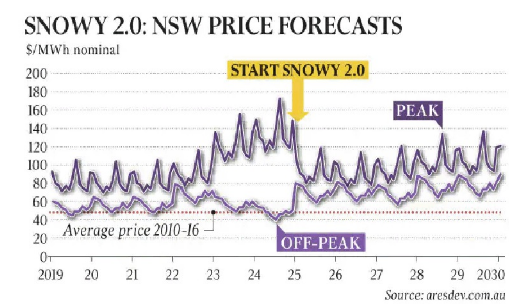


Figure 4.

This report proposes that water taken out of the pondage areas, after going through the regular turbines, is pumped back into the higher reservoirs as seen in Figure 5. Sustainable wind supply pumps water back into the higher reservoir. This provides a 'water neutral' approach for lake levels, and delivers extra capacity through the existing turbines.

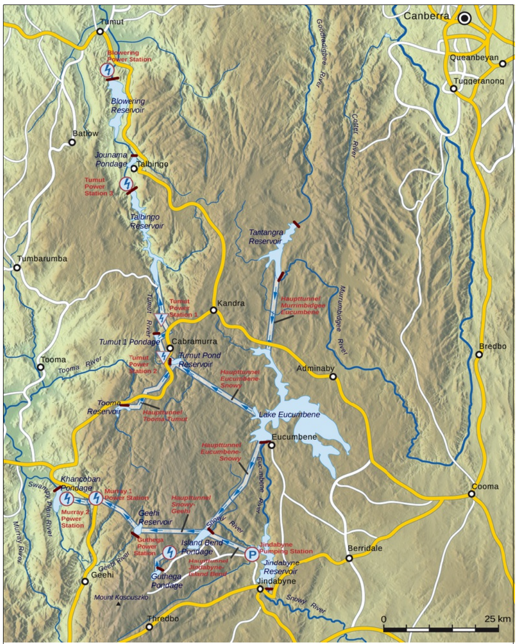


Figure 5.

The existing turbines have spare capacity to use this recycled water, because water was previously diverted from the hydro scheme back into the Snowy River to maintain a 15% 'environmental flow' to that river system.

A capital expense for this wind installation is required to cover the cost of the FT units, return pumps and buried pipelines, but is much less costly than the Snowy 2.0 proposal, and contributes extra electricity to the national grid's base generating supply.

Tasmania provides several sites where a similar process can increase despatchable power supplies.

Both Tasmania and Snowy represent places where ice can be problematic on FT units. Mitigation against this problem may include mounting the FT units at altitudes below the snow line or treating the equipment with ice shedding materials. Recent research into this aspect is provided at; *Photothermal trap utilizing solar illumination for ice mitigation*.[19]

17) Bradfield Scheme Revisited

The original Bradfield Scheme was reported in The Courier-Mail of September 20, 1938 and is attached in **Appendix-A**.

The current proposal, uses the Fuselage Turbine (FT) to generate electricity to pump the water to the west. This technique can be described as 'electric siphoning' and involves mounting a large FT unit on top of an exposed ridge to generate electricity.

An electric pump delivers water to a ridge crest storage site which is then used to drive a Pelton wheel generator, as the stored water flows to the next water storage site. Electricity from the Pelton wheel is transmitted back over the ridge, and into the feed pump, together with electricity generated by the FT. In this way, the FT supply is only used to overcome system line losses. The system relies on the efficacy of the FT system, and quantity of available water. The FT system can be scaled up as shown at reference,[12] using 2D logic. There is some research available to suggest this approach may be valid, but should be checked further.[20]

18) Coastal FT Application

Several regions of the coastline feature high cliffs - such as the shores of the Great Australian Bight. In these situations, it is possible to mount the FT on top of the cliff and use the power to lift sea water into a cliff top membrane lined storage pond. The pondage water can be released back into the sea when hydro generated power is required to be fed into the grid system as despatchable power.

Figure 6.

Figure 6 [21] shows a cliff section of the GAB off the Nullarbor Coast.

Appendix-B includes a preliminary States' analysis of several potential wind harvesting sites.

