Options for bringing water to PERTH from the KIMBERLEY

An Independent Review

Commissioned by:

Department of **the Premier and Cabinet**
Government of **Western Australia**

ACKNOWLEDGMENTS

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- Project team including: Jos Mensink, Gabrielle O'Dwyer, Nigel Goodall, Paul Byrne and David Gardner, in supporting the Panel to undertake its review.

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The purpose of this paper is to promote the findings of the Kimberley Expert Panel in assessing the feasibility of transporting water from the Kimberley to the South West of the State.

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FOREWORD

During December 2004, the State Government of Western Australia appointed an independent Panel of four experts to evaluate the technical and financial viability of transporting water from the Kimberley region to the IWSS region (Perth, Mandurah, Pinjarra, as well as communities located along the Perth to Kalgoorlie pipeline).

Their decision to appoint the Panel had been a response to growing concern about the capacity of existing local sources of water to meet ongoing increasing demand. Sustained decline in rainfall over several decades had seen dams located in the Darling Ranges less than forty per cent full, and concern being expressed about the consequences of drawing further on underground supplies, which had become the main source of supply for the metropolitan area.

The then-Premier of Western Australia, Dr. Geoff Gallop, expressed hope that the Panel's review would indicate, once and for all, whether Kimberley water was a viable new source of supply for the metropolitan region; also if so, which 'method' of transfer would be most appropriate; and the comparative cost of delivering water into the IWSS system. He also anticipated that the Panel's review would provide opportunity for interested parties to have their ideas and "alternatives" independently evaluated.

The composition of the panel brought together a wealth of expertise in the areas of: economics, engineering, environment and water expertise. The panel was well balanced and while protecting its independence was focused on the task at hand as per the terms of reference.

While the technical and financial viability of each option was a central focus of the Panel's terms of reference, equally important was the Panel's evaluation of social and environmental impacts. The Panel therefore sought consultancy reports on these impacts, and also consulted with the community in the Kimberley.

The Panel believes that its evaluation of the Kimberley water issue will be an important input for government policy decision-making regarding future water sources for the IWSS.

Reg Appleyard
Chairperson
Kimberley Water Supply Panel

THE KIMBERLEY EXPERT PANEL

Chair:

Professor Reg Appleyard

Emeritus Professor and Honorary Senior Research Fellow, Graduate School of Management (GSM), University of Western Australia (UWA). He was Professor of Economic History at UWA from 1967 to 1992, during which he held many important national and international advisory positions with CEDA, OECD, UNESCO, the International Organization for Migration (IOM) and UNHCR. Between 1993 and 1998 he was the Associate Director (Research) at the GSM. He is a Fellow of the Academy of the Social Sciences in Australia and in 1999 was appointed a Member of the Order of Australia.

KIMBERLEY EXPERT PANEL

Back row: *Professor Ian Lowe, Mr Jos Mensink (Executive Officer), Dr Don Blackmore*

Front Row: *Professor Reg Appleyard (Chair), Ms Gabrielle O'Dwyer (Senior Project Officer), Dr Beverley Ronalds*

Members:

Dr Beverley Ronalds

Chief of CSIRO's Petroleum Resources Division, Australian Resources Research Centre (ARRC), CSIRO.

Professor Ronalds has a distinguished career, both in research and in the application of that research to solving industry problems. Former Director and Woodside Chair with the University of Western Australia's School of Oil and Gas Engineering, Professor Ronalds has extensive industry experience including design, installation and operations support for fixed and floating offshore platforms in the Australian North West Shelf, the North Sea and the Gulf of Mexico. She is a fellow of the Australian Academy of Technological Sciences and Engineering.

Professor Ian Lowe

School of Science, Griffith University

Professor Lowe is now an emeritus professor at Griffith University where he was previously Head of the School of Science. He is President of the Australian Conservation Foundation, a Fellow of the Australian Academy of Technological Sciences and Engineering, and Vice-President of the Queensland Academy of Arts and Sciences. He chaired the advisory council that produced the first national report on the state of the environment in 1996 and delivered the 1991 Boyer Lectures for the ABC. In 2001 he was made an Officer of the Order of Australia and in 2003 was awarded the Centenary Medal for his significant contribution to the understanding of climate change and environmental issues.

Dr Don Blackmore

Don Blackmore has had 36 years experience in water and national resources management in Australia and in many countries around the world. He was Chief Executive of the Murray Darling Basin Commission for 15 years until his retirement in 2004; Deputy Chair of Land and Water Australia for 9 years; and a Commissioner on the World Commission on Dams. He is a Fellow of the Australian Academy of Technological Sciences and Engineering, and was made a Member of the Order of Australia (AM) in 2004. He also provides advice to the World Bank on the management of large river basins. Currently he chairs the Advisory Council for the CSIRO Flagship Program, "Water for a Healthy Country".

EXECUTIVE SUMMARY

Introduction

Reduced rainfall throughout the South West of Western Australia during the past 15 years, together with an increasing population, has created sustained interest in sourcing water from the State's Kimberley region.

Indeed the concept of transferring water to Perth from the Kimberley was a major issue at the last State election. In November 2004 the Government appointed an independent Expert Panel chaired by Emeritus Professor Reg Appleyard to review the feasibility of transporting water from the Kimberley region for inclusion into Water Corporation's Integrated Water Supply System (IWSS). The terms of reference for this review are contained in Section 2 of the Report.

After advertising both nationally and overseas, and canvassing ideas from the public, the Panel identified three possible transport options for delivering water from the Kimberley, which warranted further assessment by expert consultants. These options were by:

- pipeline;
- canal; and
- ocean transport, using either tankers or towed water bags.

The Panel then engaged consultants to evaluate delivery scenarios for the supply of 50 gigalitres (GL)/year, 100 GL/year, 200 GL/year, as well as one staged to meet the projected growth in demand for water that had been estimated by the Water Corporation as part of its strategic planning.

Analysis of technical aspects of the task was divided into five discrete elements:

- sourcing the water;
- supply by pipeline;
- supply by a canal;
- supply by ocean transport; and
- integration into the IWSS.

In engineering terms these were pre-feasibility studies designed to give an overall appreciation of the technical feasibility, implementation and operational risks and estimated costs of each option over a 50 year life cycle.

GHD Pty Ltd was selected to examine supply and delivery by pipeline and canal. Clough Engineering and Integrated Solutions (CEIS) was selected to examine the ocean transport option. These consultants were directed to take an optimistic approach to design, including likely new technologies that could reduce costs. They were also asked to estimate and evaluate the energy requirements and the consequential greenhouse gas emissions as well as the likely environmental and social impacts for each option.

As part of the process both Tenix Investments and Watering Australia Foundation were given access to the final relevant GHD report. Tenix elected to supply comments back to the Panel, which were forwarded to GHD for their review and advice to the Panel.

Based on this exchange of information the Panel recognises that there may be alternative options in regards to the design specifications for the canal, which would require further work. The advice received from GHD is based on current proven engineering practices to potable water supplies. The Panel believes that even with alternative design options this is not a viable option.

For background, the CSIRO provided its advice on existing water resources and operations of the Water Corporation, the Department of Environment provided information on groundwater resources in the Fitzroy River basin and Water Corporation provided information on integrating Kimberley water into the IWSS.

PANEL FINDINGS

Technical and Economic Issues

- The lowest cost option to supply water from the Kimberley to Perth by matching growth in water demand is through transporting water in super tankers. This was $6.70/kL, more than five times the cost of desalination.
- Incorporating a Kimberley water supply into the Water Corporation's IWSS may be expected to at least double the average annual household water bill, from $304 to over $610 per annum.
- To be competitive with other sources available to the Water Corporation, the cost of delivering water from the Kimberley would need to be reduced by 80 per cent. This was not seen as achievable by any of the options studied even taking an optimistic view of the development of new technologies in the future.
- Transporting water via a canal would be the most expensive and risk-prone option, in the context of providing a reliable water supply to urban consumers, and would have the greatest environmental impact.
- There are significant unknowns in operating a canal over such a distance, particularly with regard to the extreme cyclonic conditions that occur from time to time for a large section of its length.
- The pipeline option is based on proven engineering solutions and whilst its energy requirements are high it is the option that has the least exposure to risk and provides greater certainty for water quality.

- Whilst the water bag concept offered a unit cost comparable to super tankers, the concept would require considerable development to eliminate the design risks.
- The ocean transport options would consume more energy per kilolitre than the pipeline, canal or desalinisation plant and therefore would have the greatest greenhouse gas impact.
- Given the cost of the water from either a pipeline or canal (about 100 to 200 times more expensive than current prices for irrigation water) it could not be economically justified to use this water for any irrigation development along the proposed routes.

Environmental and Social Issues

- There is limited knowledge on the hydrogeology and ecology of the Kimberley region, in the Fitzroy River valley in particular.
- On the information available, the pipeline and canal options would require the construction of some storage in the Fitzroy valley, which could include a dam on the river and or some large off-stream storage towards the lower end of the river.
- The Indigenous Kimberley communities that would be affected did not support taking water from the region.
- The resolution of Native Title and land acquisition could be expected to take considerable time, particularly for the pipeline and canal options.
- The ocean transport option may be expected to have the least environmental impact to the land as it proposes to source its water from the Ord River, which has an existing dam. However, it generates approximately three times as much greenhouse gases as the pipeline or canal options.

Other Issues

- Renewable energy was not cost effective currently for transporting the water, other than for monitoring and valve and gate operation.
- The concept of sourcing water from the Officer Basin raised water quality issues and was not economic.
- The proposal to incorporate the G&AWS pipeline (from Kalgoorlie) into the schemes was examined and found to be impractical.

The following table outlines the comparative issues and values of the three transport options with 200 GL/year from day one of operation and up to 200 GL/year matching growth in water demand.

Table of Comparative Issues and Values

COMPARATIVE ISSUE	PIPELINE OPTION	CANAL OPTION	OCEAN TANKER	0.5 GL WATER BAG
Design Certainty	High	Uncertain	High	Unknown
Reliability of Supply	Acceptable	Unacceptable	Acceptable	Unknown
Source	Fitzroy	Fitzroy	Fitzroy/Ord	Fitzroy/Ord
Length of Delivery Chain	1900 km	3700 km	3000 km	3000 km
Water Quality Issues	Managed	Variable	Managed	Managed
200 GL/year Scenario				
Number of vessels to deliver 200 GL/year	N/A	N/A	14	35
Time in Transit (Days)	17	93	14	32
Energy Consumption kWhr/kL delivered	5.8	3.7	10.5	8.6
Greenhouse Gas Produced (Tonnes of CO_2 equivalent)	0.6 million	0.5 million	2.0 million	1.6 million
Costs from day one (200 GL/year)				
Capital Cost	$11.9B	$14.5B	$6.2B	$5.3B
Capital Cost (NPV)	$7.5B	$8.0B	$5.3B	$6.4B
Operating Cost (NPV)	$1.5B	$1.6B	$5.9B	$4.6B
Unit Cost of Water ($/kL)*	$5.1	$6.5	$5.0	$5.0
Cost for Demand Matching Scenario (20 GL/year increasing to 200 GL/year over 50 years)				
Capital Cost (NPV)	$4.5B	$8.0B	$2.7B	†
Operating Cost (NPV)	$0.6B	$1.6B	$2.5B	†
Unit Cost of Water ($/kL)*	$9.7	$20.5	$6.7	†

† Not Calculate

* Rounded to nearest ten cents.

The table shows that the lowest cost to deliver water under the 200 GL/year from day one scenario was $5.1/kL, by ocean transport options. By way of comparison the desalination plant currently being commissioned by the Water Corporation is expected to cost some $387 million and deliver 45 GL of water a year for $1.16/kL. Under the demand matching scenario, the lowest cost was $6.7/kL for the super tanker option.

Advice from the Sustainable Energy Development Office was that the energy required and greenhouse gas emitted in the 200 GL/year scenario over the 50-year period was estimated as 5.8 kilowatt hours per kilolitre (kWhr/kL) and 0.6 million tonnes of CO_2 equivalent for the pipeline compared to 10kwhr/kL and 2.0 million tonnes of CO_2 equivalent for the tanker option. The Kwinana desalination plant would require 4.5 kWhr/kL and generate 0.9 million tonnes of CO_2 equivalent for a production of 200 GL of water.

The tanker option clearly had a lower risk and the lowest cost of all scenarios. The pipeline, while of similar cost to ocean transport for the 200 GL/year option, is $2.60/kL more expensive than using tankers for the demand matching scenario. The canal option had a number of significant areas of risk and highest cost. The large water bag option had potential but a significant risk remained in developing the concept to a proven state.

Key Study Issues

Sourcing the Water

The Fitzroy River was the preferred water source for both pipeline and canal options. However, stream-flow is highly variable and in order to provide a consistent year-round water supply would require either a dam or large off-stream storage. Four alternatives for recovering water were considered by GHD:

- From a dam on the Margaret River, a tributary of the Fitzroy River, with water released to flow down the Fitzroy (termed “run of the river”) and pumped into a modest storage dam near the Willare Crossing,
- By pumping water directly from the river during high river flows at the Willare Barrage into off-stream storage;
- By pumping from the Willare Barrage during high river flows and extraction from a limited ground water borefield adjacent to the Fitzroy River into an offstream storage, and
- By extracting from an extended ground water borefield adjacent to the Fitzroy River into an off-stream storage.

Notwithstanding the Government’s “no dams” policy, the most economical solution determined by GHD was the construction of a dam on the Margaret River.

CEIS determined that the most viable option for ocean transport was to source water from the Ord River, with Lake Argyle providing the water storage. The development costs of accessing the Fitzroy and piping water offshore were substantially greater than the cost of sourcing water from the Ord River and piping it offshore despite the additional cost associated with the longer voyage.

Pipeline Option

After analysing several options, two pipeline routes were selected for detailed assessment:

- A direct route from an off-stream storage dam near the Willare Barrage on the Fitzroy River, following the Great Northern Highway for some 1900 kilometres, lifting the water 700 metres, and terminating at Westdale (80 kilometres south east of Perth) before discharging into Canning Dam.
- An indirect route of 2400 kilometres via Kalgoorlie (identified in the Watering Australia proposal) and linking with the Goldfields Pipeline.

As preliminary work showed that the direct route was a lower cost option it was used in the comparative analysis.

Canal Option

Both coastal and inland routes were examined for a canal;

- The coastal route runs for some 3700 kilometres, similar in length to the Tenix proposal, terminating at Lexis north of Perth, where the water would be treated and pumped into dams on the Darling Scarp.
- The inland route followed the coast from Willare to the De Grey River, near Port Hedland, pumped southeast in a rising main to Newman where it would flow by gravity to Westdale and discharge into Perth dams. This route was shorter and had reduced cross drainage issues but required 570 kilometres of rising main and a total lift of some 890 metres.

As the coastal route option with a dam on the Margaret River was the cheaper alternative, it was used in the comparative analysis.

Significant canal design issues included:

- Detailed surveys on two 20 kilometre sections, one at Whim Creek and one on the Zuytdorp Cliffs south of Carnarvon, were undertaken to provide sufficient data to design and cost the canal in varying terrain.
- Even with the use of best performance indicators, if operated for a full year it was estimated that a membrane and concrete-lined canal could lose some 125 GL/year regardless of the quantity of water delivered to Perth.
- Similarly some 93 GL/year could be lost from evaporation. Whilst a cover could reduce evaporation, the option was extremely expensive and an uncovered canal could deliver cheaper water and be easier to maintain.
- Flooding of the canal was a major risk factor given the many rivers and drainage lines, which would be traversed. In order to reduce the impact by flooding of these waterways, inverted siphons, flumes and culverts were included in the design. Despite the fact that the canal was designed to cope with the largest rainfall event expected every 100 years in each catchment, the canal crosses so many different catchments it is considered highly probable that the canal would be breached somewhere along its length every year.

Ocean Transport Option

Assessments by CEIS on the cost of sourcing water from the Ord against the Fitzroy Basin showed that the most economic system for the ocean transport option was to take water from upstream of Lake Kununurra on the Ord River. It was assumed that up to 200 GL was available from the Ord, but this would require further assessment.

Two concepts were considered, using conventional 0.5GL (500,000 dwt) capacity super tankers, and very large towed water bags. The difficulty in dealing with water bags was that they would be 15-20 times larger than those used elsewhere. While aspects of some water bag concepts have been tested, none has been applied to a bag of the size contemplated for the Kimberley project. However, the cost advantage due to increased scale was such that CEIS carried out an economic assessment even though the capital, operating and maintenance costs of such bags could only be conceptualised.

The shipping option has a number of advantages over the land-based options. Principal among these were the flexibility in quantity of water that could be delivered, and that the operation could be structured into discrete elements, so that they could be financed and managed separately.

Comparative Analysis

A comparative analysis of the water delivery options was carried out based on State Department of Treasury and Finance parameters specified for financial assessment of similar water supply projects to IWSS. Capital, operating costs and the unit cost of water are calculated in terms of net present value assuming a real pre-tax discount rate of six percent per annum over a project life of 50 years.

Environmental Issues

Throughout the study a number of environment issues were identified. Impacts were associated with:

- Source – modification of the Fitzroy River could result in similar impacts to those associated with damming of the Ord River and would significantly affect the floodplain's ability to support endemic and endangered species.
- Pipeline – Although buried, the construction and maintenance of service roads and pumping stations would be a permanent alteration to the landscape; route passages through RAMSAR wetlands; and high energy demands.
- Canal – The 3700 km structure following the coast would impact directly on some 330 square kilometres of land and create a permanent barrier across the country. Due to leakage and evaporation, it would need to draw at least twice the amount of water as other options considered. The potential for movement of biota along the length of the canal was also noted.
- Ocean – Generation of significant volumes of greenhouse gases and capacity to draw the required quantity of water from the Ord remained unresolved. It was noted that there were relatively fewer environmental issues than either the pipeline or canal.

Social Issues

The Panel focussed essentially on considering the technical and economic feasibility given the conceptual nature of the task. While a formal study of social impacts was not undertaken, the Panel consulted widely with Kimberley communities.

From these consultations it was established that the Kimberley community sought an outcome in which Kimberley water was not seen as a free or wasted resource, more development to be supported within its region as well as an increased awareness of the significance of environmental and cultural issues.

Indigenous communities who live along the Fitzroy River valley would be fundamentally impacted if the water was sourced from that river. All Aboriginal communities were critical if not hostile to the concept of taking water from the Fitzroy River to supplement Perth's water demand.

Other Issues

In addressing its terms of reference, the Panel received advice and drew conclusions on other issues related to the delivery of water from the Kimberley. These included:

- The scale of the concepts being examined ranked among the longest water transfer projects in the world.
- The use of the water en-route to Perth was not economically viable for irrigated agriculture, rehabilitation of native vegetation, or town and community water supplies.
- Renewable energy sources, whether solar or wind generated, were rejected as none could provide the quantity of power needed 24 hours every day. Backup power would be required, meaning an alternative power source would only be justified where the capital and operating costs of the alternative were less than the fuel saved with conventional power generation. Tidal power was also not considered an option as it would require transmission lines over a substantial distance.
- The concept of sourcing some water from the Officer Basin to the north east of Kalgoorlie was also considered. The Officer Basin option was rejected as the cost to deliver water into Kalgoorlie would be significantly higher than other supply options.
- Reversing the water flow in the Goldfields (G&AWS) pipeline to deliver water back down to Perth was considered. As the current pipeline has limited capacity and would require re-engineering with new pumps and re-configured pipework, it was concluded that it would be more cost effective to construct a new facility dedicated to the designed task. However, the concept of routing water from the Kimberley to Perth via Kalgoorlie was found to be less economically viable when compared to the direct route.

- Ocean transport was the only option that would retain a significant residual value, with the shipping fleet likely to attract a ready buyer on the international market.
- Kimberley water not only sits at the top of the cost of supply curve, it is at least five times the cost of other sources of supply. It is inevitable that if the State were to underwrite a project of this scale there would be a commensurate reduction in budget provision for other programs.
- The Panel recommends that before any commitment to further utilisation or amendment of the water resources of the Kimberley region (and the Fitzroy system in particular) is made, more research be undertaken on the hydrology and ecology of these natural systems.

Conclusion

As requested by the Premier, the Expert Panel has completed a review of the feasibility of transporting water from the Kimberley region to the Water Corporation's South West Integrated Water Supply System.

While several methods are technically capable of delivering water from the Kimberley to Perth, the water would cost much more (at least five times) than if supplied by other available options and offer no other significant advantages to the development of the State.

1 INTRODUCTION

During the last 15 to 30 years, several proposals have been put forward to bring water from the Kimberley to Perth. Declining rainfall and an increasing population has generated strong community interest in this issue. This was highlighted by the need to re-introduce water restrictions following a severe drought in 2001. The delivery of water from the Kimberley was also an issue at the last State election.

During November 2004, the Western Australian Government announced that it would initiate a study into the feasibility of suppling water from the Kimberley to the South West. In December 2004, it appointed a four member Expert Panel (the Panel) chaired by Emeritus Professor Reg Appleyard to independently review the feasibility of transporting water from the Kimberley region for inclusion into the Water Corporation's Integrated Water Supply System (IWSS)[1]. The Panel's report would provide Government with the information relating to the Kimberley option to be considered with other water supply alternatives.

The review provided for a public process involving a series of community presentations during and after the study to outline the findings of the evaluation process and to help the community understand the issues involved in analysing the Kimberley options.

The Expert Panel was asked to report its findings to the Western Australian Government by 31 March 2006.

[1] The Integrated Water Supply System (IWSS) is the integrated combination of surface and groundwater sources and their distribution system that services Perth, Mandurah and the Goldfields and Agricultural Water Supply.

2 TERMS OF REFERENCE

The five Terms of Reference given to the Panel were:

1. The Panel will call for submissions for the supply of water from the Kimberley region to supplement the Integrated Water Supply Scheme. The Panel is seeking significant proposals that can reliably deliver in excess of 50 gigalitres(GL)[2] of water per year.
2. The Panel may utilise the services of independent consultants during the evaluation of proposals. It is envisaged that consultants may assist through the provision of technical evaluation and report preparation.
3. The Panel will evaluate the Watering Australia proposal; the Tenix canal proposal and any other proposals received relating to the Kimberley region during the submission period.
4. The Panel will provide a report to Government on its findings by September 2005 (changed to 31 March, 2006 on 13 July 2005).
5. The Panel will, through the course of the evaluation process, undertake public consultation to ensure that the community is kept informed of progress and findings as appropriate.

