Lower Hawkesbury Pumped Storage
Warragamba Transfer Project
Submission to the Productivity Commission
Discussion Draft

Background

The Warragamba Dam was completed and the reservoir began to fill in 1960. It has a catchment area of 9050 km^2 and the average rainfall over the catchment is 840 mm. The long term average flow into the dam is ---- m^3/s and the dam has a capacity of 2,031,000 megalitres (2.031million m^3). Since it was built, very little catchment area or storage has been added to the Sydney water supply system even though the population served by Sydney Water has grown from less than about 2.7 million to close to 4.5 million over that time[1]. The only meaningful addition has been pumping from the Tallowa Dam on the Shoalhaven which is severely limited by operating agreements which ensure environmental health of the river. These provide that flows are passed through Tallowa dam not only to protect low flows but also to protect a portion of medium and high river flows downstream.

Some of those concerned with the environment have argued that various other measures are preferable to building new dams including conservation, storm water harvesting and recycling. While there is merit to each of these, it must be said that Sydney Water and its consumers have already achieved much in conservation. Water consumption per capita has reduced from about 600 litres/capita (lpc) in1960 to about 400 lpc at present. Storm water harvesting has severe limitations because of the limited catchment area of the Parramatta River (391.9 km^2) which occupies 40% of the coastal area and those of the other rivers: Cooks, Georges and Hacking which occupy the rest. In general, there are no natural storage sites where concentrations of flow may be intercepted. This may not be true of the Hacking River which has its estuary at Port Hacking but much of the catchment is occupied by the Royal National Park which of course, and justifiably so, is untouchable. To the west of the railway line (the Illawarra line) which generally follows the ridge are other catchments which were fully developed before Warragamba. A map of the Sydney Catchment Authority (SCA) catchments is included as Figure 1.

[1] 4,254,894 in 2005

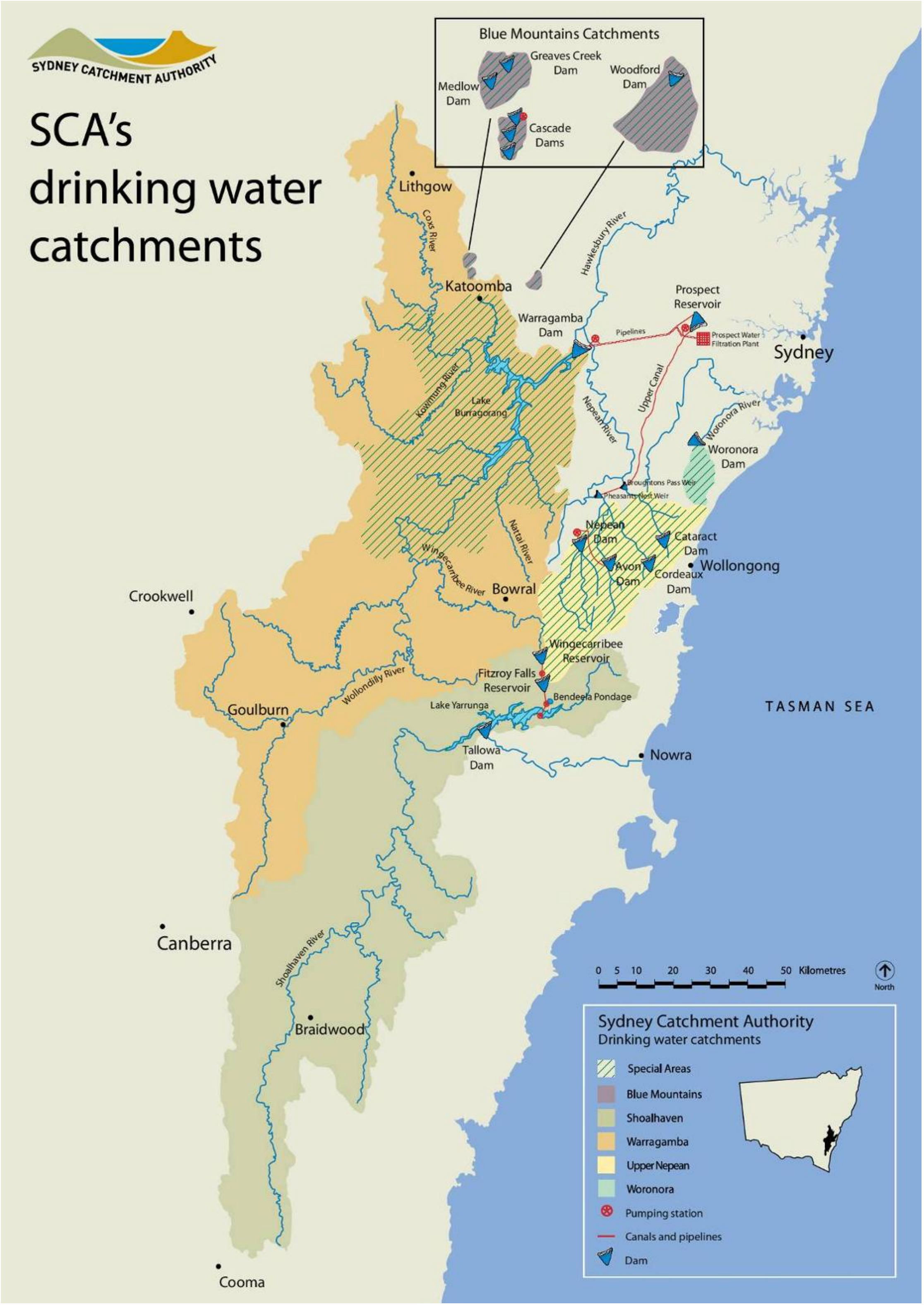

Figure 1: Sydney Catchment Authority - Catchment Map

Recycling is already carried out for industrial users, for golf courses and most notably by Sydney Water itself[2]. But Sydney Water considers that reverse osmosis treatment is required before water can be considered potable[3], and since this is the same process used in desalination, then it is obviously not economical.

Successive state governments have avoided the issue because of perceived environmental issues associated with dams, even though low impact diversions to Warragamba were proposed several years ago. Meanwhile, the NSW State Government has commissioned a desalination plant where the cost of water is several times that of water from existing dams and this is the subject of the Productivity Commission's current investigation.

On the electric power side the anti-dam sentiment has also affected hydropower development and almost no hydropower capacity has been added to the interconnected Queensland, NSW, and Victorian system since the Snowy Mountains Project which was also generally completed in the early1960s. While there has been some additional hydro capacity added to the interconnected system with the recent completion of the Bass Link connection to Tasmania, Hydro Tasmania is constrained by climatic effects which have drawn the "Roaring Forties" southwards[4]. Since "1950 eastern Australia has become significantly drier"[5]. The rainfall on Hydro Tasmania's catchments has decreased by some --- percent over that period. Since the completion of the Bass Link connection Hydro Tasmania have largely concentrated in purchasing off peak energy (produced by coal fired power stations) to enable them to partially refill their reservoirs. They have also been constrained from adding additional catchment areas since the successful campaign against the Gordon below Franklin Dam in the 1960s.

With the lack of new hydropower capacity, additions to the interconnected system, now managed by National Electricity Market (NEM), have been almost exclusively coal fired steam turbine generators with obvious atmospheric emission impacts. There is a new emphasis on such emissions with the realization that global warming is a reality and that CO_2 is also a noxious gas. There is also recognition that all of NSW power infrastructure (generation, transmission and distribution) is aging and urgent replacements are required. This is contributing to projected large increases in electricity bills. Similar projections are being made for household water bills.

