NOTES ON MILLSTREAM WATER MANAGEMENT

- Including:

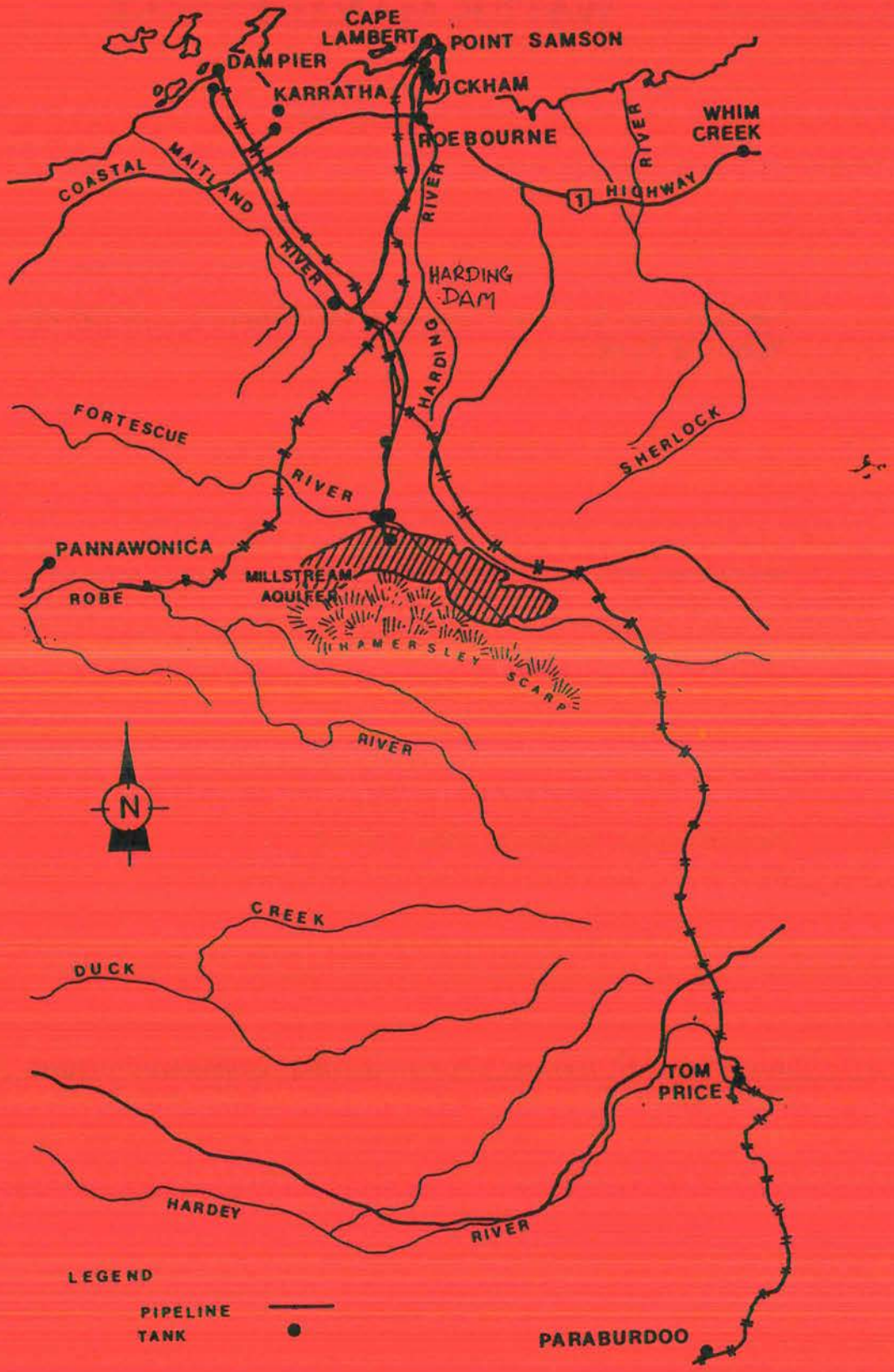
- ***Background to West Pilbara Water Supply Scheme and Millstream National Park***

- ***Summary of Millstream Water Environmental Program (EMP)***

- ***Summary of WAWA West Pilbara Water Supply Review and Development Strategy (June 1995)***

- ***Summary of Welker Environmental Consultancy (and Associates) Report on Millstream Environmental Water Requirements Study (December 1995)***

By G. Rundle
May 1996



WEST PILBARA WATER SUPPLY

1.0 Summary and Conclusions

1.1 The West Pilbara Water Supply Scheme is currently supplied from the Millstream/Harding conjunctive water supply source. This involves providing water from the Harding Dam as a priority, and from the Millstream groundwater aquifer when supplies are unavailable from the Harding Dam due to constraints on storage quantity or quality (ie. excessive turbidity). Initially the sole source of water for the scheme was the Millstream Aquifer but the Harding Dam was subsequently built to reduce reliance on the aquifer for water supply, thereby alleviating the strain on Millstream ecosystems.