19) Reviews

The following comments are associated with reviewers who have read the paper Great Dividing Range Wind Pumping Sites;[1]

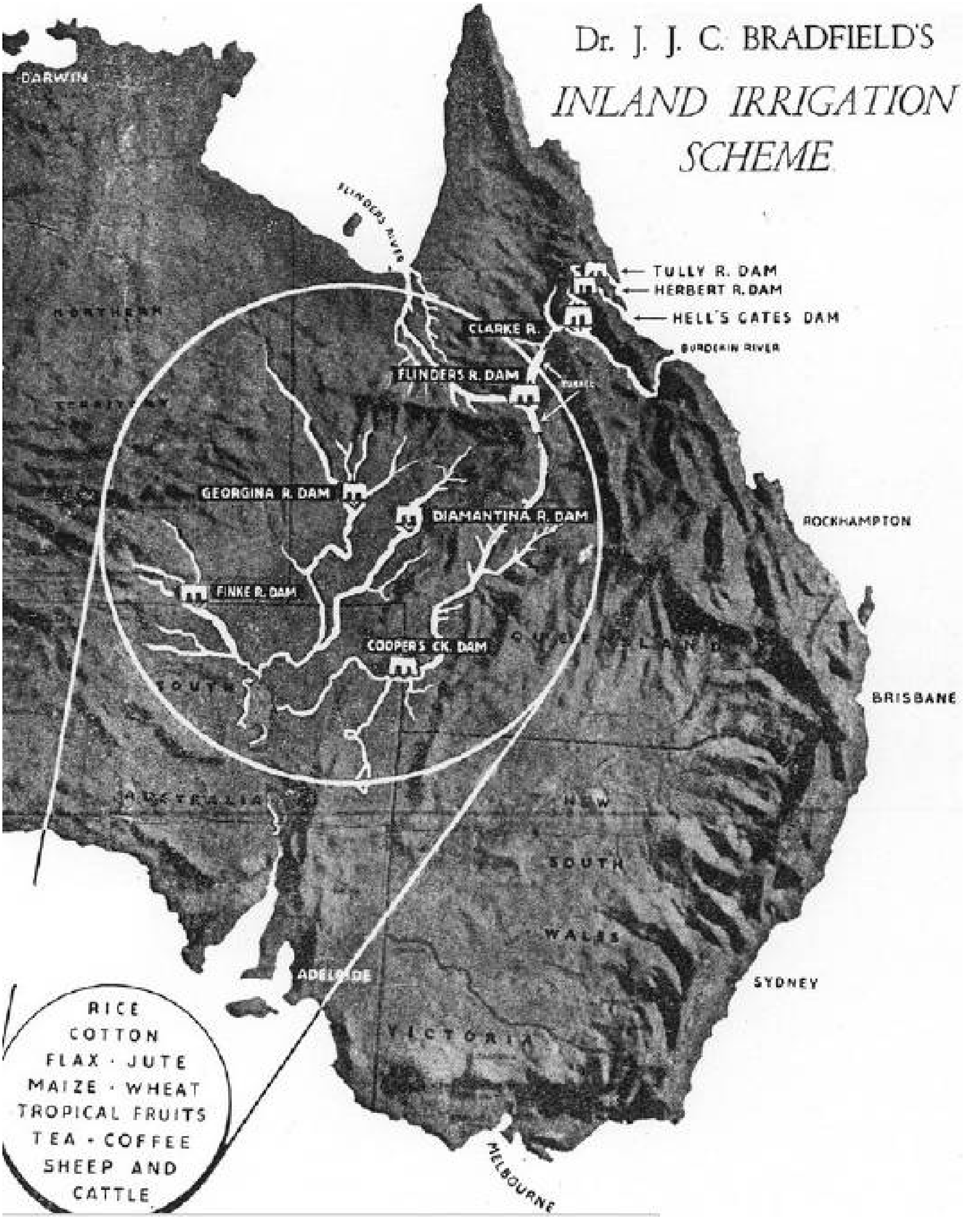
1. **John Robertson**: Retired mechanical engineer with British decoration for his time serving with the RAF.
   29/7/18 "An outstanding report. Hope to see it come to fruit."

2. **Alan Robertson**: Mechanical engineer and founder of 'Caged Rock,' Sumner Park, Brisbane. Web page is www.cagedrock.com.au
   26/8/18 "Great paper and well backed up with engineering/costing calculations."