In similar contexts, pumped storage is becoming very common in other countries, notably in China, Japan, and Korea and recently in India and Indonesia. There is also a renewed emphasis on pumped storage in Europe and the United States even when the additions are prima facie uneconomical.

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[2] Sydney Water "Water Conservation & Recycling Implementation Report 2004-2005"

[3] While Sydney Water considers this to be the case, it is a fact that people on the Mississippi for example drink recycled water all the time. It is also a fact that the effluent from some urban areas drains into the Warragamba Dam; however, it is treated, chlorinated and there is substantial aeration in the Warragamba Reservoir so there is no cause for concern. It is a fact, however, that the term recycled effluent has a pejorative connotation to people in Sydney and South East Queensland among others.

[4] The recent very wet weather over the whole of the east coastal areas of Australia have provided some respite but is noted that even after these rains Warragamba is still only about 75% full and the last time it was full was in late 1998; this is indeed a country of drought and flooding rains.

[5] CSIRO 2009: The Science of Tacking Climate Change

The Concept

The concept is simple:

- A pumped storage scheme would be constructed on the Lower Hawkesbury River north of Milson's Passage which is just upstream of the road bridge carrying the Sydney Newcastle Expressway over the Hawkesbury River.

- A water transfer scheme would also be constructed to pump excess flows at Milson's Passage to Prospect Reservoir and except for flows extracted by Sydney Water enroute and in Prospect, if necessary excess water would be pumped from Prospect to Warragamba Dam restoring it to more normal operating levels.

- These schemes are not inter-dependant but would benefit from common elements which will be elaborated later in this report.

Flows Available for Transfer

The intermediate catchment area between Warragamba and Milson's Passage is estimated at 12,371 km^2 in comparison with 9,050 km^2 for the Warragamba catchment itself. A drawing showing the boundaries of the two catchment areas of Hawkesbury River Basin is included as Figure 2. Pending a more detailed hydrological analysis, average rainfall of Badgery's Creek, Richmond, Katoomba and Prospect Reservoir were used as a proxy for the average rainfall over the intermediate catchment. The rainfall distributions for these stations are shown in Figure 3. On this basis the average rainfall over the intermediate catchment is 1178 mm in comparison with the average rainfall over the Warragamba catchment of 840 mm which is not surprising considering the intermediate catchment is generally at a higher altitude and has the advantage of orographic effects. From the above approximate analysis, indications are that the intermediate catchment would have a total precipitation of 14,500 million m^3 in comparison with that of Warragamba of 7,600 million m^3. Evapo-transpiration losses are also likely to be lower in the intermediate catchment such that the effect would be magnified. Clearly, the intermediate catchment is more than a supplementary source of water to Warragamba (similar to transfers from Tallowa Dam) and that transfers will not be limited by the amount of water available but by the capacity of the transfer scheme itself.

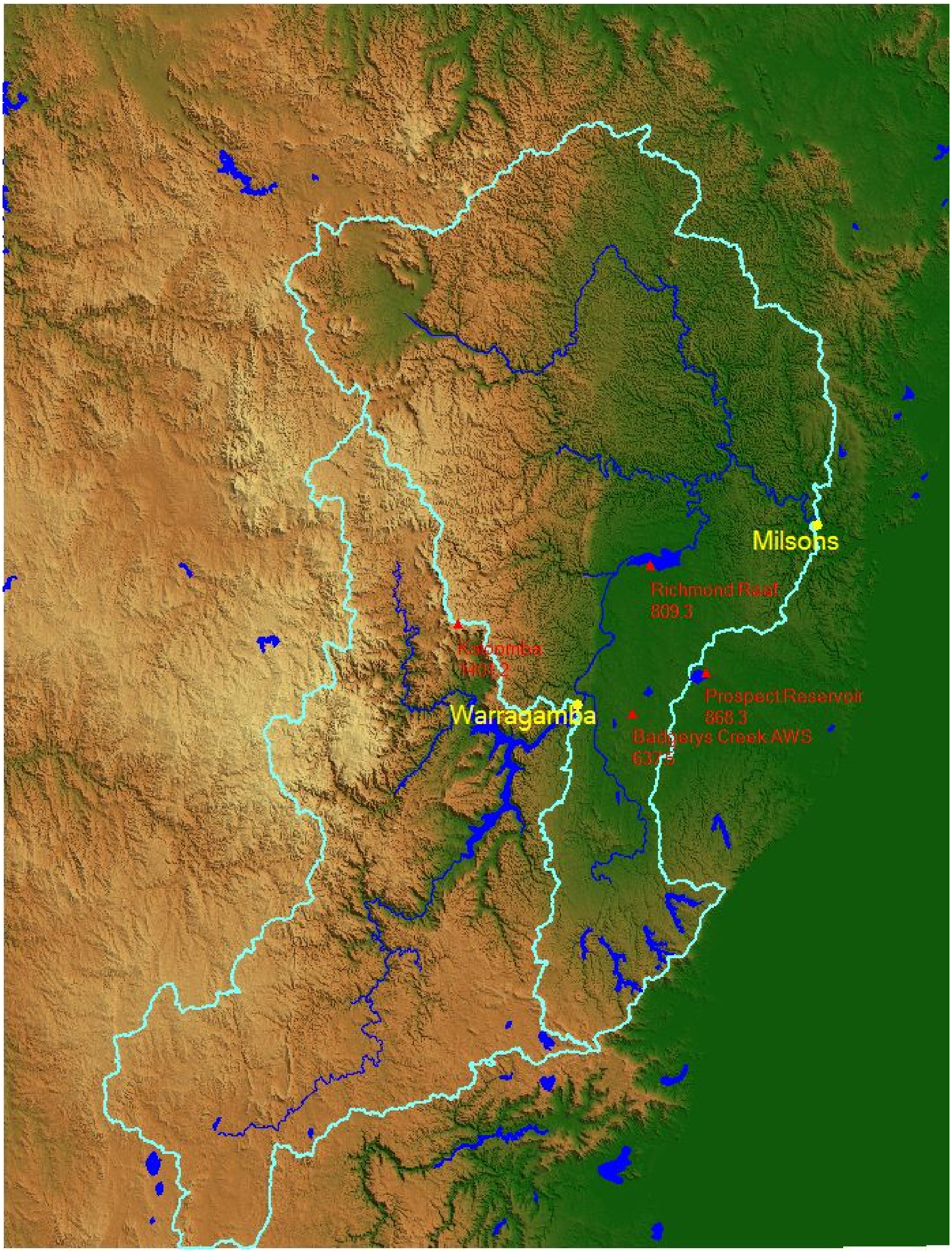

Figure 2: Hawkesbury River Basin, with Warragamba and Lower Hawkesbury sub-basins