[2] Gigalitre (GL) = 1 billion litres and is equivalent to 400 olympic sized swimming pools (Australian Water Association, 2004).

3 STUDY PROCESS

Given the variety of options for delivering water from the Kimberley, the Panel looked for an evaluation process that applied consistent criteria for each option. Following consideration of all aspects of its terms of reference, the Panel decided to adopt a two-stage process.

The first stage was to call for submissions to identify all viable concepts for the supply and delivery of water from the Kimberley to the South West. This was initiated through advertisements in Australian and international newspapers during January 2005. These sought expressions of interest from the public and organisations concerning concepts and ideas for supplying water from the Kimberley to Perth.

In response to the advertisements, thirty specific submissions were received. As well as the Watering Australia and Tenix proposals from the terms of reference, contributors ranged from interested members of the public to engineering professionals, organisations with innovative technologies and project developers. However, whilst the responses were wide ranging, the submissions were based on conceptualised projects. The Panel would like to thank all those who contributed through participation in the process.

The Panel carefully considered all submissions to determine a suite of options that warranted further investigation. More information was sought from eight of the 30 respondents to gather greater detail for further evaluation. This resulted in three possible transport options for the delivery of water from the Kimberley being examined. These were by:

- pipeline,
- canal, and
- ocean transport.

The Panel engaged independent consultants with expertise in the relevant disciplines to analyse these options, thus allowing a more comprehensive investigation of all variations put forward in each of the three transport concepts.

Independent consultants were selected by a public tender process. GHD Pty Ltd, engineering consultants, were selected to examine the supply and delivery by pipeline and canal. GHD was chosen for its extensive expertise in hydrology and water supply projects. Clough Engineering and Integrated Solutions (CEIS) was chosen to examine the ocean transport option given its experience in the marine and offshore oil and gas industry.

Whilst the terms of reference called for the delivery of at least 50 GL/year , given the projected growth in demand for water, and the specific proposals by Watering Australia and Tenix in the terms of reference, the Panel elected to consider supply scenarios[3] with capacity to deliver different quantities of water into the Water Corporation's IWSS. These were for delivery of 50,100 and 200 GL/year over a 50-year period from 2017. The 200 GL/year scenario was chosen because it approached the projected water demand expected after 50 years, and also matched the Tenix proposal. The Panel also considered a scenario that matched the growth in demand for water as projected by the Water Corporation. This scenario is referred to as the demand-matching scenario.

[3] Scenario refers to an outline of a particular circumstance. In this case, the circumstance varies from an individual analysis of a different volume of water (ranging from 50GL to 200GL) via each of the three transport options.

3.1 PRIMARY FOCUS (TECHNICAL AND ECONOMIC FEASIBILITY)

Public debate confirms that further knowledge and dissemination of the engineering and technical aspects of transporting water is essential to constructively engage the community on future discussions in regard to the viability of sourcing water from the Kimberley.

The Panel's task was, therefore, to establish:

- the technical requirements of options for delivering water,
- the viability of these options,
- the cost of delivering the water, and
- the advantages and disadvantages associated with each option.

To properly compare these options, and ultimately for the Government to be able to compare the Kimberley option with other source options, a standard financial model was used. This was one used by the Western Australian Government in which the total capital and operating costs (in net present value terms of real pre tax 2005 dollars) are expressed as dollars per kilolitre ($s/kL) of water delivered. The Panel also sought to calculate the consequential cost of this water to consumers if the Government elect to fully recover those costs.

However, given the conceptual nature of the task and the limited data available in certain areas, this study is essentially a preliminary or pre-feasibility study designed to identify the overall technical viability, cost and relative risk of the options. The Panel therefore directed the consultants to take an optimistic approach to design and estimation. For example, because the development of a scheme would take some years, consultants were required to take an optimistic view of future technologies that might be possible within the timeframe. Equally, the consultants were required to avoid adding too many contingencies into the design and cost estimates when allowing for uncertainties and lack of information.

3.2 SOCIAL AND ENVIRONMENTAL CONSIDERATIONS

The Panel was cognisant of the need to first establish the technical and economic feasibility of the concept. However, it was also aware of the broader range of environmental and social issues relating to the idea of transporting water from the Kimberley. Energy costs were also an important consideration in water management. As well as energy needed for the extraction, treatment and distribution, there is the collection, treatment and discharge of treated effluent. The Panel therefore instructed the consultants to provide advice on likely environmental and social aspects of each option being considered, the manner in which these could be addressed, an evaluation of the energy requirements of each option, the consequential greenhouse gas emissions for the different water volumes delivered and the approvals processes required.

4 BACKGROUND

In recent years real concern has been raised about the impact of climate change and the reduced rainfall in the Perth metropolitan region it is believed to have caused. Since the early 1970s, as shown in Figure 4.1, rainfall has been 14 per cent less than the long-term average, and for the seven years between 1997 and 2004, rainfall dropped by 21 per cent below the long-term average[4]. Of greater concern, because surface moisture needs to reach a sufficient level before runoff can occur, has been the decline in surface runoff into Perth dams. Surface runoff into the hills catchments fell by 52 per cent from 1975, and in the four years from 2001, runoff reduced by 88 per cent. Surface runoff in 2001 yielded only 40GL (CSIRO 2005, at Appendix 6).

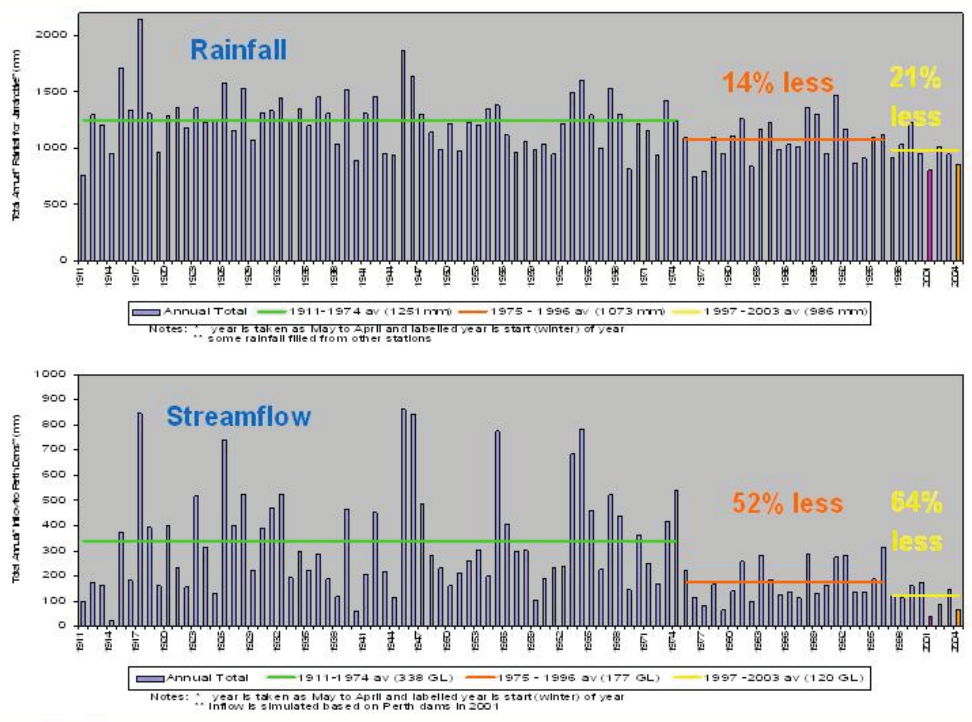

Figure 4.1 Reductions in rainfall and runoff into Perth dams. Percentage changes are relative to the 1911-1974 period (Water Corporation 2005)

Declining rainfall and runoff, together with expected population growth, has placed pressure on the supply of water necessary to meet likely demand. The Western Australia Government developed a State Water Strategy (2003), which outlined a multi-facetted approach to manage supply and demand. The objectives were:

- Water conservation and efficiency
- Water re-use
- New supplies and total water cycle management
- Innovation, research and education, and
- Resource protection and management

[4] Rainfall records for the Perth region were from 1911.

The Water Corporation in response has implemented a range of measures. On the supply side it has increased groundwater infiltration, accelerated the reuse of water, and improved transmission efficiencies. It has also upgraded security of supply by diversifying its supply source and is currently commissioning a climate-independent desalination plant.

To reduce demand, strategies include advertising to raise public awareness of the issue and the importance of using less, incentives to encourage water saving equipment, and the reintroduction of sprinkler restrictions. Currently, under the two days per week sprinkler roster, the IWSS supplies some 265 GL water per year.

Figure 4.2 Perth Water in the Swan River between the Narrows Bridge and the Causeway which varies in depth from less than 0.5 metres to 2.0 metres in dredged channels (the green shaded area) holds about 4.3 GL of water.

The Water Corporation's future planning is contained in the IWSS Source Development Plan for the period 2005-2050 (Water Corporation 2005). Current strategies planned or in place will add an additional 107 GL to available water sources. This is expected to maintain the demand/supply balance until at least 2017/18 (assuming a consumption of 155 kL/year per person as per the State Water Strategy). This includes supply of 45 GL/year from the desalination plant now under construction at Kwinana, 45 GL/year from South West Yarragadee and 17 GL/year from water trading. On current consumption trends, demand on the IWSS between 2017/18 and 2050 will require an additional 137 GL (Figure 4.3).

Water from the Kimberley region, like the desalination plant, has therefore been seen as an additional water source that is not dependant on the climate of the South West of Western Australia. However, management of water supply is an interactive process requiring a need to balance supply and quality with competing demands of the environment, industry, community and government. All options to increase supply come with costs, whether financial, environmental and or social. This report outlines the feasibility of Kimberley water as a supply option for the IWSS.

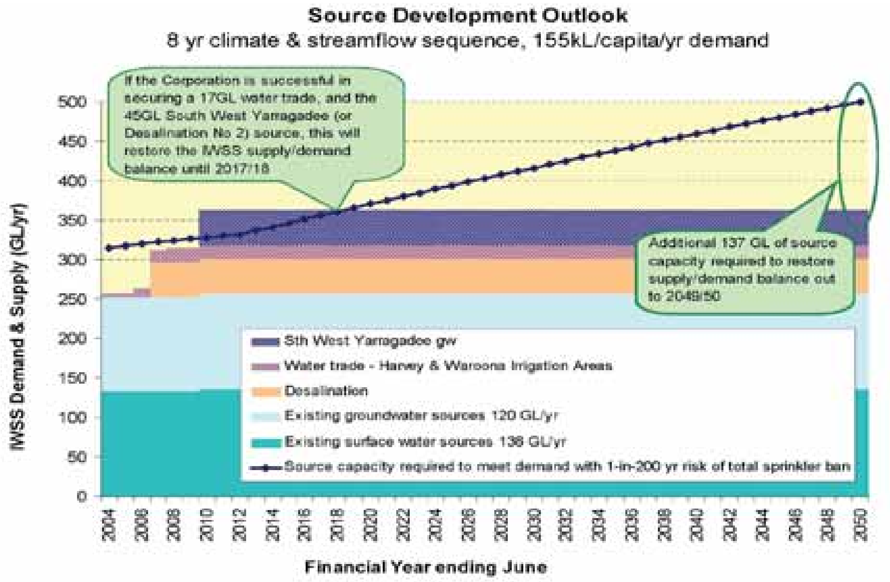

Figure 4.3 Source Development Outlook to 2050 (Water Corporation)

4.1 HISTORY

Since the establishment of the Goldfields and Agricultural Water Supply Scheme (G&AWS) during the 1890s, Western Australians have been familiar with the concept of transporting water between regions. The G&AWS scheme was built to meet the need for a water supply to service the then booming gold exploration and mining activity around Coolgardie and Kalgoorlie. At that time, the alternatives to a pipeline were to collect surface water and desalinate hyper-saline ground water by boiling and condensing the steam using locally sourced timber[5].

To put the G&AWS scheme into context, it was originally designed to deliver 5 million gallons/day (approximately 8 GL/year) over a distance of 540 km, using a 760mm diameter steel pipe and eight steam powered pumping stations. The cost was to be recovered by charging three shillings and six pence (3/6) per 1000 gallons for water delivered to the Goldfields (Evans 2001). However, because of the relatively high cost of the water, demand did not match supply, leading government to double the price of water, exacerbating the problem and causing financial difficulties for the government for a number of years (Blainey 1993).

The estimated cost of the project was 2.83 million pounds and was funded by a loan of 2.5 million pounds. This represented 80 per cent of the then State budget of 3.54 million pounds (2005-6 Budget Papers). This was for a population in Western Australia at the turn of the 20th century of 184,124 people (ABS), with approximately seven per cent living on the Eastern Goldfields. Western Australia now has a population of 1.9 million and a current State budget of $13.7 billion.

Since its construction, the original G&AWS has been substantially expanded to include distribution to agricultural areas. Of the 27 GL dispatched each year, 15 GL is delivered to Kalgoorlie. The scheme now draws more water than can be supplied from the Mundaring Weir and thus requires supplementation from other sources such as groundwater.

[5] Desalination technology used today, such as reverse osmosis, is more energy efficient.

4.2 WESTERN AUSTRALIA IN A NATIONAL CONTEXT

In 2004/05 the Water Corporation's Perth residential water customers (households) consumed on average 279 kL per year. Under current charging policies, water costs the average household $304.42 per year. Prior to the introduction of the two days a week sprinkler restriction in 2001, water consumption was 331 kL per household.

The annual average water consumption without restrictions, based on 1.8 people per household, is 180 kL per person. Since the introduction of restrictions this has been reduced to 155 kL. This is equal to the current target set out in the State Water Strategy. The Water Corporation is planning on the basis that with demand management through efficiency initiatives, education, greater re-use of water and without sprinkler restrictions consumption can be maintained at 155 kL per person into the future.

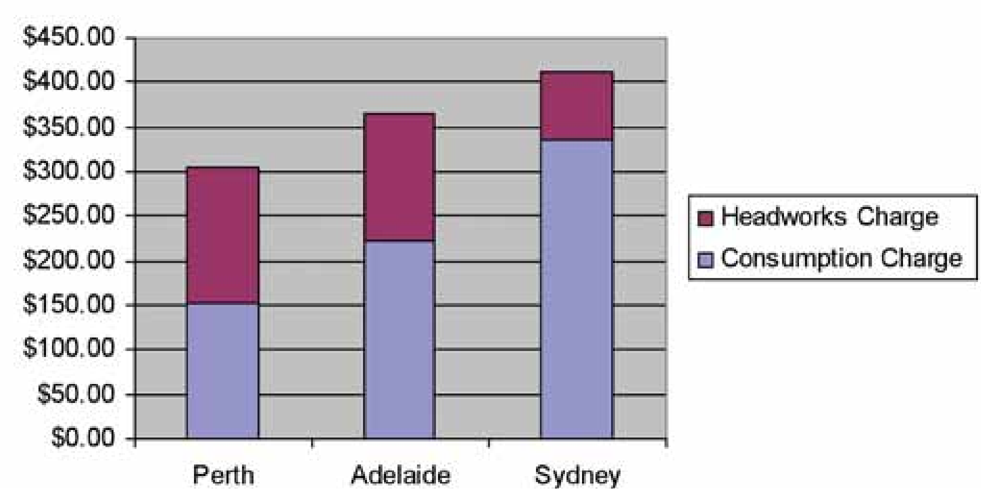

Figure 4.4 Comparative water consumption costs in Australia based on the average Perth household consumption of 279 GL/year in 2004/5.

Figure 4.4 highlights the comparative water costs for an equivalent 279 kL per year. Residential customers (households) in Adelaide pay an average $365.74 and those in Sydney $411.35 per year. It is useful to note that households in Adelaide, where climate is similar but drier than Perth, consume 234kL per household and pay $291.54 for water distributed by SA Water (SA Water). In addition, unlike other urban areas in Australia, some Perth residential customers have ready access to ground water with unregulated private bores from the superficial aquifer. This water can be considered recycled storm water that would otherwise discharge into wetlands, the river or ocean. It is estimated that about 112 GL/year of ground water is used to irrigate a third of Perth's gardens (CSIRO 2005). If this was included in average household consumption, Perth consumers would be using an average of 415 kL per year. Whilst a proportion of this borewater is used for public gardens and recreation areas, it is important to note that water consumption is significantly higher and water pricing lower for urban areas in Perth than Adelaide.

5 STUDIES UNDERTAKEN FOR THE REPORT

To undertake the task presented by Government, the Panel's first step was to determine the information available and then commission reports to assist in filling knowledge inadequacies. These reports, as well as many other published reports, have informed the Panel in its study.

5.1 PRIMARY STUDIES

- GHD undertook an analysis of the canal and pipeline options for the supply of Kimberley water. As part of its brief, GHD also developed the options for sourcing water from the Fitzroy River system[6]. Details of these findings are contained in the "Kimberley Pipeline Technical Review" (Appendix 1) and the "Kimberley Canal Technical Review" (Appendix 2).
- Clough Engineering and Integrated Solutions (CEIS) examined the various options for delivering water via ocean transport. Its report "Review Water Transport Proposals via Offshore" is attached as Appendix 3.
- The Water Corporation was requested to provide details on how water from the Kimberley could be integrated into the IWSS, and the related costs. The Water Corporation's response is contained in the report "Integration of Kimberley Water into the Integrated Water Supply Scheme" attached as Appendix 4. This report was provided to GHD and CEIS for consideration and inclusion in their studies.
- The Department of Environment was commissioned to assess the amount and quality of water available in the Fitzroy Basin. In the absence of a water planning and allocation process, a hydrogeological study was conducted drawing on existing drilling records and published papers. This study, "Hydrogeological Assessment of the Fitzroy Alluvium" by R P Lindsay and D P Commander, is attached as Appendix 5.

5.2 CONTEXT STUDIES

Other studies were commissioned by the Panel to provide the required information to place the issue into context for the community and Government:

- The CSIRO was commissioned to provide independent advice on the status of existing water resources and the operations of the Water Corporation to put into context the current Perth water supply system. Its report, "Context Report on South West Water Resources", is attached as Appendix 6.
- As part of its public consultation process, the Panel commissioned Beckwith Environmental Planning to examine Kimberley community views. Their report "Options for Transferring Water from the Kimberley – An Analysis of Kimberley Stakeholder Perspectives" is attached as Appendix 7.
- The Expert Panel agreed to support the Kimberley Appropriate Economies Roundtable held at Fitzroy Crossing during October 2005. Through participation, members of the Panel were able to gain further understanding of the needs and desires of the Kimberley community, especially the Indigenous community. The Interim Report of the Roundtable is attached as Appendix 8.

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[6] Previous studies had indicated that the costs associated with added pipeline or canal length made the Ord less economically viable than the Fitzroy for these options.

6 INTERNATIONAL STUDY TRIP

The concepts of transporting water from the Kimberley to Perth by canal or large towed water bags rank among the largest water transfer projects in the world. To better understand international best practice for such technologies, several Panel members visited large-scale inter-regional water transfer projects overseas.

6.1 UNITED STATES

During 2005, several Panel members visited the West Coast of the United States of America and inspected the All American Canal and the Coachella Canal in California's Imperial Valley region and the Californian Aqueduct near Sacramento. Panel members were briefed by the US Bureau of Reclamation on construction and maintenance practices, and water transfer issues for both canals and pipelines. Officials from the California State Department of Water Resources provided briefings on the Central Valley Project. They also investigated groundwater recharge practices.

In canal construction and operation, the most significant issues highlighted were losses due to leakage in canal operations and the need to ensure water quality on distribution. Canals inspected in the US generally carried significantly larger volumes of water, but over much shorter distances, than proposed for the Kimberley project.

The US Bureau of Reclamation's (USBR) experience with canals has been mixed. Spanning many decades of managing significant structures it showed the need for extensive regular maintenance, especially the removal of large amounts of silt. This mitigated against flexible linings for canals as the liners lifted under negative hydrostatic pressure when the canal was drained for maintenance and were potentially prone to damage when the canal was being cleaned. USBR's experience of canals lined with concrete was that the concrete liner tended to crack and cause leakage. For example, the Coachella Canal was initially installed with a flexible liner but refurbished with a concrete overlay. However, more recently, USBR's practice had reverted to using only concrete.

Cross drainage was noted as a major issue for Western Australia. However, surface water flow was not an overwhelming issue for the US canals inspected by the Panel. The need to take a canal out of service for repair and maintenance was seen as a major issue, particularly when the canal was required to supply a constant annual volume of water for an urban water market. Neither the USBR nor the Department of Water Resources used covers on their canal systems.

Figure 6.1 Coachella Canal USA

6.2 MEDITERRANEAN

The Panel members also visited several sites in the Mediterranean where ocean transfer operations use water bags. In Turkey they inspected the Manavgat water supply project, with special interest in the infrastructure requirements for exporting large volumes of water via water bags and tankers.

Although the Turkish facility was not operating during the members' visit, it had the potential to supply water to northern Cyprus and other countries. Its establishment and operation had been influenced by regional politics.

In Greece, they inspected the Aquarius operation at Piraeus. In service for the last seven years using water bags and aquatankers, the operation was relatively small, using only two 10,000 tonne (0.01 GL) polyurethane water bags delivering water over short distances. The firm had recently lost a water bag in a marine accident, and was operating only water tankers during the inspection visit.

The contract price of delivering the water 30 to 100 kilometres was $2.7/kL (1.7 euro/ kL). Anecdotal comment was made of a Norwegian operation in the region using 25,000 tonne bags, which had not been successful. Given the nature and magnitude of the Kimberley operation, the operators of the water transport business in Greece suggested that additional research would be required on the large bag option before this could be considered as a viable alternative to tankers.

7 DESCRIPTION OF THE OPTIONS

The Panel separated its analysis of the technical aspects of the task into five discrete elements:

- Sourcing the water;
- Supply by pipeline;
- Supply by canal;
- Supply by ocean transport; and
- Integration into the IWSS.

GHD undertook a study of sourcing the water from the Fitzroy River basin and delivery by pipeline and canal. CEIS examined the ocean transport option and, in addition, considered sourcing from the Ord River. GHD and CEIS were directed to include issues and costs associated with the sourcing of water and its integration into the IWSS for each transport option.

7.1 WATER SOURCING ISSUES

7.1.1 Fitzroy River

As the closest Kimberley water resource to Perth, the Fitzroy River was seen as potentially the preferred water source for both pipeline and canal. Previous studies by Binnie (1988) and the IDC (1990) had proposed sourcing water from a dam to be built on the Fitzroy River at Dimond Gorge (considered the best site for a dam structure to supply the volumes of water contemplated). However, Dimond Gorge is deemed a tourist attraction and strong connections with the river makes it highly valued by the local community.

