# REPORT OF THE KIMBERLEY PIPELINE ENVIRONMENTAL ADVISORY COMMITTEE

TO THE

Hon Ernie Bridge, JP, MLA
Minister for Agriculture, Water Resources
and the North West

Hon Ernie Bridge, MLA
Minister for Water Resources
3rd Floor, Capita Centre
197 St George's Terrace
PERTH WA 6000

Dear Mr Bridge

**KIMBERLEY PIPELINE ENVIRONMENTAL ADVISORY COMMITTEE REPORT**

On behalf of the Committee I have pleasure in submitting to you the report of the Kimberley Pipeline Environmental Advisory Committee.

Yours sincerely

P. Jennings

Philip Jennings
Convenor

June 1990

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# PREFACE

The future water supply options for the Perth Metropolitan Region have been the subject of several recent studies. It appears on current forecasts that sufficient water is available to meet Perth's needs for the next fifty years. However future sources of supply will be more expensive to develop and they are likely to have a greater environmental impact than present sources. At some stage society may wish to consider other alternatives such as the delivery of water from the Kimberley Region.

The Kimberley region contains some 75% of Western Australia's total fresh water resources, and very little of this water is used at present. Lake Argyle could supply the additional projected requirements of Perth and Adelaide for the next century. The use of these Kimberley resources would have many beneficial effects such as the protection of local ground and surface water resources in the Perth and Adelaide regions.

The Kimberley Pipeline concept has received some preliminary evaluation and further engineering studies are in progress. Little attention has been given previously to the environmental and social costs and benefits of the proposal. For this reason the Minister for Water Resources, Hon Ernie Bridge, MLA, established a Kimberley Pipeline Environmental Advisory Committee in July 1989. The main purpose of this Committee was to investigate and report to the Minister on the environmental and social aspects of the proposal.

This Report contains the results of the Committee's discussions and investigations. The Committee met on eight occasions and received reports and submissions from various Government authorities. We would particularly like to thank the Water Authority of Western Australia, Water Resources Council, Departments of Agriculture and Mines for their assistance. Chapter 3 of this report is based largely on information provided to the Committee by the Department of Mines, whilst Chapter 4 is based on that provided by the Department of Agriculture.

The Committee's views are set out in the conclusions and recommendations. We hope that the Report will be of value for future planning of water resource options for Western Australia which should take into account the wider environmental and social implications in addition to the engineering, design and economic factors.

A considerable amount of work is still required to evaluate various pipeline options and this report will provide some guidance about environmental and social factors which should be considered in those studies.

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# CHAPTER 1 : SUMMARY

The Committee was established by the Minister for Water Resources, Hon Ernie Bridge, MLA, to advise him on the potential environmental and social impacts of the proposed Kimberley National Water Supply Scheme.

## 1. Terms of Reference

The Minister set the following terms of reference:

(1) To examine and assess previous studies on potential uses of Kimberley water within Western Australia and in other parts of Australia.

(2) To formulate additional options and to recommend new studies if appropriate.

(3) To advise the Minister on long term planning for the uses of Kimberley water.

(4) To advise the Minister on the social and environmental impacts of exporting water from the Kimberley within Western Australia and to other parts of Australia.

## 2. Membership

The Minister appointed the following persons to the Kimberley Pipeline Environmental Advisory Committee:

| | |
|---|---|
| Philip Jennings, | Murdoch University (Convenor) |
| Tom Crawford, | Energy Consultant |
| David Dale, | Environmental Consultant |
| Roni Oma, | Department of Agriculture |
| Patricia Pollard, | Minister's Office (Secretary) |
| Peter Ravine, | Engineering Consultant. |

## 3. Meetings

The Committee held its first meeting on 2nd August, 1989 and then met on seven subsequent occasions.

At the fourth meeting discussions were held with senior officers of the Water Authority of Western Australia and the Water Resources Council about the Committee's investigations and the results of previous studies.

4. **Work of the Committee**

(a) **Previous Studies**

The Committee examined several previous studies of the Kimberley Pipeline Project including

"Water for the 21st Century", Western Australian Water Resources Council, 1989.

"Water for the South West in the 21st Century : Water from the Kimberleys". ("The Binnie Report") 1988.

The Committee examined the previous engineering studies of the pipeline project and cost estimates presented in the above documents.

(b) **Alternative Design Options**

The Committee observed that considerable cost reductions might be made by using an aqueduct system, combined with optimal use of the topography. In view of the looming problem of global warming the Committee considered that if the pipeline was to be constructed it should predominantly use renewable sources of energy for pumping. A concept plan was developed for an aqueduct system using renewable energy pumping systems. This is presented in detail in Appendix A.

The Committee concluded that the concept appears to be workable from an engineering viewpoint but that it would need to be fully costed to determine whether it was economically attractive. The Committee concluded that this approach could considerably reduce the cost of transporting Kimberley water to the South and South West of Australia. Other advantages could include industrial development involving the renewable energy industry and assistance for settlements, tourism, mining and agriculture in inland areas of Australia. Some potential problems perceived were the growth of organisms in the aqueduct and the possible barrier presented to fauna and wildlife movement by an aqueduct.

(c) **Other Uses of Kimberley Water**

The Committee also considered other options for the use of Kimberley water and concluded that there were substantial attractions in the use of the coastal route from the North West if the pipeline was to supply only Western Australia. Such a route would provide abundant water to existing settlements in the Kimberley, Pilbara and Gascoyne Regions and this could be the basis for substantial decentralisation programmes. The social and political advantages of such a route could well justify it from the perspective of the need for northern development and decentralisation. The coastal route could also take advantage of abundant wind power, in addition to solar power, along the north western and western coastlines.

The Committee considers that further studies should be carried out on the three coastal and inland routes proposed in the Binnie Report and on the inland gravity feed route which this Committee has proposed. The feasibility of using an aqueduct and taking advantage of favourable topography should be included in the study. Renewable energy resources should provide the main power for pumping the water.

The Committee also examined the possible use of Kimberley water for settlements, mining and agriculture along its proposed route. A summary of Committee findings is presented in Chapters 3 and 4. The general conclusion is that opportunities do exist to use the water along the route. However these are not substantial advantages of the proposal because of the remoteness of many of the locations from the markets. Nevertheless it was recognised that several isolated inland communities could benefit substantially from the project.

(d) **Social and Environmental Issues**

A major part of the Committee's work was to identify factors relevant to the environmental and social costs and benefits of the proposed pipeline. A detailed summary of the Committee's findings is presented in Chapter 5. These factors are summarised and it is apparent that there are some substantial issues to be addressed. In particular the benefits to local communities, to national security, to decentralisation and to employment creation are likely to be substantial. Amongst the matters that require further attention are the potential impacts on conservation areas, Aboriginal sites and wildlife migration.

None of these factors was judged to be sufficient to cause the project to be abandoned. In fact the Committee concluded that the project provided significant potential benefits, and that with careful design and full environmental review, the impacts could probably be regarded as acceptable to most of the community. More detailed work is required to quantify costs and benefits, however this should be deferred until a decision is made on the concept plan and possible routes for the pipeline.

## 5. Conclusions

The Committee concludes that:

(1) Any adverse environmental impacts of the proposed pipeline can probably be reduced to an acceptable level.

(2) Detailed studies should be carried out on alternative routes and designs for the pipeline including a secondary route to the Pilbara Region.

(3) It is essential to make maximum use of renewable energy sources so that the pipeline scheme does not become a significant user of fossil fuels and contributor to Greenhouse gas emissions. In this context solar ponds have significant advantages as energy storage systems in remote inland areas. Consideration should also be given to production and piping of hydrogen as an energy source for the pipeline and potential consumers.

(4) Further research is required into appropriate pipe design for use in the project.

(5) The cost of supplying water to Perth and Adelaide can be considerably reduced by using a gravity feed aqueduct system rather than a pipeline as originally proposed.

(6) It is desirable that South Australia and the Northern Territory participate in the scheme in order to achieve significant economies of scale and to optimise the planning, route selection and engineering processes.

(7) There are significant advantages for agriculture, tourism, mining and industrial development in inland Australia which would derive from the construction of the pipeline.

## 6. Recommendations

(1) Environmental economics should be applied to the evaluation of various water supply alternatives for Western Australia, including groundwater, tankering and desalination schemes.

(2) The appropriate route and design for the Kimberley Pipeline should be selected using environmental economics, including direct and external costs.

(3) Detailed studies should be carried out on alternative routes and designs for the pipeline. In particular:

- mapping of the Adelaide and Alice Springs branches and a connection from the Fitzroy River;
- investigation of the availability of renewable energy resources in the Kimberley and along the pipeline route. These should include wind, solar and tidal resources. The use of hydrogen produced from tidal power should also be investigated as an energy carrier and source of fuel for Perth;
- small scale experimental work on aqueduct and pipe design.

(4) Water supply options involving the Fitzroy River and other Kimberley Region sources should be considered as part of the scheme.

(5) Hydro-electric power from Lake Argyle would be the most economic source to operate the first 3 pumping stations of the proposed Kimberley pipeline. This should be borne in mind by Government authorities, particularly SECWA, when considering other alternative uses for this power.

(6) If the tankering option is studied in depth, prospective port sites in the Kimberley Region should be investigated.

(7) Early contact should be established with the local government authorities likely to be affected by the various routes.

(8) Support for the concept and ideas should be sought from relevant regional development organisations and Chambers of Commerce.

(9) In future regional studies for the North West of the State the possibility of using Kimberley water for decentralisation and development should be specifically addressed.

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# CHAPTER 2 : THE KIMBERLEY PIPELINE CONCEPT

## FUTURE WATER SUPPLY OPTIONS FOR PERTH

The Kimberley Region of Western Australia contains vast resources of fresh water of which only a very small proportion is used at present. In contrast the Perth Region, where three quarters of the State's population lives, has much more limited water resources. It has been predicted by the Western Australian Water Resources Council that additional supplies of fresh water will need to be brought into the Perth Region by early in the 21st Century. The main options for these alternative supplies have been identified as:

- water from the South West
- the desalination of sea water
- water from the Kimberley Region (Lake Argyle, the Fitzroy River etc.)

The Water Resources Council has completed a preliminary evaluation of these and other alternatives and they are ranked in order of the cost of water in Table 1 ("Water for 21st Century" 1989, Table 2).

**TABLE 1 : RANKED MAJOR WATER SUPPLY OPTIONS FOR PERTH**

| **Source** | **Yield (million $m^3$/yr)** | **Cost**[2] **($/$m^3$)** |
|---|---|---|
| Forest thinning | 29 | 0.05 |
| Excess drainage | 40 | 0.30-0.55 |
| South West sources | 810 | 0.53 |
| Moore sub-region groundwater | 110 | 0.54 |
| Brackish water | 37 | 1.00 |
| Re-use of wastewater[1] | 43 | 0.70-1.70 |
| Sea-water desalination | >500 | 1.80 |
| Tankering (from the Kimberley) | >300 | 3.30 |
| Pilbara pipeline | 210 | 4.90-5.10 |
| Kimberley pipeline | 870 | 5.35 |

(1) not for domestic use
(2) cost in January 1988 dollars, at 6% discount rate

It is clear that several of these options may have undesirable environmental impacts and that these have not been included in the cost estimates. For example, there is likely to be strong public opposition to a major program of forest thinning or to further damming of South West rivers. The current sustainable use of shallow groundwater in Perth has an impact on wetlands and the banksia woodlands. There have recently been proposals put to the Water Resources Council by the Hollick Committee to consider drawing down the water table over the Gnangara and Jandakot groundwater mounds in preference to damming South West rivers (Hollick Report, 1989, Recommendation 1). While such an approach may protect the South West Region from undesirable environmental impacts in the short term it would do so at great cost to the environment of the northern Swan Coastal Plain.

Desalination is another option but it is a heavy consumer of energy. With rising concern about the effects of carbon dioxide emissions on the Earth's climate there could be considerable opposition to this approach if the source of energy is fossil fuels. Other options which the Water Resources Council has considered include better use of drainage water, the recycling of waste water and water harvesting on bitumenised areas. However these could only make a small contribution to Perth's water supply.

There is probably considerable scope for a substantial reduction in water consumption through a vigorous program of water conservation and pricing controls and this should be given a high priority.

Another issue which was not considered by the Water Resources Council is the optimal size of Perth's population. It could be argued that we are reaching the limits of the population that can be sustained with a high standard of living on the northern Swan Coastal Plain and that we should now be planning seriously for decentralisation. By concentrating population growth in areas such as the Kimberley Region, where ample water resources are available, we could overcome the problem of approaching water shortages on the Swan Coastal Plain. Such issues should be seriously and urgently addressed as long term planning will be required to implement solutions. However, even with such planning it is still likely that there will be substantial water shortages in Perth by 2050 unless large alternative sources of supply are found. The situation in Adelaide, which relies to a great extent on water supplies from the Murray River, is at least as serious.

**The Pipeline Options**

Despite its unfavorable costs the Kimberley water supply offers many advantages for avoiding the undesirable environmental impacts of the other water supply options listed in Table 1. The Water Resources Council estimates that more than 7000 million cubic metres of fresh water is available for use in the Kimberley Region. Perth currently uses 400 million cubic metres of fresh water per annum and it is expected that this will more than double by mid 21st Century. ("Water for the 21st Century" page 4 figure 1).

Lake Argyle alone has an estimated yield of 1900 million cubic metres per year. A vast amount of high quality fresh water is already available in Lake Argyle which could be used to supply the Pilbara, Goldfields and Perth Metropolitan Area if an economical method of transporting it could be devised.

With these considerations in mind the Kimberley Regional Development Advisory Committee commissioned Binnie and Partners, Consulting Engineers, to investigate the possibility of supplying Kimberley water to other parts of Western Australia (Binnie Report 1988). Three pipeline options were considered:-

(1) Inland Route : via the Great Sandy Desert and the Eastern Goldfields to Perth.

(2) Pilbara Route : through the east Pilbara via Newman and Meekatharra to Perth.

(3) Coastal Route : via Broome, Port Hedland, Carnarvon and Geraldton to Perth.

These alternative pipeline routes are shown in Figure 1.

In addition the authors of the Binnie Report considered the possibility of transporting water to Perth from the Kimberley using large tanker ships. This approach was found to be cost effective for relatively small volumes of water and it may be an attractive and flexible method of supplying water to coastal communities in the north of Western Australia and possibly overseas in future years. However tankering is also a heavy consumer of fossil fuels and it is not as attractive if large continuous volumes of water are required. However it could be attractive as a stopgap solution if serious water shortages develop elsewhere in the State. The Committee recommends that the tankering option should be fully investigated and costed with this possibility in mind.

The Binnie Report presents the estimated costs for supplying water to Perth via a pipeline and by tankering. Both high and low volume schemes were costed and the results are shown in Table 2. In their calculations they assumed that the water would be pumped to Perth in a steel pipe using electrical energy supplied by a transmission line running parallel to the water pipeline.