3. **Viv Forbes**: Editor and founder of "Carbon Sense" an independent newsletter produced for the Carbon Sense Coalition, an Australian based organisation which opposes waste of resources, opposes pollution, opposes the baseless war on carbon fuels and promotes climate sense and the rational un-subsidised use of all energy resources including coal, oil, gas, hydro, nuclear, wind, solar and geo-thermal.
   Web page http://www.carbon-sense.com/
   27/8/18 "I had read that report (Wind into Water) but just read it again a bit more carefully. You have an agile, innovative mind which I admire. That is a challenging report, and evidence of a lot of thought and work." and "Yes electric-assisted siphoning sounds a great idea."

Appendix - A

The Courier-Mail of September 20, 1938
Augmenting Queensland's Inland Water Resources By Dr. J. J. C. Bradfield, C.M.G., DSc. Eng., D.E., M.E., M.Inst. C.E., M.Inst E. Aust.



In The Courier-Mail of September 20 (1938) the Premier (Mr. Forgan Smith) stated that in June the estimated flow from 1808 artesian bores was 278,000,000 gallons daily— equivalent to a flow of 515 cubic feet a second. DURING the last 20 years this artesian flow has diminished steadily— And if the flow continues to decrease uniformly during the next 20 years, most of the artesian bores will become sub artesian, that is, the water will have to be pumped. In the terms of the musical advice given to Phyllis, surely the writing on the wall reads: — "Be wise in time, O Queensland mine, Pray beware, have a care." Within an area of 17,000 square miles, the head waters of the Tully, the Herbert, the Burdekin, and the Clarke rivers have their origin, also the head waters of the Flinders River on the other side of the divide. In this region the storm king holds sway, flooding these coastal flowing rivers with the heavy monsoonal rains as the clouds drift in from the ocean and break with fair regularity against the main divide and the subsidiary ranges. It is possible to combine and store their flood flows in one or more reservoirs from which a permanent stream can be fed to traverse Queensland from near Hughenden to Windorah and the Queensland border. May Queensland be granted vision to see where her opportunity lies, before it is too late, and her rain forests destroyed on these mountain tops.

★ The diversion of the flood waters and, portion of the normal flow of these coastal rivers would begin adjacent to the Tully Falls. The Tully River rises on a plateau of scrub west of the Cardwell Range, and flows in a northerly direction until it reaches the Tully Falls. The catchment area above the Falls is 140 square miles in extent, and is subjected to a heavy rainfall of about 75 inches per annum. A suitable site for a dam occurs about 300 yards up stream of the Tully Falls, where a dam 120ft high and 700ft long could be constructed on a basaltic bar extending across the river, which would afford a shallow foundation for the dam wall. The right bank is solid rock covered with about lft of soil; on the left bank the rock outcrops through the heavy scrub. Here are primitive rain forests practically untouched by man. The sluices would constantly by pass a minimum of water equal to or greater than 'the normal summer flow, improving the present irregular discharge. The water liberated to flow down the Tully could operate an hydro-electric plant flood-lighting the Falls, and so adding to their attractiveness and supply current to the adjacent northern towns. The impounded water, by an open cut less than a mile in length, can be led into Blunder Creek, a tributary of the Herbert River.

1.— The picture shows the Tully River just above the Tully Falls and the rain forests which clothe its banks. Mountains Bellenden Ker and Bartle Frere, the latter 5287ft, 7ft more than a mile high, tower, above the mountain range northward of the sources of the Tully and Herbert rivers. The latter river has a total catchment of 3500 square miles, of which 2038 square miles are above the Herbert River Falls, and would be utilised by the scheme. Average rainfall is over 36in per annum. The principal tributaries of the Herbert are Wild River and the Mill Stream, a constantly running river, also Rudd Creek, fed by springs.

2.— The Mill Stream Falls are some distance above the dam required across the Herbert River, and show the volume of water which normally passes over these falls into the Herbert River. Across the Herbert River a wall 100ft high, about 1000ft long, can be built, founded on an extensive bar of red granite across the bed of the river.