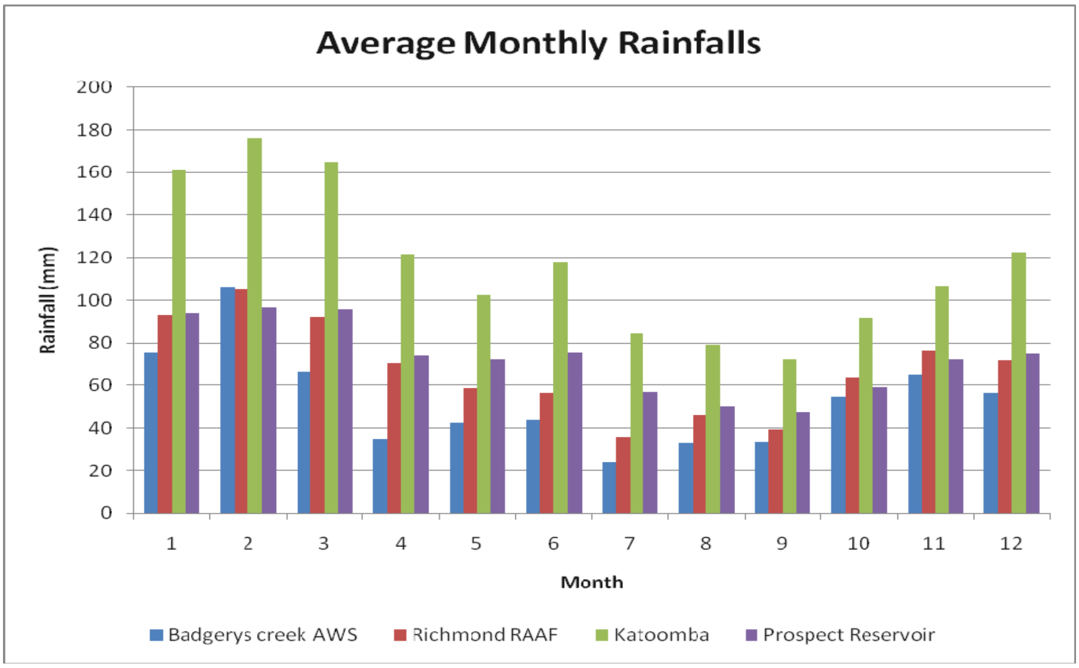

Figure 3: Monthly Rainfall at Selected Stations

The Pumped Storage Scheme

A pumped storage scheme typically consists of a lower reservoir, an upper reservoir and an underground powerhouse with reversible pump/turbines and motor/generators between the two.

Lower reservoir: in the present situation, it is likely that a lower reservoir of any size, would not be required since the Hawkesbury River and its tributaries in this area have such a large volume. However, to prevent salt water intrusion during periods of low flow in the river and to allow marine traffic to pass both upstream and downstream directions a control structure of some form would be required. This structure would also ensure no interruption to migratory fish passage if this is indeed an issue. The form of this structure would be defined later in the development stage, but could consist of an inflatable rubber dam although experience with these has been mixed. If a rubber dam were to be adopted, there could be a side channel which would allow recreational traffic through (fast in the downstream direction, but quite a slog in the upstream direction. For the purposes of this Concept Paper, the control structure is assumed to be a rubber dam about 500m in length with, if necessary a side channel bypass to allow recreational traffic to move upstream and downstream past the weir. The envisaged location of the rubber dam is shown in Figure 4. If a rubber dam proved to be infeasible, the control structure could consist of an ogee type weir about 500m in length which would normally be submerged but be above water at low tides. A section of this weir would provide the upstream and downstream movement of marine traffic and fish, and may consist of a structure which at higher river flows would allow interrupted flows but at low tides may function as a lock. In all cases water upstream of the weir would be fresh.

Upper Reservoir: An upper reservoir (or pond) probably be located on the northern side of the river where there is a suitable storage location almost immediately to the north of

Milson's Passage bordering the Sydney to Newcastle expressway on the eastern side. On the western side it is close to the Hawkesbury River as it turns sharply north just upstream of Milson's passage. A contour drawing of the upper reservoir is shown as Figure 4, together with the arrangement of the required structures. On the basis of publicly available ASTER (**A**dvanced **S**paceborne **T**hermal **E**mission and **R**eflection Radiometer) digital elevation data, a preliminary location for the reservoir has been fixed for the purpose of this concept paper. The reservoir would be contained between two dams one located at the north end and the other at the south end. The eastern border of the reservoir is generally parallel to and in some cases close to the Sydney to Newcastle Freeway. To avoid interference with the freeway the Full Supply Level (FSL) has been placed at Elevation 180 m with a Minimum Operating Level (MOL) of say 160m. The crest levels of the dams may be slightly higher. The average head would be in the order of 170m and the active storage 23.73 million and the overall area enclosed at a Full Supply Level at 180 m would be 1.45 km^2. Reservoir Volume and Area versus Elevation curves are included as Figure 5(a) and Figure 5(b).

Underground Power House Pumping Station: An intake/outlet structure situated on the eastern side of the Upper Reservoir would pass flows via a pressure shaft and a high pressure vertical shaft to reversible pump turbines and motor generators located in an underground powerhouse and thence to a low pressure tailrace tunnel and outlet/intake structure in Moonee Moonee Creek about 500 m upstream of the control structure. Assuming an average of four hours daily generation and 4.8 hours pumping, the installed capacity of the generators might be 1990 MW in seven units each of 284 MW installed capacity with the pumping capacity being 18 percent larger. The turbine design flow would then be about196 m^3/s per unit and the pumping design flow 231 m^3/s per unit. However, considering the need for reserve capacity (and because 8 is a lucky number in Chinese) it is currently assumed that there would be eight units rather than seven. It also simplifies the layout.