Whilst the Government adopted a "no dams" policy in 2001, there would be significant cost savings by drawing water from a dam on the river. The consultants in taking a financially optimistic approach have evaluated a site on the Margaret River, a tributary of the Fitzroy River, because of its engineering and cost advantages.

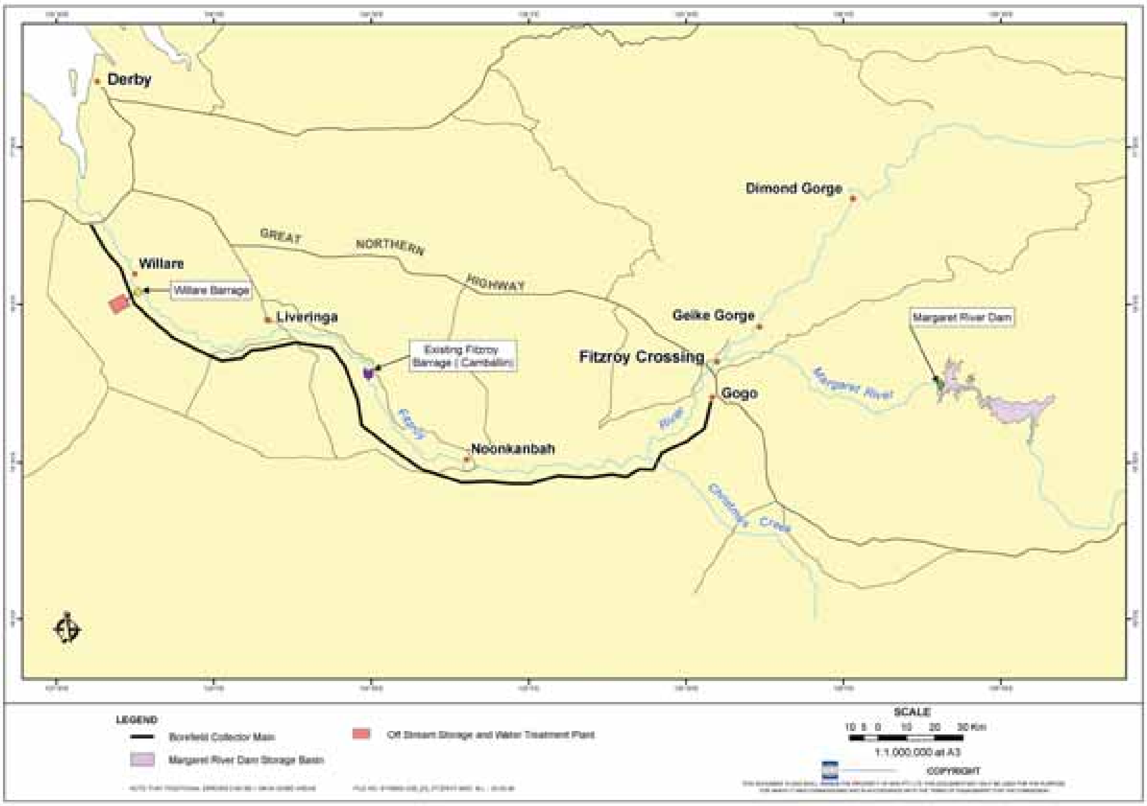

Figure 7.1 Water Source Options from the Fitzroy River System

GHD studied a range of concepts including damming the river and using a barrage with off-stream storage, as well as gathering groundwater from borefields.

Figure 7.2 illustrates that streamflow in the Fitzroy is highly seasonal with significant annual variability. Indeed, 2005, the year of the Panel's investigations, was a relatively dry year.

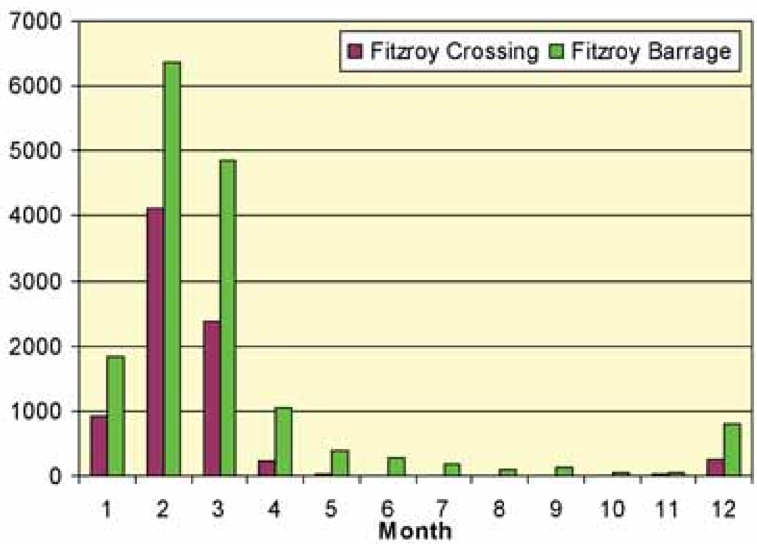

Figure 7.2 Monthly Distribution of Streamflow in the Fitzroy River for the Period 1987 to 2004.

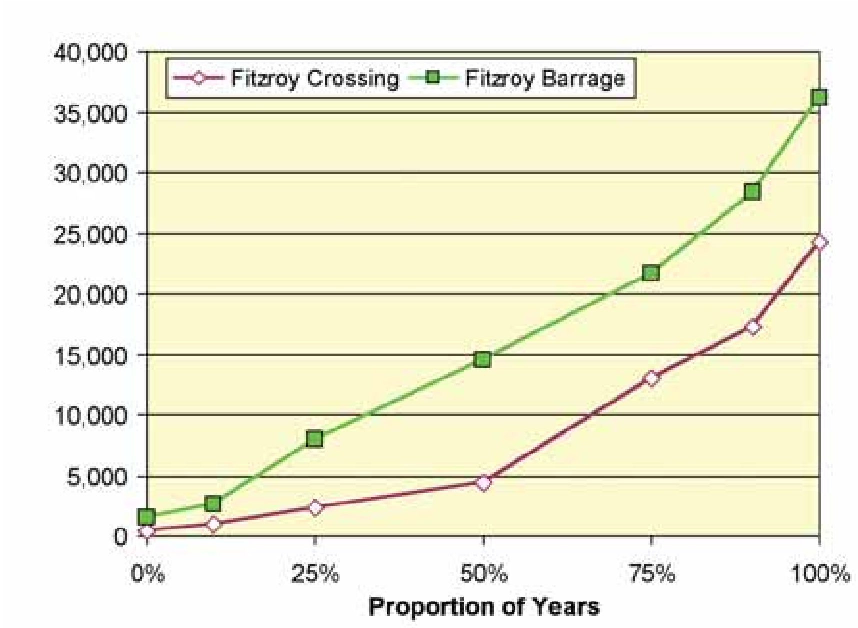

Figure 7.3 Annual Streamflow Variability at Fitzroy Crossing and Fitzroy Barrage (Liveringa) showing the proportion of years the streamflow is less than the volume shown. (e.g. 1 year in 4 the flow at Liveringa is less than 8000 GL).

Given the extreme variability of the Fitzroy's streamflow, both seasonally and from year to year, each option considered for taking water from the Fitzroy River called for storage either by a dam on the river or by off-stream storage. The following sourcing alternatives were considered.

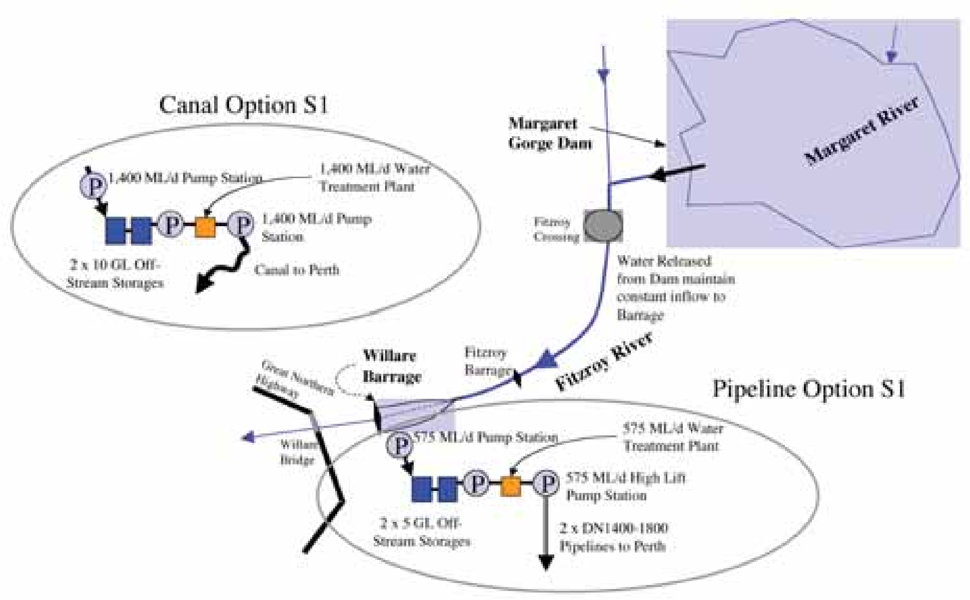

Figure 7.4a Source Alternative S1 - A dam on the Margaret River.

Alternative S1 is for a dam on the Margaret River, with water released to flow down the Fitzroy (termed "run of the river") and pumped out at a barrage near the Willare Crossing. The significant issues with this alternative are the impact from headwaters of the dam and the modification of the Fitzroy River downstream from the dam, where the flow would change to a regulated environment with less flooding and a constant baseline flow.

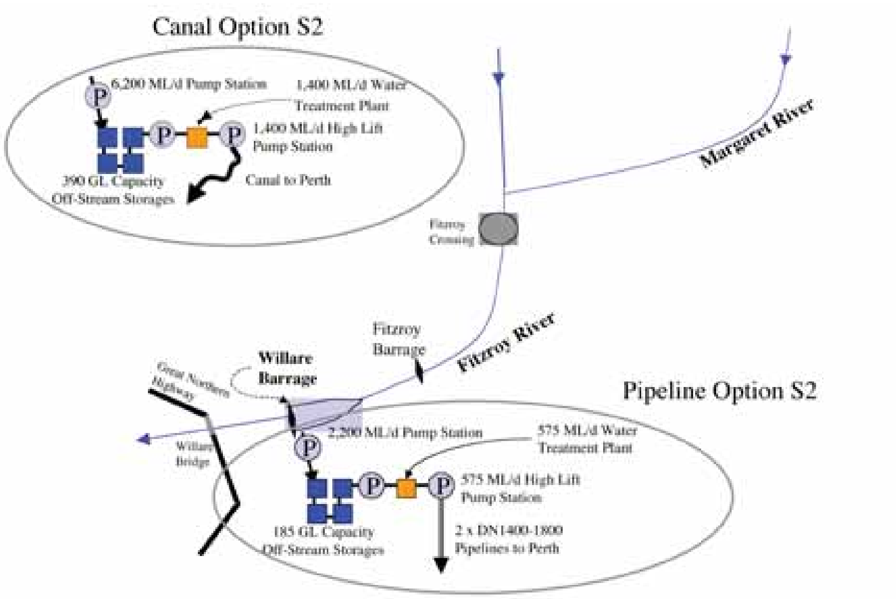

Figure 7.4b Source Alternative S2 - By pumping water directly from the river.

Alternative S2 is by pumping water directly from the river during high river flows at the Willare Barrage into an off-site storage facility and then into the pipeline/canal. Whilst the river flow upstream from Willare would be largely unaffected by this alternative, the construction of the very large off-stream storage dams would have a significant impact on the local area.

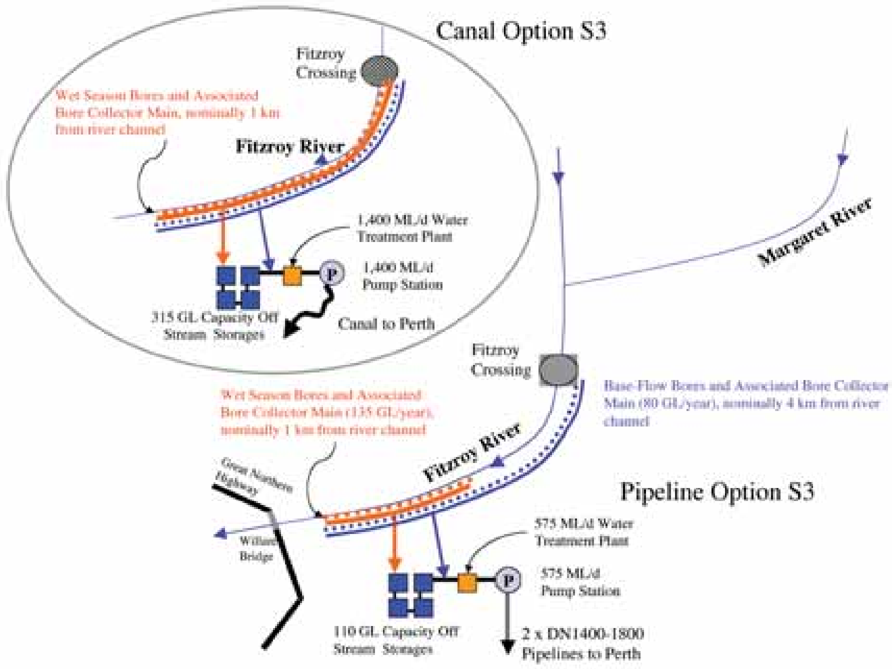

Figure 7.4c Source Alternative S3 - By pumping during high river flows and extraction from a limited ground water borefield.

Alternative S3 is by pumping from the Willare Barrage during high river flows and extracting from a partial ground water borefield adjacent to the Fitzroy River into an off-site storage impoundment and then into the pipeline/canal. While the off-stream storage is less than alternative S2, it would still be substantial with the added impact of a borefield along the river.

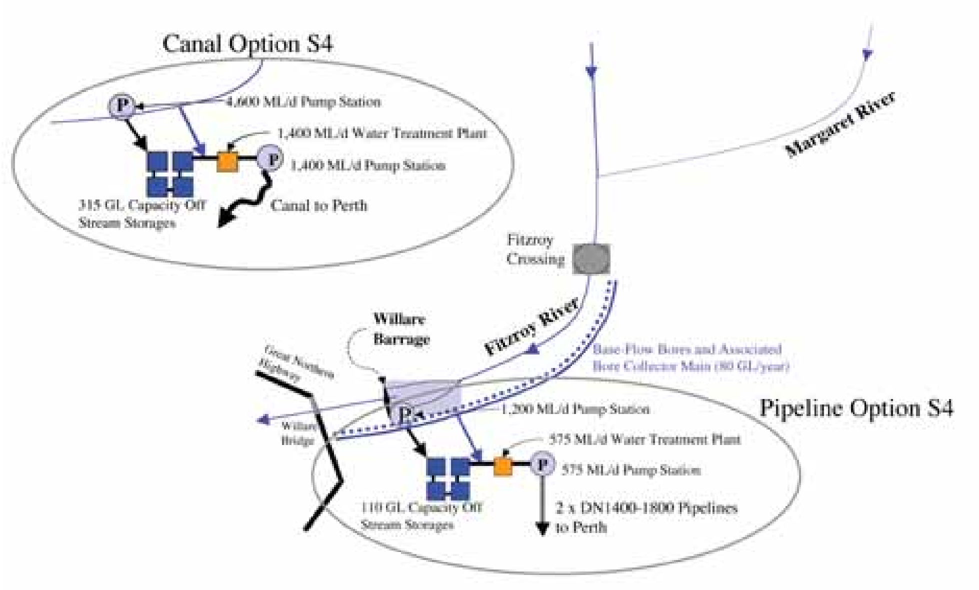

Figure 7.4d Source Alternative S4 - Extraction from a ground water borefield.

Alternative S4 is for extracting from an extended ground water borefield adjacent to the Fitzroy River and pumping into an off-site storage impoundment, then into the pipeline/canal. In addition to off-stream storage, this alternative would require a borefield extending along some 180 kilometres of the Fitzroy River basin.

The design for ground water extraction was based on the work done by Lindsay and Commander (Appendix 5). However, salinity in the alluvial aquifer is poorly understood. Indications from dry season flows are that parts of the alluvium contain groundwater exceeding 500 mg/L, partly as a result of discharge from underlying regional aquifers. As a result, extraction may have to be extended over a larger area to obtain the required water quality.

7.1.1.1 Off-Stream Storage

For the source alternative (S1) incorporating a dam, off-stream storage prior to pumping into the canal or pipeline would be relatively modest at between 10 GL and 20 GL. However, for the no-dam alternative, the size of the off-stream storage was estimated to be from 110 GL to 390 GL, depending on the extraction and transport option utilised and the volume of water to be delivered. An off-stream dam for storage of 110 GL would need to be more than two kilometres on each side, 30 metres deep and lined to limit seepage losses. The volume of earthworks required would be some 16 to 20 million cubic metres. A 390 GL storage would require a series of dams totalling more than 16 square kilometres in area, 30 metres deep and more than 70 million cubic metres of earthworks.

A significant constraint with source alternatives relying solely on off-stream storage would be the cost of constructing the dams. GHD estimated that it would cost some $0.6 billion to construct a 390 GL facility. For this reason, canal and pipeline options utilising a dam on the river were significantly cheaper and, hence, used by GHD for comparative analysis.

7.1.2 Ord River

The ocean transport option had more flexibility in its source option. The cost of taking water from the Fitzroy River, and piping it to an offshore loading facility was greater than the additional transport cost to access water from the Ord River. CEIS therefore opted to source the water from Lake Kununurra on the Ord River. This had the advantage of proximity to established infrastructure as well as a relatively short distance to pipe the water to an off-shore loading facility.

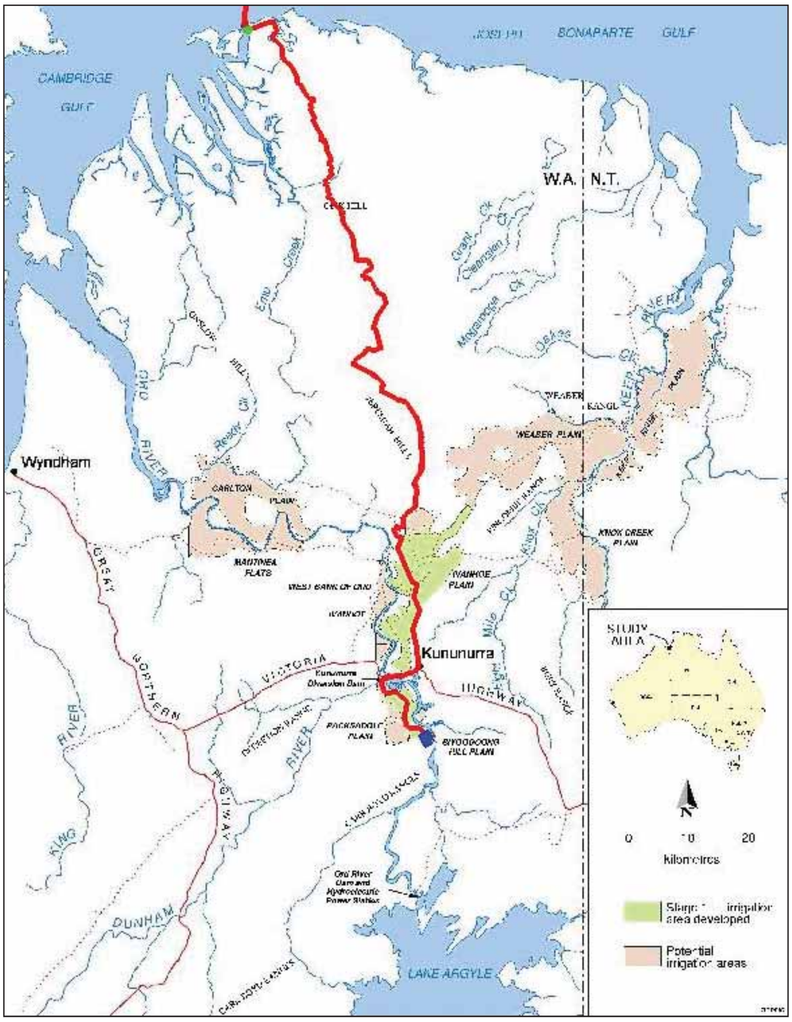

Figure 7.5 Sourcing Water from the Ord River and Piped to an Offshore Loading Facility Located in Joseph Bonaparte Gulf.

Irrigated agriculture began in the Ord River Irrigation Area (ORIA) in 1963 when the Kununurra Diversion Dam was completed. The Diversion Dam formed Lake Kununurra, and enables water to be diverted from the Ord River and distributed to irrigators in the ORIA. However, it has insufficient storage (capacity of 100GL) to ensure a reliable water supply for the ORIA. The Ord River Dam, located 60 km upstream, was completed in 1972 to provide the necessary storage. The resulting lake, Lake Argyle, had an initial storage capacity of 5800 GL (to the base of the spillway). A 30 MW hydroelectric power station was constructed at the Ord River Dam in 1996 to supply the electricity demands of Argyle Diamond Mines and the towns of Kununurra and Wyndham. As part of this development, the spillway base was raised six metres which increased Lake Argyle's storage capacity to10,700 GL.

Since 1996, releases from Lake Argyle have been dominated by the power station demand. Quantities released for power generation are typically between 1800 and 2100 GL/year, depending on the water level in Lake Argyle and the power demand on the station. The water diverted at Lake Kununurra in the last two years (to the end of October 2005) has ranged between 305 and 330 GL/year[7] and used to irrigate approximately 12,000 ha[8] in the ORIA.

The State Government is well advanced in planning the development of the Stage 2 -M2 Channel Supply Area. The full project involves establishing 30,000 ha of additional farmland, although it is likely to be developed in stages. The Department of Water has said that an initial 400 GL/year is planned to be available for new diversions from Lake Kununurra. A further 115 GL/year is to be made available for diversion from the lower Ord River, downstream of House Roof Hill, approximately 58 km below the Kununurra Diversion Dam. These initial allocations reflect the need to maintain sufficient flows in the lower Ord River to protect the riverine environment and existing commitments for generating hydroelectric power at the Ord River Dam. The Department of Water is preparing a Water Allocation Plan for the Ord River, detailing the basis of these allocations. This is due for release by mid 2006.