**TABLE 2: UNIT COST OF WATER DELIVERED TO PERTH**

| Option | Length (km) | Normal Demand ($/m$^3$) | High Demand ($/m$^3$) |
|---|---|---|---|
| 1. Pipeline Route 1 | 1,960 | 5.77 | 4.92 |
| 2. Pipeline Route 2 | 1,840 | 5.35 | 4.53 |
| 3. Pipeline Route 3 | 2,100 | 6.02 | 5.12 |
| 4. Tankering | 2,500 | 3.33 | - |

**(Binney Report, 1988, Table 2)**

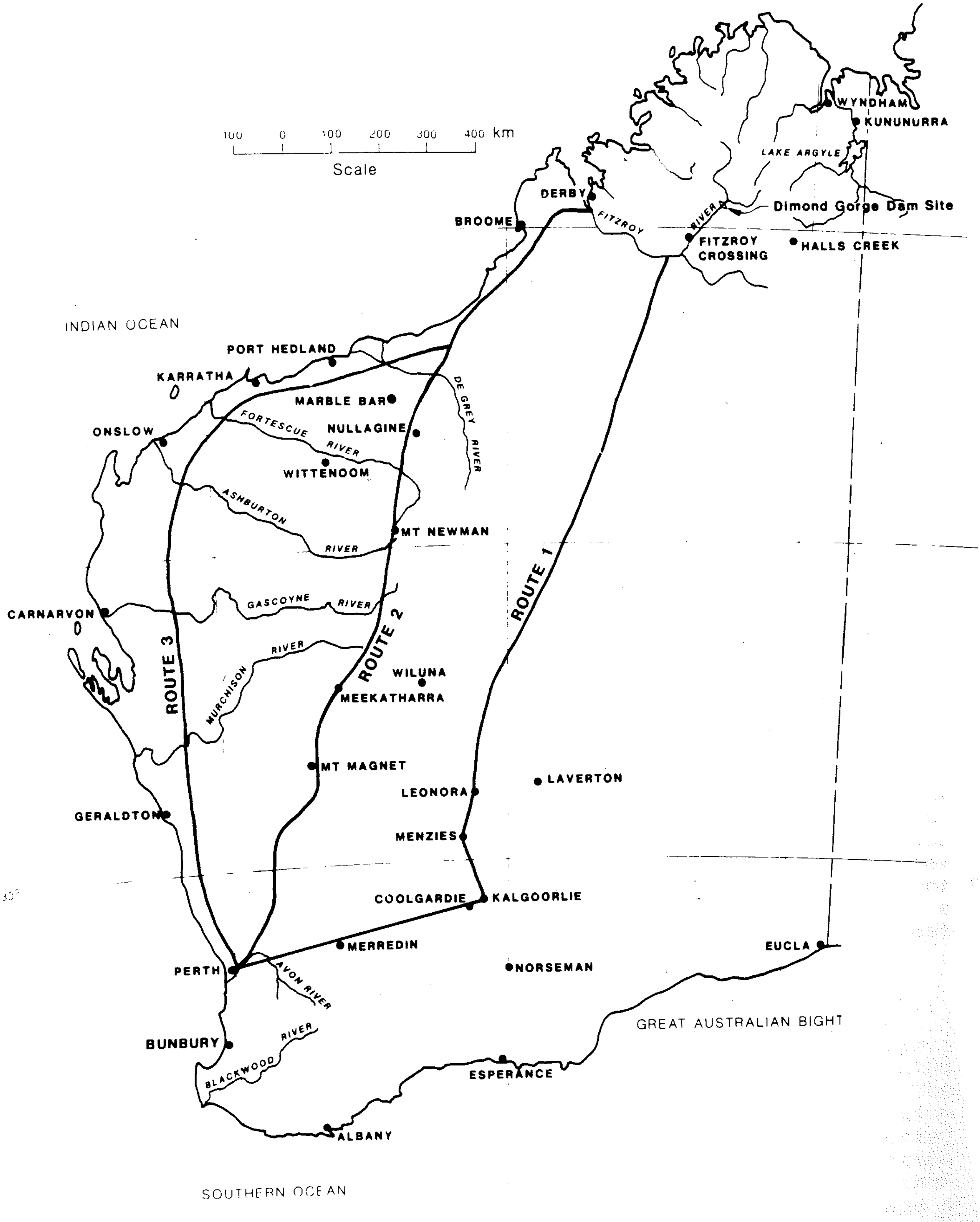


**Figure1: Alternative Kimberley-Perth pipeline routes**

(Map courtesy of the W.A. Water Resources Council)

Recently these costs have been re-evaluated by the Infrastructure Development Corporation, Sydney, which has concluded that the costs for pipeline route 1 could be reduced to $3.45 per cubic metre of water delivered to Perth. This report was not considered in detail by the Committee.

Brief consideration was given in the Binnie Report to a scheme to supply water to both Adelaide and Perth but, based on the assumptions made in the Report, the cost of the water delivered was higher.

On the basis of this information the Water Resources Council concluded (Water for the 21st Century, Conclusion 13) that the Kimberley pipeline option was not a realistic means of supplying fresh water to the Perth Metropolitan Region because it appeared to be more expensive than desalinating sea water. The Council did conclude however that Kimberley water had the potential to be economically competitive for the supply of water to the Pilbara Region and for large-scale irrigation projects in the Kimberley Region (Water for the 21st Century, Conclusions 11 and 12).

It is apparent that if a more cost effective method of delivering Kimberley water to Perth could be developed then it could be competitive with the cost of desalination. It is therefore possible that a careful re-evaluation of the Binnie costings could help to justify a scheme that may be cost effective in the first half of the 21st Century. If the environmental and social benefits of that scheme can be optimised then the use of Kimberley water in southern Australia could become attractive even sooner.

In this study we have identified factors for external costs and benefits of the Kimberley pipeline proposal. These were not considered in any detail in the Binnie Report. It is important that such costs and benefits should be considered before any final decisions are made about future water supply options for Perth. The industrial, social and environmental benefits of the Kimberley pipeline could greatly offset its relatively high capital costs and thus justify serious consideration of this project in the long term.

We have also considered an alternative pipeline design which was proposed by a member of the Committee. This gravity aqueduct concept is described briefly below and further details are provided in Appendix A. The Committee believes that this option also deserves serious consideration as a means of producing an environmentally acceptable design with competitive costs for water delivered to Perth and Adelaide.

**The Gravity Aqueduct Concept**

A substantial environmental objection to several of the possible future water supply options is the considerable amount of fossil fuel and raw materials which they would consume. For example the

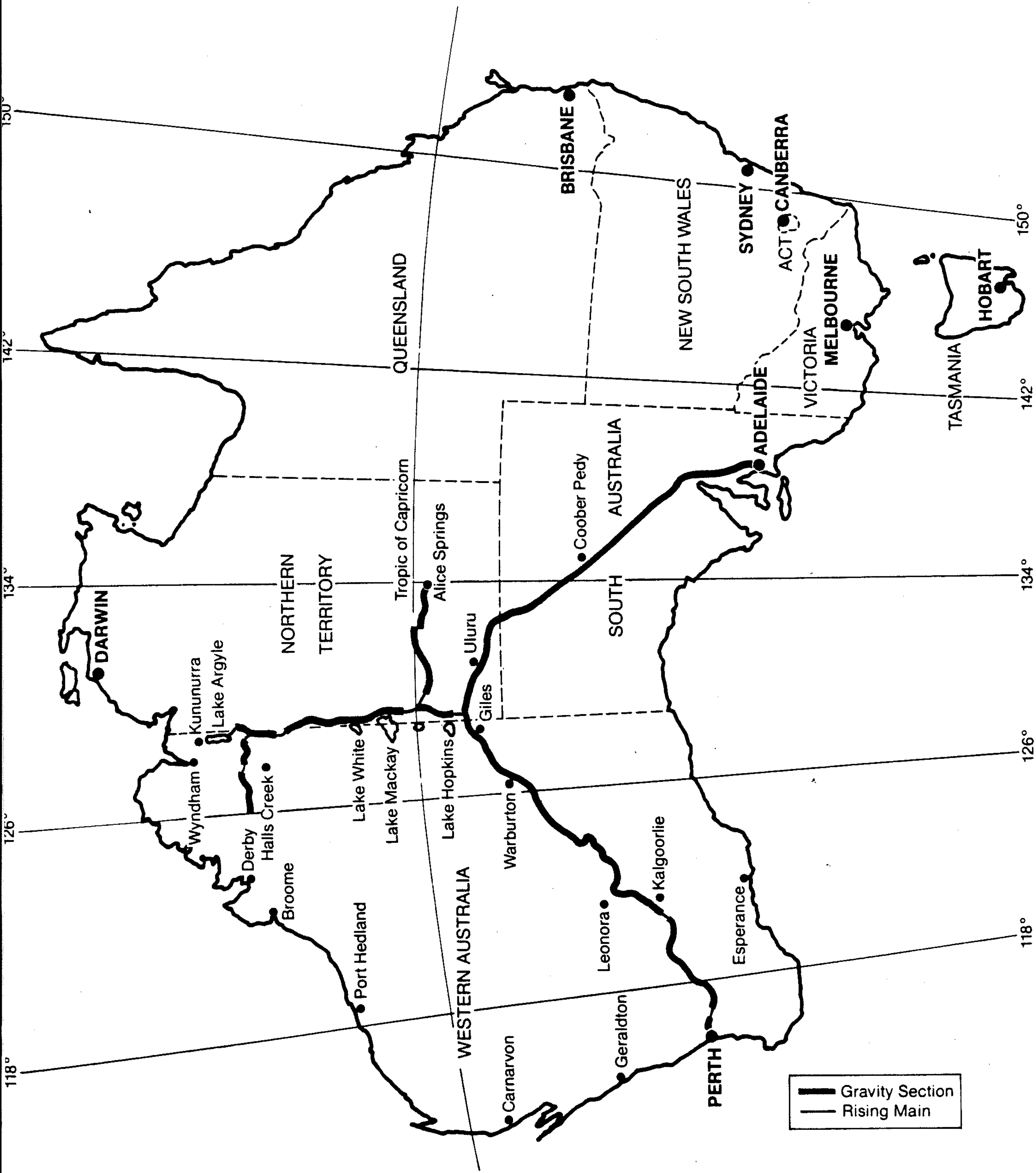


**FIGURE 2:**
**PROPOSED NATIONAL KIMBERLEY WATER SUPPLY SCHEME**
**June 1990**

Binnie concept for the Kimberley pipeline would require huge quantities of steel and the pumping would be carried out by electrical energy generated by gas or coal-fired power stations. Desalination would also require large amounts of power.

An alternative approach is to consider how the use of fossil fuels and raw materials might be minimised. This design takes advantage of the substantial renewable resources of solar and wind energy in central Australia and tidal and hydro-electric energy in the Kimberley Region. To reduce pumping costs the water would flow wherever possible under gravity in a covered aqueduct. Some sections of closed siphon would be required. Where feasible, pumping would be carried out using energy generated from solar ponds or wind generators and hydro or tidal power (for the initial stages). Some diesel backup would also be required.

Another energy option would be to generate sufficient hydrogen to supply all pumping energy using the abundant tidal resources of the Kimberley region. A small hydrogen pipeline would need to be constructed alongside the water pipeline/aqueduct. Large pumping stations would use gas turbine driven water pumps and the smaller stations, would use gas engine driven pumps. This option has not been costed, but the concept of generating hydrogen from Kimberley tidal power is being studied by the Western Australian Parliamentary Select Committee on Energy and processing of resources in the North West.

The proposed route to Perth is the border route shown in Figure 2. It makes maximum use of the topography to minimise pumping costs. Possible branch routes to Alice Springs and Adelaide are also indicated.

The detailed costing of this concept is presented in Appendix A. This indicates that such a scheme is comparable in cost with the low end of the Binnie estimates (ie roughly $2 per cubic metre). In addition this alternative concept has many specific advantages including:

- minimal carbon dioxide emissions
- ready availability of water to users along the route
- reduced consumption of raw materials
- industrial development opportunities arising from increased use of new energy technologies.

These and other issues associated with the alternative concept are discussed in further detail in Chapter 5 and in Appendix A. Conclusions and recommendations for further studies are presented in the Summary section at the beginning of this Report.

# CHAPTER 3: BENEFITS TO MINING

(This chapter is based on information provided by the Western Australian Department of Mines)

**WESTERN AUSTRALIAN SECTION**

1. **Kununurra - Billiluna Section**

The principal current mining operations within 50km of the pipeline route proposed in the Binnie report are:

Argyle Diamond Mine
Bow River Diamond Mine

The Argyle Diamond Mine obtains most of its water from Lake Argyle, with a small portion from local groundwater supplies.

Significant mineral prospects close to the pipeline route:

Brockman Rare Earth Deposit
Sally Malay Nickel Deposit
Panton Sill Platinum Prospect
Koongie Park Lead-Zinc Deposit
Speewah Fluorite Deposit
Mt Bradley - Dry Creek Gold Deposits.

There are no known large groundwater resources in the vicinity of these prospects. Potential water requirements are unknown at this stage.

In addition there are numerous small gold mining operations and prospects in the vicinity of Halls Creek. Halls Creek is an area where groundwater supplies are limited, and difficulty has been experienced in locating such supplies.

2. **Billiluna - Warburton Section**

There are no current mining operations in this area, and no prospects likely to be developed in the near future. The mineral potential of the area is still poorly understood due to limited exploration related to access problems. About 100km east of the pipeline route there are gold mining operations in the Tanami area of the Northern Territory. Close to Warburton there are small deposits of copper, lead, zinc and fluorite, but no significant mining operations are planned.

The groundwater potential of this section has not been assessed, but many of the small supplies currently obtained from bedrock sources are brackish.

The Canning Basin area south of Billiluna has some potential for petroleum and several test holes have been completed. No significant finds have been reported to date, but the area requires further exploration to adequately establish any future potential as a source of oil and gas.

There are large resources of groundwater in aquifers overlying potential oil and gas reservoirs in the Canning Basin.

3. **Warburton - Laverton Section**

This section of the pipeline route crosses the Officer Basin, which only has low potential for oil and gas. The area is under-explored, however, and future developments are still possible. Near Yamarna, about 150km east of Laverton the pipeline route enters the Yilgarn Craton, a highly prospective geological unit which extends from this area to Perth's eastern suburbs. Between Yamarna and Laverton there are areas of gold mineralisation near Cosmo Newbery and Thatcher Soak, and the Mt Barnicoat gold project 10km east of Laverton will commence production in 1990. North of Mt Barnicoat the Admiral Hill prospect could be developed in the short to medium term. Small to medium-sized uranium and base-metal deposits occur in the Cosmo Newbery - Yamarna area but no developments are currently planned.

There are large resources of fresh to brackish groundwater in aquifers in the Officer Basin. Between Yamarna and Laverton saline process water is likely to be available in palaeochannels.

4. **Laverton - Leonora Section**

This area is a highly mineralised part of the State with many significant gold, nickel and copper-zinc deposits. Current important gold mining operations are as follows:

Lancefield
Sons of Gwalia
Mt Morgans
Harbour Lights
Mertondale
King of the Hills (Arboyne NL)
King of the Hills West (Mt Edon Gold Mines)
Lancefield (Golconda)
Cork Tree Well - King of Creation/ Craigiemore (Hillmin)
Murrin Murrin
Yundamindera
Beasley Creek
Tower Hill - Mt Redcliffe

Mines shortly to commence production are Granny Smith and Mount Marven.

The only other significant mine is the Windarra Nickel Mine, but a major rare earth deposit is under feasibility study at Mt Weld. The Laverton - Leonora area is still subject to intensive mineral exploration, and additional mining developments are certain.

Requirements for process water are currently met by saline groundwater in bedrock and in palaeochannel aquifers.

5. **Leonora - Kalgoorlie - Coolgardie Section**

The section of the proposed pipeline's route between Leonora and Coolgardie is the State's most productive region for gold and nickel, and contains many mines and mining projects in advanced stages of development. Important current gold mines/plants are:

Fimiston
Mt Charlotte
North Kalgurli
Paringa
Kambalda Group
Paddington
Mt Corlac/Rona Lucil
New Celebration
Lady Bountiful
Mt Pleasant
Gimlet South
Mt Percy
Jubilee
Hannans South Plant (fed by a number of small mines in the region)
Bardoc
Goongarrie Plant - Sand King mines
Mt Martin
Dark Horse
Bent Tree
Gibraltar
Catherwood - Premier
Trafalgar (tailings)
Central Kalgoorlie (tailings) - Mt Ferrum Plant
Greenfields Plant
Bayleys (King Solomon, Kings Cross, Consols)
Prince of Wales (temporarily closed)
Coolgardie (tailings) - Burmill
Victory
White Flag
Riverina

Gold mines which commenced production in 1989 or which will start up in 1990 include:

Station Creek
Mulwarrie
Burbanks
Kanowna Deep Leads
Kaltails (tailings)
Lady Bountiful Extended
Great Lady
Panglo
Patricia Jeans
Three Mile Hill and Tindalls redevelopment
New Fimiston Plant (NKM)
Racetrack - Royal Standard

Most of the gold mines have installed their own borefields to provide saline process water from palaeochannel aquifers. The Study on Eastern Goldfields Water Demand and Availability for Mining and Processing commissioned by the Western Australian Department of Resources Development concludes that groundwater would be available to meet current and forecast needs.