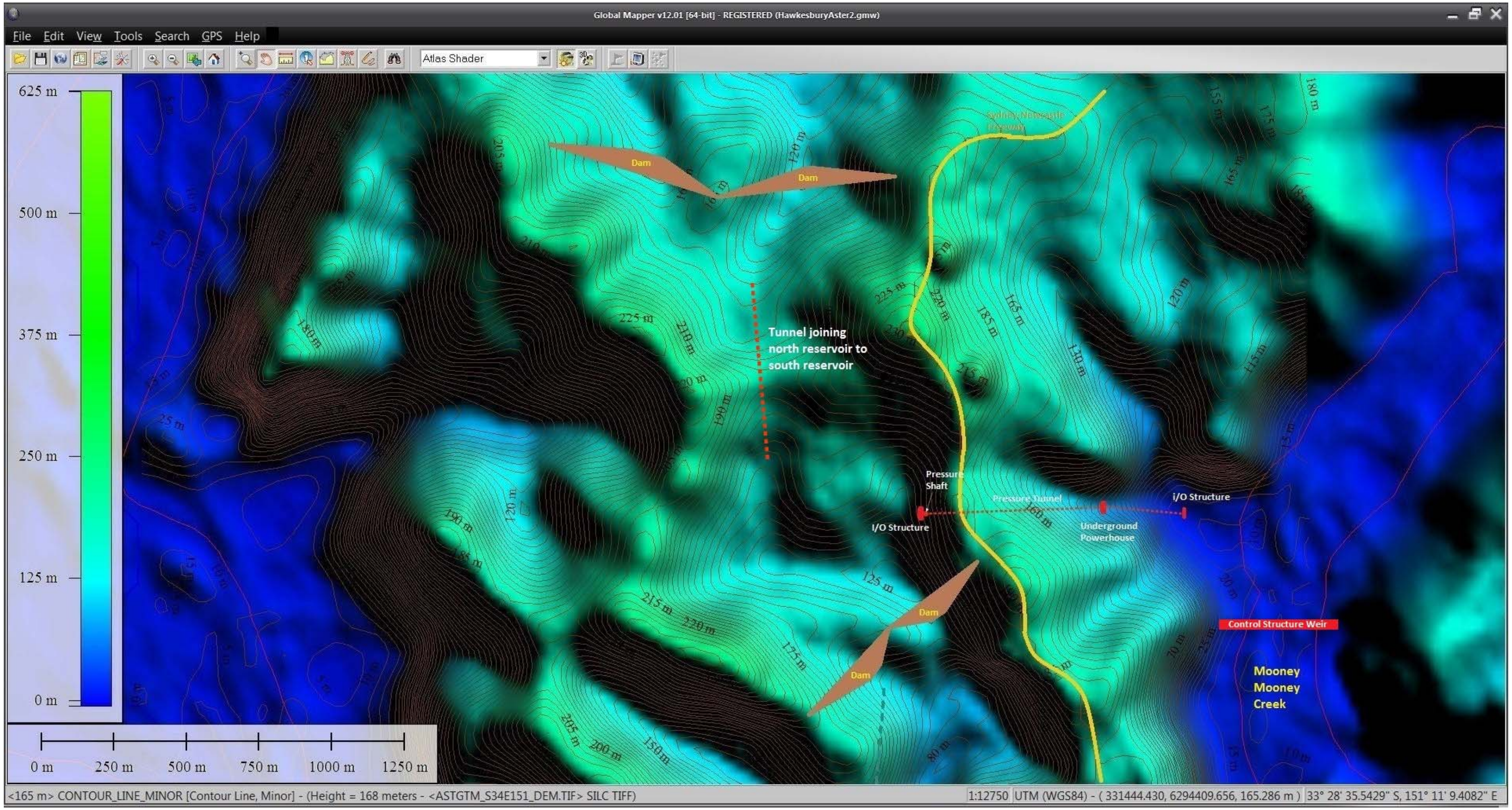

Figure 4: Upper Reservoir - Contours and Arrangements

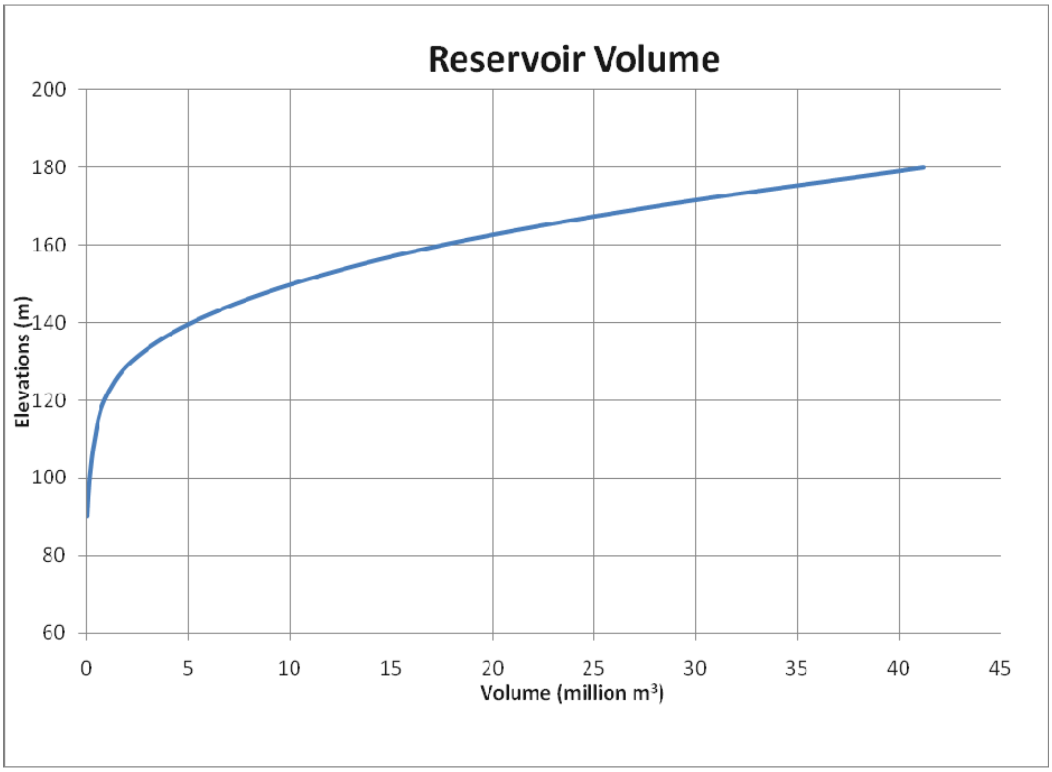

Figure 5a: Upper Reservoir Volume

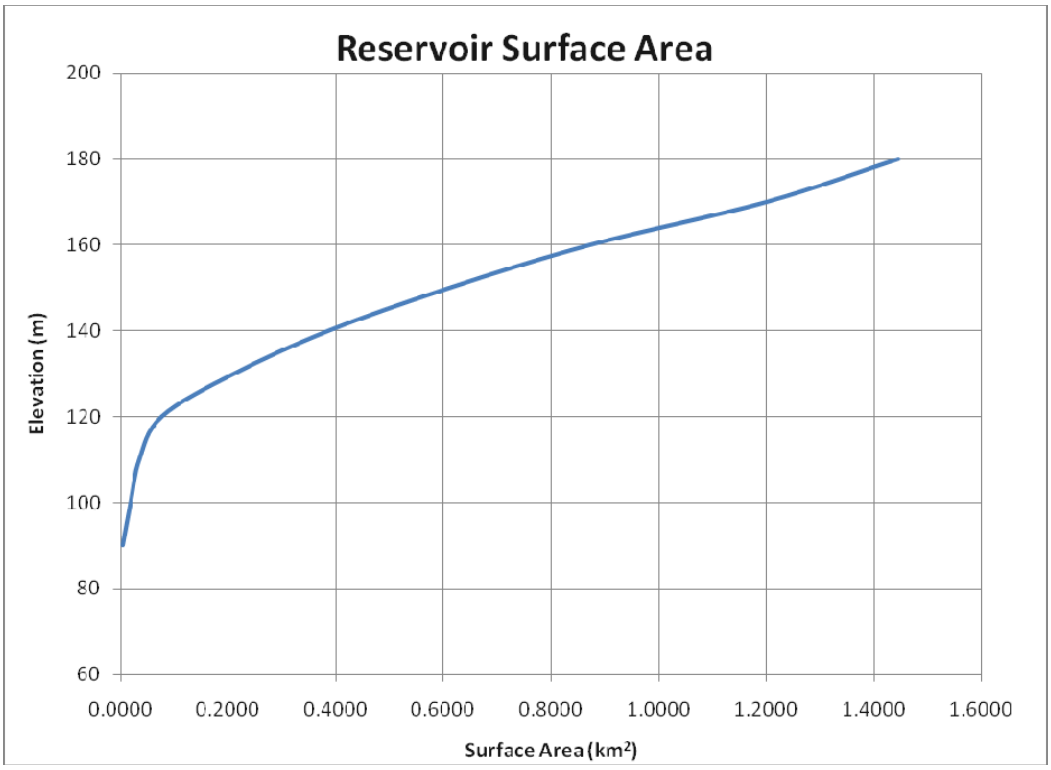

Figure 5b: Upper Reservoir Surface Area

Individual Elements of the Pumped Storage Project

The Upper Reservoir Dams

It is likely that both dams would be constructed of Roller Compacted Concrete (RCC) although other dam types would of course be considered at the feasibility stage. Considering the catchment controlled by the dam is very small the spillways if required would probably be a stepped spillway. The approximate volumes of the two dams are $713x10^3$ m^3 and $595x10^3$ m^3 for the north and south dams respectively.