Elements of the plan are to be reviewed and updated over the subsequent 12 to 18 months. These include updating knowledge of the hydrology of the Ord River catchment and completion of a comprehensive assessment of the current environmental water requirements (EWRs) for the lower Ord River.

The amount of water available beyond that already allocated to the environment and ORIA would depend on the water demand for crops on the ORIA with the added constraint of providing sufficient water to meet the requirements for hydro electricity generation. It has been assumed for the purposes of this study that up to 200 GL could be taken from the river upstream of the Diversion Dam. This would require further study to determine the actual allocation available. CEIS proposed construction of an intake structure upstream from Lake Kununurra, which would minimise the potential for contamination from agricultural activities, and therefore treatment costs.

[7] Irrigators that pump directly from the Ord River or Lake Kununurra divert approximately 7-8 GL/year. Depending on the wet season, Water Corporation diverts about 4 GL/year to flush and fill the M1 Channel. The remainder is diverted by the Ord Irrigation Cooperative.

[8] This includes irrigated areas supplied by the Ord Irrigation Cooperative and areas supplied by water pumped directly from the river.

7.2 PIPELINE OPTION

7.2.1 Design Concept

In keeping with the study brief, the focus was on using the best pipeline design principles but with an optimal design to technology advances. As construction would be some years away, following a lengthy approvals process, the latest trends in pipeline design as well as anticipated potential improvements such as higher pressure rubber-ringed jointing were incorporated.

7.2.2 Pipeline Route

Two routes were considered. The first was a direct route starting at the off-stream storage dam near the Willare Barrage on the Fitzroy River and following the Great Northern Highway for some 1900 kilometres. This route would require the water to be lifted up to 700 metres and it would terminate at Westdale, 80 kilometres south east of Perth, where the water would be released into Canning Dam.

The second, indirect route of 2400 kilometres, via Kalgoorlie and the G&AWS Pipeline was proposed in the Watering Australia concept. In addition, a staged approach that initially took water from the Officer Basin and later linked with the indirect route from the Kimberley was considered but dismissed. This option is discussed at Section 15.3.

Being 500 kilometres longer, the option that included the G&AWS was significantly more expensive. As preliminary work showed that the direct route was cheaper, it was chosen for the comparative analysis. The issue of reversing the G&AWS pipeline is addressed in Section 15.4.

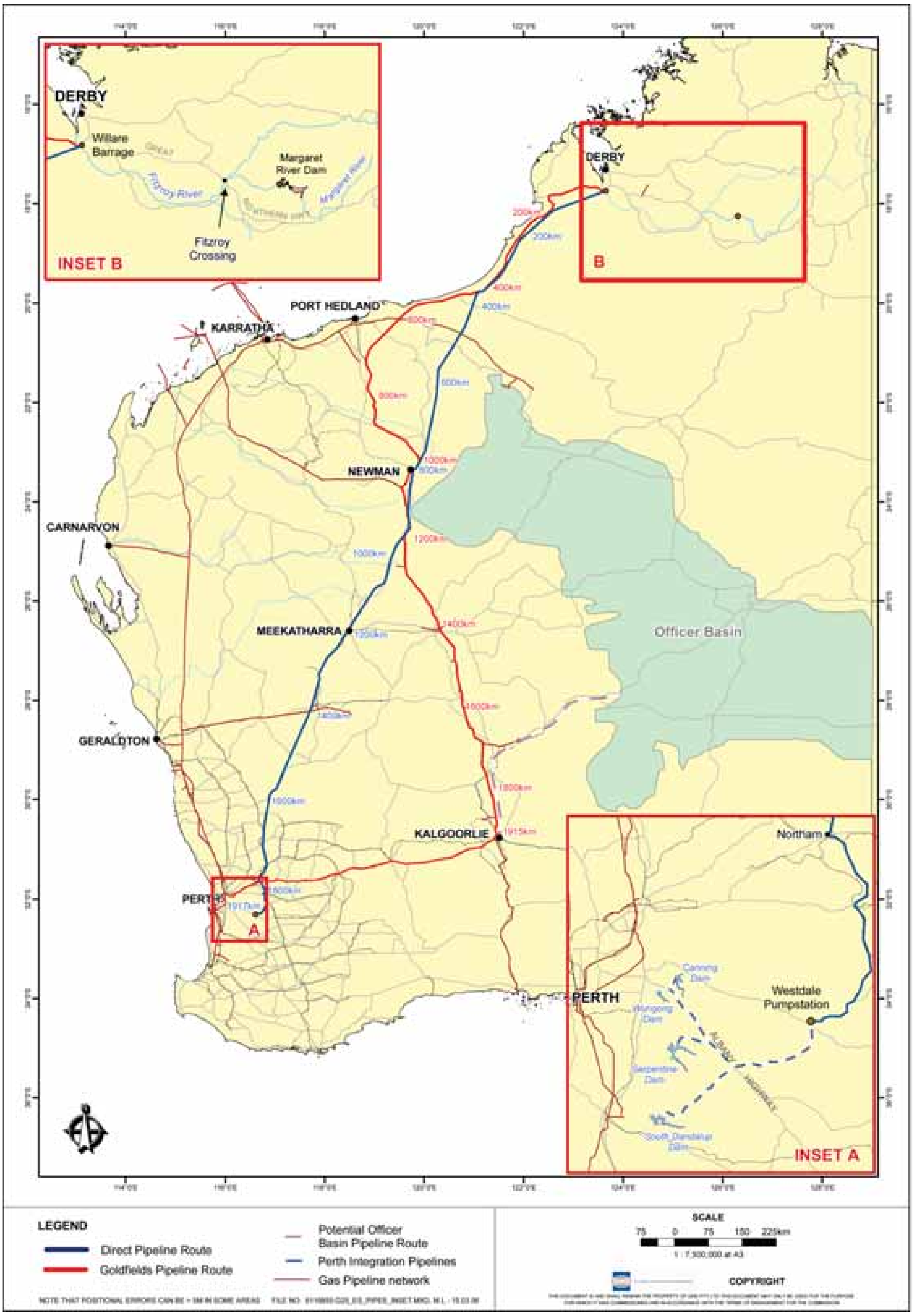

Figure 7.6 Pipeline Route Options

7.2.3 Pipeline Design

Pipeline design is a balance between capital cost, which is largely pipe size, versus the cost of energy needed to overcome pipe friction. The GHD study considered a range of pipe sizes depending on demand scenario and capital cost. Options considered were for 1400mm, 1600mm and 1800mm diameter steel concrete-lined pipes. For reasons of security, the impact on land and water quality, the pipeline would be buried. The pipeline corridor would be 50 metres wide.

The design for the 100 GL/year and 200 GL/year scenarios was straightforward. However, the key criteria for the scenario of matching delivery to the IWSS demand meant minimising the front-end capital cost whilst matching supply with demand growth. In the 100 GL/year and 200 GL/year cases, GHD elected to use one and two 1800mm diameter concrete-lined steel pipes with rubber ring joints. The demand matching design called for two 1600mm pipes, with the second pipe and pumping capacity incrementally added to meet demand.

Figure 7.7 Overland Pipeline Installation (Image courtesy of CEIS).

The design incorporated rubber-ringed jointing operating at a maximum head of 350 metres. This is not current industry practice, but was expected to be adopted in the foreseeable future. The higher pressure would allow for fewer pump stations.

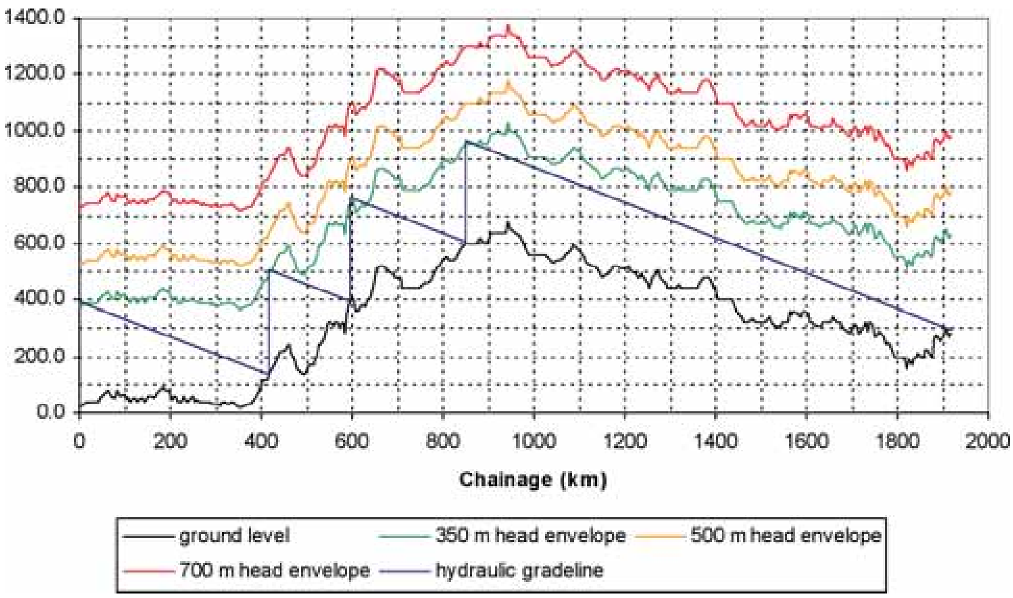

Figure 7.8 Hydraulic Profile of the Direct Route for the 100 GL/year and 200 GL/year Scenarios.

The preliminary design of the direct route called for four pump stations for the 100 GL/year and 200 GL/year scenarios (Figure 7.8), while the demand-matching scenario called ultimately for seven pump stations. The difference is because of the greater friction losses with smaller pipes. However, the need for additional pumping would be necessary only in the later years, thereby delaying capital expenditure. The power consumption over time for the 100 GL/year and the 200 GL/year options would be 5.78 kWhr/kL, whereas for the demand scenario it would peak at 12 kWhr/kL before the construction of a second pipe was warranted. This is illustrated in Figure 7.9 below.

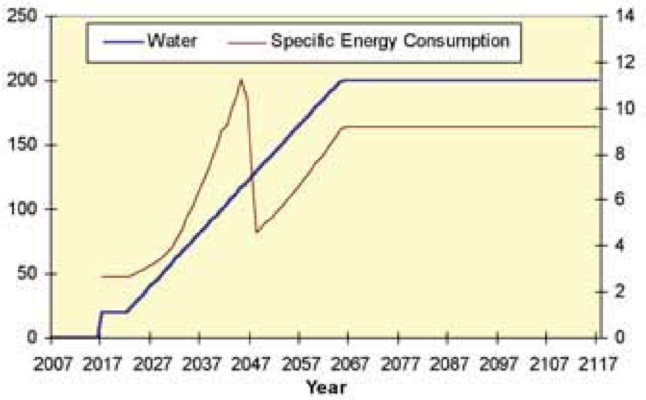

Figure 7.9 Specific Energy Consumption for the Demand Scenario (The spike is the peak energy consumption prior to pipe duplication).

Power demand along the route would vary depending upon the scheme adopted and pump station locations. However, the least cost scheme would require 100 MW at the source headworks at Fitzroy, and 30 MW for each pump station along the route. Due to the power demand and remote location, the most economic energy source would be a natural gas pipeline from the North West Shelf. The opportunity for renewable energy supply was considered and is addressed in Section 15.2.

7.2.4 Water Treatment

The proposed primary water treatment would be at the Fitzroy River off-stream storage pump station. In keeping with water industry practice, water would be treated to a high level to minimise deterioration in transit and ensure compatibility with the water quality in Perth dams. Prior to dispatch, the source water would therefore be subjected to:

- Screening;
- Coagulation, sedimentation and granular media filtration;
- Disinfection; and
- Lime and carbon dosing.

Given the length of the pipeline and concern with potential algal growth, it was expected that a booster chloranimation treatment plant midway along the pipeline would be required.

At Westdale it was likely that treatment by dissolved air floatation/filtration followed by ozone and granular activated carbon filtration would be required.

Although the water treatment proposed is conventional industry practice, the specific methods to be used would depend on a detail design analysis.

7.2.5 Pipeline Financial Summary

The unit water costs calculated for the assumed Kimberley Pipeline development concept using the base case cost estimates, and assuming a real pre-tax discount rate of six per cent per year, are summarised in Tables 7.1, 7.2 and 7.3.

Item	Unit Water Cost (2005$/kL)		
	Capital^	O&M*	Total
Source Headworks	1.07	0.17	1.24
Kimberley Pipeline	7.23	0.84	8.07
Integration Works	0.35	0.07	0.41
Total	**8.64**	**1.08**	**9.72**

^ Including capital replacement costs.

* Operating and maintenance costs.

Table 7.1 Unit Water Costs Ignoring Residual Asset Value: Staged Demand. (Initial 20 GL/year, Increasing to 200 GL/year).

Item	Unit Water Cost (2005$/kL)		
	Capital^	O&M*	Total
Source Headworks	0.37	0.14	0.51
Kimberley Pipeline	3.77	0.58	4.35
Integration Works	0.19	0.09	0.27
Total	**4.33**	**0.81**	**5.14**

^ Including capital replacement costs.

* Operating and maintenance costs.

Table 7.2 Unit Water Costs Ignoring Residual Asset Value: Constant 200 GL/year Demand.

Item	Unit Water Cost (2005$/kL)		
	Capital^	O&M*	Total
Source Headworks	0.64	0.15	0.79
Kimberley Pipeline	4.20	0.66	4.86
Integration Works	0.16	0.08	0.24
Total	**5.00**	**0.90**	**5.90**

^ Including capital replacement costs.

* Operating and maintenance costs.

Table 7.3 Unit Water Costs Ignoring Residual Asset Value: Constant 100 GL/year Demand.

Tables 7.1, 7.2 and 7.3 exclude the residual value of the pipeline assets. As a result, the price of water is marginally higher than used in the comparative analysis.

7.3 CANAL OPTION

GHD undertook a technical review of the proposal to deliver water via canal. As an open system, canals raise a number of significant issues that need to be addressed. Because canals have to follow the contour of the country, location is dictated by landform and is therefore relatively inflexible. Also, a canal becomes a permanent barrier across the land, which interrupts the natural surface water flow and impacts on existing land use. Canals also suffer significant losses in transmission from evaporation and leakage. As a result, at least twice the volume of water needs to be dispatched into the canal than for the pipe or ocean transport options to deliver the required volume to Perth. In addition, unlike a pipeline or ocean transport where multiple pipes or vessels could be used, the canal, as a single structure, would need to be sized in order to deliver the maximum 200 GL/year from day one. Figure 7.13 illustrates a schematic of the canal.

7.3.1 Canal Route Selection

After initial assessment of potential routes, the GHD study considered two alternative routes: coastal and inland. The coastal route would run for some 3700 kilometres[9], which was similar in length to the Tenix[10] concept. It would require eight pump stations with 127 kilometres of rising main[11] giving a total lift of 450-500 metres. Other piped sections would be required as inverted siphons in order to pass the canal water under the larger rivers and watercourses. The canal would terminate at Lexia north of Perth, where the water would be treated and then pumped via a pipeline into Water Corporation dams on the Darling Scarp.

The inland route would follow the coast from Willare to the De Grey River, near Port Hedland, where the water would be pumped south east in a rising main to Newman. There it would be re-introduced into a canal to flow by gravity to Westdale before flowing into the Perth dams. Here the canal would run into a holding dam, where the water would be treated and fed into the main dams. This route was shorter and had reduced cross drainage issues but required 570 kilometres of rising main and a total lift of some 890 metres. Requiring significantly more energy.

Although a more definitive study would be required to select the final route, given the length of piping and higher pumping demand for the inland route, the coastal route option, with a dam as the source alternative was used in the comparative analysis.

9 While a direct route would be some 2000 km, the 3700 km reflects the necessity to follow the land contour.

10 The Tenix proposal was part of the terms of reference.

11 Rising mains are piped sections at strategic locations, where the canal water has to be lifted to enable the water to continue flowing by gravity.

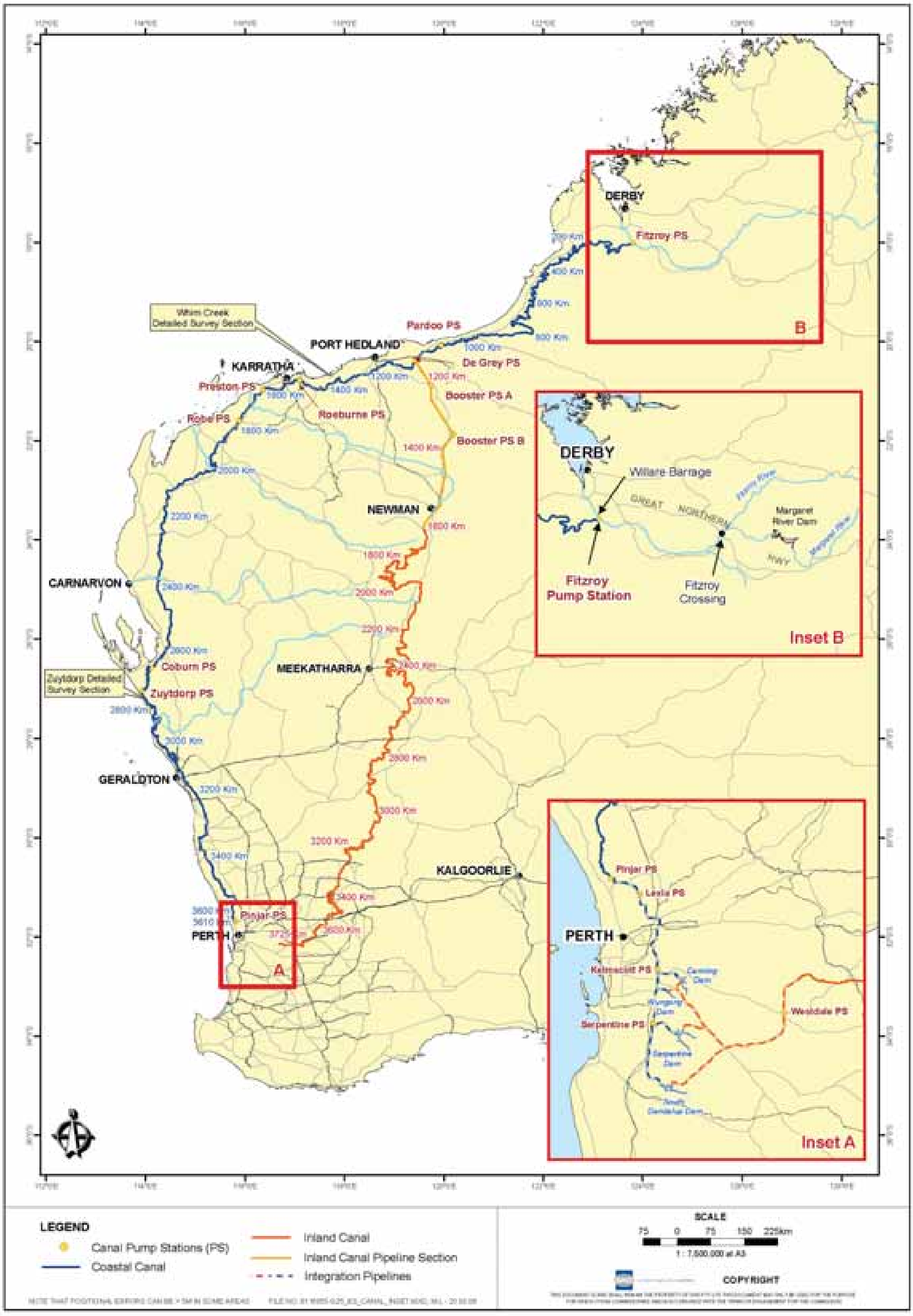

Figure 7.10 Canal Route Options

7.3.2 Canal Design

GHD undertook a conceptual canal design, which considered the canal shape and fall, or gradient, so that it could deliver water under a range of flows and velocities. The design sought to minimise fall along the route in order to keep pumping to a minimum, whilst also ensuring that velocity was kept within limits that avoided scouring or stagnation. Figure 7.12 illustrates the hydraulic profile of the canal. The flow parameters include accounting for losses due to evaporation and leakage under different climatic conditions as the water traversed the canal, which was designed for the 200 GL/year option. Where lesser volumes were required they could be delivered by shorter operating times or lower flow rates.

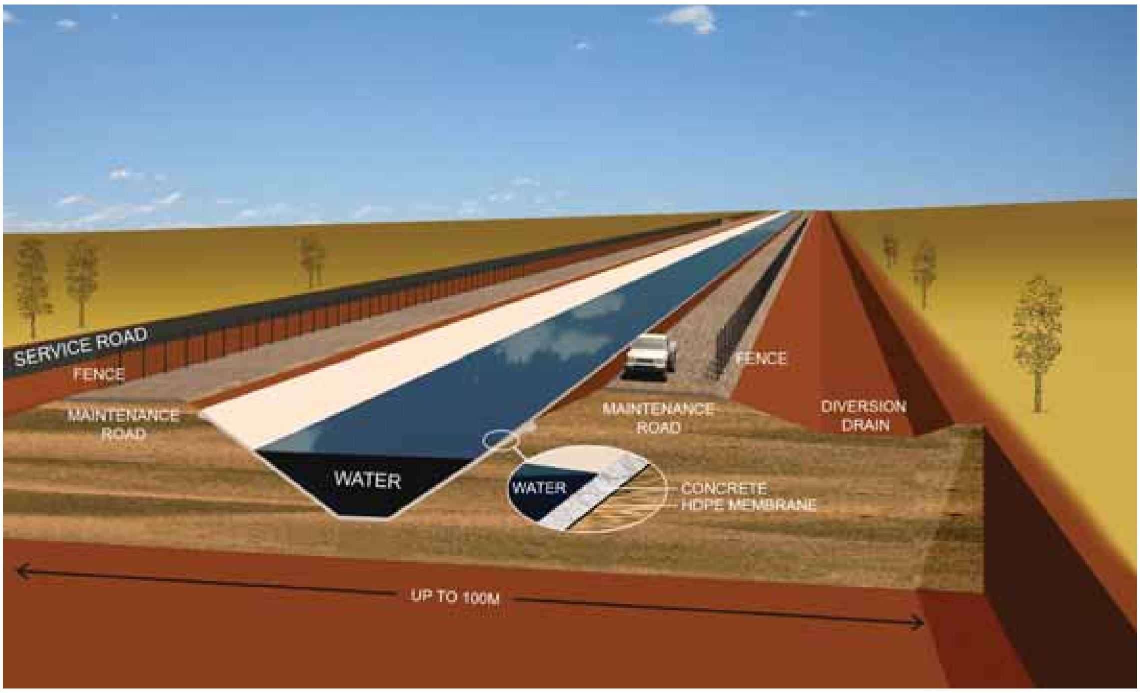

Figure 7.11 Diagrammatic Cross Section of the Proposed Canal.