3.— The site of the dam would be below the small Falls in the Herbert River, where there is a splendid foundation for a gravity dam. From the Herbert dam a constant discharge of about 3000 cubic feet per second, inclusive of the Tully River water, could be diverted by tunnel and open cut into the Burdekin River, near Wairuna; the distance from the Herbert River, at the dam site, to the Burdekin River is 13 miles, the bed of the Herbert River being 46ft higher than the bed of the Burdekin River. The Burdekin is the second largest coastal river in Queensland, having a watershed of 50,975 square miles; the Fitzroy, the largest, has a drain age area of 53,000 square miles. Flood waters would be collected from 7204 square miles of the catchment of the Burdekin River, including the Clarke River ,and its other tributaries above Hell's Gate, where the river in some prehistoric era cut a channel for itself between the Blue Range and the Perry Range. A dam across the Burdekin at Hell's Gate, about 15 miles below its confluence with the Clarke River, is the important feature of the scheme.

4.— The Hell's Gate Gorge is 2000ft wide and 400ft deep. A granite bar runs across the Burdekin, and. the dam wall could be founded without difficulty, here the combined waters of the Tully. Herbert, and Upper Burdekin would be stored and provide for a constant stream of 6000 cubic feet per second after allowing for evaporation. he problem Is how to get this water through the Divide into the Flinders River by one of its tributary streams. It can be achieved by aqueduct and tunnel levels taken along the Flinders indicate that the main supply tunnel would discharge in the vicinity of Blantyre, where there are many suitable gorges for impounding the water. The Flinders River rises in the western slopes of the Great Dividing Range, at an altitude of 2546ft, flowing south until Jardine Creek junctions it near Mount Arthur. Its watershed area above this point is about 1000 square miles, with an average rainfall of over 21 inches; the rain comes in fitful heavy showers with a good run off.

5.— In the Flinders River a series of large coolamons — the aboriginal name for a water-basin — one below the other would be established to hold the pent-up waters which would be fed into Jardine Creek, thence by an open cut connected with Skeleton Creek and the head waters of the Thomson River. Some of the water, however, would be by passed down the bed of the Flinders River to meet the requirements of pastoralists in the Richmond and Hughenden districts. Much of it would disappear by seepage and evaporation, but it would not be lost. Mr. S. E. Fearson, who knows the country well, has informed me that from Hell's Gate it appears feasible to follow the contours and deliver the water by canal and aqueduct to Webb's Lake at the head of Amelia Creek, a tributary of the Cape River. At this point in the Dividing Range is a low gap, which, he stated, is not more than 1200ft high, so that the water could be passed into Torrens Creek without a tunnel and thence into the Thomson River. Once in the Thomson River the water can be led where required and be used to irrigate about 3000 square miles of the richest agricultural land in the State near Windorah, or some water could be led by existing water courses and excavated channels into the Diamantina River.

★ ALLOWING 20 square miles of dry, country, to every square mile of irrigated land, about 60,000 square miles of country, now most sparsely stocked or unoccupied on account of the very low rainfall, could be heavily stocked, as in addition to the natural fodder the irrigated land would supply all the fodder required in good and bad seasons, and there would always be water available in times of drought for watering stock. True, it might have to be pumped, but windmills or electric power generated by the scheme would be available. In these rich inland rolling downs on the south-western confines of the State, with adequate fodder and water, it should be possible to depasture a sheep on every two acres and so add 20,000,000 sheep to Queensland's flocks. Our shallow wells are gradually reducing the ground water, lowering its level. The sun for ages past has by capillary attraction, drawn up moisture from the earth; the deeper down this water is the less effective is the power of the sun and less moisture is sucked up into the atmosphere. This moisture drawn up by the sun falls again as rain in local thunderstorms. Nature over millions of years has established a subtle balance between soil and vegetation on the one hand and the rainfall to support animal life on the other. The advent of closer settlement is upsetting the balance, and unless something is done we may, in years to come, have an inland waste almost devoid of vegetation. At the dawn of history Menes, the first or one of the first Egyptian Kings, diverted the Nile to flow through the middle of Egypt, whilst Amenemhat, who reigned 2300 B.C., created Lake Moeris, an area of 970 square miles, to regulate the flood flow of the Nile. Shennong, the Divine Husbandman of China, who reigned 4770 years ago instructed his people in irrigation. In Peru, centuries before Australia was known to civilisation, aqueducts, some of them 450 miles in length, fed by mountain springs, watered the whole inca Empire. And what these ancient nations have done Queensland can do, and more.