The Upper Intake/Outlet Structure

There are at least two possible configurations: (a) the structure would be free standing in the reservoir and would contain vertical trash racks and screens, stop logs and service gates); it is likely that the structure partially set into the abutment such that it would be directly connected to the pressure tunnels located in the abutments; (b) the structure would be located entirely underground in a rectangular shaft. Each inlet, and there may be four, one for each two units, would be of rectangular shape and be bell mouthed to reduce the velocity through the screens and would be situated far enough below the Minimum Operating Level (MOL) to avoid vortices. Downstream of the inlets/outlets, the rectangular waterways would transition to circular pressure tunnels

The High Pressure Tunnels and Shafts

It is currently assumed that there would be eight power conduits, one for each pumping/generating unit. Based on a longitudinal cross-section not shown in the drawings, it appears that there would be low pressure tunnels each about 250 m long followed by gradual 90 degree vertical bends leading to vertical pressure shafts about 150 m deep and gradual 90 degree bends leading to horizontal high pressure tunnels. It appears that it would be desirable to position the underground powerhouse quite close to the shafts to minimize the length of steel lining. In this case the high pressure tunnels leading to the power/pumping station would only be about 100 m long. It is assumed, based on experience that the velocity in the pressure tunnel and shafts along the length that is not steel lined is 4.5 m/s and that the velocity in the steel lined sections is 6.0 m/s than the diameters (to the inside of the lining) would be about 7.5 m and 6.5 m respectively. The length of steel lining would depend on the insitu stresses in the rock which would in turn depend on the tectonic situation. The east coast of Australia is not considered to be seismically active, but it is evident from the rock exposed in the cuts in the highways north of Sydney that in the past the rock has been affected by strong tectonic influences. The criterion, which determines whether or not steel lining is needed, is that the ratio of the minimum principal stress in the rock should exceed the maximum water pressure inside the tunnel by a safety factor of about 1.5.

The Underground Powerhouse and Transformer Cavern

At this stage the cross sectional dimensions of the caverns are assumed to be similar to the Upper Cisokan Pumped Storage Project in Indonesia which will be implemented shortly. The Cisokan Project has four units whereas the proposed project has eight, and therefore the length is assumed to be double that of Cisokan.[6]

The Draft Tubes and Tail Race Tunnels

The draft tubes and low pressure tunnels would rise gradually towards the inlet/outlet structure in Moonee Moonee Creek. The total length of each tunnel would be about 650m. The inlet/outlet structure would again be protected by gates and stop logs and would be sufficiently below water level to avoid vortices.

The Water Transfer Scheme

Water would be transferred from the Upper Reservoir of the pumped storage to Prospect Reservoir via a tunnel via a fairly direct route with total tunnel length being approximately 50.0 km. The envisaged route is shown in plan in Figure 5 and a longitudinal section is shown in Figure 6. It is envisaged that vertical shafts to the surface would be provided at changes of directions of the tunnel. Access tunnels would also service these tunnels and water supply pipes may run within the access tunnels. The vertical shafts would take water to the surface with individual water treatment plants and possibly elevated reservoirs provided at these locations, but this concept may be modified in accordance with Sydney Water requirements if the project proceeds to the next stage. Of course, water could also be transferred to the south of the Hawkesbury extending Sydney Water's system as required. Water transfer would only be carried out in times of excess flow in the Hawkesbury.

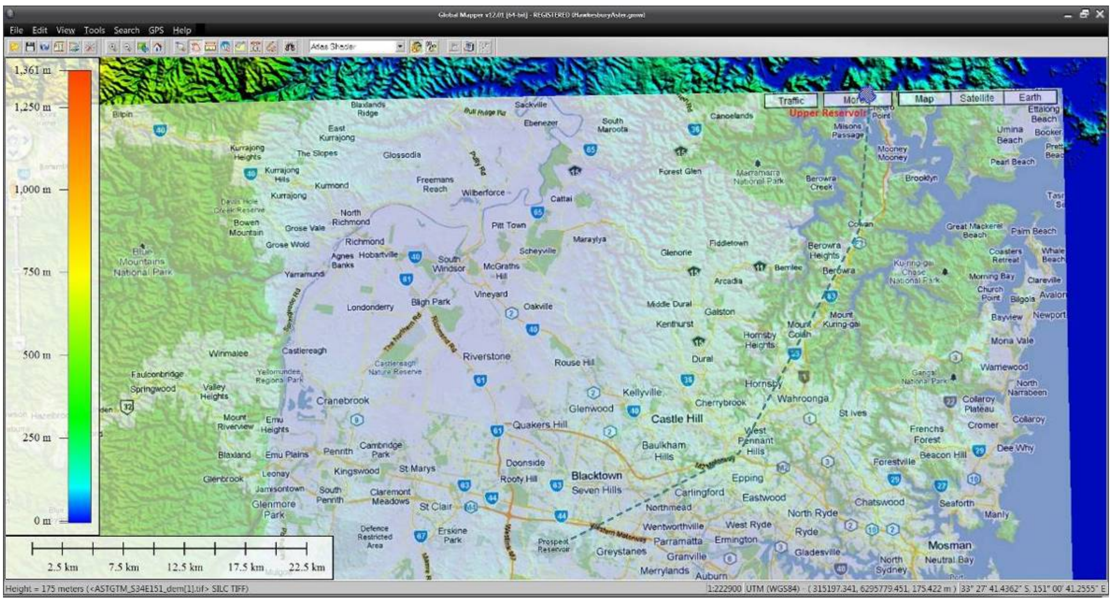

Figure 6: Water Transfer Tunnel Route (Dash line)

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[6] The Cisokan units have a slightly lower installed capacity and the head is higher; therefore the generating units will be larger. However, a recent Project Review Panel Report recommended that the cavern span could be reduced somewhat; therefore the cavern span originally proposed should be about right. By doubling the length of the powerhouse one is assuming two assembly bays whereas one might be sufficient. Therefore the assumption of maintaining the original cross sectional dimensions and doubling the length is considered to be about right.

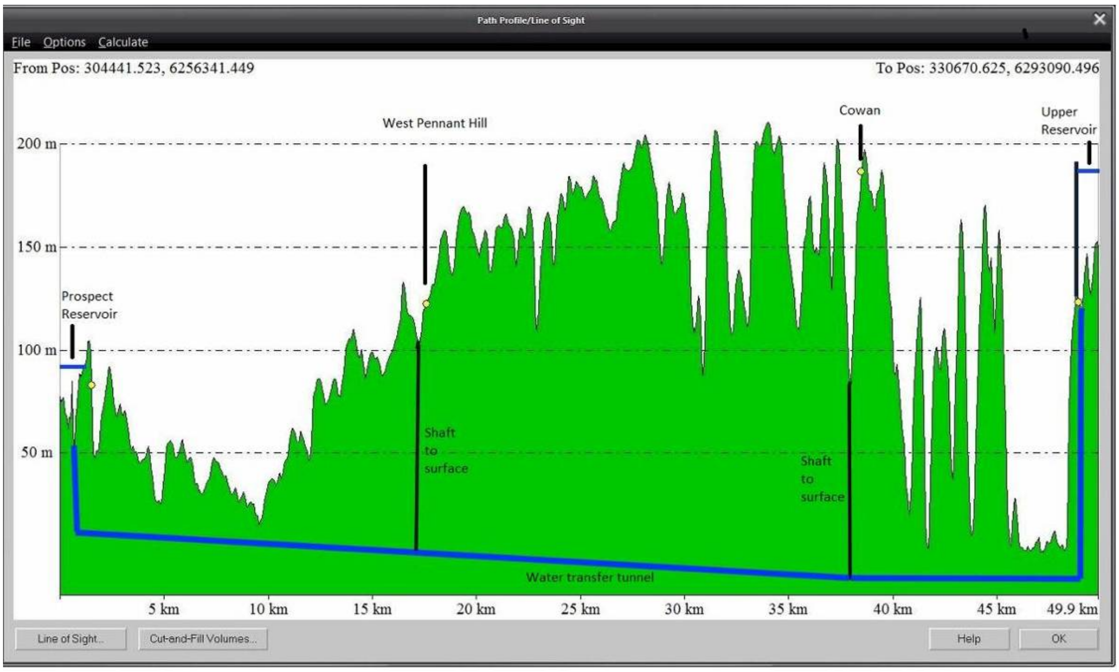

Figure 7: Water Transfer Tunnel Route - Longitudinal Section

Elevations

These are not exactly known but can be approximately determined from published data and satellite mapping:

River Level Lower Hawkesbury:	El. 0
FSL of Upper Reservoir:	El. 180 m
Prospect Reservoir:	El. 50 m
Warragamba FSL:	El. 150 m.
Warragamba LWL:	El. 50m

When full (which would normally be the case during water transfer) the FSL of the Upper Reservoir at 180 m is well above the level of Prospect Reservoir of about El. 50 m. Therefore it is likely that the water would be pumped directly from the underground pumping station under the Hawkesbury River and that tunnel would be initially horizontal and would then rise as shown on Figure 6. A critical factor in determining the initial elevation of the tunnel would be the lowest level of basement rock in the river bed. It is recalled that in building the Hawkesbury River Road Bridge an old deeply incised river channel was found so therefore the next stage of the study would need to include geophysical investigations supplemented by diamond core drilling. At least initially, the pumping capacity would be much greater than the transfer needs, and it is therefore assumed that the initial internal tunnel diameter would be in the order of 9.0 m, with an excavation diameter close to 10 m since this is a size that can be easily driven with a Tunnel Boring Machine (TBM). With an average velocity of 3.5 m/s, the transfer capacity would be 220 m^3/s and the pumping head (equal to the gross head plus the head loss) would be about 60m, which is substantially less than the 170 m+ pumping head of the pumped storage scheme. Therefore separate pumps, or some of the pumps being variable speed, would need to be considered. In fact in the current context of an interconnected system with very low hydropower capacity it is assumed for the purpose of this Concept Paper that all units are variable speed units. Another significant aspect in a pumped storage plant is the choice of the most suitable starting method in pumping mode. Among the several ones technically possible, HV asynchronous/synchronous back-to-back is chosen for the current purpose. Based on Figure 3 it is assumed that the pumping station would operate continuously for six months of the year during the high flow season in the Hawkesbury River. It would not operate for the other six months. The pumping capacity needed to be devoted to this would be 129 MW and the pumping energy would be about 566.6 GWh/year.

At Prospect, it is understood that a small hydropower station has recently been installed. While pumping back into Warragamba has been considered, it is likely that there would be no need for this, since the intermediate requirements and associated water treatment plants would take the pressure off Warragamba and Prospect, allowing Warragamba to fill from its own inflow and thus the head on the new hydropower station would increase. These units are likely to be Francis units which could accommodate the head range. However, additional generating units may be required.

Cost Estimates

The great majority of costs are those associated with the transfer tunnel, the upper reservoir of the pumped storage component, the underground works at the upstream end and the mechanical and electrical works mainly attributable to the pumped storage components. The control structure across the Hawkesbury River would also add to the costs but no attempt has been made to estimate these costs at this stage. Similarly, estimation of costs associated with shafts to service water treatment plants has not been attempted at this stage.

The Transfer Tunnel

Depending on circumstances which it is not possible to predict at this stage, TBMs with more than 15km of operations should be refurbished at a cost of 60% to 80% of the cost of a new TBM. Therefore it seems appropriate to carry out the tunnel boring using three TBMs assuming that reasonable access can be obtained to launch the TBMs close to the changes of direction of the tunnels as shown on Figures 6 and 7. Access could be provided either in the form of tunnel or a large size open pit. The cost of each TBM is to some extent related to the type of TBM. At this stage it is assumed that excavation in Hawkesbury sandstone can be carried out without face support, and that precast concrete tunnel lining segments will be used which is a common solution for TBM driven tunnels of this size. Whether a single or double gripper TBM should be used has a lesser influence on costs and can be decided at a later stage based on time and cost optimization.

Taking the above assumptions into account, the cost of a TBM depends primarily on its weight which is estimated at 2000 to 2500 tonnes, while the average cost per tonne of TBM is currently between EUR 8,000 to 10,000 per tonne. Thus the cost of a new TBM of the size and assumed characteristics is about EUR 20 million or conservatively EUR 25 million. Assuming 80% of this is written off over the cost of the project, the assumption is made that the capital cost chargeable to the project for the TBMs is EUR

60 million. Operating costs are estimated at EUR 2,750,000 per TBM and year. The equivalent USD cost is 3,575,000 . The operating cost for three TBM's and for three years of operation amounts to approximately USD 10,725,000.

The Power House and Equipment

An approximate estimate of civil costs can be obtained from a recent estimate of costs for the Upper Cisokan Pumped Storage Project which will be commenced shortly. The estimate was prepared by Messrs. Francesco Piccoli and Alberto Lugaresi who, as international cost estimators, were contracted by the World Bank to prepare an updated cost estimate for the project since the project had an unusually long gestation period. As noted previously the two projects are similar in many ways, but different in other ways. Nevertheless, the similarities enable an approximate estimate to be derived.

The mechanical and electrical costs including pump/turbine and motor/generator costs are based on bids received from the Tehri Dam Pumped Storage Project where variable speed units pump back from the lower reservoir formed by Koteshwar Dam to the upper reservoir formed by Tehri High Dam. All three projects are owned by THDC India Ltd. THDC is a Government of India Company dealing with the construction of hydro power projects. The Company owns and operates the Tehri power house complex and has undertaken the construction of Tehri pumped storage station. The scheme of the pumped storage station has been optimized by THDC based on several studies both on the civil and M&E fronts.

The estimate prepared on this basis is as follows (all numbers are in US$ million).

The Pumped Storage Project

Upper Reservoir

Mobilization Etc,	10.000
Reservoir Clearing, Excavation etc.	15.000
Dams	
Southern Dam	67,200
Northern Dam	57,400
Total	149.240

Civil Works associated with Power and Pumping Station

Mobilization ETC,	10.000
Intake Outlet Structures	20.000
Tunnels and Shafts	125.000
Caverns and associated tunnels (access, drainage etc)	1,100.000
Total	1,255.000
Total Civil Works	1,404.240

Design, Supply, Installation and Commissioning of M&E Equipment (including gates and valves)	713
Base Cost of PS Project	2,117.240
Engineering	211,724
Contingencies	373,320
Overnight Cost	**2.702,284**

The Water Transfer Project

As noted previously these are primarily associated with the transfer tunnels. No attempt will be made to estimate costs of shafts to the surface until Sydney Water gets on board. Similarly no attempt will be made to estimate costs of the control structure which prevents salt water intrusion into the lower intake/outlet structure. Overall all of these costs are considered to be minor.

The capital cost of the water transfer tunnel is estimated at EUR 60 million or USD 80 million. However, to this should be added the operating costs during construction which are estimated at USD 10.725 million. However, an allowance of $15 million has been made for regulatory works. The Overnight Cost of the transfer tunnels is estimated at $120.875 Million including a contingency allowance of 10 percent.