The concept considered was for the canal to begin at the off-stream storage near the barrage at Willare on the Fitzroy River. It would follow the contour of the land in a 100 metre wide corridor, be fenced to exclude stock and native animals, but include crossings for people, wildlife and stock. Where the canal intersected with natural watercourses, structures such as siphons and flumes would be built. For the large watercourses the canal would be siphoned under the riverbed. On smaller catchments, diversion drains on the up-stream side of the canal, would divert the surface water run-off to culverts or flumes to avoid contaminating the canal water with surface water and sediment.

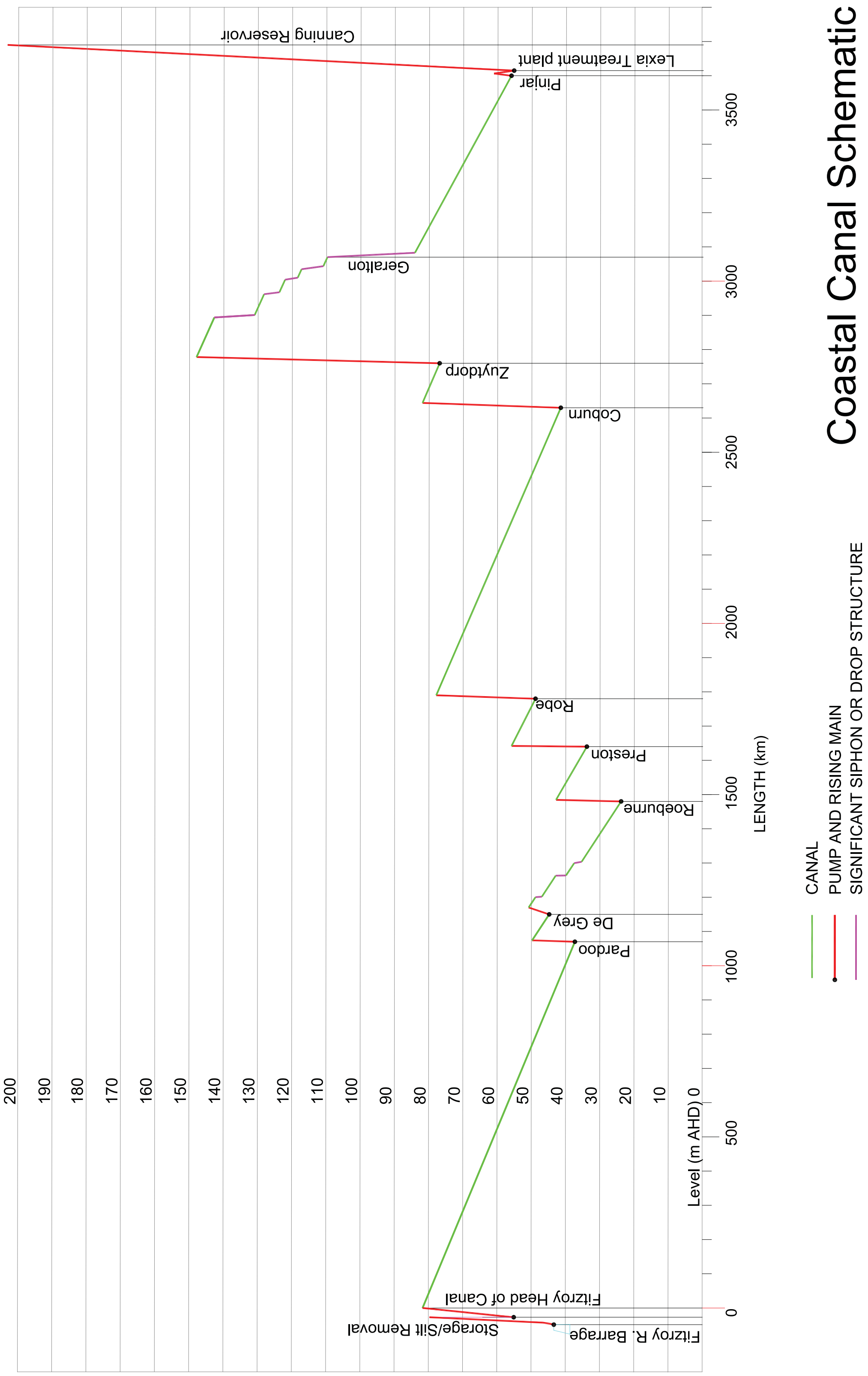

Figure 7.12 Hydraulic Profile Along Coastal Canal Route.

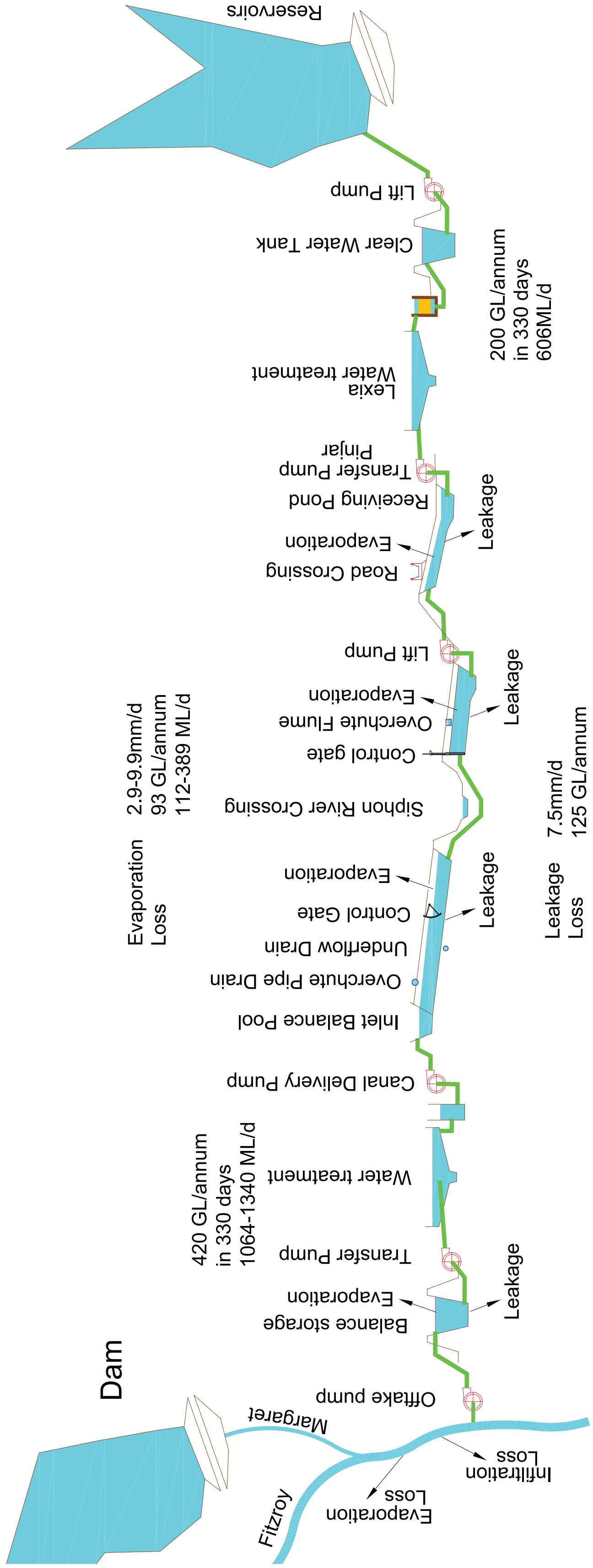

Figure 7.13 Schematic of the Canal Showing Typical Structures and Water Losses along the Route.

To test the conceptual design, two 20 kilometre sections selected as typical of the coastal route were subjected to survey allowing more detailed design. The sections chosen were on the coastal plain at Whim Creek and one on the Zuytdorp Cliffs south of Carnarvon. Here digital terrain modelling was applied to estimate the earthworks quantities and indicative costs of the trial design. Although only two 20-kilometre sections were analysed with the 10 metre contour mapping that was available, in keeping with the optimistic design philosophy, this was considered acceptable for the degree of certainty required for this study.

GHD proposed powering the pumping with natural gas sourced from the North West Shelf, or where the canal was close to existing local power providers, for example at Port Hedland, the opportunity to outsource the supply could be considered.

7.3.3 Water Treatment

Taking an estimated 90 days to flow down the canal, water would be exposed to sunlight and the atmosphere thus creating potential for contamination. It would therefore require treatment at the southern end of the canal before being pumped into the IWSS. At the Fitzroy end of the canal, the focus would be on screening and sediment removal from the water at the off-stream storage before it entered the canal. Consideration may also be required for sediment removal en-route, particularly if the canal is subject to contamination from surface water. This would form part of a regular maintenance regime.

7.3.4 Key Design Considerations for a Canal

Alignment

The route of a canal is relatively inflexible. Route selection is a trade off between the cost to construct a canal against the opportunity to pipe a section over a shorter distance, albeit at a higher unit cost. Elsewhere the base level of the canal was determined by significant geographical features. As an example, the level of the section for the coastal route south from Onslow to Carnarvon was determined by the level of the land at Giralia in order to avoid routing the canal another 200 kilometres around the Exmouth Peninsula.

Canal Lining

An inherent weakness of a canal is the potential to leak, which is a function of the canal lining and in situ soil conditions. This would be especially so for a canal from the Kimberley where 15 per cent of the canal is located on highly permeable soil and a further 70 per cent on medium permeable soil. GHD based its design on Guidelines for Channel Seepage Remediation prepared by the Australian National Committee on Irrigation and Drainage (ANCID). ANCID has reported benchmarking data and performance indicators for the irrigation industry in Australia. In keeping with its brief, GHD used the most optimistic outcome from those guidelines in its design. Given the length of the canal and therefore its large wetted area, GHD estimated that even using the best lining techniques available, the canal, if operated for a full year, would lose some 125 GL/year regardless of the quantity of water delivered to Perth. Based on best practice and overseas experience, GHD proposed a duplex geo-membrane liner topped with concrete to give optimal durability and maintenance capability over the life of the asset, whilst providing the most effective leakage minimisation. A further concern, although not fully investigated, was deterioration of the lining during the canal's lifespan.

Figure 7.14 Photo of a typical canal lining operation (Image courtesy of GHD).

Canal Cover Design

GHD estimated that without a cover net evaporative loss would be around 6.5mm/day, which equates to some 93 GL/year. This evaporation meant that not only would more water be needed from the source, but the relative salinity would increase. Although a cover offered benefits from reduced wind-borne debris and weed growth, and in helping exclude wildlife, it would be costly, would impact on maintenance operations, and require regular replacement and disposal of used fabric. For example, if made of polyethylene shade cloth, it would require the replacement and disposal of more than 520 hectares (one thousand tonnes) of material each year. For these reasons GHD estimated that it would be less costly to dispatch sufficient water to compensate for the evaporation, rather than include a cover in the design.

Flow Control Structures

The GHD design provided for control valves (gates) every 10 kilometres along the canal in order to control the flow of water. Without control gates, in the event of needing to stop the flow for maintenance, it would require up to 93 days to empty the canal and than another 93 days to refill it. The canal would hold an estimated 20 GL of water at any one time. Operation of the control valves and gates as well as the supervisory control and data acquisition (SCADA) system would be viable by solar panel and battery backup.

Figure 7.15 Photo of a Typical Control Gate (Image courtesy of GHD).

Hydrology Design

River crossings and surface water run-off were seen as major challenges in designing a reliable water delivery system. GHD elected to design a canal that could cope with the largest rainfall event expected every 100 years. For major rivers such as the Ashburton, the design allowed for the canal to pass under the river in inverted siphons. Elsewhere, water would be collected on the upstream side of the canal and passed over or under the canal in flumes or culverts.

The length of the canal and the number of individual catchments it would cross create significant issues. GHD estimated that even if a rainfall event severe enough to disrupt the canal occurred only once in a century in each catchment, the canal crosses so many different catchments that the overall probability of the canal being breached in any year would be over 98 per cent. In other words, the canal would fail somewhere along its length almost every year. To reduce the probability of the canal failing in the average year to less than 50 per cent, it would have to be designed to withstand rainfall events only expected once every 3000 years. Such an upgrade would require a very large increase in the scale of canal structures, and a comparable escalation in the cost.

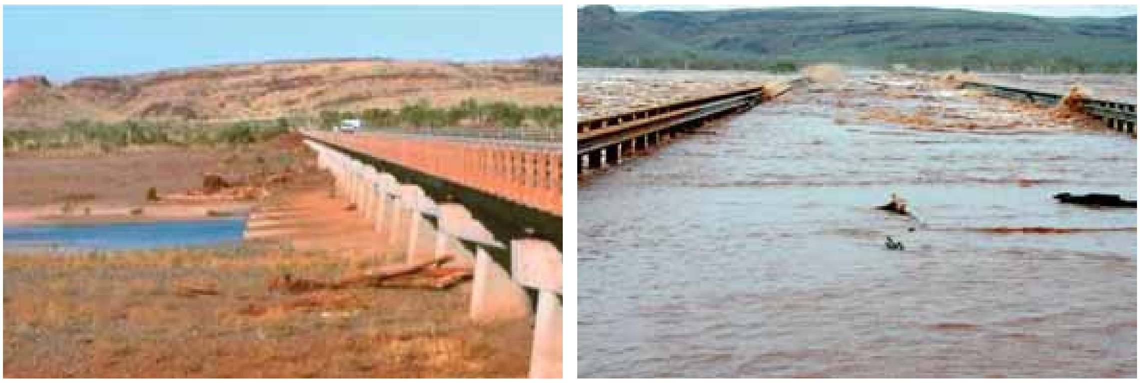

Figure 7.16 Bridge over Fortescue River - in the dry and after Cyclone Monte (Image courtesy of Main Roads WA).

Figure 7.17 Homestead near Harding Dam in the Pilbara (Image courtesy of Water Corporation).

Figure 7.18 View South over Robe River (Image courtesy of Main Roads WA).

Figure 7.19 Bridge over the Maitland River (Image courtesy of Main Roads WA).

Figures 7.17, 7.18 and 7.19 illustrate problems associated with the installation and operation of infrastructure in cyclone prone areas of Western Australia.

Fencing and Security

Consideration was given to the design of the barrier fencing proposed for both sides of the canal. The prospect of water being available in an arid environment would attract animals. While the design would provide for frequent crossing points for vehicles and animals, the barrier fence would need to be a two metre high chain link fence with a finer screen at and below the ground surface to exclude large native, stock and feral animals as well as smaller rodents, marsupials and reptiles. Vegetation and wind-blown sediment build-up on the fence line and within the canal corridor would also have to be controlled. Regardless of automated systems, this would require frequent and regular inspection and maintenance.

Figure 7.20 Emus on the Vermin Fence (Image courtesy of AgricultureWA).

7.3.5 Canal Financial Summary

The unit water costs calculated for the assumed Kimberley Canal development concept using the base case cost estimates and assuming a real pre-tax discount rate of six per cent per year, are summarised in Tables 7.4 and 7.5.

Item	**Unit Water Cost (2005$/kL)**		
	Capital^	**O&M***	**Total**
Source Headworks	0.41	0.07	0.48
Kimberley Canal	4.60	0.69	5.28
Integration Works	0.46	0.24	0.70
Total	**5.47**	**1.00**	**6.47**

^ Including capital replacement costs.

* Operating and maintenance costs.

Table 7.4 Unit Water Costs Ignoring Residual Asset Value: Constant 200 GL/year Demand.

Item	**Unit Water Cost (2005$/kL)**		
	Capital^	**O&M***	**Total**
Source Headworks	1.37	0.11	1.48
Kimberley Canal	15.26	1.85	17.11
Integration Works	1.54	0.33	1.87
Total	**18.17**	**2.29**	**20.45**

^ Including capital replacement costs.

* Operating and maintenance costs.

Table 7.5 Unit Water Costs Ignoring Residual Asset Value: Staged Demand (Initial 20 GL/year, increasing to 200 GL/year).

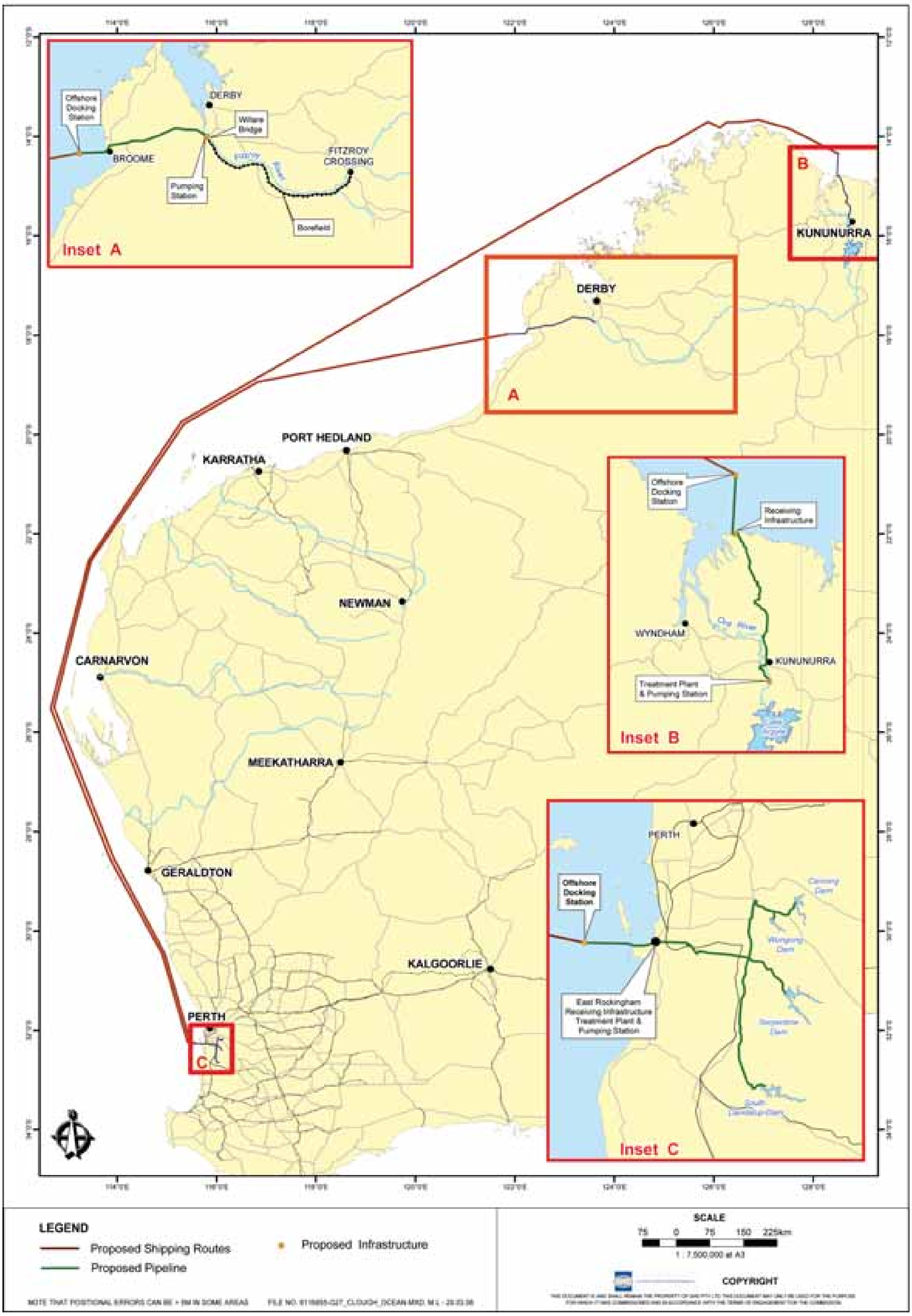

Figure 7.21 Ocean Transport Route

7.4 OCEAN TRANSPORT OPTION

Clough Engineering & Integrated Solutions (CEIS) examined ocean transport options, including how and where the water would be collected, its delivery to the coast, the loading facilities, the ocean route, vessel type, weather conditions, shipping times, loading and unloading rates, storage and treatment facilities and integration into the Water Corporation IWSS. Two concepts were considered, using conventional tankers and towed water bags.

7.4.1 Sourcing and Loading Facilities

Whilst the Fitzroy River was considered as a possible water source offering the advantage of shorter sailing distance to Perth, CEIS determined that for ocean transport it was more economic to source water from the Ord River at Kununurra due to the cost of extracting water from the Fitzroy River, the established infrastructure at Kununurra and proximity to the Joseph Bonaparte Gulf. Taking water from the Ord eliminated the need to construct a dam on the Fitzroy River, or off-stream storage. The selected pipeline route from the source to the loading facility is illustrated in Figure 7.5.

CEIS proposed constructing an intake structure on the Ord River between Lake Argyle and Lake Kununurra, and pumping via a 162 km pipeline constructed largely in existing road reserves to the coast northeast of Wyndham. After water treatment, the water would be pumped through a 47 km sub-sea pipeline to a single point mooring (SPM) loading facility in 30 metres water in the Joseph Bonaparte Gulf. The design criterion was to minimise the length of the sub-sea pipeline, as this was significantly more expensive than pipelines on land. Plans for constructing sub-sea pipelines need to take into account the availability and cost of pipe-laying equipment. The CEIS design was for an initial 1200mm epoxy coated welded steel pipe, with a second pipe to be added as the volumes approached 200 GL/year.

Figure 7.22 Single Point Mooring Facility (Image courtesy of CEIS).

A single point mooring enables the loading and unloading of liquid cargoes without having to build a substantial wharf structure, thereby saving costs. The design of the SPM system involved a range of issues. These are similar for both loading and unloading, with the location needing to consider ocean and weather conditions, as well as vessel approach alignment to allow a vessel to moor easily and quickly.