★ A RIVER having a capacity of 6000 cubic feet of water per second represents over 14,000,000 tons of water daily, or over 5,000,000,000 tons of water per annum poured into the dry west. What the effect of such a volume of water on the dry inland areas of Queensland would be is almost beyond our ken. But what a different Queensland it would be under closer settlement, and what a sturdy, self-reliant white race would be bred. Population makes for prosperity and safety. 'Audax et Fidelis' — 'Daring and True' — is the Scheme, and daring and true would be the race who would hold Queensland against the menace of any nation bordering on the Pacific littoral, as, sooner or later Australia must fight to hold what Australia possesses. Queensland must be true to herself and live up to the motto emblazoned on her coat of arms by her pioneers, 'Auriax et Fidelis.'

Appendix-B

Specific Electric Siphon Applications in Australia.

Victoria
Galaga National Park. 828m 4km to coast.
The Grampians 1160m, 6km Lake Muirhead, then 4km Mount William creek 245m
Angohook Lorne SF, 667m, sea 6km.
Mirimbah 1733m 10km, Woolomgella River 600m, then King River 828m.

New South Wales
Bolaro State Forest 680m 4km to coast.
Barren Grounds 665m 4km to coast.
Illiwarra Escarpment 400m, 2km to coast.
Royal National Park, Otford, 300m, 1km to coast.
North point head, 103m, 500m.
Singletons Mill, 230m 500m to Hawksbury River. Many similar sites.
Dooragan National Park, 498m, 2km to coast.
Hat Head, 297m, 1.5km to sea.
Tallerwang 566m, 50km to Hunter river at 266m, then 12km to Talebregar River at 404m then to the Darling River.

Queensland
Lamington NP, 1200m, 10km to 26m coast.
South Stradbroke Island, 225m 2km to coast.
Mount Glorious 775m 10km to Wivenhoe Dam,
Deer Reserve NP. 706m, 3km to Lake Somerset 99m
Pinelands 775m 40 km to Wivenhoe at 62m, then 20km to Condamine at 415m
Conondale 892m, Cedar ck, 128m, 15km
Bunya Mountains 1164m, 60km Brisbane River 175m, then 60km to Condamine 360m
Carnarvon NP 1251m, 50km to Brown river 207m, then 80km to Warrego River 579m
Blachbraes NP 1057m, 160km to Clarke River at 365m, then 60km Norman River 487m, or 120km to Flinders River at 266m

Northern Territory
The NT currently operates three power distribution regions including Darwin-Katherine, Tennant Creek, and Alice Springs. Preliminary assessment of opportunities to install FT systems at each location include:-

1) Darwin-Katherine

Darwin is generally low lying, but the area around Belyuen has 50m elevations in close proximity to the sea. This offers the opportunity for low head hydro operation, given that the quantity of water is not a limitation.
Katherine, some 1,500m to west side of gorge is 243m high ground suited to FT location. The gorge is at 109m level, providing 134m of hydraulic head. The water returned to the gorge via a Pelton wheel generator provides neutral water use.

2) Tennant Creek

Tennant Creek has an elevated ridge near Kaczinsky Road at 420m, 1,000m away is the Mary Ann Dam 374m elevation providing 46m head. This FT installation would be a higher volume design providing neutral water use.

3) Alice Springs

Alice Springs has a ridge near Desert Park at 894m. Larapinta is 1,500m away at elevation 589m, providing an hydraulic head of 305m. Water supplied from the Amadeus Basin can be used to operate the FT system before adding it to the Alice Springs reticulated water supply.

Other regions of the NT where topography favours FT operation include; Kakadu, 558m, 80km to coastal flats, and Keep River 266m some 20km to the coast.

West Australia

Hamersley range 712m, and 150km to coast.
Darling range 330m, and 50km to coast.

South Australia

Great Australian Bight 100m high and 50m to 350-700km long coast line.
Numerous salt water hydro opportunities.
Mount Remarkable NP 966m, and 20km to coast.
Yorke Peninsular 160m, and 20km to coast.
Mount Barker, 714m, and 20km to coast.

Tasmania

Ben Lomond NP 1050m, and 20km to South River.
Numerous hydro electric dam recycling opportunities.
Mount Field NP 1088m, and 12km to Derwent River 88m elevation,
Rossarden 943m and 5km to South Esk River 198m elevation.

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