1.2 The Environmental Review and Management Program (ERMP) for the Harding Dam indicated that the dam was to operate conjunctively with the Millstream Aquifer and provide an annual yield of 28GL based on 50% environmental supplementation for the Millstream ecosystems. A Millstream Water Management Program was developed for the water supply manager (then Public Works Department) in 1984 by a consultant to take into account Millstream environmental needs. This was subsequently reviewed in 1992 and the Water Authority of WA replaced it with an Environmental Management Program (EMP) that had been developed in consultation with CALM and the EPA.

1.3 There are a number of significant management issues involved with water and erosion management at Millstream. Firstly, the dynamics of the aquifer level is not fully understood in relation to recharge, natural discharge, water supply abstraction and local environmental demands and supply mechanisms. Managed manipulation of the system cannot be confidently made in regard to potential long term environmental implications without more research and monitoring.

1.4 At the present time there is a buffer level of water supply demand by West Pilbara centres (currently about 9.2GL annually) and the calculated sustainable conjunctive supply of 28GL/y. However, the second significant management issue is what buffer level needs to be maintained between demand and supply ability of the current (and expanded) West Pilbara Water Supply System. Prolonged drought events can affect supply ability to coastal centres, and meeting formal demand commitments (eg. covered by agreements with major resource developers) could result in reducing environmental supplies. The demand for water from the West Pilbara Water Supply Scheme will also increase substantially if the forecasted growth of mineral resource processing industries in the Roebourne/Wickham/Karratha/Dampier area is realised.

1.5 The third significant issue is the implication of continued dynamic channel erosion in the bed of the Fortescue River in the area of river pools adjacent to the Millstream Aquifer. This is a transition zone of the Fortescue River system where a more youthful coastal stream (lower Fortescue) has cut back and intercepted the high level valley of an older stream (upper Fortescue, which once flowed to the present day Robe River), and captured it. There is a relatively steep gradient in the transition zone between the 'young' and the 'old' courses, resulting in headward erosion. If this erosion succeeds in reaching the upper pool of the system (Deep Reach Pool) and lowers its level, it would predicably result in the aquifer level also dropping and diminish the water yield potential for both the local environment and the water supply scheme.