Most of the State's nickel is mined at Kambalda, about 50km south of Kalgoorlie, and reserves are sufficient to sustain mining for many years. The Blair nickel mine is located nearer to Kalgoorlie.

Nickel ore processing currently relies on the Goldfields and Agricultural Water Supply Scheme, but the Eastern Goldfields Study concluded that future expansion would need to use local groundwater supplies.

6. **Coolgardie - Perth Section**

This area includes gold mines immediately west of Coolgardie and a large number of gold mines in the Southern Cross area. Current important gold mines/plants are:

Bulla Bulling
Glendower - Evelyn Molly
Marvel Loch New Plant (Mawson Pacific)
Copperhead - Three Boys
Estonia
Marvel Loch Super Pit ) Processed at Marvel Loch
Edwards Find ) New Plant
Marvel Loch Underground )
Transvaal
Hopes Hill - Coriunthia
Nevoria
Great Victoria
Frasers

This area was also investigated by the Eastern Goldfields Water Demand and Availability Study, which showed that requirements of gold mines were being met by local supplies of saline groundwater.

Gypsum deposits are mined at Lake Brown (Nungarin), Yelbini (Trayning), Hines Hill (Nungarin), Hines Hill (Kellerberrin) and Wyalkatchem. The Koolyanobbing area has potential for future gypsum and iron ore production.

7. **Fitzroy Crossing - Billiluna Connection**

The only significant current mining operation is the Cadjebut Lead-Zinc mine. However, future mining operations could be located at Blendevale and similar deposits close to Cadjebut, including Prices Creek. The area has considerable mineral potential for lead, zinc, copper, gold and rare earth elements.

The Cadjebut mine has a problem of excess water, with large inflows into the workings. Other similar deposits, if developed, would be in the same situation. There are also large supplies of groundwater available from aquifers in the Canning Basin.

**COMMENTS**

**WESTERN AUSTRALIA SECTION**

The proposed pipeline would cross an area containing many mining operations (principally gold mining). It is estimated that current process water consumption associated with all the gold mining operations totals approximately 25 million cubic metres per annum. Although this demand is being largely met from local groundwater sources, it should be noted that use of saline to brackish water does have certain deleterious effects in plants (eg salt affects chemical reactions, and over time builds up in circuits and causes metal corrosion). Availability of fresh water might also assist some future mining developments by dispensing with the need for individual mines to explore for local water resources. It would also, of course, be beneficial to mining communities in terms of providing water of a standard acceptable for domestic purposes.

**NORTHERN TERRITORY SECTION**

The proposed water supply pipeline from the Kimberley Region to Adelaide and Perth would traverse the south western corner of the Northern Territory for a distance of about 400km near the boundary between the Musgrave Block and the Amadeus Basin. Two producing hydrocarbon fields (Mereenie and Palm Galley) and five uneconomic occurrences of gypsum are located within 100km of the pipeline. Groundwater supply for this region is from a shallow superficial aquifer to the south and from various sandstone beds to the north.

Most of the area is Aboriginal land on which no active mineral exploration is taking place. The geological maps are old and outdated. The Northern Territory Geological Survey is presently conducting detailed geological and geophysical mapping in the Musgrave Block which may enhance and encourage mineral exploration. There are over 20 exploration licence applications pending approval from the Aboriginal traditional owners.

Perhaps the more prospective area from the mineral exploration and exploitation point of view is The Granites - Tanami Block which holds good potential for gold deposits. This area is over 200km to the east of the pipeline route proposed in the Binnie Report but lies along the route outlined in the alternative concept advanced by the Committee.

In summary, the mineral potential of the area in the south western corner of the Northern Territory through which the pipeline is proposed to pass is inadequately tested, but is probably low, and no major water usage can be foreseen at this stage.

**SOUTH AUSTRALIAN SECTION**

Existing mining developments and their water sources within the corridor are:

- Mintabie — Opal mining - population approximately 500 - local groundwater supply.
- Coober Pedy — Opal mining and tourism - population approximately 2500 - local water supply is from the Great Artesian Basin, with a recently installed desalination plant.
- Andamooka — Opal mining and tourism - population approximately 350 - local dam with carting of water from Roxby Downs during droughts.
- Tarcoola — Gold exploration and small scale mining - population approximately 100 - local groundwater.
- Roxby Downs — Copper - Gold - Uranium mining - population approximately 2500 - current water usage of 9ML/day from Great Artesian Basin wellfield and desalination plant.

Overall these current mineral developments located within 100km of the proposed pipeline have relatively small water requirements with the exception of Roxby Downs which may ultimately use 33ML/day from the Great Artesian Basin. A source of extremely cheap, good quality water would have to be made available to change that source of Roxby Downs water, which is assured in terms of an Indenture. However there is concern about drawdown of the water table and the long term ecological impacts.

Further south on the pipeline route are the coastal towns of the "iron triangle" with a total population of approximately 55,000. There is active iron-ore processing at Whyalla, lead-zinc smelting at Port Pirie and electricity generation facilities at Port Augusta. Currently water is supplied to these centres from the Murray River via pipeline.

Apart from the obvious benefits of the pipeline to the coastal towns and inland Aboriginal communities, the northwest part of the State has significant potential for the discovery and development of mineral, petroleum and coal resources within 100km of the proposed pipeline. There are no likely developments in the short term. However, three coal deposits, all designated for power generation, are regularly reviewed as potential future energy sources. The three deposits are:

**Arckaringa Basin Coal** near Wintinna, which will require extensive dewatering of either an opencut or underground mine. There is abundant groundwater which would need to be desalinated.

**Lake Phillipson Lignite** which has a very high chloride content may benefit from washing in fresh water.

**Lochiel Lignite** which is located in an area already supplied by scheme water. Local groundwater is also available for power station use.

Water requirements for coal development would be small, eg to supply a population of the order of 1,000, unless the decision was made to build a power station at a mine site, in which case large amounts of cooling water would be needed. Water for power station cooling must be extremely cheap otherwise the fuel is transported to a coastal site and seawater used for cooling.

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# CHAPTER 4 : BENEFITS TO AGRICULTURE

(This chapter is based on information provided by the Western Australian Department of Agriculture)

The Western Australian Department of Agriculture (WADA) has undertaken a preliminary desk top study of the potential to develop new horticultural enterprises along the national pipeline route. The study included an assessment of areas of suitable soils and crops.

The soil types were determined from the Atlas of Australian Soils (scale 1:2.5 million). The assessment indicates that there are large areas which are potentially suitable for a range of horticultural crops, and that soils are not a limiting factor for the development of horticulture.

A wide range of horticultural crops could be grown along the pipeline route, the major limiting factor being climatic requirements of various crop types.

In the southern area around Kalgoorlie, a wide range of vegetables but a very limited range of fruit can be grown. The susceptibility of frosts in this area limits the range of fruit which can be grown.

In the central section (Leonora, Wiluna and northwards) the low annual rainfall is uniformly distributed during the year. This does not affect the range of vegetables, but the susceptibility of this area to heavy falls during the cyclone season limits the range of suitable fruit crops.

The study included an assessment of the total area which could be irrigated for horticulture, assuming that a dam with a capacity of 1,000 Million $m^3$ is constructed on the Fitzroy. Assuming that 400 Million $m^3$ could be allocated to the development of the Camballin area, and 300 Million $m^3$ would be available for development of horticulture along the pipeline route, WADA estimates that three nodal developments each of 5,000 hectares could be developed based on an annual requirement (for vegetables and fruit) of $60km^3$/ha.

**REMARKS**

WADA indicated that horticultural developments outside of existing areas (ie Kununurra, Wiluna) could only be attractive if the water was provided at low cost (eg current 44c/$m^3$ for Perth).

Looking at horticulture to offset some of the high costs of bringing water to Perth is unrealistic. Horticulture is therefore more likely to expand at existing centres - Kununurra, Wiluna, Perth. However, if cheap water was provided 'on tap', there is significant potential to expand existing centres, thereby maximising use of established infrastructure and benefiting local economies and communities. If the pipeline provided water to Kalgoorlie, this regional centre could be promoted as a new major horticultural centre.

WADA's study examined vegetable and fruit crops, which have a short shelf life, are difficult to store and transport and have a very high water requirement.

It is suggested that nuts, dates and other crops such as jojoba, have advantages over vegetable and fruit crops and therefore should be investigated further. These advantages include longer shelf life, ease of transportation and lower water requirements (around $20{,}000m^3$/ha for nut crop). In regard to such crops there is little information available for Western Australian conditions. Macadamias may have potential in the north, whereas pistachios and dates may be suitable in the southern area. There is some suggestion that demand exists to establish a Californian date farm in Western Australia. Dates are a reasonably attractive proposition for the Kalgoorlie area. A large date farm in this area could provide the impetus for the development of a large horticultural industry.

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# CHAPTER 5 : ENVIRONMENTAL AND SOCIAL IMPACTS

## ENVIRONMENTAL IMPACT STUDIES

The Kimberley pipeline proposal will, if fully implemented, concern:

- The Western Australian,
- South Australian,
- Northern Territory,
- and Commonwealth Governments and their relevant agencies,
- many local Governments,
- individual settlements and communities,
- affected land owners,
- the general public,
- private sector, and
- contractors involved in the development.

Environmental and planning considerations will need to encompass:

- The source of water (probably Lake Argyle but possibly a dam in the Fitzroy River catchment),
- dam development,
- impact on river ecosystems,
- alternative routes for the pipeline,
- storage and pumping sites,
- likely spur lines,
- associated road, rail and other transport routes,
- settlements and services,
- construction programs,
- physical and environmental impacts,
- ongoing management commitments,
- other developments (eg mining, industrial) and projects (eg irrigation) likely to result from the pipeline,
- energy usage,
- station and other land owners,
- Aboriginal reserves and communities,
- conservation areas.

A pipeline from the Fitzroy River or further south as a branch off a pipeline from Lake Argyle, (if Lake Argyle is the preferred water supply source for the Kimberley pipeline) needs to be considered. This branch pipeline could transport water to the Pilbara Region, to supply anticipated industrial, mining and residential growth.

Alternatives to the main proposal will also need to be considered. These include reasonably accurate cost-benefit appraisals of alternative water sources in and outside the Kimberley Region. If the tankering option involving Kimberley water is investigated seriously the development of suitable port facilities and shipping operations will also need to be considered. Alternative port sites include Black Rocks on King Sound near Derby, Shoal Bay and Secure Bay to the east of Koolan Island, and sites near Wyndham in Cambridge Gulf.

If the Kimberley pipeline project proceeds the State Government will presumably request the Water Authority of Western Australia to act as the proponent, possibly in conjunction with other State Government departments. If the South Australian and Northern Territory Governments become involved, well defined processes for joint consultations and counterpart arrangements will need to be set in place. If a private consortium becomes involved in the project this will have to be clearly spelled out for the public.

Any pipeline and associated developments will need to be preceded by comprehensive environmental and social impact studies. These are required under the Environmental Protection Act in Western Australia and other relevant Commonwealth, State and Territory Acts.

The formal public review process will necessitate Environmental Review and Management Programmes and/or Public Environmental Reports for different stages of the project (dam, main pipeline etc). The following list identifies a few of the many aspects that will have to be covered in the different reports:

- Dam - public health; ecosystems; loss of habitat; river impacts.
- Pipelines - routes; construction impacts; excavation proposals; topsoil protection; management commitments; access routes; pumping sites and infrastructure; access to and for Aboriginal groups, station owners etc.

**EVALUATIONS OF COSTS AND BENEFITS**

In October 1989 the Western Australian Government committed itself *Towards Sustainable Development in Western Australia* and a month later launched *The Environmental Charter for Western Australia*. Previously, the *World Conservation Strategy* was released by the International Union of Conservation of Nature and Natural Resources (IUCN) in 1980, the *National Conservation Strategy for Australia* by the Commonwealth Government in 1983 and the *State Conservation Strategy* in 1987. All these strategies strongly promote 'sustainable development'.

According to Michael Reddit, "The term 'sustainable development' suggests that the lessons of ecology can, and should, be applied to economic processes. It encompasses the ideas in the World Conservation Strategy, providing an environmental rationale through which the claims of development to improve the quality of (all) life can be challenged and tested." *(Sustainable Development, 1987)*

In Mustafa Tolba's book *(Sustainable Development, 1987)* the concept of sustainable development is said to encompass,

- "the idea of cost-effective development using differing economic criteria to the traditional approach, that is to say development should not degrade environmental quality, nor should it reduce productivity in the long run;
- the great issues of health control, appropriate technologies, food self-reliance, clean water and shelter for all;
- the notion that people-centred initiatives are needed; human beings, in other words, are the resources in the concept."

Although there are many different definitions of 'sustainable development' there is general agreement that it centres on the need to integrate economics and environment and that there is also a need to rapidly develop environmental economics. Some thirty years ago cost-benefit analysis techniques were developed and are now widely accepted. The same applies to pioneering land use planning work at that time. There is an analogy between the acceptance achieved by those methodologies and the similar acceptance which is now needed for the application of cost-benefit techniques in the integration of economics and environment.

There is a rapidly growing recognition and acceptance of the need to financially appraise the environmental and social costs and benefits in the development planning process. It is also important to integrate sustainability concepts into cost-benefit analysis. Projects which can generate environmental benefits and/or are less environmentally destructive than alternative projects need to be given preference. This should apply to the planning of future sources for water supplies, the current focus being on the proposed Kimberley national water supply scheme.

A major problem facing governments, economists, ecologists and planners wishing to integrate economics and environment is how to ascribe economic values to ecological resources. This challenge has been taken up by several governments, particularly in Western Europe, and has been addressed by well known individuals such as energy expert Amory Lovins in the USA and UK economist David Pearce.

Difficult though it may be, an attempt should be made to apply and if necessary develop environmental economics to evaluate the costs to the community of different water supply development options. The Resources Assessment Commission, established by the Commonwealth Government last year following its decision to oppose the paper and pulp mill proposed for Wesley Vale in Tasmania, and the Commission for the Future are two Government agencies that might assist this evaluation process.

In fact the Commission for the Future, by recently releasing the report "Sustainable Development - Challenges for Australia" by economist Lyuba Zarsky has done much to identify pathways for the integration of environment and economics and for accounting for both in costings for development projects.

The environmental economics approach advocated here should involve evaluations based on " Sustainable National Income", rather than Gross National Product. This will emulate work already done in several countries in Western Europe, including France, Norway and West Germany. It will involve accounting for natural resources as capital and discounting, rather than counting as "income", the money spent responding to activities that contribute to the deterioration of human or ecological health.

The important assumptions have been made for the envisaged Kimberley national water supply scheme, that innovative, low cost pipeline and pumping systems will be developed and that the main energy sources will be renewable. The values costed for this scheme will need to be evaluated against the other schemes (including tankering Kimberley water) for expanding water supplies for Perth and Adelaide.

Financial and engineering/developmental, as well as environmental and social, costs and benefits will need to be evaluated for the various water supply schemes. Water conservation (involving higher pricing for water, more controls and charges on use of underground water resources, increased public education, etc) should obviously be considered as one of the alternatives.

In making cost comparisons between the alternatives a determined effort should be made to ensure that the different financial values reflect the true costs to society of the alternative schemes for water production and use. For instance, a national tax of US$50/tonne for carbon emissions (as proposed in the United States by the Worldwatch Institute in 1989) could be applied when evaluating the costs of using non-renewable as well as renewable energy power sources to pump water. The real benefits (environmental, scenic, recreational etc) of not developing different areas for water supply sources also need to be considered.

Factors which should be considered in respect of the Kimberley national water supply scheme have been identified in the following pages. The list, although extensive, is by no means comprehensive and no attempt has yet been made to ascribe financial values to any of the factors. In fact most of the factors tabulated involve both costs and benefits. Initial value judgements (as shown by crosses) have been made as to whether costs outweigh benefits or vice-versa. As environmental and social factors are often very difficult to determine, much more precise judgements will need to be made, and financial values allocated to many of the factors identified.