These contingency allowances are some 5% above what would be assumed for a project at feasibility study stage. In view of the fact that most major costs are based on recently bid projects and detailed cost estimates about to be bid, then these allowances are considered to be reasonable.

Overall Cost Estimate

The overall" overnight" capital cost, or as they call it in China static cost is estimated at USD 2.823,159 million. These costs do not include Owner's costs, which could be substantial. The Engineering cost allowance of 10% should include most consultancy costs.

Operating Costs

Major water resource development projects are highly capital intensive and operating costs are relatively minor. A figure of 2% of capital cost per year as fixed costs for the upstream power and pumping station works including dams. No fixed operating costs have been assumed for the tunnels, since these are dwarfed by pumping energy costs relating to the water transfer costs and these will be discussed later.

Construction Aspects

The tunneling construction would undoubtedly be on the critical path to completion of the water transfer scheme. The construction time needs to be considered further in the future but will depend on the delivery time of a new tunneling machine, the abrasivity characteristics of the rock among other factors. The delivery time may or may not be important depending on the schedule of conditions precedent (see later discussion). As a rule of thumb one year can be taken as the delivery time of a new TBM plus six to eight weeks for on site erection. If the delivery time is critical, it is likely that refurbished machines would be used since TBMs of circa 10m diameter machine are very common. In this case the delivery time would be about half that of a new TBM. Based on precedent experience 36 months should be adequate for construction after assembly of the TBMs.

The pumped storage scheme would have its own critical path but typically access to the underground powerhouse, the excavation of the underground powerhouse and the erection of the mechanical and electrical equipment forms the critical path. This would be in the order of 3.5 years after award of the main civil works contract. The supply of the electrical and mechanical and electrical equipment is usually less critical.

Thus it can be seen that the construction times of the two critical activities are similar, about 3.5 years. The RCC dam could be constructed within this time as could the control structure across the Hawkesbury

Before contracts can be awarded there are a number of conditions precedent, in technical, procurement, land acquisition, environmental and other governmental approvals. The latter are less predictable. However, matters can proceed in parallel and it is not unusual for a preliminary works contract to be awarded after initial approvals such that construction of access roads and tunnels can be completed before main contracts are awarded.[7]

Economic versus financial analysis

There is in fact a difference between economic and financial analysis. Economic analysis is from the viewpoint of the National or State Government. In the case of Sydney Water Supply both Commonwealth and State Governments are involved. The current submission is to the Productivity Commission of Australia, but the primary responsibility of supplying water to NSW rests with Sydney Water which is regulated by the Australian Consumer and Competition Commission (ACCC) which is clearly a Commonwealth Government entity.

Financial analysis is from the viewpoint of the developer and will be considered carefully by its financiers.

In both forms of analysis Net Present Value (NPV) of Cost or Benefit – Cost Ratio is used as is B/C Ratio. In economic analysis an internal economic Rate of Return (IERR) may be generated and a corresponding FIRR is generated in financial analysis. However, the discount rate used is different. In both economic and financial analysis the discount rate is the opportunity cost of capital. In the former cost it is that of the host country or state; in the latter it is the cost of capital of the developer whether public or private. Economic analysis will exclude taxes and may also include conversion factors (which convert financial price to economic price) for things which are important to the

[7] The procurement method also needs to be considered carefully. Recently, one of the authors has had very good experience in assisting the Client (THDC) in preparing a set of bid documents for civil contracts which offers a middle path between the "turnkey" fixed price date certain approach and the traditional approach generally advocated for hydropower works where the risk profile is very different from a thermal power project. The NSW RTA has also had good experience with a Partnering approach as used on the Inner West Busway along Victoria Road Project which included the construction of a new bridge over Iron Cove.

Government. In a market economy as exists in Australia the primary differences between economic and financial analysis are the following: (a) the discount rate; (b) the exclusion or inclusion of taxes; both analyses will usually include embedded taxes which are difficult to separate such as income tax, but sometimes a project of national importance will be exempt from duties and taxes but this is considered to be unlikely in Australia; (c) whether or not there is a “public goods” context. However, it is likely that the Lower Hawkesbury Project if implemented will stand firmly on its own two feet from both economic and financial viewpoints without financial input from either Government. However, both Commonwealth and State Government support will be needed in the “conditions precedent” referred to earlier.

Economic Analysis or Project Justification

The demonstrated willingness to pay is often used as a proxy for economic benefit and these numbers are fairly easy to find in a market economy as exists in Australia.

The willingness to pay for water can be found from a document prepared for Sydney Water by the Centre for International Economics (CIE) in July 2010 in relation to the Sydney Water desalination plant. These showed that the near term projected price for water from the desalination plant, under three scenarios of operating restrictions. The unit costs derived were in fact quite close so therefore the median of $0.84[8] per kl or $8.40 per Gl or m^3 if these units are preferred. Frankly this is huge. Since this is only a short term forecast it can be assumed to be a “constant” price. Constant prices are used in economic analyses and these prices are not escalated in line with general inflation. However, projected price increases which exceed the rate of general inflation, such as energy prices are included in the inflation. Similarly, the discount rate used is the real rate that is the rate before inflation.

For electricity prices, the AEMO website www.aemo.com.au is instructive. Firstly the entire demand of the interconnected system is only 15,000 MW so a pumped storage plant of 4,800 MW would probably be developed in stages; the proposed Project is amenable to staged development because there is a ridge crossing between the north and south portions of the reservoir and only a low dam would be needed to separate the two. The south dam would then be built first. For the power facilities in the powerhouse civil works and those associated with the inlet and outlet works might be completed as part of the first stage; starter tunnels would be left in both the powerhouse and the intake/outlet works so that these works could be completed as a second stage. Pumping/generating units would be added progressively as the demand increased; however for this preliminary exercise it is assumed that the power facilities are completed in a single phase and the generation sales and pumping costs will commence immediately after commissioning. The second aspect is that there is already a shortfall in reserve capacity of about 120 MW and this will presumably increase with time as aging coal plants are de-commissioned. The AEMO website doesn’t not give directly what is needed for the analysis but it does provide an Excel spreadsheet table of historical prices for 2010-2011. If these are sorted from lowest to highest and the 25th percentile is taken at both the lower end then the selling price for generation can be taken as $973 per MWh and the buying price for pumping power can be taken as $22/MWh. Both energy prices are expected to rise with the cost of fuel but it is difficult to say how much.

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[8] These costs are expressed in AUD terms; however since the USD and the AUD are close to parity at present they can also be assumed to be USD costs.

Therefore for this analysis no escalation beyond general inflation is assumed. The website also indicates that the market for energy is tightening so for the purposes of this concept paper a value of $1000/MWh is taken as the selling price and $25 is taken as the buying price for pumping energy. The ratio of 40 might seem surprising to the layman but is not surprising to those in the business of buying and selling power.

The discount rate for use in economic analysis: Theoretically, the social time preference rate should be used which is defined as a lower discount rate applied to a long-term public-sector investment project, because society as a whole discounts long-term projects less than individuals do. In Australia it may well be close to or equal to the Reserve Bank of Australia (RBA) rate currently 4.75%. In the short term rates will stay on hold but in the long term, economists expect them to rise so a rate of 5% is adopted for this concept note.