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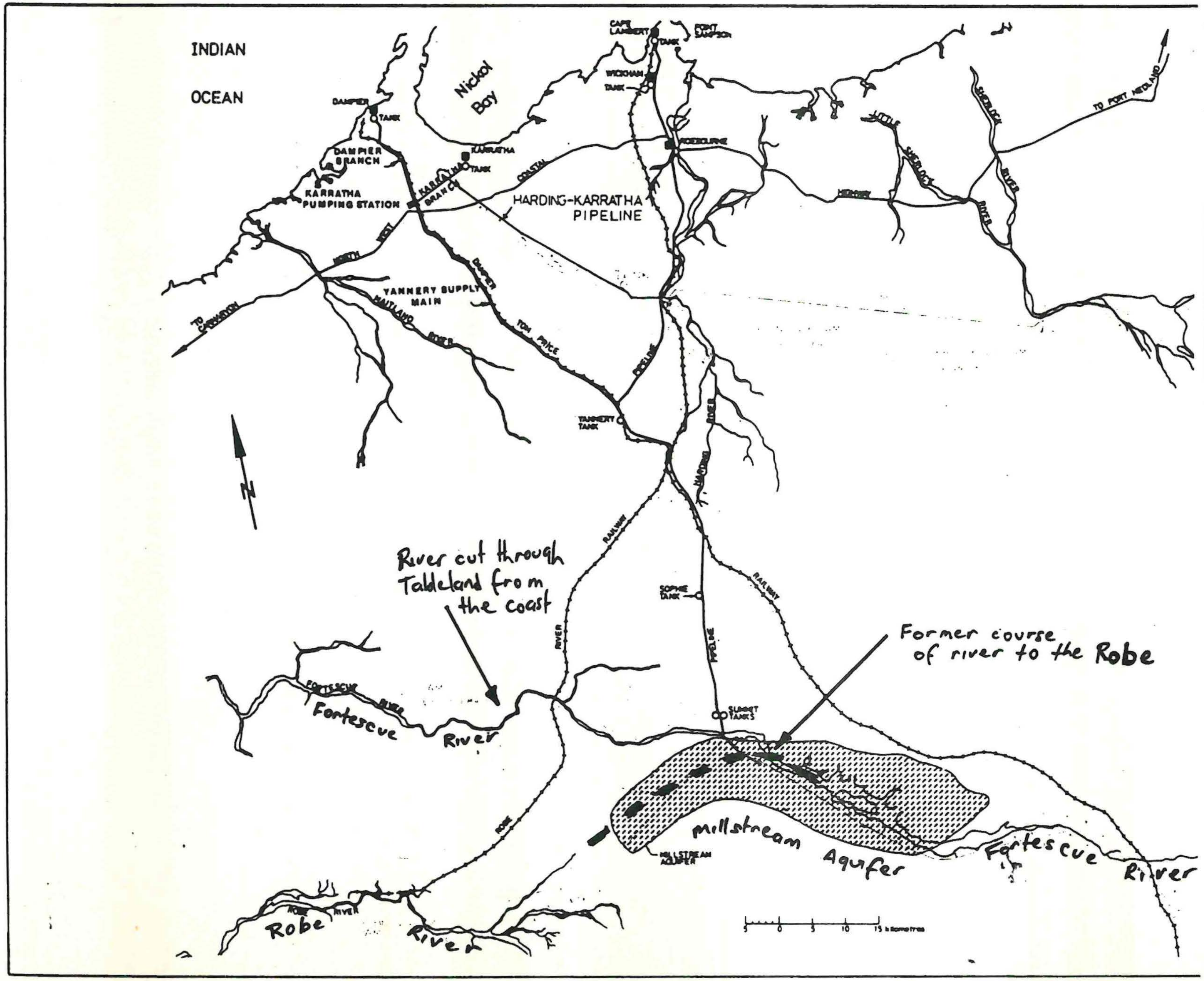
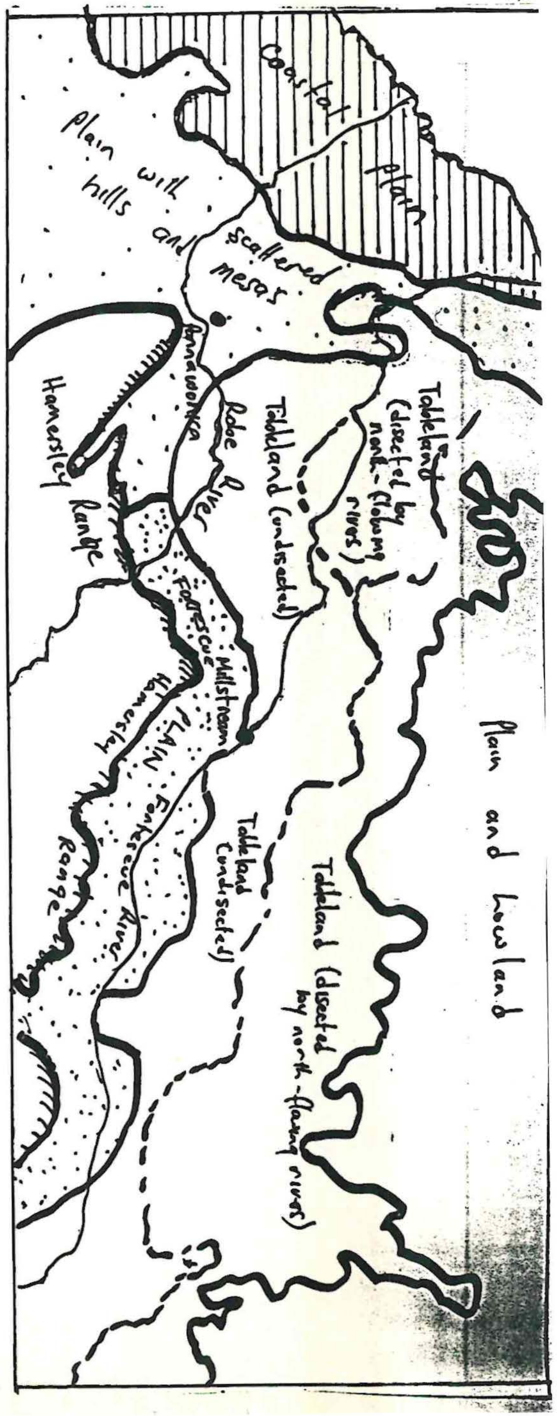

INDIAN
OCEAN
Nickol Bay
CAPE LAMBERT
PORT SAMPSON
WICKHAM
DAMPIER
TANK
DAMPIER BRANCH
KARRATHA
KARRATHA PUMPING STATION
ROEBOURNE
HARDING-KARRATHA PIPELINE
YANNERY SUPPLY MAIN
TO CARNARVON
TO PORT HEDLAND
YANNERY TANK
SOPHIE TANK
SUMMIT TANKS
RAILWAY
MILLSTREAM AQUIFER
River cut through Tableland from the coast
Former course of river to the Robe
Fortescue River
Millstream Aquifer
Fortescue River
Robe River
kilometres