7.4.2 Tankers

A range of ship options was examined to test the economics and the availability of appropriate vessels. Because CEIS' analysis showed substantial benefits from economies of scale where cost was minimised by using the largest vessel size at the fastest speed for the minimum number of vessels, it focussed on the use of specially-designed water super tankers of 500,000 dwt capacity. These vessels would load and unload at an offshore SPM system similar to that used in the oil and gas industry. Vessels of this size would need minimum water depths with at least 25-30 metres of water to operate.

Figure 7.23 Typical 500,000dwt Supertanker. Vessels of a similar size were used in assessing the water tankering option. (Image courtesy of CEIS).

At a practical maximum average speed of 15 knots, it would require at least four ships of 500,000 dwt operating on a continual 14-day delivery cycle to deliver 50 GL/year. Fourteen of the same tankers would be needed to deliver 200 GL/year. The practicality of using oil tankers back-loading, as well as re-fitting second hand ships was also considered, but this raised significant water quality issues (further outlined in the CEIS report). Therefore, new purpose-built, dedicated ships were adopted for the analysis. Tankers of this size were estimated to cost around $200 million each and have a useful life of 25 years. The replacement of tankers over the life of the project was included in the analysis. Foreign registered and crewed ships would have lower operating costs, but for the analysis, costs were on the basis of Australian registration and crewing.

There is potential for cost variations if tanker designs were further developed. Installation of energy saving devices such as solar panels may offer reductions in the amount of greenhouse gases entitled. this is further analysed in sections 11.4 and 15.2.

7.4.3 Water Bags

Several respondents advocated using very large water bags. However, CEIS found it difficult to examine these in detail because the size proposed was many times greater than those being used elsewhere. The largest bags currently in use are around 25,000 tonnes, 20 times smaller than those proposed for the Kimberley route. The small bags would be much less cost effective for the long distances and large water volumes being considered.

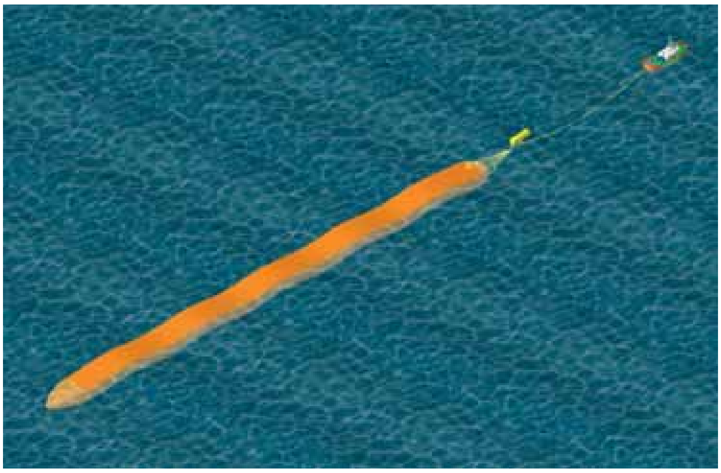

Figure 7.24 Schematic showing a possible towed waterbag using a large tug. An assumed 4 m maximum wave height is shown (Image courtesy of CEIS).

The proposed water bag would be approximately 700 metres long, up to 160 metres wide, a free board of 0.8 metres and with an assumed draft of 25 metres. There were several proposals using different structural configurations. While aspects of some of these concepts have been tested, none has been applied to a full-sized bag.

CEIS concluded that a range of issues would need to be studied in relation to the water bag concept. The concept would require considerable development work, prototype modelling and testing. Issues included selection and integrity of the fabric, structural integrity (how it would be held together), drag characteristics, its speed and towing requirements, stopping, tug specifications, transportation when empty, the filling and emptying process, anti-fouling, potential for collision with ocean debris, its behaviour in different ocean conditions, and repairing and maintaining the bag. CEIS conceptualised that when designed the bags would cost from $5 million to $15 million, depending on size and have a seven to ten year useful life. Cost of replacement was included in the analysis.

Based on existing maritime practice, CEIS proposed that tugs with an optimum speed of 10-12 knots, when towing full water bags would be restricted to an average speed of 4.5 knots. This gave a design cycle time for tankers of 14 days and for the water bags 32 days. Higher speeds were considered in the sensitivity analysis.

Within the terms of the optimistic design philosophy, CEIS considered that while doubling current capacity to say 0.06 GL (60,000 tonnes) was achievable today, the proposed larger bags would require extensive research and development. For its comparative analysis, CEIS used the 0.5 GL (500,000 tonnes) water bags as the advantage of scale indicated a lower cost, even though the capital, operating and maintenance costs of such bags could only be conceptualised.

7.4.4 Water Treatment

In line with the pipeline option, water treatment for sea transport would occur close to the source, i.e. at the shoreline prior to loading on to the tanker/water bag. The water would be subject to:

- Screening;
- Coagulation, sedimentation and granular media filtration; and
- Disinfection.

An assessment would need to be made on the extent of treatment at the Perth end at East Rockingham before pumping into the Water Corporation reservoirs. However, at a minimum, this would include aeration flocculation and granular activated carbon filtration similar to that proposed for the pipeline option.

7.4.5 Ocean Transport Route

The ocean transport option took into account the best route for tankers and bags, delivery cycle times, travel speed, water depths, loading and unloading requirements and selection of the SPM locations.

The shipping route from the Kimberley to Perth was selected to ensure adequate draft and avoiding marine parks and all known hazards such as, reefs, shoals, offshore gas platforms and associated sub-marine pipelines. This would entail using the Troughton Passage to avoid tracking too far north and going to the west of Barrow Island, the Houtman Abrolhos and Rottnest Island to terminate at the SPM some 10 km west of Point Peron.

7.4.6 Benefits of an Ocean Transport Option

The shipping option has a number of advantages over the land based options. Principal among these is the flexibility individual transport vessels offer. While the operational cost of tankers and water bags is proportionally higher, for the demand matching scenario, this cost is only incurred when demanded. Equally the volume delivered via an ocean transport option can be varied, both seasonally and yearly and could readily exceed the 200 GL/year design limit.

A further advantage is that the operation can be structured into discrete elements, so that they could be financed and managed separately for the Kimberley segment, the marine segment and delivery into the IWSS. Also considered was the opportunity to hold the water in a bag moored offshore until required. Given the relatively low cost of the water bag an inventory of bags could be managed whilst optimising the use of tugs. This did not meet the Water Corporation's integration requirements but would be worthy of consideration if the concept were taken further.

7.4.7 Ocean Transport Financial Summary

The unit water costs calculated for the ocean transport concepts using the base case cost estimates and assuming a real pre-tax discount rate of six per cent per year, are summarised in Table 7.6.

ROUTE	SOURCE	Design Yield Million m³/yr	INDIRECT[2]	UPSTREAM		MIDSTREAM		DOWNSTREAM		TOTAL	
				CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX	Cost	Cost/ kL
500,000-dwt Supertanker	Ord River	50	$97	$714	$209	$668	$937	$580	$195	$3,400	$6.10
		100	$144	$919	$647	$1,358	$1,905	$657	$357	$5,988	$5.31
		200	$261	$1,483	$1,246	$2,716	$3,811	$1,110	$615	$11,241	$4.98
		Staged[3]	$93	$1,087	$723	$760	$1,315	$804	$404	$5,185	$6.70
	Fitzroy Basin	50	$162	$2,126	$322	$542	$719	$579	$181	$4,613	$8.33
		100	$206	$2,361	$753	$1,106	$1,467	$664	$439	$6,997	$6.30
		200	$378	$4,272	$1,120	$2,213	$2,935	$1,143	$651	$12,711	$5.72
500,000 m³ Towed Bag[4]	Ord River	50	$87	$731	$212	$886	$746	$583	$251	$3,497	$6.29
		100	$123	$919	$749	$1,848	$1,335	$653	$331	$5,958	$5.36
		200	$221	$1,500	$1,227	$3,719	$2,752	$1,131	$616	$11,166	$5.02
	Fitzroy Basin	50	$149	$2,112	$322	$669	$546	$547	$153	$4,498	$8.10
		100	$195	$2,479	$760	$1,400	$996	$736	$331	$6,898	$6.21
		200	$360	$4,509	$1,134	$2,823	$2,074	$1,323	$651	$12,875	$5.79

2 Indirect costs include client costs to review and approve documents, environmental and authority costs, management costs, engineering costs during definition and detailed engineering and project management costs. Upstream, midstream and downstream costs have been identified above.

3 Capital costs appears lower than expected due to the effect of accounting for net present value on delayed capital expenditure.

4 The calculations shown here assume the availability of technology to produce large towed waterbags, which is still in the early stages of research and development at this stage.

Table 7.6 The unit water costs calculated for the ocean transport option in Net Present Value (NPV) of capital and operating costs in millions of dollars.

7.5 INTEGRATION INTO PERTH'S WATER SUPPLY

Water from the Kimberley would generally constitute a base load[12] source delivering water into the IWSS at a relatively constant rate. However, demand in the IWSS fluctuates daily and seasonally, generally lowest in winter (currently about 440 ML/day) and highest in summer (about 970 ML/day). Because supply would be greater than demand in winter months, a Kimberley supply would need to go into storage reservoirs until the higher demand of the warmer months. Canning and Wungong storages, previously used for meeting peak demand conditions, were nominated by the Water Corporation as the initial location for storing Kimberley water. However, available storage capacity is limited and transferring water between Serpentine and South Dandalup would be necessary should delivery from the Kimberley exceed 100 GL/year.

To reduce the risk of contaminating the system, the Kimberley water would have to meet Australian Drinking Water Quality Guidelines (ADWG, NHMRC/NRMMC, 2004) before it was mixed with water in the Water Corporation system.

The Water Corporation has planned on the probability that a total sprinkler ban would not occur in more than one in 200 years. For Kimberley sourced water this would require that equipment failures and significant weather events affecting canal or pipeline outages - or tanker or water bag movements - be managed to avoid impacting on the system's reliability. This would require the supply option having sufficient reserve capacity to ensure the total volume of water delivered every year is equal to the design yield (50, 100 or 200 GL/year).

To meet the projected water demand, Kimberley water would need to come on stream in 2017/18 if it were to be considered a viable option.

[12] Base load is the constant delivery volume with the peaks being met from other sources.

8 COMPARATIVE ECONOMIC ANALYSIS

To undertake a comparative analysis of these water delivery options, and provide a benchmark on which to compare these options with others to be considered by government, the Panel directed the consultants to present their findings in terms of net present value (NPV) and the unit cost of water delivered into the IWSS assuming a real pre-tax discount rate of six per cent a year over a project life of 50 years, as recommended by the Department of Treasury and Finance.

The respective options were costed for each delivery scenario and the costs applied to a financial analysis. On the basis of preliminary work, the most cost effective solution for each option was chosen. For the pipeline and canal, the source of water was a dam on the Margaret River with the run-of-river to a pumping station at Willare Barrage. The pipeline option analysed was the direct route from Willare via Newman to Westdale. The canal option was the coastal route to the Lexia treatment facility and pumped to the Water Corporation dams. The ocean transport option was to pump from the Ord River, to a SPM in the Joseph Bonaparte Gulf.

Three options were costed for ocean transport; using 0.5 GL (500,000 tonne) tankers and using either 0.06 GL (60,000 tonne) or 0.5 GL water bags, however only the 0.5 GL bags were used in the comparative analysis. Cost comparisons were run for the various scenarios for the life of the project. Table 8.1 sets out the costs associated with 200 GL/year from day one whilst Table 8.2 is based on the expected demand matching scenario. The model called for water delivery starting in 2017 and for the project to run for 50 years.

Given the preliminary nature of the detailed design in all cases, there is the potential for cost variations when the design is further developed. This would be especially relevant to very large water bags and any opportunities for energy saving devices. However, these modifications could be considered where they offer a saving relative to the costs adopted for this analysis.

Criteria	**Pipeline**	**Canal**	**Ocean Transport Tanker**	**Ocean Transport 0.5GL Water Bag**
Capital Cost	$11.9B	$14.5B	$6.2B***	$5.3B***
Capital Cost (in Net Present Value Terms)	$7.5B	$8.0B	$5.3B	$6.4B
Operating Expenditure* (in Net Present Value Terms)	$1.5B	$1.6B	$5.9B	$4.6B
Unit Cost of Water ($/kL) **	$5.1	$6.5	$5.0	$5.0

Table 8.1 Cost comparison for the 200 GL/year Scenario.

* Operating Expenditure is the NPV for operation, maintenance and replacement costs.

** Rounding.

*** Capital cost to commence operation, but does not include cost to replace ocean fleet during the 50 years.

Criteria (in Net Present Value Terms)	**Pipeline**	**Canal****	**Ocean Transport Tanker**	**Ocean Transport 0.5GL Water Bag*****
Capital Cost	$4.5B	$8.0B	$2.7B	N/A
Operating Cost	$0.6B	$1.6B	$2.4B	N/A
Unit Cost of Water ($/kL)*	$9.7	$20.5	$6.7	N/A

Table 8.2 Cost comparison for the Initial Demand Matching Scenario.

* Rounding.

** Although there would be some cost saving to deliver lesser volumes of water down the canal, most of the capital cost for the full 200 GL/year project would be required regardless of the volume delivered.

*** Due to the conceptual nature the costs for the water bag option were not calculated.

The above tables show that whilst the pipeline option was comparable with the ocean transport option for the 200 GL/year scenario, the more realistic scenario of matching the expected water demand shows that the ocean transport was significantly less expensive.

By way of comparison, the desalination plant currently being commissioned by the Water Corporation is expected to cost some $0.387 billions. It has been designed to supply 47 GL of potable water per year at an estimated cost of $1.16/kL including operating costs.

8.1 SENSITIVITY ANALYSIS

A sensitivity analysis was carried out for each of the options. The ten most likely variables were tested using the most realistic scenario (the demand-matching scenario), but for the canal option, this was for 200 GL/year.

For the pipeline option, the unit cost of water was very sensitive to the discount rate. Increasing the discount rate[13] from six per cent to eight per cent caused an increase in the unit water price by between $3 and $4/kL. The four next most significant of the other nine parameters were the design friction resistance, dam construction cost, cost of steel and cost to lay the pipe. However, none of these in isolation influenced the cost by more than $0.40/kL within a realistic range of values.

Costs for the canal option were most sensitive to a change in the discount rate. Increasing the discount rate to eight per cent caused an increase in the unit rate for water of between $1.50 and $2.00/kL. Of the other ten parameters, the next four most significant were the extent of rock excavation, the cost of concrete, the quantity of earthworks required to form the canal and the cost of constructing the dam. Over the ranges assessed (variously between 20 per cent and 50 per cent), none of these influenced the cost of water delivered by more than $0.20/kL.

The sensitivity analysis for the tanker option was similar to the pipeline and canal options, where a change in the discount rate resulted in the greatest impact on the cost of water. Doubling the discount rate from four per cent to eight per cent resulted in a change in the delivery cost of $2.20/kL or an increase of 43 per cent. Cost of tanker and pipeline construction, and the cost of fuel were the next most sensitive items. At $400 per tonne fuel was estimated to be approximately 50 per cent of the operating expenditure for a tanker. Doubling the fuel cost with all other parameters being kept constant resulted in an increase in the cost of water of $0.85/kL.

For the water bag operation the fact that the technology was still in a development stage resulted in uncertainties with respect to: the design and cost of the bag, bag deterioration, tug speed, tug cost and adverse weather conditions. The sensitivity for these variables reflected these uncertainties and gave a water cost in the range from $3.70 to $11.90/kL.

In summary, for all options the capital cost, and hence the discount rate, was by far the most significant parameter in estimating the cost of delivering water.

8.2 CONSEQUENTIAL COST TO PERTH CONSUMERS

In 2005, the charge for the average individual household using 279 kL of water a year was $304.42. Introducing 200 GL/year of Kimberley water into the IWSS, using the lowest cost delivery option would have the effect of increasing this to at least $610 in 2005 dollars if the Government elected to pass on all the costs to the consumers. This was calculated on the basis of the cost of current and planned water sources remaining constant and introducing 200 GL of Kimberley water delivered via ocean transport at a cost of $5.00 per kL.

[13] The discount rate is the rate at which revenue flows from the sale of water in future are adjusted so that they can be compared with values in the present.

9 ENERGY CONSIDERATIONS

9.1 COMPARATIVE ENERGY CONSUMPTION

The energy consumption needed to deliver water is usually expressed as the Specific Energy Consumption (SEC) measured in kilowatt hours per kilolitre of water delivered. For example, the new desalination plant being commissioned for the Water Corporation at Kwinana is expected to operate at 4.5 kWhr/kL. The power required to treat and transport the water from the Kimberley and discharge it into the Water Corporation system varies according to the quantity of water delivered, the balance between installed capacity at any time and the pumping/transport energy required. However, for comparative purposes the energy required to deliver in the 200 GL/year scenario is detailed in Table 9.1.

SCENARIO	PIPELINE OPTION	CANAL OPTION	OCEAN TANKER	0.5 GL WATER BAG
Delivering 200 GL/year in kWhr/kL	5.8	3.7	10.5	8.6

Table 9.1 Specific Energy Consumption in Kilowatt-Hours per Kilolitre for the 200 GL/year Scenario.

For the pipeline option in the demand matching scenario, where smaller pipes are used, delivering 200 GL/year would ultimately require 9 kWhr/kL. This is illustrated in Figure 7.9. Hence, the energy required for delivering water from the Kimberley in all but the canal option exceeds that required for desalination.

9.2 COMPARATIVE GREENHOUSE GAS EMISSIONS

In addition to comparing the total energy required to deliver water from the Kimberley, the types and amounts of fuels would differ between the options. The amount of greenhouse gas emitted therefore varies between the options according to the energy source and amount used. It has been proposed that the energy to be used for most of the water treatment and pumping would be natural gas, whereas at the Perth end of the canal, power would be sourced from the Western Power grid which is a coal/gas fuelled source. For the sea leg of the ocean transport option the fuel used would be heavy marine fuel oil. Advice from the Sustainable Energy Development Office (SEDO) on the quantities of greenhouse gases produced by each option is detailed in Table 9.2 and Appendix 11.

	PIPELINE OPTION	**CANAL OPTION**	**OCEAN TANKER**	**0.5 GL WATER BAG**
Tonnes of CO_2 Equivalent per year	0.6 million	0.5 million	2.0 million	1.6 million

Table 9.2 Maximum Greenhouse Gas Emitted Annually in Tonnes of CO_2 Equivalent for the 200 GL/year Scenario.

The ocean transport options of tanker and water bag are both more energy demanding than the pipeline or canal and the greenhouse gas generation is proportionately greater using fuel oil rather than natural gas.

10 RELATIVE RISK ANALYSIS

A risk assessment requires a sequence of steps to determine the relative risk of a range of events occurring. The sequence is to first identify all the risks that could conceivably occur, determine the significance of the event, the probability of it occurring and the capacity to remedy the situation after the event. The significance of an event can often be expressed as a $ cost and the frequency given a statistical probability. For large engineering projects these can then be computed as a cost provision in determining the overall project budget. However, in considering the Kimberley water proposals where design certainties are variable and the environmental and social factors are only at the conceptual level, a rigorous risk analysis was impractical. As a consequence the Panel adopted a relative risk analysis, focussing on making a judgement on the relative risk of one option to the others.

Table 10.1 summarises the relative risk profile of the options. However, the relative risk of the options during initiation, construction and operation is detailed as follows:-

10.1 RISKS IN INITIATION

- **Technology/Design Risk**. Water bag design at the scale proposed is an untested concept. Therefore, it was assessed as a high risk relative to the other options. Canal design is well understood, but not applied over the distance contemplated; hence it has a higher risk than use of either tankers or pipelines.
- **Sustainable Water Yield**. Water extraction from the Ord River is relatively better understood than for the Fitzroy River, particularly if the Fitzroy ground water option was to be considered. However, whilst there is a large volume of water in both systems, the Ord River is close to being fully allocated.
- **Government Approvals**. Given the work already done on approvals for the Ord Stage 2 development, it can be assumed that the ocean transport option has a higher level of certainty than the pipeline, particularly when considering the Government's stated position of "no dams". The concept of approving a canal that traverses 3700 kilometres of coastline, with impacts on National Parks and the introduction of a permanent barrier over much of its length was seen as a very high-risk option.
- **Native Title Clearance**. Given the importance of the concept of "living water" and the stated opposition by all the Aboriginal communities to taking water from the Fitzroy River, resolution of Native Title was seen as high risk. Given the recent agreement reached with the Miriuwung Gajerrong on Ord Stage 2 and that much of the pipeline route for the ocean option was proposed within existing road reserves, the ocean transport option had a relatively lower level of risk.
- **Right of Way/Land Acquisition**. Where the Kimberley water proposal is constructed as a public work, compulsory acquisition could be expected. The level of interference by a pipeline with current land use is largely confined to the construction phase of a project. However, the quantum and significance of land requirements for a canal make this option significantly more risky.
- **Community Perception**. It may be expected that the environmental and social implications of a canal would cause that option to be less well received than other alternatives.

10.2 RISKS DURING CONSTRUCTION

- **Cost Overruns**. Due to untried technology of the water bag and route difficulties of the canal, these options were perceived as more risky than either the tanker or pipeline options which given their scale could be seen as moderately risky at this point in development.
- **Earthworks**. All large civil engineering works involving significant earthmoving are risky until detailed site evaluation has been undertaken to determine the extent and degree of difficulty with rock excavation. The extent of earthworks for both the canal and the pipeline would require further evaluation for this risk to be reduced.
- **Disturbance of State Forest.** The pipeline option traverses State Forest accessing the Perth dams. The selection of the actual route and methodology to be adopted would have risks attached.
- **Impact on National Parks.** The pipeline and ocean options do not impact on National Parks. A pipeline can be routed to avoid areas, whereas a canal route is dictated by the topography of the land and the necessary gradient, regardless of the obstacle to be overcome.
- **Supply of Labour and Materials**. It may be expected that the tankers/water bags would be fabricated overseas; hence the greatest supply impact would be in materials and labour for the land options. A canal and pipeline project would be of world scale and therefore present some risk. The supply of tankers would depend on ship fabrication.
- **Time to Bring On line**. Delays in delivery time relate to the level of certainty for the option. Whilst design and construction of tankers and pipelines are well understood, the design uncertainty for the water bags and the geographic challenges for the canal give those options a higher level of risk.