On the basis of the above, the NPV of the Water Transfer Project is $51,128,086 million and the Benefit/Cost Ratio is 155,603. The NPV of the pumped storage project is calculated as $54.499 billion and the Benefit / Cost Ratio is 8.00

Financial analysis

A full financial analysis depends on a financing plan, and this is not yet known. However an approximate financial analysis can be determined by eliminating taxes and duties from the cost streams. GST is assumed to be 10% but the tariff regime for imported large M&E equipment is not known at this stage, but for the purposes of the concept paper a further 10% is added. However, a further assumption has to be made with regards to discount rate which is the cost of capital to the developer. A real rate of return, i.e. excluding inflation, is assumed for the purposes of this exercise to be eight percent. On this basis the NPV of the water transfer project is $51.128 million and the Benefit/Cost Ratio is 169.5. The NPV of the pumped storage project is calculated as $35,191,840 billion and the Benefit / Cost Ratio is 130,453

Environmental Impacts

Water Quality: The intermediate catchment drains some of the suburban areas of Sydney, but this is a relatively small part of the intermediate catchment. While the intermediate catchment is inhabited, so is that of Warragamba. Inspection of satellite imagery indicates that, as might be expected, population density in the intermediate catchment is less than that of Warragamba, and there is considerable natural aeration of any effluents via the wild rivers which form most of the tributaries. Fortunately, most of Sydney's suburban effluent drains towards the ocean. Inland treatment works have tertiary treatment with nutrient removal.

The Pumped Storage Project: the "footprint" of the project is relatively small, certainly in proportion to the installed capacity. Most of the work is underground, and the location of the surface reservoir has been chosen such that there appears to be minimal impact. However, it is located within the Popran National Park and the lower intake/outlet works are located in Mooney Moonee Creek which along with the Sydney to Newcastle Expressway is located in the very large Brisbane Water National Park which extends to the coast. It is not unusual for hydropower projects and pumped storage projects to be located in national parks. The factors which make hydropower attractive: steep topography and in the case of hydropower high rainfall, also make the areas unfit for human habitation and therefore they often declared forest areas or national parks. However, as far as is known, there is no ecological “hot spot” in the area and that is important. Detailed environmental studies would obviously be required at a later stage and some trade-offs may be required as is often the case. In Moonee Moonee Creek there are some existing houses even though they are in an area designated as national park, and particular care has been taken in the preliminary design that recreational traffic can pass upstream and downstream of the small control structure. Sydney people pay dearly for waterfronts and love their boats.

From the atmospheric emissions point of view, it could be argued that since coal will be the fuel used in pumping and the overall conversion efficiency will be in the order of 85 percent that the project is actually adding to environmental emissions rather than reducing them. However, an independent study carried out by a U.K. Government Authority on Dinorwic pumped storage project in Wales has shown that, in a similar environment of very low installed capacity of hydropower in the system, Dinorwic is definitely beneficial from the atmospheric emissions viewpoint. While the commercial agreements associated with the Dinorwic project are not available to the general public, it is understood that First Hydro, the owners of Dinorwic, gains one third of its revenue from the generators providing reserve capacity, one third from the grid for ancillary services and one third from bidding into the power market. Similar conclusions have been reached from studies in California and by Electricite de France (EdF) in relation to pumped storage in Iran.

The Water Transfer Scheme: Prima facie the environmental impacts appear to be negligible and limited to construction stage impacts such as construction waste disposal etc.

Conclusions and Recommendations

It is concluded that the project is economically and financially viable. Frankly, the figures are very high and final checks were made on all of the numbers before the Concept Paper is formally submitted to the Productivity Commission. However, there is absolutely no doubt that the economics are robust and the proposed project should proceed to the next stage which is prefeasibility and possibly feasibility, but as early as possible the involvement of Sydney Water is needed. Goran Stojmirovic who is listed as a peer reviewer suggested that when we are ready we should hand over the project to Hydro Tasmania Consultants who now call themselves Entura. I believe we are ready. All of us have worked in development and I believe all of us consider ourselves more missionary than mercenary but we all have financial obligations of one sort or another and so therefore our motives in preparing this submission are not entirely altruistic.

Disclaimer

The authors have received no remuneration for this Concept Paper and make no claim as to the accuracy of the figures derived. Moreover the analysis is preliminary and experience has shown that as the project is developed hidden costs are found. However, it is believed that the concept is good and the Concept Paper is submitted on this basis.

The Authors

Barry Trembath was the originator of the concept. Based in Sydney since July 2005 he has the background. He also wrote the text of this submission with inputs from others as the concept gradually developed. He is also mostly responsibility for the overall planning aspects of the project, the economic and financial analysis, and carried out the rudimentary hydrology necessary to get the project off the ground. He also project managed the preparation of the Concept Note which in another context he has said this is akin to “herding cats”

Peter Ko lives in Montreal but is rarely there. Barry and Peter have known each other at least as far back as 1986 in Malaysia but it could be longer. Barry is technologically challenged. Peter, besides being an expert hydrologist, hydraulic specialist and a pretty good meteorologist, is technologically unchallenged. Peter is responsible for all of the figures and drawings in the report and as the concept gradually developed worked closely with Barry on the planning aspects. Fortunately, World Bank work tentatively scheduled for early to February 2011 and after Chinese New Year did not eventuate and Peter was able to concentrate on the development of the Concept Note. During that time considerable development has taken place. Peter also worked with Barry on a similar Concept Note for the development of the Ngalimbu River which is on the island of Guadalcanal close to Honiara in the Solomon Islands. At that time they were both under contract to the World Bank. This proceeded to a prefeasibility study contracted to HTC (now Entura) in which Goran was the prime mover. Phase 1 of the feasibility study is now complete and Phase 2 has been launched. The schedule for completion is still under discussion.

Harald Wagner lives in Austria near Linz and/or Bangkok. He and Barry first met in relation to the Wanzhajai water transfer scheme in China and that goes way back. They subsequently worked together on Tongbai Pumped Storage Project while Barry was still with the World Bank and Harald was on the Project Review Panel. More recently they worked closely together on the Vishnugad Pipalkotti Hydropower Project in Uttarakhand, India. Harald was on the PRP for the Project and Barry, although retired from the Bank, was an observer for the World Bank. In both cases the Client was THDC and the person responsible for design and technical specifications for the entire civil works was Rajeev Vishnoi. For the current concept paper Harald is responsible for all tunneling aspects including cost estimates.

Rajeev Vishnoi is a late addition to the team. Barry’s association with Rajeev and his team goes back to 2006 where they set about bridging the gap between the turnkey (fixed price date certain) advocates and the advocates for the traditional approach. This effort culminated in a meeting on the weekend in a small conference room in a World Bank office in New Delhi where Barry, Harald, Rajeev and his team collaborated to come up with a stand alone risk management package for construction of a mandatory 12.0 km of tunnel by TBM. Paradoxically for the current concept paper Rajeev is responsible for the Mechanical and Electrical costs associated with the variable speed reversible units for the pumped storage project. He has also checked the civil costs of the pumped storage works and found them to be conservative and suggested the addition of an item for Regulatory works for the Water Transfer Project.

Goran Stojmirovic met with Barry in the office of Nigel Hall of the European Investment Bank in Sydney some time in the third or fourth quarter of 2010 and during a break reviewed the additional material (at that time he had only received the text when Barry asked for a reality check). After seeing the additional material, he made some helpful suggestions and suggested that when we were ready we should hand it over to HTC as mentioned above. Goran and Barry first met in relation to Fiji Hydro probably in 2005 or 2006. At the time of the Sydney meeting he had already moved to India and now spends as much time on aircraft of various sizes as he does on the ground.