TABLE 3A

Implications for Western Australia of the Kimberley Pipeline and Dams for Water Storage and Power Generation

| ENVIRONMENTAL | COST | BENEFITS |
|---|---|---|
| Impacts of water storage dam(s) on the Fitzroy River and/or tributary ecosystems | X | |
| Impacts of dam(s) for hydro and/or tidal power generation | X | |
| Impacts of the Pipeline and associated developments on conservation areas | X | |
| Impacts of the Pipeline and associated developments on existing flora and fauna | X | |
| Improved quality of water supplies, particularly reduced salinity | | X |
| Possible microbiological problems affecting the pipeline | X | |
| Improved local electricity generation systems | | X |
| Increased scientific (especially biological, hydrological and horticultural) and engineering understanding | | X |
| Increased capacity for environmental management in Australia's arid zone | | X |
| Small horticultural and agroforestry developments | ? | |
| Fitzroy Valley irrigation projects ($200km^2$ area?) | ? | |
| Substitution of hypersaline groundwater used by mining companies in the Goldfields | | X |
| Restoration of degraded pastoral areas | | X |
| Reduced generation of Greenhouse and acid rain gases if renewable energy water pumping systems are used | | X |

| SOCIAL | COSTS | BENEFITS |
|---|---|---|
| Improved quality of water supplies for Perth and Kalgoorlie | | X |
| Improved water supplies for Fitzroy Crossing, Derby and Broome | | X |
| Increased scientific (especially biological, hydrological and horticultural) mapping and engineering knowledge | | X |
| Potential Impacts on Aboriginal sites | X | |
| Employment and project opportunities (mining, agricultural, manufacturing, processing, tourism etc) for Aboriginal and other communities | | X |
| Improved water and electricity supplies for communities | | X |

| | | |
|---|---|---|
| Improved education, health and stability for communities | | X |
| Improved water - related amenities (eg parks, pools,) and recreational benefits | | X |
| Small horticultural, agricultural and agroforestry projects | ? | |
| Fitzroy Valley irrigation projects | | X |
| Some flood mitigation in the Fitzroy River catchment | | X |
| Faster decentralisation from the Perth Region | | X |
| New and improved services (eg medical) and transport routes (road, rail and air) for inland and North West Australia | | X |
| Increased tourism for inland and North West Australia | ? | |

**TABLE 3B**

**Implications on the Delayed Development of Water Resources nearer Perth**

| ENVIRONMENTAL | COSTS | BENEFITS |
|---|---|---|
| Saving of Perth water (14% of current production) piped from the Region for the Goldfields and Agricultural Water Supply | | X |
| Delayed demand for development of water resources nearer Perth | | X |
| Decreased community concerns for water conservation | X | |
| Delayed Government programs for decentralisation from Perth | X | |
| Reduced draw on non-renewable energy power sources for water pumping | | X |
| Improvements (health, taste etc) in the quality of Perth's water supplies | | X |
| Delayed future impacts in System 6 on - | | |
| . existing flora and fauna | | X |
| . conservation and recreation areas | | X |
| . wetlands | | X |
| . rivers (eg Murray) from dam development | | X |

| SOCIAL | COST | BENEFITS |
|---|---|---|
| Decreased future impacts in System 6 on - | | |
| . Aboriginal sites | | X |
| . Recreational areas | | X |
| Significantly reduced threats of future water rationing | | X |
| Water supply-related employment opportunities | X | |
| Renewable energy industry employment | | X |

**TABLE 4A**

**Implications for South Australia and the Northern Territory**

| ENVIRONMENTAL | COSTS | BENEFITS |
|---|---|---|
| Factors yet to be specified. | | |

| SOCIAL | COSTS | BENEFITS |
|---|---|---|
| Improved quality water supplies for Adelaide and other places | | X |
| Better protection for the Murray, Darling and Murrumbidgee rivers, catchments and their ecosystems | | X |
| Improved capacity nationally for strategic responses | | X |
| Employment opportunities | | X |
| Increased technological and intellectual knowledge | | X |
| Enhanced inter-Governmental and other collaboration between the affected States and Territories | | X |
| Enhanced international standing | | X |
| Enhanced Australian potential for contracts overseas | | X |

**TABLE 4B**

**Some engineering and developmental factors:**

| ENGINEERING/DEVELOPMENTAL | COSTS | BENEFITS |
|---|---|---|
| <u>Implications for Western Australia</u> | | |
| Construction programs | X | |
| Development of innovative pipeline and pumping systems | | X |
| Development of tidal and hydro power sources and subsequent industries | | X |
| Development of hydrogen fuel technology and supplies | | X |
| Development of large renewable energy pumping systems (solar photovoltaics, wind turbines, zinc-bromine battery storage etc) | | X |
| Development of settlements in Australia's interior | | X |
| Development of desert technologies | | X |
| Accelerated development of mining and heavy industries | | X |

Recommendations

1. Environmental economics should be applied to the evaluation of various water supply alternatives for Western Australia, including groundwater, tankering and desalination schemes.

2. If the tankering option is studied in depth, prospective port sites should be investigated.

3. Early contact should be established with the local government authorities likely to be affected by the various routes.

4. Support for the concept, ideas and information should be sought from relevant regional development organisations and Chambers of Commerce.

5. Multi-disciplinary scientific field studies of Dimond Gorge, the adjacent King Leopold Ranges and the Fitzroy River (upstream as well as downstream) should be initiated as soon as possible, preferably in 1990. The Department of Agriculture and the Water Authority of Western Australia and/or Water Resources Council could provide valuable geological, biological, soil, water and hydrological information. They would hopefully participate in and help direct the studies.

   Other State Government agencies which could provide valuable inputs include the Departments of Conservation and Land Management, Aboriginal Sites, and Regional Development, the Geological Survey and the WA Museum. Non-government organisations and individuals, particularly from tertiary education institutions and people based in the Kimberley, should be encouraged to become involved in the field studies.

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# ACKNOWLEDGEMENTS

1. Australian Survey and Land Information Group - topographic mapping.

2. Western Australian Department of Agriculture - topographic mapping.

3. Western Australian Department of Land Administration - topographic mapping.

4. University of Western Australia Geography Department - topographic mapping.

5. Western Australian Geological Survey Department - sand ridge information.

6. Conversation with Dr Karl-Heinz Wywoll, University of Western Australia.

7. Westrail. ANR costs. Tarcoola - Alice Springs railway.

8. Water Authority of Western Australia - Lake Argyle levels.

9. Water Authority of Western Australia - water treatment.

10. Water Authority of Western Australia Perth - water supply connection.

11. Water Authority of Western Australia - water piping.

12. State Energy Commission of Western Australia - gas pipeline.

13. Western Australian Department of Agriculture - agricultural potential.

14. Western Australian Department of Mines - mining potential.

15. Conversation with Mr Colin Murray, Western Australian Environmental Protection Authority.

# APPENDIX A

## THE GRAVITY AQUEDUCT CONCEPT

P Ravine and T Crawford

# THE GRAVITY AQUEDUCT CONCEPT

The concept is aimed at providing an essential infrastructure able to supply substantial areas with good quality potable water across the Australian continent from north to south. It is not aimed at solving water problems in particular areas such as could possibly be provided by desalination plants.

The plan is aimed at reducing capital costs and energy requirements together with the use of renewable energy as far as considered practicable.

The proposed Kimberley national water supply scheme consists of alternating lengths of rising mains of pressure piping followed by gravity aqueducts located as far as practicable along hydraulic gradient elevations. Water in the gravity aqueducts would flow with a free surface except for inverted syphon sections where the supporting ground is below the hydraulic gradient.

A possible route location is shown in Figure A1.

The link from Lake Argyle to a Western Australian/South Australian junction with a longitudinal profile is shown in Figure A2. The branch to Perth is shown in Figures A3 and A4.

A possible aqueduct section is shown in Figure A5. Estimated water flow rates based upon the Manning hydraulic formula are shown in Table A1.

A design capacity of $800Mm^3/yr$ is proposed for gravity aqueduct sections between Kirkimbie on the North West of the Great Antrim Plateau and Lake Hopkins and $400Mm^3/yr$ between the W.A/S.A junction and Perth and between the W.A/S.A junction and Adelaide. Rising mains and inverted syphons could be constructed in increments of $100Mm^3/yr$ between the Kimberley and the W.A/S.A junction and $50Mm^3$ between the W.A/S.A junction and Perth and Adelaide.

If required, water could be obtained from a dam on the Fitzroy River probably at Dimond Gorge. It would cost more than the present proposal. Maps are on hand to locate a connecting route but time did not permit a location plan and profile to be included at this stage.

Maps would need to be obtained to locate a gravity aqueduct route to Adelaide. It is envisaged that very little, if any, pumping would be required. Based on the aqueduct length located between the W.A/S.A junction and Bulla Bulling, an aqueduct length to Adelaide from the W.A/S.A junction could be about 2000km.

A branch to Alice Springs is proposed. Its design capacity could be determined after considering present and likely future water consumption. Most of the maps required to locate the connection are available.

(Maps, tables and figures referred in this text are located at the end of this Appendix.)

**LAKE ARGYLE - KIRKIMBIE**

Water would be pumped from Lake Argyle to Kirkimbie. The Lake Argyle intake would be located so that it can draw water when the lake level falls to elevation 75m, some 10m below normal water level. Water quality is understood to be highest at the Lake Argyle water surface.

An intake tower located near Lincoln Yard at the entrance of the Ord River into Lake Argyle with its base below elevation 75m is proposed. Multiple controllable openings would be made in the tower so that surface water could be drawn off as the lake level changes.

The rising main would run from the intake in a south easterly direction till it joins the Duncan Highway alignment. It would follow the Duncan Highway until the highway starts to climb out of the Negri River valley. The rising main would follow the south side of the Negri valley and continue on the west side of Moonbool Creek until it reaches the proposed aqueduct inlet at elevation 425m at Kirkimbie. The total length of the rising main is 175k.

Three pumping stations are shown on the rising main in Figure A2. It should be possible to reduce them to two by increasing pumping pressures.

The estimated pumping power required from elevation 75m (allowing for a rising main hydraulic gradient of 1 in 1000, a 0.95 capacity factor and an overall pumping efficiency of 70%) is $25MW/100Mm^3/yr$. A 1.6m internal diameter pipe would accommodate the flow.

If the Argyle Diamond company does not take up the capacity of a hydro-electric station at the Lake Argyle Dam, then it should be possible to supply the pumping power required for the first stage from that source via a 130km transmission line from the dam to the first pumping station. A connecting transmission line about 130km long would be needed for the second pumping station.

If Argyle Diamond takes up the Lake Argyle Dam hydro-electric capacity then additional tidal power would be required from the Gut near Wyndham using additional installed hydro capacity at the Lake Argyle Dam and at Bandicoot Bar at Kununurra to smooth out the supply. A 110km transmission line would be needed between the Gut and the Lake Argyle Dam.

About 75MW of tidal power could need to be installed at the Gut together with a doubling of the 30MW normal capacity of the Lake Argyle Dam to 60MW plus about 8MW at Bandicoot Bar. The estimate is based upon using the foregoing tidal power arrangement.

For increased throughput, pumped storage would be needed together with additional tidal power. It should be the subject of an ongoing study.

Another option is a wind farm on the Carr Boyd Range. A study should be made of wind velocities on the Range and of pumped storage sites there.

**KIRKIMBIE - MT LANE**

Water would gravitate from elevation 425m at Kirkimbie to a pump inlet at Mt Lane at elevation 397m via a 228km long aqueduct. It includes a 20km inverted syphon crossing Sturt Creek under a maximum head of 60m. An internal diameter of 2.6m would be required for a hydraulic gradient of 0.1 in 1000 at the syphon for an increment of $100Mm^3/yr$. It may be possible to refine the hydraulic gradient to steepen it along the syphon length to reduce the diameter required there.

A reservoir is considered to be needed at Mt Lane, not to store water as an insurance against the Lake Argyle/Kirkimbie pumping system failing, but to hold water discharging from the aqueduct while any unforeseen fall in the Mt Lane pumping rate is rectified. The aqueduct itself would store a considerable volume of water over its length.

The Mt Lane storage would normally be empty so that its capacity to prevent wastage of incoming water is maximised. Water from the aqueduct would overflow into it whenever the Mt Lane pumping rate falls below the incoming rate from the aqueduct. Spare capacity would be used to empty the reservoir again when the full pumping rate is resumed. Reservoir roofing may not be needed but it is allowed for in the estimate. A storage capacity of 24 hours is proposed.

2MW of solar pond generating capacity is proposed together with 2MW of back up diesel generating capacity. Salt may need to be trucked in from Tanami Downs or some other source to supply the solar ponds. Salt recovery via an evaporating pond is proposed during operation.

Water would be pumped via a 7km 1.6m internal diameter rising main to an aqueduct inlet at elevation 430m.

Abencerrages near the Giles Meteorological Station. It skirts around the north and west of Warakurna before descending towards Warburton Range.

The route passes the Warburton Range roughly 25km to the east of the Warburton Aboriginal Community and then skirts around the east and south sides of Baker Lake. From there the route runs in a westerly direction via the McIllwraith Range to follow higher ground on the south east side of the Laverton-Warburton Road passing to the east of Lake Throssell via the Newland Range and then to the west and south west of Yeo Lake.

It then goes in a south westerly direction following the west side of a chain of lakes towards Lake Minigwal. It passes between Lake Minigwal and Lake Carey to cross Lake Raeside approximately 75km south east of Leonora.

It should be possible to provide a gravity aqueduct connection to Leonora from a point where the aqueduct runs into an inverted syphon to cross the Lake Raeside basin.

The route continues to the east of Boomerang Lake passing between it and Lake Rebecca and then on to cross the Kalgoorlie-Leonora railway at Broad Arrow before running to the pump inlet north of Bulla Bulling.

Water would be pumped via a 25km 1.2m internal diameter rising main to the following aqueduct inlet at elevation 470m at Bulla Bulling. Pumping power required would be 2.5MW/50$Mm^3$/yr.

Solar pond power generation could possibly be installed using salt from nearby salt lakes but it may be more convenient to use power from the W.A. grid via a 25km transmission line from Bulla Bulling.

Water required for Kalgoorlie could be pumped from the aqueduct inlet into the nearby Bulla Bulling reservoir presently connected to the existing Goldfields Water Supply.

**BULLA BULLING - PERTH**

Water would gravitate from elevation 470m at Bulla Bulling to a pump inlet at elevation 211m at Castle Rock, 10km south of York, via a 676km aqueduct.

The route would head towards Koolyanobbing, passing to the north of it before following a chain of lakes and low ground to eventually follow the Avon River valley near Beverley to the pump station.

The gravity aqueduct hydraulic gradients between Bulla Bulling and Perth are generally steeper than the previous sections with a minimum slope of 0.1 in 1000. Inverted syphons total 40km in length with a maximum pressure head of 37m.

At Castle Rock, water would be pumped via a 10km 1.2m diameter rising main to a point at elevation 330m from where it would gravitate to Mundaring Weir at elevation 140m via a 72km aqueduct and then on to the Greenmount Reservoir at approximately elevation 70m via a 15km 0.9m internal diameter pipeline to enter the Perth metropolitan water supply system.

Pumping power required at Castle Rock is $3.5MW/50Mm^3/yr$. A connection with the grid is envisaged assuming that adequate transmission lines exist nearby. If not, a 10km transmission line from York may be needed.

A possible refinement may be to re-route the aqueduct to Helena Weir to run via Helena Hill from where it may prove practicable to restore some power to the grid with a water turbine.

Water treatment is envisaged before entry into Perth's Greenmount Reservoir as a precaution against any contamination en route. The treatment plant could possibly be located at Mundaring Weir.

**SAND RIDGES**

Much of the route crosses sand ridges. Researchers have postulated that they were formed by the wind during a previous warmer age some thousands of years ago when the present vegetation was not present. The ridges are considered to be stable now. The sand hardly moves, even during the strongest winds. The worst conditions occur after severe bush fires and, even then, roots tend to hold the sand.

Aqueducts would need to cut through the ridges with cuttings left open to avoid excessive overhead loading and to accommodate a permanent adjacent inspection and maintenance road.

Some concern was expressed by a member of the Geological Survey Division of the Western Australian Mines Department that sand may eventually refill cuttings. However, Dr Karl-Heinz Wywroll, geomorphologist at the University of W.A., has researched sand ridges. He said that some oil exploration seismic lines which were cut through sand ridges a few years ago showed little sign of refilling.