10.3 RISKS IN OPERATION

- **Earthquake**. Earthquakes have occurred in Western Australia and as such present a measure of risk for the pipeline and canal options but this would fall into the manageable category.
- **Native/Stock Animals Drowning**. The large off-stream storage areas and the 3700 kilometres of open canal present an unprecedented potential for entrapment of animals.
- **Human Drowning**. From US experience, fatality of trespassers within a canal corridor is a risk inherent with open bodies of water.
- **Sediment/Algal Build up**. The potential for algal growth and sediment entrainment in the canal can be managed to a degree. However, there remains a level of uncertainty as to the quantity that would need managing. On another level algal or marine organisms have potential to affect the drag of a water bag. The extent of this is unquantified.

- **Transmission of Organisms**. Water industry practice should give an acceptable level of risk to the pipeline and ocean transport options. However, a risk remains with the open water body in the canal where organic matter, insects and animals would have the opportunity to use the canal as a corridor south. Of note, the question of access by cane toads would remain a public issue.
- **Water Loss En-route**. All water transmission systems require an allowance for loss in transmission. Properly maintained tankers and pipelines can retain this within acceptable limits. One of the greatest uncertainties, and therefore risk, for the canal option is estimating the amount of leakage that may be expected.
- **Cross Drainage Flows**. Based on the Main Roads WA experience, managing cross drainage flows through an extended cyclone affected coastline is likely to present an unacceptable level of risk for the canal option. Whilst the major watercourses can be traversed by inverted siphons, the number of minor catchments and the volumes of water that would be experienced with a canal would present a statistically unacceptable high risk of failure.
- **Water Quality**. Applying water industry standard practice would ensure an acceptable level of risk on water quality for the ocean and pipeline options. The high risk for water quality for the canal option is compounded by the risks from cross drainage flows and potential from algal and sediment entrainment.
- **Reliability of Supply**. Reliability of supply from the tanker and pipeline options would equate with levels currently experienced elsewhere. However, given the conceptual nature of the water bag option and the geographic exposure and quality issues of the canal these may be seen as high risk.
- **Cost of Energy**. While the cost of energy is a significant operating cost, particularly for the ocean transport, the risk from increased energy costs for all the options is relatively small compared with the financing exposure.
- **Greenhouse Gas Production**. The ocean transport options of tanker and water bag, being powered with fuel oil, both generate three times more greenhouse gasses than either land based options.
- **Financing Costs**. All the options produce a cost to supply a number of times greater than the current cost to supply from other sources ($0.80-$1.20/kL). All the options are capital intensive and highly sensitive to changes in the discount rate.

RISK	PIPELINE	CANAL	OCEAN TANKER	OCEAN WATERBAG
Initiation				
Technology / Design risk	L	H	L	H
Sustainable water yield	M	M	M	M
Government approvals	M	H	L	L
Native Title clearance	H	H	M	M
RoW / Land Acquisition	M	H	M	M
Community perception	M	H	M	M
Construction				
Cost overrun	M	H	M	H
Earthworks	M	H	L	L
Disturbance of State Forest	M	L	L	L
National Parks	M	H	L	L
Supply of labour and materials	M	M	L	M
Time to bring online	M	H	L	H
Operation				
Earthquake	M	M	L	L
Drainage Shadows	M	H	L	L
Native/stock Animals drowning	N/A	H	N/A	N/A
Human drowning	N/A	M	L	L
Sediment/algal build-up	L	H	L	L
Transmission of Organisms	L	H	L	L
Water Loss En-route	L	H	L	X
Cross drainage flows	L	H	L	L
Water Quality	L	H	L	L
Reliability of Supply	M	H	M	H
Cost of Energy	L	L	L	L
Greenhouse Gas Produced	M	M	H	H
Financing Costs	H	H	H	H

Table 10.1 Relative Risk Profile of the Options.

Key

H	High likelihood/Risk of occurring	M	Moderate likelihood/Risk of occurring
L	Low likelihood/Risk of occurring	X	Information not available
N/A	Not Applicable		

In summary, there is less risk attached to the ocean tankering option, with the pipeline subject to sourcing risk. There were a number of significant areas of risk for the canal option, whilst the large water bag option had potential but a significant technical risk remained in getting the concept to a proven process.

11 ENVIRONMENTAL ISSUES

The nature and scale of each option under consideration and the relatively limited information available on the Kimberley environment raises considerable uncertainty with all options. Prior to any commitment to a Kimberley water supply project, significant further work would be required to reduce this level of uncertainty. Any proposal would require approval under environmental legislation and, given the scale of the proposals, all options may be expected to require a full Environmental Review and Management Program, the highest level of environmental assessment.

As well as the environmental impacts of obtaining water from the Kimberley, there would be environmental issues involved in moving the water to Perth by any of the transport methods considered. As discussed below, a canal or pipeline would impact on a land corridor, while ocean transport would have a different range of effects on the marine environment. Each method of transport involves the production of greenhouse gases, with the potential to exacerbate climate change and its effect on Perth's water supply.

In addition, all water delivered into the Water Corporation IWSS would have to meet Australian Drinking Water Guidelines (ADWG). Depending on how the water was delivered, there would be different treatment requirements, with environmental issues for each. As with water distribution, these are energy intensive processes.

11.1 WATER SOURCE ISSUES

Whilst noting that it was inconsistent with the "no dams" policy of the Government, the water sourcing option using a dam on the Margaret River and run of river for delivery downstream may be expected to have a similar environmental impact to that resulting from damming the Ord River some 40 years ago. Construction of a barrage at Willare would have similar impacts to the Camballin Barrage. Flooding the Margaret River valley would permanently modify a significant area of country and reduce the regional bio-diversity.

A dam on the Margaret River with collection downstream would change a seasonal river flow pattern, with intermittent flooding, to one continuous flow with reduced flood events (as has happened on the lower Ord). This would alter the physical structure of the river, the permanent water holes, and impact on the riparian vegetation, which in turn would affect the structure of the river ecology. The Willare Barrage would be likely to impact on the riverine-estuary

Figure 11.1 Riparian species (Acacia glaeotricha) on CALM Declared Rare and Priority List (Image courtesy of A. Storey).

Figure 11.2 Dwarf Sawfish, Endangered IUCN 2002 (Image courtesy of A. Storey).

interface. These impacts have been documented in work done on the Fitzroy River system by the Water and Rivers Commission (A. Storey et al 2001). Although there is very limited data on the interconnectivity of the surface and groundwater, it would be expected to have an impact on endemic and rare and endangered species.

The alternative proposal to source the water from a borefield would have different impacts on the Fitzroy River environment. The borefield itself would be spread over a long stretch of the river with numerous pumping sites. Further research is needed to determine what level of pumping from the riverine system would avoid negative impacts on the dry-season hydrology of the river, the natural vegetation and the wildlife. If chosen, this option would require a very large off-stream storage facility with a capacity of 110 to 390 GL. As discussed in Section 8.3, these would be very large structures, and have a very significant impact on the local environment.

In summary, limited data is available to determine the extent of environmental impact, but it seems likely that the damming and run of the river options would have a significantly greater impact than accessing a borefield.

For the ocean transport option, sourcing the water from the Ord River would have significantly less environmental impact. With the construction of first the Diversion Dam in 1963 and subsequently the Argyle Dam in 1973, the Ord River has been turned into a regulated waterway resulting in the lower reaches being declared a RAMSAR wetland. In 1999 the Water and Rivers Commission assessed the health of the Ord River and the EPA subsequently determined an interim environmental water allocation for the river. The taking of water from the river is likely to impact on other water users, more so than on the environment.

11.2 PIPELINE OPTION

The construction and operation of pipelines is a well-understood process with numerous water and gas pipelines operating in Western Australia. With a 50 metre wide corridor, the direct route option may be expected to impact on 90 square kilometres of land. Even though the pipeline would be buried, there would be an environmental impact from a service road and pump stations located along the route. Work to date indicates that no National Park need be disturbed, although one possible route would affect a Class A Reserve. Each route considered would potentially impact on two RAMSAR wetlands, triggering investigation under the 1999 Commonwealth legislation, the Environmental Protection and Biodiversity Conservation Act. There would also be significant impacts on major river systems during construction.

Current practice would require detailed surveys to identify and address such issues as Threatened Ecological Communities and rare and endangered flora and fauna species. An issue already identified is the likely impact on mulga communities resulting from the disturbance of ground in constructing a pipeline. While the direct route would traverse some 700 km of mulga woodlands, the Goldfields route would affect about 1400 km. The direct route would also affect some protected fringing vegetation in the Swan River catchment. While it would probably be possible to manage these issues, a significant research effort would be required to provide confidence in the outcomes.

A significant issue to be considered for the pipeline option would be the energy use and greenhouse gas produced during construction and operation. A preliminary estimate by GHD suggested that the pipeline would release about 0.6 million tonnes of carbon dioxide a year to deliver 200 GL of water. It would require between 70,000 and 250,000 hectares of actively growing forest to sequester an amount of carbon dioxide equivalent to the amount that would be released for the pipeline option. This is comparable with the existing blue gum plantations in Western Australia.

11.3 CANAL OPTION

The canal option has significantly greater environmental impact than the pipeline. In addition to drawing additional water to cater for evaporation and seepage loss, the coastal canal option is longer and wider than the pipeline proposal, impacting directly on some 330 square kilometres of land. More importantly, a canal route is dictated by tying the alignment to the canal gradient to enable the water to flow at a specific rate. Too steep a grade would cause scouring and require frequent pumping to lift the water and too shallow a grade would prevent the water flowing. As a result, a canal has much less flexibility in location than a buried pipeline and except for sections of siphon or rising main, the canal creates a permanent barrier across the country. This barrier would impact on the surface hydrology with consequential effects on the flora and fauna along the route.

In addition, the construction of secure fencing along the canal would prevent the movement of animals across the landscape. On the basis of US experience, it could be expected that people and animals would breach the fence and drown.

Extensive flora and fauna studies beyond the work done to date would need to be undertaken to minimise the environmental impact of the canal. Work done to date, shows that a canal would impact on a number of environmentally sensitive areas. These would include three Class A National Parks, three Class A Nature Reserves, Heritage listed areas and Water Protection areas. The canal route would pass near two RAMSAR wetlands, triggering investigation under the Commonwealth Environmental Protection and Biodiversity Conservation Act as discussed for the pipeline option.

The GHD study noted that the construction of a canal would clear more than 330 square kilometres of vegetation, including significant plant communities. It would also create a permanent barrier, disrupting surface water flows along its length as well as affecting migration routes of fauna. In these ways a canal would inevitably have the effect of fragmenting populations. As GHD noted, some of the impacts could be mitigated by cross-drainage structures and fauna crossings, but "the canal would still have a severe impact on the ecology of all areas that it passes through". The report also warned of the capacity of a canal to allow movement of biota along its length, referring specifically to the example of cane toads.

Although a canal requires less lifting of water than a pipeline, it would still require very large amounts of energy for operation, because losses from leakage and evaporation mean a much greater volume of water would have to be transported to deliver the required quantity to Perth. SEDO estimated that delivering 200 GL/year of water would release about 0.5 million tonnes of carbon dioxide a year.

11.4 OCEAN TRANSPORT OPTION

The ocean transport option would raise relatively fewer environmental issues than the pipeline or canal alternatives. For example, it would source its water from the Ord River, already significantly disturbed from its natural flow regime by the Argyle Dam and the Diversion Dam down-river. While obtaining the water does not pose the serious issues involved with the Fitzroy, impacts on the Ord River of the proposed level of extraction would need to be assessed.

The pipeline for connecting to the marine element, including the sub-sea sections, is unique to this option. Issues associated with these sections would need to be addressed. The marine stage of this option is likely to raise environmental issues with respect to benthic disturbance[14] and interaction with aquatic life. Here studies would need to identify a route suitable to address issues such as interaction with migration of whales. A comprehensive marine traffic management program would also need to be developed.

As with other options, greenhouse gases would be generated in the transport task. This option generates significantly more greenhouse gases than for the pipeline or canal. The majority of fuel used would be heavy marine fuel oil. This would generate proportionally more greenhouse gases than options using natural gas fuelled gas turbines. Much of the fuel use would be eliminated if the proposal to use solar panels proved financially viable.

[14] Very large ships have potential to cause disturbance to the seabed when travelling through shallow water.

12 SOCIAL ISSUES

Whilst the Panel recognised that social issues would be paramount for any of the conveyance options given the lack of clarity around the proposals, it remained focussed on the technical and economic issues. Therefore, the Panel did not undertake a comprehensive social impact study of the likely social consequences associated with the transfer of water from the Kimberley to Perth. However, as part of the terms of reference, the Panel and its consultant met with a range of stakeholders both in the Kimberley and the south west of the State. Details of these issues are contained in the stakeholder perspectives report by Beckwith (2005), in Appendix 7.

12.1 DIFFERENTIAL SOCIAL IMPACTS

A project of this scale will impact at different levels on various sectors of the community. With water sourced from the Fitzroy River, the greatest impact could be expected on the Indigenous communities who live along the river valley. These communities still largely maintain a traditional association with their country and this association would be altered, particularly if the run of river extraction method was adopted. The Aboriginal concept of "Living Water" identifies the Fitzroy River as fundamental to their way of life. It is expected that with a dam and run of river extraction, the riverbed would be significantly altered. Previously permanent water holes would silt up and the river ecology would be modified. Aboriginal communities have a strong cultural association with these permanent waterholes and are dependent on the changing river environment for their dietary requirements over the annual river cycle. From the community consultation undertaken by the Panel and noted in the Beckwith Report, all the Aboriginal communities were critical if not hostile to the concept of taking water from the Fitzroy River. The Panel recognises that any proposal to extract large volumes of water from the Fitzroy River for transport to the South West of the state would therefore be very strongly opposed by local Indigenous people.

Figure 12.1 Kimberley Appropriate Economies Roundtable, October 2005 (Image courtesy of M. Mann).

Landholders and residents in close proximity to the project would also be directly affected. Issues such as land severance, management of local surface drainage, security of the water corridor, and dislocation during construction would require detailed consideration.

12.2 GOVERNMENT POLICY

Current government policy is not to construct dams on the Fitzroy River. To comply with this policy requires taking the water from the Ord River as considered in the ocean option or through a borefield and/or the run of the river model without a dam on the Fitzroy, estimated to cost in the order of up to an additional $0.6 billion.

Policy positions with respect to National Parks, conservation areas, and the environment and greenhouse gas generation would also need to be considered. There is also the potential to impact on Commonwealth Government legislation and international conservation agreements.

12.3 SOCIAL INFRASTRUCTURE

During construction and ongoing operation, communities adjacent to the project would be variously affected by issues such as accommodation, employment and the delivery of services, typical of large projects in remote areas.

In a more general sense, the attitude of the Perth metropolitan community to dependence on sourcing some of its water from such a distance may also be important, particularly if reliability of supply and the energy required to deliver it are identified as major issues.

13 COMPARATIVE ENVIRONMENTAL AND SOCIAL EFFECTS OF THE OPTIONS

13.1 COMPARATIVE ENVIRONMENTAL IMPACTS

The environmental impacts on sourcing water from the Fitzroy are similar for the pipeline and canal options. Both proposals utilise a dam on the Margaret River. The impoundment area of the dam and the subsequent regulation of the river would have a significant impact on regional bio-diversity.

On sourcing water, the significant difference between the pipeline and canal is that the canal option requires significantly more water to compensate for losses to evaporation and leakage. The canal option requires larger off stream storage and this is particularly significant under the lower delivery volumes where the allowance needed for evaporation and leakage is disproportionately larger. The run of river extraction may be expected to have a profound impact on the riverine ecology, completely modifying the flow characteristics with significantly lower flood events and with a continual baseline flow.

Along the pipeline route some 90 square kilometres of country would be impacted, especially during the construction phase, with significant earthworks and the building of an all weather access road along the route. As the pipeline would be buried, its impact on surface water flows may be ameliorated to a large extent.

The environmental impact of the canal is expected to be very significant. Given its structure, the earthworks involved, fencing and the need for fire protection, the 100 metre wide corridor would require modification of the entire natural surface over some 330 square kilometres of country. This would include impacting on National Parks and conservation areas. The canal corridor would be a permanent barrier to native wildlife, and a significant modification to the surface runoff pattern along the route.

The ocean transport option offers the least terrestrial environmental impact. The proposal calls for sourcing the water from the already modified Ord River system. The pipeline route from Kununurra is planned to be located in existing road reserves. Some issues remain with the location and construction of the undersea pipeline and offshore loading and unloading facilities. These could potentially be managed. However, the energy consumption and greenhouse gas generation is significantly higher than either the pipeline or canal.

13.2 COMPARATIVE SOCIAL IMPACTS

As the social impacts of the transport of water from the Kimberley would be largely confined to the Kimberley and communities along the route, there is a significantly greater impact from sourcing the water from the Fitzroy River basin than pumping from the Ord River. As highlighted in community consultation undertaken to date, the West Kimberley communities and the Indigenous community in particular, see extracting water to satisfy the Perth metropolitan demand as depriving the region of a resource as well as irrevocably destroying an essential part of the Indigenous culture and food source. These arguments also apply, although to a lesser degree, to extraction from the Ord River.

The overland route corridors would impact on current land use activities. Here the impact from pipelines for the pipeline and tankering options, because they are buried, would be largely confined to the construction phase. It would require consultation with the affected communities and landholders. Activities such as cropping and stock access would be issues to manage. The tankering/waterbag option requires 162 kilometres of pipeline between Kununurra and Wyndham along road reserves through largely pastoral country, and some 36 kilometres of trunk main through the Perth southern suburbs. In contrast, the direct route pipeline option of 1900 kilometres traverses mostly unoccupied Crown land pastoral lease and freehold agricultural land. However, it also crosses State Forest land and impacts would have Native Title implications.

In contrast, the canal option could be seen as an order of magnitude more significant with substantially greater earthworks and the creation of a permanent barrier across the landscape. This may be expected to cause ongoing frustrations over access and division of property and community interaction.

From a positive aspect, the canal option maybe expected to generate more opportunities in the local communities for employment during the construction and ongoing maintenance than for a pipeline operation. In contrast, it is likely the majority of construction of either the water tankers or the water bags would be undertaken outside of Australia.

A further social impact that may be considered in proportion to the relative capital cost of the options is the loss of opportunity for public spending as a result of commitments to a Kimberley water option. Borrowings that would be needed for the supply of water would diminish government spending on other programs.

14 COMMUNITY CONSULTATION

The Panel was keen to listen to community views and keep stakeholders informed of its study progress. The principal focus for community input was with the Kimberley communities. During the course of the study the Panel met on a number of occasions with key Kimberley stakeholders including local government, chambers of commerce, the Kimberley Regional Development Commission, industry representative bodies, the Kimberley Land Council and other Indigenous, environmental and academic groups. Feedback from the open discussions held in those consultation meetings focussed on:

- Getting an outcome for the Kimberley in which water was not seen as a free resource;
- Recognition that the Fitzroy River water is not going to waste, but valuable in sustaining the ecosystem of the flood plain and King Sound;
- Getting more development into the Kimberley region; and
- Raising an awareness of the significance of environmental and cultural issues.

In its consultations, the Panel received some guarded, localised support that acknowledged a major water project as an economic driver.

Figure 14.1 The Panel meeting with Shire of Broome and Broome residents.

Discussions with the Kimberley Land Council (KLC) focussed on the needs of Indigenous communities. Professor Appleyard outlined the need for a full study of the aquifer, including a drilling program along the river's edge to determine interconnections between surface and groundwater, water quality and the size of the resource. The KLC was unwilling to give support to the program within a timeframe that took into account the wet season constraints. As a result the hydro-geological study of the Fitzroy River was confined to using previously published studies and drilling results already available.

As part of the study the Panel participated in and contributed funding to the Kimberley Appropriate Economies Roundtable held at Fitzroy Crossing from 11-13th October 2005. The objective was to discuss options, principles and actions that promoted appropriate and sustainable economic development in the Fitzroy Valley and the wider Kimberley region. The Kimberley Roundtable built upon a similar forum held for Cape York Peninsula in 2003. The forum explored existing and potential economic activities that would improve (rather than degrade) the cultural and environmental conditions of the Fitzroy and Canning basins.

The Roundtable provided an ideal opportunity for the Panel to hear first hand the regional aspirations of the community. Whilst the Panel undertook its own consultation program, these discussions assisted in further focusing and adding value to that program. The Roundtable also captured the Indigenous interests and concerns in a manner that was culturally appropriate. The Roundtable consisted of six workshop sessions: Land Management; Culture and Arts; Pastoralism; Agriculture; Tourism; and Partnerships in Conservation. The Interim Report of the Roundtable is included at Appendix 8. The Panel gave a commitment to maintain contact and continue visiting the Kimberley region to provide information and meet with interested parties after the release of this report.

In a more general community consultation process, Professor Appleyard made presentations on the project to the Committee of Economic Development of Australia (CEDA) in June 2005, Infrastructure WA Conference in October 2005 and the Australian Water Summit in Melbourne in February 2006. Two newsletters have been produced and distributed to a variety of stakeholders and interested parties.

15 OTHER ISSUES

15.1 WATER USE EN-ROUTE

As with the Watering Australia concept, some previous studies into the Kimberley water proposal advocated use of the water en-route to Perth. As part of this study a review was undertaken on the viability of water demands en-route for:

- irrigated agriculture;
- rehabilitation of native vegetation; and
- town and community water supplies.

15.1.1 Supply of Water for Irrigated Agriculture

The study by GHD looked at the nature of irrigated agriculture in Australia, the types of crops grown and the viability of such enterprises.

Of the estimated 2.4 million hectares of irrigated land in Australia, 54,000 hectares are in Western Australia, including at Harvey in the South West, on the Gascoyne River at Carnarvon and the Ord River Irrigation Area (ORIA) based at Kununurra. The average charge for water supplied for irrigation across Australia has been calculated at 3.7c/kL (ANCID 2005). By comparison, if used for agriculture, the 200 GL/year proposed for the pipeline could irrigate 13,000 hectares of land if applied at the rate of 15 ML/ha/year.

The profitability of agricultural enterprise depends on a wide range of variables, including the natural environment, introduced weeds, pests and diseases, distance to transport the product, and market costs. Given the relativities, broad-acre crops such as cotton and sugar were not considered. To test the viability of the potential for irrigated agriculture en-route, returns for high-value horticultural crops relative to the likely cost of water were compared. Applying water prices of $0.50-$2.00/kL to water near the source and at a price of $2.00-$4.00/kL at Carnarvon, indicated that in almost all cases the cost of water exceeded the gross margin likely to be realised for a broad range of high value horticultural crops.