It may be prudent to take some anti wind erosion precautions such as planting a belt of trees on the windward side of the aqueduct to act as a wind break and planting appropriate vegetation on cutting slopes to stabilise exposed sand.

**GRAVITY AQUEDUCTS**

The aim of the aqueduct system is to reduce cost by minimising internal water pressure forces and external loading.

Water loss by percolation through the earth would be prevented by a plastic membrane. Evaporation losses would be minimised by a roof covering.

Much of the route is understood to be on reasonably firmly bound sandy soil over which wind formed sand ridges of uniformly graded sand often exist. The soil is understood to be able to support road vehicles without deformation until frequent use causes rutting. In such material, 1:1 covered side slopes to aqueduct channels could be expected to be stable.

It is envisaged that construction would start by forming an appropriate running surface on each side of the channel alignment to support travelling platforms straddling the channel. The travelling platforms would carry appropriate equipment for geometric control of the channel section.

Channel excavation would normally be carried out by equipment mounted on a platform, possibly, in the first instance by an appropriate rotary cutter with the soil being conveyed clear sideways, followed by inclined trencher type cutters with similar soil removal.

In areas where the material is too loose for 1:1 slopes, it is proposed to contain it in appropriately sized fabric sleeves. These would be filled and laid longitudinally from a travelling overhead platform using appropriately sized filling equipment designed on the lines of a sausage filling machine.

When boulders, soft rock and hard rock are encountered, rough shaping would be carried out in advance using conventional techniques followed by appropriate back filling with material suitable for channel shaping.

Folded sheet metal side bearers would be laid along the top edges of the as yet unlined channels followed by laying the plastic lining. It is envisaged that all the work needed would be carried out either from a travelling platform or from attachments to it.

Roof laying would follow closely behind laying the plastic lining so that the top edges of the plastic are firmly gripped against the side bearers. As before the work would be carried out from an appropriately equipped travelling platform.

A bitumen seal would be placed at each side to exclude surface water. The roof would then be covered by sand held in fabric sleeves laid from side to side by appropriate platform mounted equipment followed by a thin layer of sand to protect the sleeve fabric from damaging ultra violet light. If needed a light fabric mesh could be laid with the final layer of sand to stabilise it.

The purpose of the sand filled sleeves is to impart rigidity to the arched roof sheeting to enable it to more effectively resist dead loading and an appropriate live loading as commonly applied to roof design.

It is not envisaged that roof design loading would normally allow access by large animals, people or vehicles. Appropriate fencing would be needed on each side to safeguard the integrity of the roof and to prevent accidents.

Appropriately designed vehicle crossings would be provided at frequent intervals, say at 5km spacing. They could take the form of pre-fabricated arched metal troughs supported on pre-fabricated or cast in situ abutments.

Maintenance is envisaged to take place from travelling platforms designed to be supported on two self propelled road trucks.

When travelling on a road, the trucks would be in line. When used on maintenance, they would drive on to a crossing where each truck would be pivoted so that they straddle the aqueduct and the fencing on each side. They would be designed to clear the fencing. The use of gates could be avoided in this way.

Distress should not be caused to animals or to pedestrians by the fencing. In addition to the vehicle crossings, pedestrian crossings should be provided wherever needed. A study should be made of animal movements to ensure that they are adequately accommodated. Pedestrian crossings could be designed on the lines of the vehicle crossings but for much lighter loadings.

The roof sheeting would be lapped in alternative directions so that in the event of an accidental overload, such as a vehicle driving on to it, only a few sections would collapse. Such a collapse would not, however, be expected to stop the flow of water in the aqueduct.

A warning system would be installed to detect damage to the roof and to alert maintenance staff.

Some sand could be washed down the aqueduct. Silt traps could be installed at intervals, say housed in small sheds in the fenced enclosure. Grilles at the traps could prevent any persons or objects from being carried down the length of an aqueduct. Silt in the silt traps would be periodically pumped out as a normal maintenance operation.

The traps could also be designed for use as ventilation points for the aqueduct.

A public water supply hand pump should be installed at every vehicle crossing as a service to the public and to avoid damage by anyone needing water in an emergency. This is a unique advantage of an aqueduct over a pipe under pressure. A tap can be left running, however, when pumping stops, the flow from a hand pump stops.

A vandal proof hand pump design should be developed. Maintenance staff should be equipped to replace or repair damaged hand pumps.

**ARGUMENTS FOR AND AGAINST AQUEDUCTS**

The system presents an opportunity to reduce construction costs and to increase the area of waterway so that relatively flat hydraulic gradients can be used with consequent reduction in the amount of pumping needed. An aqueduct has an inherent advantage in that, not being under pressure, it cannot burst.

Duplication is not considered to be necessary or desirable. It would reduce hydraulic efficiency. A major unforeseen event, such as an abnormal flood, could just as likely cut both channels at the same time.

The main areas to be served have existing sources of water supply. Those with substantial water storages, such as the Perth metropolitan reservoirs, could draw more heavily on those sources while aqueduct flow is being restored after an emergency event.

An appropriately equipped maintenance organisation would be needed. It should be ready to be called out in an emergency to restore water flow as rapidly as possible when needed.

Sand bags are widely used for emergency flood control. They could be largely replaced in this case by mechanically filled sleeves using appropriately developed equipment.

Paints have been developed for under water application. If an under water adhesive for sealing plastic lining lap joints has not already been developed, underwater paint technology could possibly be applied in that direction.

Roof sections could be lifted by appropriate equipment mounted on a maintenance platform on the lines of a fork lift. Sand could be removed from sand sleeves by side tilting or by an air pump on the lines of a vacuum cleaner via a suitably grilled nozzle inserted into sleeves.

New plastic liners could be placed in an aqueduct at a later date if necessary.

The fencing would require substantial maintenance but that would not necessarily be a disadvantage. A maintenance organisation would need to carry out routine inspections. Fencing maintenance could help to ensure that inspections are more than cursory so that early steps can be taken to prevent minor faults from deteriorating with time.

Much of the maintenance effort needed could be to control wind erosion. The maintenance organisation would need to be appropriately equipped to deal with it. The equipment could include a mobile spraying system to apply a thin clay suspension on to any particularly troublesome areas of loose sand. Clay pans exist along the route .

The possibility of toxic organisms forming in an aqueduct could cause concern. It may call for disinfection of the water at pumping stations and for periodic visual inspection of the interior of an aqueduct. Inspection could be carried out either by remote video camera with appropriate lighting mounted on a raft or by physical inspection from a manned raft.

The fencing seems likely to cause most objection.

In non-pastoral areas it may be claimed that it would restrict cross country movement. With the number of vehicle crossings proposed together with additional pedestrian and fauna crossings wherever needed, the grounds for objecting on that score should be reduced.

In pastoral areas the fencing could assist in controlling stock movement, particularly if pastoralists are allowed to install gates at crossings should they so desire. A generous policy should be applied to siting crossings at locations convenient to land owners.

The strongest objections could be raised on aesthetic grounds. Fences would undoubtedly detract from the wilderness nature of an area. However, beauty is largely in the eye of the beholder. If, as suggested, a hand pump is installed at every vehicle crossing, the beholder is likely to view the fencing as a welcome sign leading to much needed water in an arid region.

**LOW PRESSURE PIPES**

Low pressure pipes are designed to resist external forces, leakage and corrosion. New low cost construction methods should be developed such as a system developed for metal culverts termed "Spirolock" or similar.

The piping could be formed on site from continuous strip metal with interlocking edges and wound spirally to a required diameter.

A plastic lining could be formed in a similar manner simultaneously or, alternatively, a plastic lining could be inserted separately.

Recent advances in "pulltruded" fibre reinforced plastic (FRP) sections could possibly enable FRP strip to be used competitively instead of metal for spiral winding.

Strengthening to resist modest water pressures could possibly be achieved by adding one or more straps to the spiral winding.

The system could be mechanised to operate from travelling platforms straddling a pipe line. A rotary cutter of appropriate diameter could shape the pipe bed in natural ground, if it is suitable, or else in pre-placed and compacted suitably graded material.

The spoil could be used to cover the upper portion of the conduit for protection and thermal insulation. If needed a light fabric mesh could help to stabilise the soil cover.

External loading could be minimised by locating the base at an optimum depth. Fences to exclude vehicles could reduce external loading. They could, if designed appropriately, prevent the cover from being disturbed. Frequent vehicle crossings together with additional pedestrian and animal crossings wherever needed could prevent the fencing from becoming a significant physical barrier.

**PRESSURE PIPES**

Pressure pipes are designed to resist working pressures, external forces and corrosion.

Unplasticised polyvinylchloride (UPVC) is commonly used for smaller diameter pipes. It resists corrosion admirably but it does not have the strength to resist working pressures and external forces applied to larger diameters.

The Water Authority of Western Australia is understood to use plastic pipes for up to 200mm in diameter, cement lined ductile iron for 200 to 300mm diameter and cement lined steel for diameters over 400mm. Cement lining thicknesses given in the Binnie report are 25mm for 1400mm diameter and 32mm for 1800 and 2000mm diameter.

Cement lining is preferred by the Water Authority of Western Australia for lining steel pipes because of its alkalinity. The pH of any water seeping through it is raised, thereby inhibiting corrosion.

However, cement's brittleness requires the piping to be rigid. Thinner steel sections are avoided resulting in far more steel often being used than would be required for resisting water pressures and external forces alone.

Mass of steel used is a major component of the cost of a steel pipe.

Steel pipes are often bitumen lined. Bitumen linings 3 to 5mm thick are generally considered to give adequate protection against corrosion. They have been used successfully overseas for many years.

Current Water Authority of Western Australia practice is understood to be to sleeve weld large diameter steel pipes. Joint areas are faced internally with cement mortar after welding to complete internal anti-corrosion protection.

Rubber ring jointed steel piping is now starting to be used. It costs somewhat more but laying costs are reduced considerably by avoiding both site welding and making good internal and external anti-corrosion protection.

The Binnie report states that a full study of alternative pipe materials would need to be carried out if a full feasibility study is warranted. However, its estimates appear to be based solely upon current Water Authority of Western Australia practice.

The report states that for the range of diameters under consideration, cement lined steel pipes are expected to be competitively priced but that could be a reflection on the present state of competition.

To achieve a greater degree of efficiency in material use and pipe laying, consideration should be given to developing plastic pipes with steel jackets for larger sizes. The flexibility of plastic should prevent it from being damaged by minor distortions, allowing steel thicknesses to be designed to resist working pressures and external forces alone without having to be rigid enough to resist all distortion.

Joints can be designed so that contact between steel and water is prevented. A design somewhat on the lines of the "Harditite" jointing system for glass reinforced plastic pipes would permit rapid pipe laying.

External protection could largely follow present practice for steel pipes or, alternatively, the steel could be hermetically sealed between internal and external plastic sleeves. An appropriate corrosion inhibitor could be applied between plastic and steel. If needed, electrical bonding connections could be attached to the steel for cathodic protection.

Another pressure pipe option could be to use steel piping, with some type of rapid jointing system, but without any internal lining. Long continuous flexible internal plastic linings could be inserted after laying. A temporary inflatable stop somewhat on the lines of a large plastic beach ball could block the pipe while an internal plastic sleeve is unrolled and pressed against the steel pipe wall by air pressure. Lap joints between adjacent sleeves lengths could be sealed with an adhesive.

Another option could be to use a small rubber tyred trolley with a frame holding a circular array of rollers, instead of air pressure, to press the plastic lining against the pipe wall.

The Water Authority of Western Australia should take an active role in pressure pipe development to minimise pipe line costs. Industry can give cost efficiency a lower priority than price maintenance. Industry may need encouragement and some leadership from the Water Authority of Western Australia to develop more cost effective pressure piping.

**GENERAL COMMENTS ON RENEWABLE ENERGY SYSTEMS FOR PUMPING WATER FROM THE KIMBERLEY REGION TO PERTH**

The major problem with most forms of renewable energy is their intermittent availability which seldom matches demand. The only renewable energy based electricity generating systems which incorporate long term energy storage are biomass fuelled, hydro-electric and solar pond systems.

Biomass systems would require water from the pipeline for crop irrigation. They would be labour intensive and could not be operational during the initial years of pipeline operation. They are not therefore considered further.

For an aqueduct following the inland route a major portion of the pumping energy is required for the first three pumping stations up to Kirkimbie. It seems best to inter-connect these three stations electrically and to provide continuous pumping energy from a combination of tidal power near Wyndham, Lake Argyle hydro power and hydro pumped storage.

The final two pumping stations near Perth could be connected to the SECWA grid. The cheapest option for supplying renewable energy to these stations would be to locate a wind farm on the West coast capable of supplying, over the year, the same amount of electricity that the pumping stations extract from the grid. A wind farm of about 20MW peak output would be suitable to supply energy equivalent to the 6MW continuous pumping load. It would cost about $30m but has not been included in the overall cost estimates.

Solar pond electricity generating systems are suggested for the three intermediate very remote pumping stations. This technology stores solar energy as hot water at the bottom of a pond having a saline gradient. The very saline water at the bottom of the pond suppresses the normal tendency of hot water to rise to the surface. It should be possible to harvest salt or concentrated brine from natural salt lakes within a reasonable distance. Fresh water to make up evaporative losses would be available from the pipeline.

The solar pond stations which have operated in Israel and at Alice Springs have used chlorofluorocarbons as a working fluid.

The hot water from the pond vaporises the fluid. The vapour is expanded through a turbine and is condensed by cold water from the top of the pond or by direct air cooling. No greater loss of chlorfluorocarbons would be expected than from a large airconditioning system. However chlorofluorocarbons are implicated in destruction of the ozone layer thus other organic fluids such as butane, or alternatively a direct steam cycle, should be tested, before a commitment was made to solar pond technology. The development and use of such systems in Australia could well result in export markets for Australian technology and industry.

Solar ponds require operators to maintain the salinity gradient and the clarity of the water. The larger pumping stations at Lakes Mackay and Hopkins would justify full time staffing, but it may be more economic to use photovoltaic or wind power with pumped storage or electrochemical batteries at Mt Lane, so that this small pumping station and power generating plant can be automated. However for the present estimates a small solar pond has been assumed to be installed at Mt Lane.

A skeleton staff could stay at each pump station to carry out routine operations under direction from Alice Springs. Accommodation could be provided at the pump stations for larger crews to carry out more extensive periodic maintenance tasks.

**SOLAR PONDS**

After considering both wind and solar photo-voltaic power generation, solar pond power generation with stand-by diesel power was seen as being more cost effective. Solar pond power is available night and day because it involves a substantial amount of thermal storage. Additional energy storage is not required for normal operation.

The salt needed should be available at lakes such as Mackay and Hopkins. It could be trucked to Mt Lane from the nearest convenient source. Fresh water for maintaining the salinity gradient needed would be available from the water supply scheme.

Considerable experience in solar pond technology has been obtained at Alice Springs where a training establishment could be located to train staff. All the solar ponds could be controlled from Alice Springs. Each pond could be equipped with extensive instrumentation giving direct remote readings at an Alice Springs control centre. The controls could be operated directly.

If the alternative of a coastal route is chosen it will be possible to use wind farms, operating in parallel with the Pilbara and South West power grids, to supply a significant part of the pumping energy.

## COSTING

### Aqueducts

The cost per kilometre of aqueduct is considered to be comparable in many ways to constructing a railway.

The as built average cost of the 830km Tarcoola/Alice Springs railway excluding buildings and base facilities in 1980 dollars was $167,000/km which is equivalent to approximately $334,000/km in 1990 dollars.

Relevant major cost items are:

| | $000/km (1980) | $000/km (1990) |
|---|---|---|
| Survey | 2.7 | 5.4 |
| Engineering | 2.4 | 4.8 |
| Clearing | 1.7 | 3.4 |
| Earthworks | 19.6 | 39.2 |
| Bridges and culverts (cross drainage) | 31.7 | 63.4 |
| Track laying | 17.0 | 34.0 |

Using the foregoing costs as a guide for non-material costs, a notional estimate for a fully developed 5m deep covered aqueduct is as follows:

| | $000/km |
|---|---|
| Survey | 5 |
| Engineering | 5 |
| Clearing and earthworks | 50 |
| Cross drainage | 75 |
| Sand reinforcing fabric | 60 |
| Plastic lining | 100 |
| Roof material | 60 |
| Aqueduct laying complete | 60 |
| Fencing | 10 |
| Crossings at $50,000 each at 5km intervals | 10 |
| Contingencies | 65 |
| Total | 500 |

The concept needs to be developed much further before closer cost estimates can be made. At this stage it is proposed to use the above rate for all sections of gravity aqueduct, irrespective of slope or design capacity, for the purpose of a preliminary estimate.

Annual operation and maintenance costs are taken to be 2% of capital cost. This compares with 0.5% for pipelines in the Binnie report.

**Piping**

Unit pipe costs are assumed to be reduced from those given in the Binnie report by changing the type of piping used as previously discussed and by using more cost-effective joints. They are reflected in the unit costs applied in the cost estimates.

## RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that further studies be undertaken as follows:

* ADELAIDE BRANCH

  Appropriate mapping should continue to be obtained followed by preliminary horizontal and vertical location.

* ALICE SPRINGS BRANCH

  As above. Most of the mapping needed has been obtained except for a small gap in the middle of the route. Future water demand should be studied.

* FITZROY CONNECTION

  Mapping has been obtained. Preliminary horizontal and vertical location should continue.

* GEOLOGICAL DATA

  1:250,000 geological survey maps covering the routes should be studied together with accompanying notes.

* AIR PHOTOS

  Stereoscopic pairs of existing aerial photographs covering the routes should be studied together with satellite air photos.

* AQUEDUCT DEVELOPMENT

  Small scale model experimental work could be put in hand aimed at developing principles upon which larger experimental models could be based.

* LOW PRESSURE PIPE DEVELOPMENT

  A study should be made of existing developments in this area. Small scale model experimental work may also be appropriate.

* PRESSURE PIPE DEVELOPMENT

  Expressions of interest could be obtained from Australian and overseas manufacturers for developing more cost-effective pressure piping. They may be reluctant to take actions that could upset the existing pipe market. Contracting out specific experimental work by the Water Authority may be more effective.

* TIDAL POWER

Tidal power prospects at the Gut near Wyndham should be investigated together with appropriate pumped storage sites and the prospects for hydrogen as an energy transport medium.

* WIND POWER

Wind velocities on the Carr Boyd Range should be monitored together with wind velocities on Mt Lane, the Kintore Range and Bloods Range so that wind energy can be considered as an alternative or supplementary option. Pumped storage sites should be investigated.

* FIELD SURVEY

For details see Appendix B.
Estimated cost $30500.

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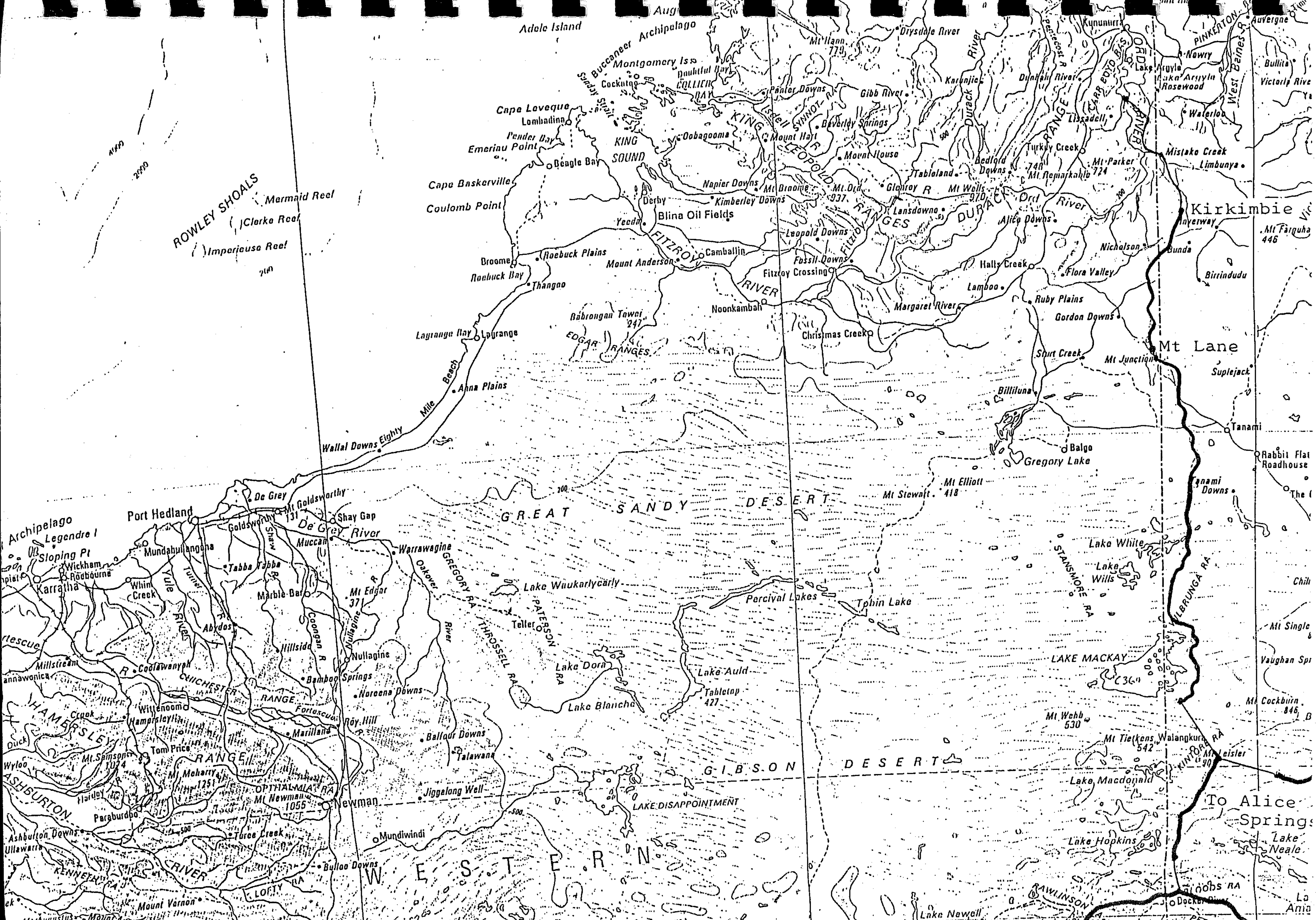
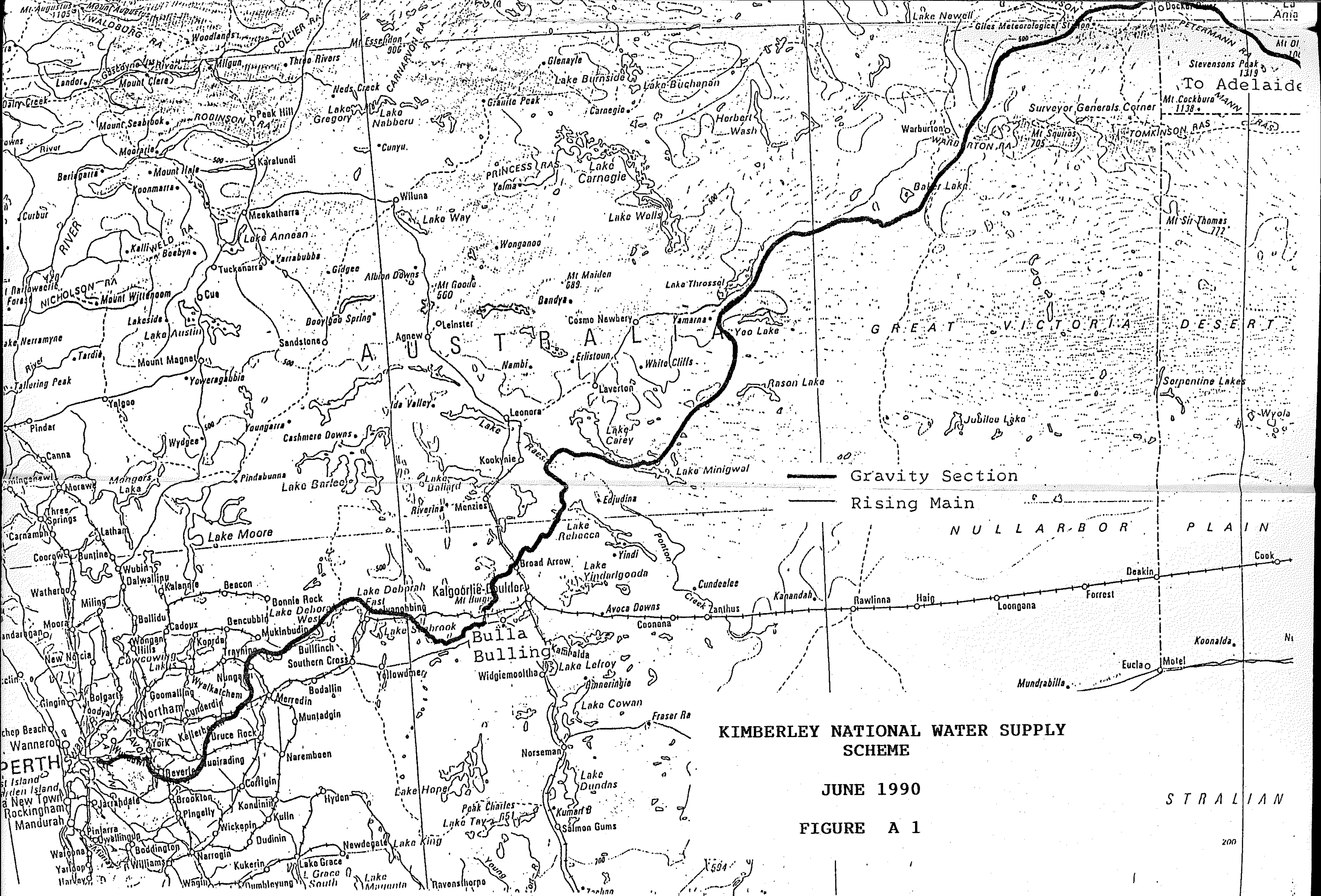
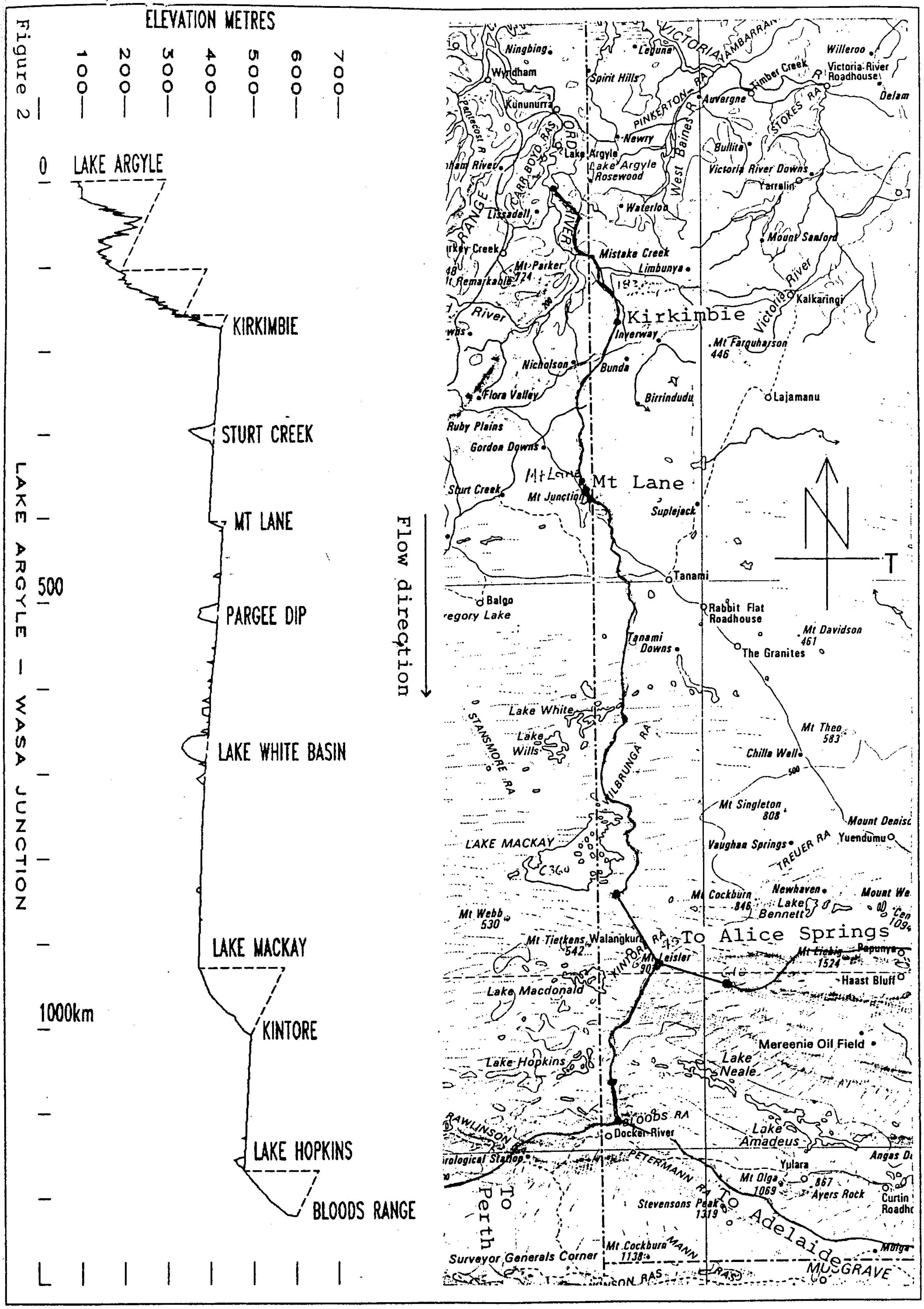

Kirkimbie
Mt Lane
To Alice Springs
Port Hedland
GREAT SANDY DESERT
GIBSON DESERT
WESTERN
ROWLEY SHOALS
Mermaid Reef
Clerke Reef
Imperieuse Reef
Adele Island
Buccaneer Archipelago
Montgomery Is
Cape Leveque
Lombadina
Pender Bay
Emeriau Point
Beagle Bay
Cape Baskerville
Coulomb Point
KING SOUND
Derby
Blina Oil Fields
Yeeda
FITZROY RIVER
Camballin
Mount Anderson
Broome
Roebuck Bay
Roebuck Plains
Thangoo
Lagrange Bay
Lagrange
Eighty Mile Beach
Anna Plains
Wallal Downs
KING LEOPOLD RANGES
DURACK RANGE
Kununurra
ORD RIVER
Lake Argyle
Drysdale River
Gibb River
Durack River
Mount House
Mount Hart
Oobagooma
Napier Downs
Kimberley Downs
Leopold Downs
Fossil Downs
Fitzroy Crossing
Noonkambah
Christmas Creek
Margaret River
Lamboo
Halls Creek
Ruby Plains
Gordon Downs
Flora Valley
Nicholson
Alice Downs
Lansdowne
Tableland
Turkey Creek
Mistake Creek
Limbunya
Nowry
Auvergne
Bullita
Victoria River
West Baines R
Waterloo
Rosewood
Inverway
Bunda
Birrindudu
Mt Farquhar 446
Supplejack
Mt Junction
Sturt Creek
Billiluna
Balgo
Gregory Lake
Tanami
Rabbit Flat Roadhouse
Tanami Downs
Mt Elliott 418
Mt Stewart
EDGAR RANGES
Lake Waukarlycarly
Percival Lakes
Tobin Lake
Lake White
Lake Wills
STANSMORE RA
LAKE MACKAY
Mt Cockburn 846
Mt Webb 530
Mt Tietkens 542
Walangkura
KINTORE RA
Mt Leisler 901
Lake Macdonald
Lake Hopkins
Lake Neale
RAWLINSON RA
Lake Newell
LAKE DISAPPOINTMENT
Lake Dora
Lake Auld
Tabletop 427
Lake Blanche
PATERSON RA
THROSSELL RA
GREGORY RA
Teller
Oakover River
Warrawagine
De Grey River
De Grey
Mt Goldsworthy
Goldsworthy
Shay Gap
Muccan
Mundabullangana
Tabba Tabba
Marble Bar
Mt Edgar 371
Coongan R
Nullagine
Hillside
Bamboo Springs
Noreena Downs
Roy Hill
Balfour Downs
Talawana
Jiggalong Well
Newman
Mt Newman 1055
OPTHALMIA RA
Mundiwindi
Marillana
Abydos
Whim Creek
Yule River
Turner
Karratha
Wickham
Roebourne
Sloping Pt
Legendre I
Cooyapyah
CHICHESTER RANGE
Fortescue
Wittenoom
Hamersley
HAMERSLEY RANGE
Tom Price
Mt Samson 1074
Mt Meharry 1251
Paraburdoo
Hardey R
ASHBURTON RIVER
Ashburton Downs
Ullawarra
Turee Creek
Bulloo Downs
LOFTY RA
Mount Vernon
KENNETH RA
Millstream
Wyloo