It was also noted that irrigators proposing to base an operation on water supplied from this scheme, would be competing with irrigators operating on the ORIA with access to very low cost water (the historic charge for water delivered to the ORIA was 0.003c/kL) as well as irrigators in the West Kimberley region with access to good quality ground water from private bores. The report concluded that the supply of water from a pipeline or canal for irrigated agriculture would not be viable.

However, the report also concluded that establishing local irrigation schemes in some areas could have social benefits, although these would require further case by case study as to the relative economics.

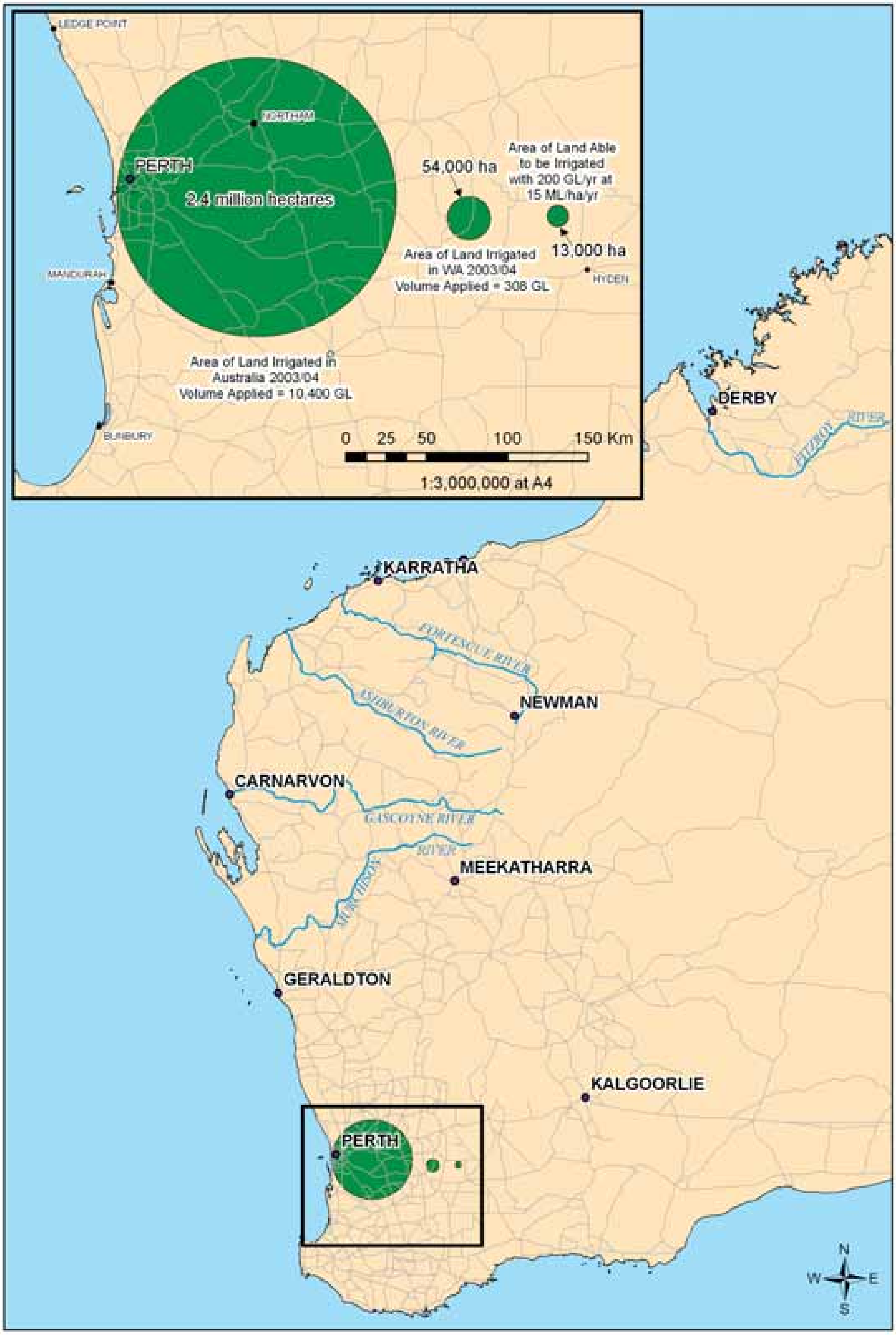

Figure 15.1 Graphic Representation of Land Area Irrigated in Australia and Area capable of being Irrigated by 200 GL/year at an Application Rate of 15 ML/ha/year[15].

[15] The irrigation rate in Australia is between 4.3 and 5.7 ML/ha/year. This is because most of the irrigation is to supplement existing precipitation. However, an application rate of 15 ML/ha/year would be typical for horticultural crops grown in areas of intermittent rainfall and high evaporation.

15.1.2 Rehabilitation of Native Vegetation

The concept of supplying water to facilitate the rehabilitation of degraded areas adjacent to old mine sites and eroded areas was considered. However, the temporary nature of such activity and the limited areas to which this could apply, could not justify the expense even without considering a return on the cost of water delivered.

15.1.3 Supply of Water to Towns and Communities En-Route

With each option for transporting water, there is the potential to supply communities in close proximity to the delivery route. The ocean transport option considered coastal communities accessing the water-carrying vessel as it travelled down the Western Australian coast. Previous studies had found that to supply substantial volumes en-route would entail a commensurate increase in capital and operating costs. Currently the cost to the Water Corporation of supplying water to regional customers is significantly greater than the revenue received. This differential is recouped by the Water Corporation receiving a community service obligation (CSO) payment from the Government, which in 2004/5 was $288 million (ERA 2005). The supply of water en-route would have no benefit in terms of unit cost to Perth consumers. In summary, any such supply would have to be justified on the perceived social benefits realised by the communities, and any additional cost recovered through a CSO or by an increase in the price paid by all consumers.

15.2 RENEWABLE ENERGY

Natural gas was selected by consultants GHD as the fuel for land based transport options. An earlier study implied that renewable energy could be used to power the water delivery systems. The "Report of the Kimberley Pipeline Environmental Advisory Committee" (June 1990) refers to the substantial renewable resources of solar and wind energy in central Australia and tidal and hydroelectric energy in the Kimberley Region.

The GHD study identified solar technologies as the most appropriate technology for the SCADA communication stations. Solar power has long been used for valve and gate operations in remote locations and was selected as the technology of choice for these applications.

However, renewable energy sources whether solar or wind generated cannot provide the quantity of power needed 24 hours every day, 365 days per year. The canal option would require 11 pump stations of between 1.3 MW and 10 MW capacity, while the pipeline option would require 100 MW at the river off-take, and 30 MW capacity at each of the inline pump stations. To put this into perspective, the total power required is similar to the output of the Collie Power Station, which has a capacity of 300 MW. Were an alternative source of power to be used, backup power generation or storage would therefore be necessary. This need for backup power means an alternative power source could only be justified where the capital and operating costs of the alternative are less than the fuel saved with the conventional power generation. Hence the GHD study concluded that renewable energy was not cost competitive with conventional gas fired power generation for the pumping task, although it noted that the situation could change if mandatory renewable energy targets and or emission trading requirements change. It also noted that should the Federal Government's Low Emissions Technology Development Fund be continued beyond 2006, the concept of a 50+MW Solar Tower (estimated to cost $150 million) could prove viable to power the pumping stations in other than cyclone prone areas. This would limit a large proportion of the coastal canal route option. Tidal power was dismissed as an option as it would require transmission lines over substantial distances and with the cost of construction and line losses would not be cost competitive.

An innovative proposal put forward for the ocean transport option was the installation of solar panels on the tankers. CEIS considered this proposal. However, there was limited information on the cost and operation of this concept. Hence an analysis was done on the basis that were such devices incorporated in large tankers and they halved fuel consumption of the transport vessel, they would be viable where the cost to install was less than $70 million for each vessel. In any event, the cost of fuel would not have a significant impact on the cost of water.

15.3 OFFICER BASIN

One of the concepts included a staged pipeline option initially drawing water from the Officer Basin, an artesian basin located some 600 kilometres northeast of Kalgoorlie. It has been estimated that the basin had a sustainable yield of 90 GL/year and, on the basis of limited data available, salinity was estimated to be in the range of 500-2,000mg/l[16].

The GHD study reviewed available data on this source and considered the infrastructure needed to abstract 20 GL/year as well as the cost of treating and delivering this amount into the G&AWS system at Kalgoorlie. It also considered the implications of allowing a portion being pumped west along the CY O'Connor (G&AWS) Pipeline. As a further consideration, it compared this cost to the unit cost of water from the G&AWS and the price of water from the United Utilities Australia proposal for a separate seawater desalination plant located at Esperance.

Notwithstanding some uncertainties with regard to the reliability and quality of the resource, the study estimated a cost of $4.43/kL to deliver water into Kalgoorlie from the Officer Basin via a piped scheme using 800 mm steel pipe. This was significantly higher than the average unit cost of approximately $1.70/kL to supply water through the G&AWS and also significantly higher than the estimated unit cost of $2.05 to $2.20/kL to supply desalinated seawater from Esperance. It was also similar to the average avoided cost[17] of providing additional water via the G&AWS to meet future demand, which had been estimated at $4.65/kL for the eight-year climate scenario (ERA 2005). On this basis the Officer Basin option was not considered further.

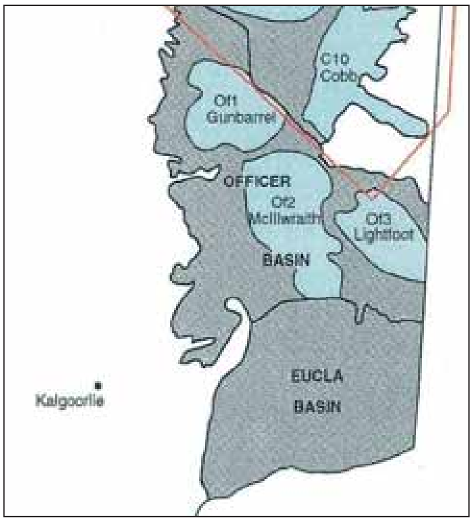

Figure 15.2 Officer Basin and Potential Groundwater Resource Locations (Modified from Allen et al 1992)

[16] 500mg/l is the maximum salinity under the Australian Drinking Water Guidelines.

[17] The avoided cost is the cost to the Water Corporation that could be saved were it to purchase water from a third party rather than install additional equipment.

15.4 REVERSE FLOW IN THE GOLDFIELDS WATER PIPELINE

One of the issues raised with integrating the Kimberley water supply with that to the Goldfields was the proposal to utilise the existing G&AWS to reverse the water flow and deliver water back down the pipeline to Perth. Existing infrastructure could reduce or delay the capital cost of transporting water over that portion of the route. However, the current pipeline has the capacity to deliver only some 15 GL/year to Kalgoorlie, operating at a relatively low maximum pressure of 120 m head. To reverse the flow would require re-engineering with new pump-sets and re-configured pipework. GHD estimated that 35 to 55 GL/year was the maximum flow possible along the Main Conduit, but this would exceed the pressure rating on much of the structure. It concluded the cost of constructing a new facility dedicated to the designed task would be significantly more cost effective were this a realistic option.

15.5 OTHER WATER SOURCES EN-ROUTE FROM THE KIMBERLEY

One aspect to consider in supplying water from the Kimberley to augment the Perth water supply is other sources from within Western Australia. Whilst it is recognised that the Kimberley region accounts for 75 per cent of the State's fresh water resource, other river systems and ground water resources exist, most notably the northern extension of the Yarragadee ground water aquifer, the Gascoyne River, the Ashburton Fortescue, Sherlock, Shaw and Coongan Rivers in the Pilbara region, and the Canning Basin ground water resource. A preliminary estimate identified a "potential" divertible yield from these sources totalling over 800 GL of water annually.

Whilst no study was done on these sources, they would present environmental and social impact challenges comparable to sourcing water from the Kimberley. A brief summary of these resources is at Appendix 9.

15.6 RESIDUAL VALUE

A separate consideration is the value of assets in the event of closure or cessation of the project. Depending on the residual life of pumping equipment, both the canal and pipeline options would have little value beyond that of the scrap metal recovered. It would depend on scrap metal values as to whether the buried pipe was worth recovering. In contrast, the ocean transport option's major investment is in the shipping fleet and this would most likely attract a ready buyer on the international market.

It is also probable that the ocean transport operation could attract a buyer as an ongoing business to supply water to an offshore destination. The ocean transport of fresh water has been carried out on a number of occasions in the past, for example to Hong Kong and the Gulf States. The actual residual value of the ocean transport option would depend on market forces at the time. This also raises the issue of export of water in parallel with deliveries to Perth. However, most of the cost of the ocean transport option is in the shipping and as a result would only marginally reduce the cost to deliver water to Perth.

15.7 IMPACT ON THE STATE'S FINANCES

Discussions were held with the Western Australian Treasury Corporation and the Department of Treasury and Finance (DTF) on the financing alternatives available to Government to fund a project as large as the supply of water from the Kimberley. Consistent with current government practice, a discount rate of six per cent was used in the financial analysis. Advice from DTF is contained in Appendix 10.

A previous report (Chase 1990) had advised on the options available to finance the Kimberley water supply. This was reviewed by the Western Australian Treasury Corporation. The options available are public financing, private financing or a mix of both. On the expectation that the scale of the project would be beyond the capacity of the Water Corporation, public funding would entail a very large additional borrowing program for the State. For private financing, there would need to be a high level of certainty over the cash flow to attract funding. This would result in the State needing to enter into a take or pay arrangement. On the cost side, a significant consideration in project financing is to demonstrate that a project's costs rank in the lower end of the industry cost curve. The Kimberley water project not only sits at the top of the cost of supply curve, but also is several multiples of cost above other methods of supply.

In considering a public-private funding option, considerable difficulties would be experienced identifying the split in risk and revenue sharing. Over and above the political and approvals risks, there are substantial engineering and construction risks that would require a large amount of work to define the project. This would result in very high transaction and bid cost overheads. A further consideration is with the scale of the project. There would be limited opportunity for competitive bidding. Of the options, the ocean transport offers greater opportunity for segmenting the tasks into the sourcing, transport and final delivery. There is also greater flexibility in the ocean transport option to vary the financial exposure, where the tankers could be diverted to other uses in the event of a cessation or termination of the operation.

It is inevitable that if the State were to underwrite a project of this scale there would be a commensurate reduction in budget provision for other programs. The total capital works budget for 2005-06 was $4.7 billion, $715 million of which was for water related projects and maintenance.

16 FUTURE FOR KIMBERLEY WATER

Whilst it is understood that there is a very large quantity of water flowing into the Timor Sea from the Kimberley, notably in the Fitzroy and Ord Rivers, the Panel noted the limited knowledge on both the surface and ground water throughout the region. It is the Panel's view that before there was any commitment to further utilise or amend these natural systems, a substantial amount of research would be required to better understand their hydrology and ecology. This would determine if there is a source large enough to supply a project of this nature for up to 50 years.

17 COMPARATIVE SUMMARY

	Pipeline	Canal	Ocean Transport Tanker	Ocean Transport 0.5GL Water Bag
Cost of Delivery ($$/kL) for the 200 GL/year Scenario.	$5.1	$6.5	$5.0	$5.0
Relative Risk	Moderate	High	Low	Moderate
Energy Consumption kW/kL	Moderate	Moderate	High	High
Greenhouse Gas Emitted Tonnes	Moderate	Moderate	High	High
Relative Environmental Impact	Moderate	High	Moderate	Moderate
Relative Social Impact	Moderate	High	Low	Low

Table 17 Comparative Summary of the Options for the 200 GL/year Scenario.

18 PANEL FINDINGS

Technical and Economic Issues

- The lowest cost option to supply water from the Kimberley to Perth by matching growth in water demand is through transporting water in super tankers. This was $6.70/kL, more than five times the cost of desalination.
- Incorporating a Kimberley water supply into the Water Corporation's IWSS may be expected to at least double the average annual household water bill, from $304 to over $610 per annum.
- To be competitive with other sources available to the Water Corporation, the cost of delivering water from the Kimberley would need to be reduced by 80 per cent. This was not seen as achievable by any of the options studied even taking an optimistic view of the development of new technologies in the future.
- Transporting water via a canal would be the most expensive and risk-prone option, in the context of providing a reliable water supply to urban consumers, and would have the greatest environmental impact.
- There are significant unknowns in operating a canal over such a distance, particularly with regard to the extreme cyclonic conditions that occur from time to time for a large section of its length.
- The pipeline option is based on proven engineering solutions and whilst its energy requirements are high it is the option that has the least exposure to risk and provides greater certainty for water quality.
- Whilst the water bag concept offered a unit cost comparable to super tankers, the concept would require considerable development to eliminate the design risks.
- The ocean transport options would consume more energy per kilolitre than the pipeline, canal or desalinisation plant and therefore would have the greatest greenhouse gas impact.
- Given the cost of the water from either a pipeline or canal (about 100 to 200 times more expensive than current prices for irrigation water) it could not be economically justified to use this water for any irrigation development along the proposed routes.

Environmental and Social Issues

- There is limited knowledge on the hydrogeology and ecology of the Kimberley region, in the Fitzroy River valley in particular.
- On the information available, the pipeline and canal options would require the construction of some storage in the Fitzroy valley, which could include a dam on the river and or some large off-stream storage towards the lower end of the river.
- The Indigenous Kimberley communities that would be affected did not support taking water from the region.
- The resolution of Native Title and land acquisition could be expected to take considerable time, particularly for the pipeline and canal options.
- The ocean transport option may be expected to have the least environmental impact to the land as it proposes to source its water from the Ord River, which has an existing dam. However, it generates approximately three times as much greenhouse gases as the pipeline or canal options.

Other Issues

- Renewable energy was not cost effective currently for transporting the water, other than for monitoring and valve and gate operation.
- The concept of sourcing water from the Officer Basin raised water quality issues and was not economic.
- The proposal to incorporate the G&AWS pipeline (from Kalgoorlie) into the schemes was examined and found to be impractical.

Conclusion

As requested by the Premier, the Expert Panel has completed a review of the feasibility of transporting water from the Kimberley region to the Water Corporation's South West Integrated Water Supply System.

While several methods are technically capable of delivering water from the Kimberley to Perth, the water would cost much more (at least five times) than if supplied by other available options and offer no other significant advantages to the development of the State.

19 GLOSSARY

ABS	Australian Bureau of Statistics
ACF	Australian Conservation Foundation
ADWG	Australian Drinking Water Standards
ANCID	Australian National Committee on Irrigation and Drainage
CEDA	Committee of Economic Development of Australia
CEIS	Clough Engineering & Integrated Solutions Pty Ltd
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Community Service Obligation
DTF	Department of Treasury and Finance
DWT	Dead Weight Tonnes
EPA	Environmental Propection Authority
ERA	Economic Regulation Authority
G&AWS	Goldfields and Agricultural Water Scheme
GL	Gigalitre (1,000,000,000 litres)
IWSS	Integrated Water Supply Scheme
KLC	Kimberley Land Council
kL	Kilolitre (1,000 litres)
km	Kilometre
kWhr	Kilowatt hour
LRMC	Long Run Marginal Cost
ML	Megalitre (1,000,000 litres)
MW	Megawatts
NHMRC	National Health and Medical Research Council
NRMC	National Resource Management Council
ORIA	Ord River Irrigation Area
PGA	Pastoralist and Graziers Association
RAMSAR	Convention on Wetlands (intergovernmental treaty)
RoW	Right of Way
SCADA	Supervisory Control and Data Acquisition
SEC	Specific Energy Consumption (kWhr/kL)
SEDO	Sustainable Energy Development Office
SPM	Single Point Mooring
USBR	United States Bureau of Reclamation
UWA	University of Western Australia
WC	Water Corporation
WWF	World Wildlife Fund

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21 APPENDICES

1 Kimberley Pipeline Technical Review. Final Report GHD March 2006. Executive Summary and CD ROM.

2 Kimberley Canal Technical Review. Final Report GHD March 2006. Executive Summary and CD ROM.

3 Review Proposal for Transporting Water via Offshore. Final Report CEIS March 2006. Executive Summary and CD ROM.

4 Integration of Kimberley Water into the Integrated Water Supply Scheme. Strategic Planning Concept and Cost. Water Corporation August 2005. Executive Summary and CD Rom.

5 Hydrogeological Assessment of the Fitzroy Alluvium. R.P. Lindsay & D.P. Commander. Department of Environment September 2005. Summary and CD Rom

6 Context Report on South West Water Resources Report to WA Government. CSIRO March 2005. Executive Summary and CD ROM.

7 Options for Transporting Water from the Kimberley an Analysis of Kimberley Stakeholder Perspectives. Beckwith Environmental Planning December 2005. Executive Summary and CD ROM.

8 Kimberley Appropriate Economies Roundtable. Interim Report October 2005. Introduction, background and objectives, and CD ROM.

9 Summary Statement on Water Resources between Perth and the Kimberley. GHD March 2006.

10 Advice on Impact of Financing from the Western Australian Treasury Corporation and the Department of Treasury and Finance. March 2006.

11 Advice on Energy and Greenhouse Emissions from Sustainable Energy Development Office. April 2006

APPENDIX 1

GHD
Technical Review of
Kimberley Water Supply.
Executive Summary: Pipeline

APPENDIX 2

GHD
Technical Review of
Kimberley Water Supply.
Executive Summary: Canal

APPENDIX 3

CEIS
Review Proposal for Transporting Water via Offshore.
Executive Summary

APPENDIX 4

Water Corporation
Integration of Kimberley Water into the
Integrated Water Supply Scheme
Strategic Planning Concept and Cost.
Executive Summary

APPENDIX 5

Department of Environment Hydrogeological Assessment of the Fitzroy Alluvium. Summary

APPENDIX 6

CSIRO
Context Report on South West Resources
Report to WA Government.
Executive Summary

APPENDIX 7

Beckwith Environmental Planning
Options for Transporting Water from the Kimberley an Analysis of Kimberley Stakeholder Perspectives.
Executive Summary

APPENDIX 8

Kimberley Land Council
Kimberley Appropriate Economies Roundtable, Interim Report.
Introduction, background and objectives

APPENDIX 9

GHD
Summary Statement on Water Resources between Perth and the Kimberley.

APPENDIX 10

Western Australian Treasury Corporation and the Department of Treasury and Finance Advice on Impact of Financing.

APPENDIX 11

Sustainable Energy Development Office
Advice on Energy and Greenhouse Emissions.

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