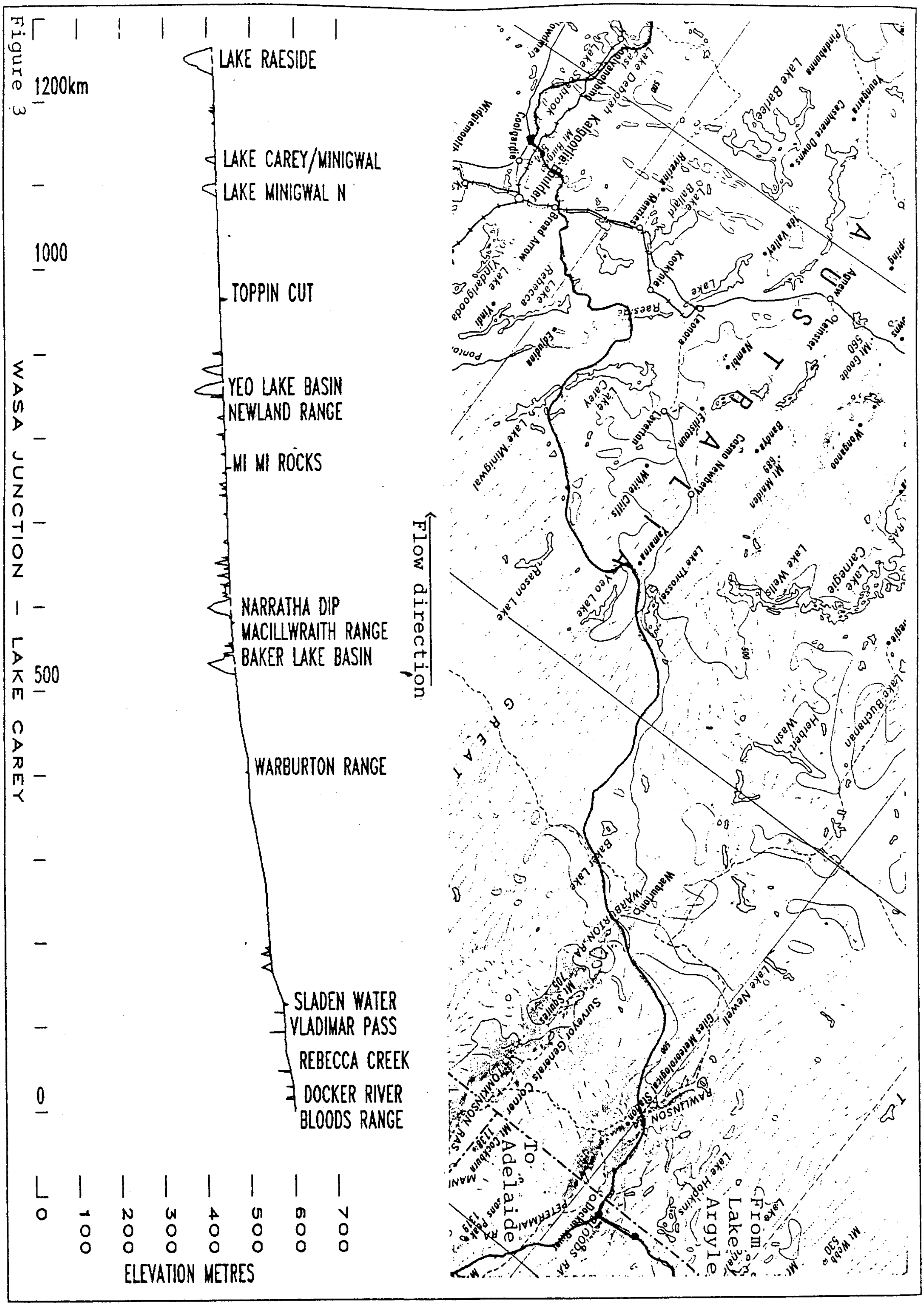

KIMBERLEY NATIONAL WATER SUPPLY SCHEME

JUNE 1990

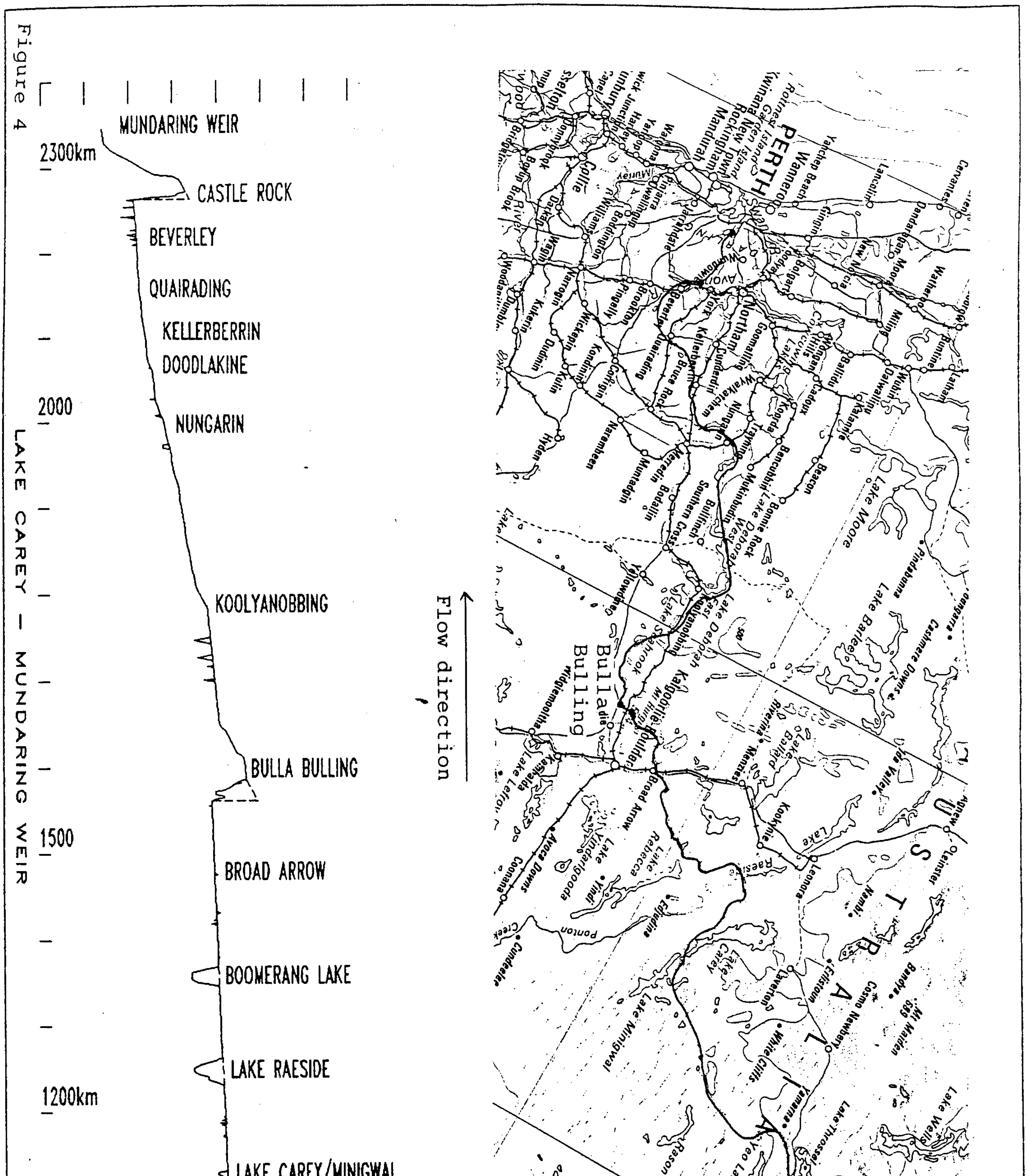
FIGURE A 1



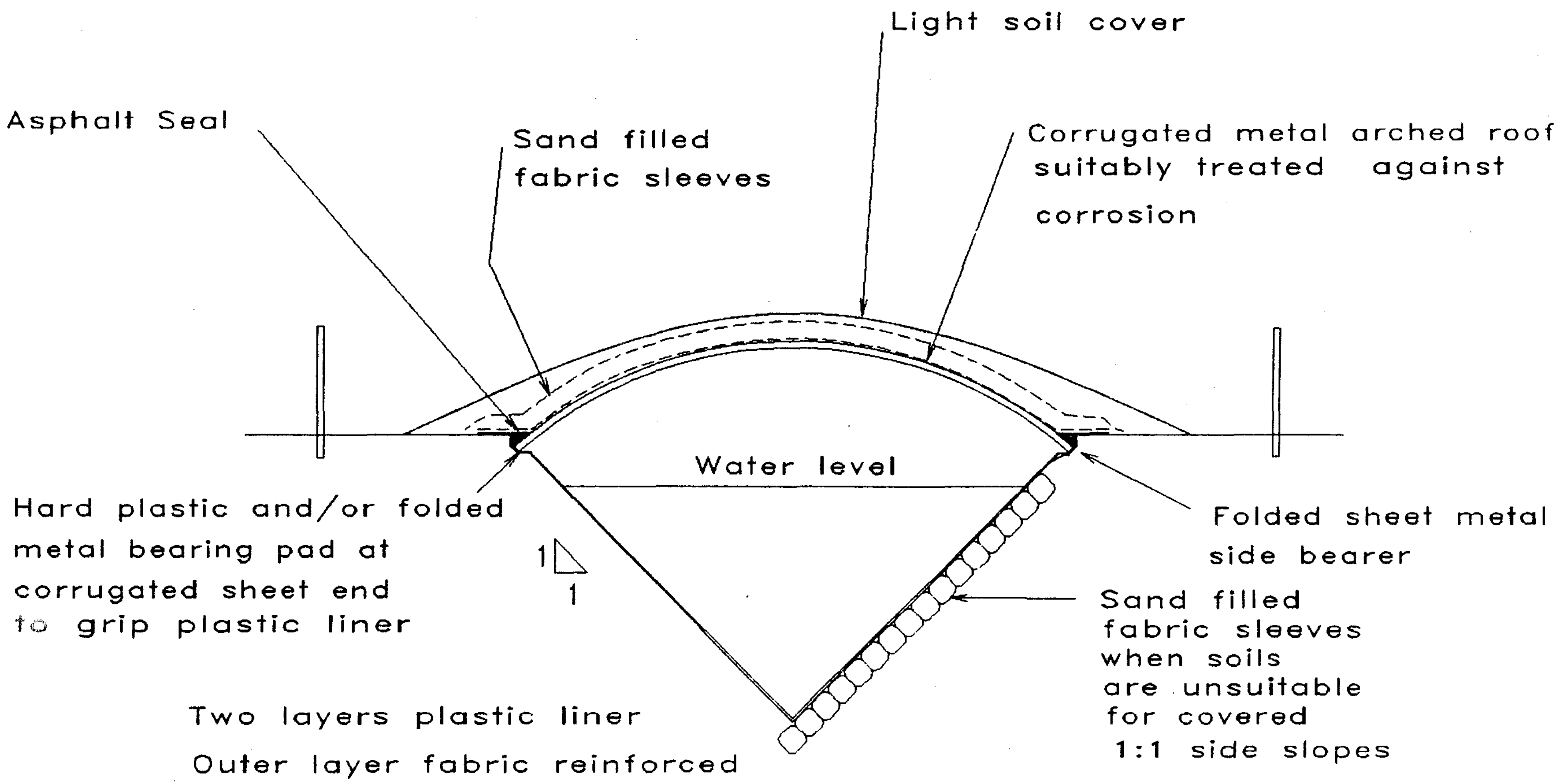

**LAKE ARGYLE - W.A./S.A. JUNCTION**
**Figure A2**




**W.A./S.A. JUNCTION - LAKE CAREY**
**Figure A3**




**LAKE CAREY - MUNDARING WEIR**
**Figure A4**




AQUEDUCT CROSS-SECTION

Figure A5

KIMBERLEY NATIONAL WATER SUPPLY SCHEME

TABLE A1

ESTIMATED AQUEDUCT FLOW RATES

"V" section. 1:1 side slopes. Plastic lining

Flow in $m^3$/sec
($Mm^3$yr @ .95 capacity factor)

| Flow depth | Slope per thousand | | | | | | |
|---|---|---|---|---|---|---|---|
| m | 0.04 | 0.06 | 0.1 | 0.2 | 0.4 | 0.6 | 1.0 |
| 1 | .32 (10) | .39 (12) | .51 (15) | .72 (22) | 1.01 (30) | 1.24 (37) | 1.6 (48) |
| 2 | 2.0 (60) | 2.7 (74) | 3.2 (96) | 4.5 (135) | 6.4 (192) | 7.8 (234) | 10.1 (302) |
| 3 | 5.9 (178) | 7.2 (216) | 9.5 (284) | 13.4 (401) | 18.9 (566) | 23.2 (695) | 29.9 (895) |
| 4 | 12.8 (382) | 15.5 (465) | 20.3 (608) | 28.7 (859) | 40.6 (1215) | 49.8 (1491) | 64.2 (1925) |
| 5 | 23.1 (693) | 28.1 (844) | 35.9 (1075) | 50.8 (1523) | 71.6 (2147) | 88.0 (2638) | 113.5 (3403) |

*****

**TABLE A2**

DISCOUNTED COSTS

| Year | Stage No. | M & E replace StageNo | Annual flow $Mm^3$ | Init. cap. $M | M & E replace $M | Op. & mtce. $M | Energy cost/y $M | Total costs $M |
|---|---|---|---|---|---|---|---|---|
| 1996 | 1 | | 0 | 1146 | | | | 1146 |
| 1997 | | | 0 | 1146 | | | | 1146 |
| 1998 | | | 0 | 1146 | | | | 1146 |
| 1999 | | | 0 | 1146 | | | | 1146 |
| 2000 | | | 0 | 1147 | | | | 1147 |
| 2001 | 2 | | 56 | 782 | | 94 | 6 | 882 |
| 2002 | | | 76 | 782 | | 94 | 8 | 884 |
| 2003 | | | 98 | 783 | | 94 | 10 | 887 |
| 2004 | | | 118 | | | 122 | 12 | 134 |
| 2005 | 3 | | 140 | 739 | | 122 | 14 | 875 |
| 2006 | | | 162 | 740 | | 122 | 16 | 878 |
| 2007 | | | 180 | 740 | | 122 | 18 | 880 |
| 2008 | | | 200 | | | 150 | 20 | 170 |
| 2009 | | | 218 | | | 150 | 22 | 172 |
| 2010 | | | 238 | | | 150 | 24 | 174 |
| 2011 | 4 | | 256 | 739 | | 150 | 26 | 915 |
| 2012 | | | 274 | 740 | | 150 | 27 | 917 |
| 2013 | | | 290 | 740 | | 150 | 29 | 919 |
| 2014 | | | 308 | | | 178 | 31 | 209 |
| 2015 | | | 324 | | | 178 | 32 | 210 |
| 2016 | | | 342 | | | 178 | 34 | 212 |
| 2017 | 5 | | 360 | 739 | | 178 | 36 | 953 |
| 2018 | | | 378 | 740 | | 178 | 38 | 956 |
| 2019 | | | 396 | 740 | | 178 | 40 | 958 |
| 2020 | | 1 | 414 | | 323 | 207 | 41 | 364 |
| 2021 | | | 432 | | | 207 | 43 | 250 |
| 2022 | 6 | | 450 | 739 | | 207 | 45 | 991 |
| 2023 | | 2 | 470 | 740 | 184 | 207 | 47 | 1178 |
| 2024 | | | 488 | 740 | | 207 | 49 | 996 |
| 2025 | | | 506 | | | 235 | 51 | 286 |
| 2026 | | | 524 | | | 235 | 52 | 287 |
| 2027 | | 3 | 540 | | 184 | 235 | 54 | 473 |
| 2028 | 7 | | 556 | 739 | | 235 | 56 | 1030 |
| 2029 | | | 570 | 740 | | 235 | 57 | 1032 |
| 2030 | | | 586 | 740 | | 235 | 59 | 1034 |
| 2031 | | | 602 | | | 263 | 60 | 323 |
| 2032 | | | 616 | | | 263 | 62 | 325 |
| 2033 | | 4 | 632 | | 184 | 263 | 63 | 510 |
| 2034 | | | 643 | | | 263 | 64 | 327 |
| 2035 | 8 | | 660 | 739 | | 263 | 66 | 1068 |
| 2036 | | | 674 | 740 | | 263 | 67 | 1070 |
| 2037 | | | 688 | 740 | | 263 | 69 | 1072 |
| 2038 | | | 704 | | | 292 | 70 | 362 |
| 2039 | | 5 | 718 | | 184 | 292 | 72 | 548 |
| 2040 | | 1 | 734 | | 323 | 292 | 73 | 688 |
| 2041 | | | 748 | | | 292 | 75 | 367 |
| 2042 | | | 758 | | | 292 | 76 | 368 |
| 2043 | | 2&4 | 768 | | 368 | 292 | 77 | 737 |
| 2044 | | 6 | 776 | | 184 | 292 | 78 | 554 |
| 2045 | | | 786 | | | 292 | 79 | 371 |
| 2046 | | | 796 | | | 292 | 80 | 372 |
| 2047 | | 3 | 800 | | 184 | 292 | 80 | 556 |
| 2048 | | | 806 | | | 292 | 81 | 373 |
| 2049 | | | 810 | | | 292 | 81 | 373 |
| 2050 | | | 816 | | | 292 | 82 | 374 |
| 2050 | Resid.Values | | | -4713 | -797 | | | -5510 |
| Totals | | | 24488 | | | | | 31065 |

| Present values: | | |
|---|---|---|
| 4.0% rate | 6418 | 12941 |
| 6.0% " | 3680 | 9127 |
| 8.0% " | 2258 | 6759 |

| Discounted cost of water: | $/kl |
|---|---|
| Zero discount rate | 1.27 |
| 4.0% " " | 2.02 |
| 6.0% " " | 2.48 |
| 8.0% " " | 2.99 |

# TABLE A3 - ESTIMATE COSTS OF THE GRAVITY AQUEDUCT SYSTEM

## LAKE ARGYLE-W.A./S.A. JUNCTION

| NO. | ITEM | CAPITAL COST | | | | ANN.OP. & MTCE. | | M&E REPL |
|---|---|---|---|---|---|---|---|---|
| | | Quant. | Unit | Rate $M | Amt. $M | %Cap. Cost. | Amt. $M | Cost $M |
| A | LAKE ARGYLE - KIRKIMBIE | | | | | | | |
| 1 | Tidal power. The Gut. | 75 | MW | 2 | 150 | 1.5 | 2.3 | 34 |
| 2 | Hydro power. Lake Argyle | 30 | MW | 1 | 30 | 1 | 0.3 | 7 |
| 3 | Hydro power. Bandicoot Bar | 8 | MW | 2 | 16 | 1 | 0.2 | 4 |
| 4 | 220kV transmission line | 110 | km | 0.08 | 9 | 2 | 0.2 | |
| 5 | 132kV transmission line | 260 | km | 0.07 | 18 | 2 | 0.4 | |
| 6 | Substations | 4 | no | 5 | 20 | 2 | 0.4 | |
| 7 | Pumps incl. 50% back up | 37.5 | MW | 0.9 | 34 | 2.5 | 0.9 | 17 |
| 8 | Water treatment plant | 288 | Ml/d | 0.1 | 29 | 10 | 2.9 | 14 |
| 9 | 1.6m dia. rising main | 175 | km | 0.8 | 140 | 0.5 | 0.7 | |
| B | KIRKIMBIE - MT LANE | | | | | | | |
| 1 | Aqueduct | 208 | km | 0.5 | 104 | 2 | 2.1 | |
| 2 | 2.6m inverted syphon | 20 | km | 1.5 | 30 | 0.5 | 0.2 | |
| 3 | Solar pond power. Mt Lane | 2 | MW | 5 | 10 | 5 | 0.5 | 3 |
| 4 | Diesel back up | 2 | MW | 0.7 | 1 | 2.5 | 0 | 1 |
| 5 | Pumps incl. 50% back up | 3 | MW | 0.9 | 3 | 2.5 | 0.1 | 2 |
| 6 | Covered reservoir | 288 | Ml | 0.056 | 16 | 0.5 | 0.1 | |
| 7 | 1.6m dia. rising main | 7 | km | 0.8 | 6 | 0.5 | 0 | |
| C | MT LANE - KINTORE | | | | | | | |
| 1 | Aqueduct | 393 | km | 0.5 | 197 | 2 | 4 | |
| 2 | 2.2m dia. inverted syphon | 55 | km | 1.2 | 66 | 0.5 | 0.3 | |
| 3 | 2.6m dia. low head syphon | 70 | km | 1.3 | 91 | 0.5 | 0.5 | |
| 4 | Sola pond power L.Mackay | 10 | MW | 5 | 50 | 5 | 2.5 | 13 |
| 5 | Diesel back up | 10 | MW | 0.7 | 7 | 2.5 | 0.2 | 4 |
| 6 | Pumps incl. 50% back up | 15 | MW | 0.9 | 14 | 2.5 | 0.4 | 7 |
| 7 | Covered reservoir | 288 | Ml | 0.056 | 16 | 0.5 | 0.1 | |
| 8 | 1.6m dia. rising main | 80 | km | 0.8 | 64 | 0.5 | 0.3 | |
| 9 | 33kV transmission line | 80 | km | 0.05 | 4 | 2 | 0.1 | |
| D | KINTORE - W.A./S.A. JUNCTION | | | | | | | |
| 1 | Aqueduct | 151 | km | 0.5 | 76 | 2 | 1.5 | |
| 2 | 2.2m dia. inverted syphon | 19 | km | 1.1 | 21 | 0.5 | 0.1 | |
| 3 | Solar pond power L.Hopkins | 8.5 | MW | 5 | 43 | 5 | 2.2 | 11 |
| 4 | Diesel back up L.Hopkins | 8.5 | MW | 0.7 | 6 | 2.5 | 0.2 | 3 |
| 5 | Pumps incl. 50% back up | 12.75 | MW | 0.9 | 11 | 2.5 | 0.3 | 6 |
| 6 | Covered reservoir | 288 | Ml | 0.056 | 16 | 0.5 | 0.1 | |
| 7 | 1.6m dia. rising main | 53 | km | 0.8 | 42 | 0.5 | 0.2 | |
| | Totals carried forward | | | | 1340 | | 24.3 | 126 |

ESTIMATE (Continued)

## W.A./S.A. JUNCTION - PERTH & ADELAIDE AND ALICE SPRINGS BRANCHES

| NO. | ITEM | CAPITAL COST | | | | ANN.OP. & MTCE. | | M&E REPL |
|---|---|---|---|---|---|---|---|---|
| | | Quant. | Unit | Rate $M | Amt. $M | %Cap. Cost. | Amt. $M | Cost $M |
| | Brought Forward | | | | 1340 | | 24.3 | 126 |
| E | W.A./S.A. JUNCTION - BULLA BULLING | | | | | | | |
| 1 | Aqueduct | 1288 | km | 0.5 | 644 | 2 | 12.9 | |
| 2 | 2.2m dia. inverted syphon | 28 | km | 1.2 | 34 | 0.5 | 0.2 | |
| 3 | 2.1m dia. inverted syphon | 22 | km | 1.1 | 24 | 0.5 | 0.1 | |
| 4 | 2.0m dia. inverted syphon | 52 | km | 1 | 52 | 0.5 | 0.3 | |
| 5 | 1.8m dia. inverted syphon | 27 | km | 0.9 | 24 | 0.5 | 0.1 | |
| 6 | 2.2m dia. low head syphon | 154 | km | 0.9 | 139 | 0.5 | 0.7 | |
| 7 | 33 kV transmission line | 25 | km | 0.05 | 1 | 2 | 0 | |
| 8 | Diesel backup | 2.5 | MW | 0.7 | 2 | 2.5 | 0.1 | 1 |
| 9 | Pumps incl. 50% back up | 3.75 | MW | 0.9 | 3 | 2.5 | 0.1 | 2 |
| 10 | Covered reservoir | 144 | Ml | 0.056 | 8 | 0.5 | 0 | |
| 11 | 1.2m dia. rising main | 25 | km | 0.5 | 13 | 0.5 | 0.1 | |
| F | BULLA BULLING - PERTH | | | | | | | |
| 1 | Aqueduct | 780 | km | 0.5 | 390 | 2 | 7.8 | |
| 2 | 1.7m dia. low head syphon | 40 | km | 0.7 | 28 | 0.5 | 0.1 | |
| 3 | Diesel backup Castle Rock | 3.5 | MW | 0.7 | 3 | 2.5 | 0.1 | 2 |
| 4 | Pumps incl. 50% back up | 5.25 | MW | 0.9 | 5 | 2.5 | 0.1 | 3 |
| 5 | Covered reservoir | 144 | Ml | 0.056 | 8 | 0.5 | 0 | |
| 6 | 1.2m dia. rising main | 10 | km | 0.5 | 5 | 0.5 | 0 | |
| 7 | Water treatment plant | 144 | Ml/d | 0.1 | 14 | 2.5 | 0.4 | 7 |
| 8 | 0.9m dia. pipe to Gmt.Res. | 15 | km | 0.3 | 5 | 0.5 | 0 | |
| G | ADELAIDE AND ALICE SPRINGS | | | | 1500 | | 25 | 15 |
| | Communications and control | | | | 35 | 2 | 0.7 | 18 |
| | Vehicles, depots, land | | | | 200 | | | 100 |
| | Sub-totals | | | | 4477 | | 73.1 | 274 |
| | Miscellaneous items 10% | | | | 448 | | 7.3 | |
| | Design and admin. 10% | | | | 358 | | 5.8 | 22 |
| | Contingencies | | | | 448 | | 7.3 | 27 |
| | Totals | | | | 5732 | | 93.5 | 323 |

TABLE A 4 - ESTIMATE
UPRATING COSTS

| NO. | ITEM | CAPITAL COST | | | | ANN.OP. & MTCE. | | M&E REPL |
|---|---|---|---|---|---|---|---|---|
| | | Quant. | Unit | Rate \$M | Amt. \$M | %Cap. Cost. | Amt. \$M | Cost \$M |
| 1 | Tidal Power | 100 | MW | 2 | 200 | 1.5 | 3 | 45 |
| 2 | Pumped storage Civil* | | | | 100 | 0.25 | 0.3 | |
| 3 | Pumped storage M&E | 90 | MW | 1 | 90 | 1 | 0.9 | 23 |
| 4 | Solar pond power | 20.5 | MW | 5 | 103 | 5 | 5.2 | 26 |
| 5 | Diesel back up | 26.5 | MW | 0.7 | 19 | 2.5 | 0.5 | 10 |
| 6 | Pumps incl. 50% back up | 30.75 | MW | 0.9 | 28 | 2.5 | 0.7 | 14 |
| 7 | Pipelines | | | | 784 | 0.5 | 3.9 | |
| 8 | Covered reservoirs | 1152 | Ml | 0.056 | 65 | 0.5 | 0.3 | |
| 9 | Water treatment plants | 432 | Ml/d | 0.1 | 43 | 10 | 4.3 | 22 |
| 10 | Adelaide and Alice Springs | | | | 400 | | 3 | 15 |
| 11 | Communications and control | | | | 7 | 2 | 0.1 | 4 |
| | Sub totals | | | | 1839 | | 22.2 | 159 |
| | Misc. items 10% | | | | 184 | | 2.2 | |
| | Design and Administration 8% | | | | 147 | | 1.8 | 12 |
| | Contingencies 10% | | | | 184 | | 2.2 | 16 |
| | Totals | | | | 2354 | | 28.4 | 187 |

* First uprating only

**ABBREVIATIONS:**

| | | |
|---|---|---|
| Ann.Op.& Mtce | : | Annual operation and maintenance cost |
| M&E Repl. | : | Mechanical and electrical replacement |
| Quant. | : | Quantity |
| Amt. | : | Amount |
| %Cap. cost | : | Percentage of capital cost |
| Incl. | : | Including |
| Misc. | : | Miscellaneous |
| dia. | : | Diameter |
| MW | : | Megawatts |
| km | : | Kilometres |
| Ml | : | Megalitres |
| Ml/d | : | Megalitres per day. |

# APPENDIX B

## PROPOSAL FOR AN INITIAL FIELD SURVEY

The following assumptions are made for the initial field survey:

1. The survey group will involve ten members, including officers from the Water Authority and the Water Resources Council of Western Australia, leaders from one or more inland Aboriginal communities, and the pilot.

2. The survey will take about three weeks and not be carried out during the hottest months of the year. About one week will be required for each of the three main sectors proposed for the pipeline route. These are Perth to Bloods Range (near Giles), Bloods Range to Adelaide and/or Alice Springs, and Bloods Range to Lake Argyle.

3. A six seater plane will fly along the whole route, landing where and when planned. The plane will carry five people and the pilot. Two four wheel drive vehicles will provide ground transport and support for the plane passengers. The vehicles, each carrying at least two people, will be driven from Perth to Bloods Range and proceed north while the plane flies on to Alice Springs, and possibly Adelaide, before it returns past Bloods Range. The vehicles and plane will continue north to Kununurra and then return to Perth, via Wyndham, Derby and Broome.

   The plane will overfly tidal power and tankering port sites near Wyndham in the Cambridge Gulf, and tankering port sites at Black Rocks, north of Derby, Shoal Bay and Secure Bay. It will also overfly dam sites at Dimond Gorge and eleswhere in the Fitzroy River catchment on the way back to Perth from the Kimberley Region.

4. If any team members (eg. the Minister for Water Resources) visiting Alice Springs, and possibly Adelaide, need to fly directly back to Perth by commercial aircraft, their seats in the light plane could be filled from Giles by other members of the group. Provision has been made for this in the cost estimates.

## Estimated costs of a three week field trip for ten people

| | |
|---|---|
| Charter of six seater light plane - 9500 kms travel | 7 900 |
| Air travel - Alice Springs or Adelaide to Perth (2 @ $400/ticket) | 800 |
| Four wheel drive hire and running costs (2 Vehicles for 3 weeks) | 6 300 |
| Charter of a four seater helicopter for one day probably at Kununurra (6 hours @ $800/hour) | 4 800 |
| Charter of a boat for one day at Wyndham | 500 |
| Hotel and living costs (10 people for 6 nights @ $60/day) | 3 600 |
| Camping and living costs (10 people for 15 days @ $24/day) | 3 600 |
| Insurance | 1 000 |
| Other field costs (photography, hire of equipment etc.) | 2 000 |
| | $30 500 |

Notes

1. Field costs for members of any film crew accompanying the group could be kept fairly low since they would mainly travel as passengers in the four wheel drive vehicles, fully costed above.

2. No allowance has been made for participation by any persons representing the South Australian, Northern Territory and/or Commonwealth Governments. Should a decision be made to expand the group to include such persons or additional representatives from Western Australia a second light plane (four or six seater) will need to be chartered and at least one more four wheel drive vehicle hired. This would of course increase overall costs.

3. No allowance has been made for any payments for fees, fares, reports etc involving consultants, pilots etc.