Coastal plain
Plain with hills and scattered mesas
Hamersley Range
Robe River
Tableland (undissected)
Tableland (dissected by north-flowing rivers)
Millstream
Fortescue
PLAIN
Fortescue River
Hamersley Range
Tableland (undissected)
Tableland (dissected by north-flowing rivers)
Plain and Lowland

1.6 The Millstream location on the Fortescue River is a truly unique situation, being the point of contact between a 'new' downgrading river which has intercepted an ancient and stable old river valley (with a valley floor aquifer) in the vicinity of Deep Reach Pool. It is considered that the Fortescue River above Millstream was originally part of the Robe River system, flowing past today's Pannawonica. In this old drainage line between two rivers of today, is the Millstream Aquifer formed from calcrete, derived from underlying dolomite. At Millstream, the calcrete aquifer passes across Deep Reach Pool and then arcs southward away from the Millstream area in the old valley toward the Robe River.

1.7 Above the Millstream area, the Fortescue River flows across the broad Fortescue Plain. Here, it does not occupy clearly defined channels but spreads across the plain where, during floods, it may be up to 25km in width. At Millstream however, the river is incised into the edge of the tablelands (which separate the old valley from the coastal plain), forming a distinct gorge-like valley, narrowing from about 1600m above Deep Reach Pool to 200m at Gregory Gorge a further 20km downstream. The Millstream locality is therefore a dynamic transition zone, like a "spillway", between the old valley and a drop into a newer river valley that has cut back reaching the floor of the old valley.

1.8 Passing through the tableland between the high and low plains, the river is actively down cutting through a much narrower valley. Over the 20km distance between Deep Reach Pool and Gregory Gorge, the river drops about 50m and the river bed gradient varies from 1:1200 above Deep Reach Pool to 1:300 at Gregory Gorge. Within the narrowing valley of the Millstream area, the flow is confined to one or more channels spread across the valley floor, such pools occupying the deepest parts of the main channels. It appears that they were formed by the scouring action of the relatively high velocity river flows as the Fortescue drops over the lip of the "spillway" from its old course.

1.9 There is a natural discharge from the Millstream Aquifer which maintains both groundwater and permanent surface flows along the Fortescue River and adjacent areas between the aquifer and river. A special habitat feature is the Millstream Delta which is a significant wetland. The Millstream Area as a whole is regarded as an important refuge that is significant for contributing to Australia's biological diversity. Most of the important habitat areas have been included in the Millstream National Park. It is important therefore that, while the groundwater resource at Millstream continues to be utilised in water supply schemes, for appropriate water management to be in place to protect those elements of the local environment that are also dependent on this resource. Implementation (of the 1992 EMP (see para 1.2) involves both the water resource manager and Park manager, and is overseen by inter-department committees.

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1.10 More recently the water demand projection and local environmental implications have been further reviewed, and study reports involved are commented on the following sections of these notes. However, neither of these studies address the critical issue of dynamic channel/pool erosion occurring in the Fortescue River itself (para 1.5). While the NPNCA/CALM have more recently considered that development of a Park management plan is a necessary prerequisite to considering the erosion problem in more detail - **it would probably be more appropriate to develop a strategic overview for addressing Millstream Area issues rather than a management plan for the Park as a whole.**

1.11 The 1995 Millstream Environmental Water Requirements Study consultants have concluded that there is a need for a formal joint management approach between the "water manager" and CALM to ensure cost effective solutions to maintaining the environmental values in the Millstream Area. They believe there is also a need to determine objectives for vegetation management which would require the development of a management plan involving the NPNCA, CALM, the "water manager", EPA and a public consultation process. As water resource management and utilisation has now been legislatively split between the Water Corporation and the Water and Rivers Commission, respectively, there is an additional need to clearly understand the new water management responsibilities at Millstream. This and suggestions in the 1995 study for redirecting monitoring objectives indicate an urgent need to revise the 1992 Millstream EMP.

1.12 *The NPNCA should seek a briefing on the situation from the Perth-based Millstream Review Committee (which includes CALM's Dr. Tony Start), and relevant officers from both the Water Corporation and the Water and Rivers Commission. Such a briefing should deal with the most recent Triennial Report submitted to the Review Committee; the implications of unmanaged/managed river channel erosion; the implications and proposed action relating to the two recent reviews -*

- *West Pilbara Water Supply Source Review and Assessment*
- *Millstream Environmental Water Requirements Study.*

If such a briefing is arranged, attendance should also be sought for the CALM Millstream EMP "management officer" - who is a member of the Karratha-based Millstream Management Committee and who is also involved in monitoring at Millstream and the preparation of annual reports (para 3.8).

Prior to arranging such a briefing, the NPNCA/CALM need to develop some idea of the scope, form a desirable agenda, and identify desirable outcomes they wish to achieve and pursue.

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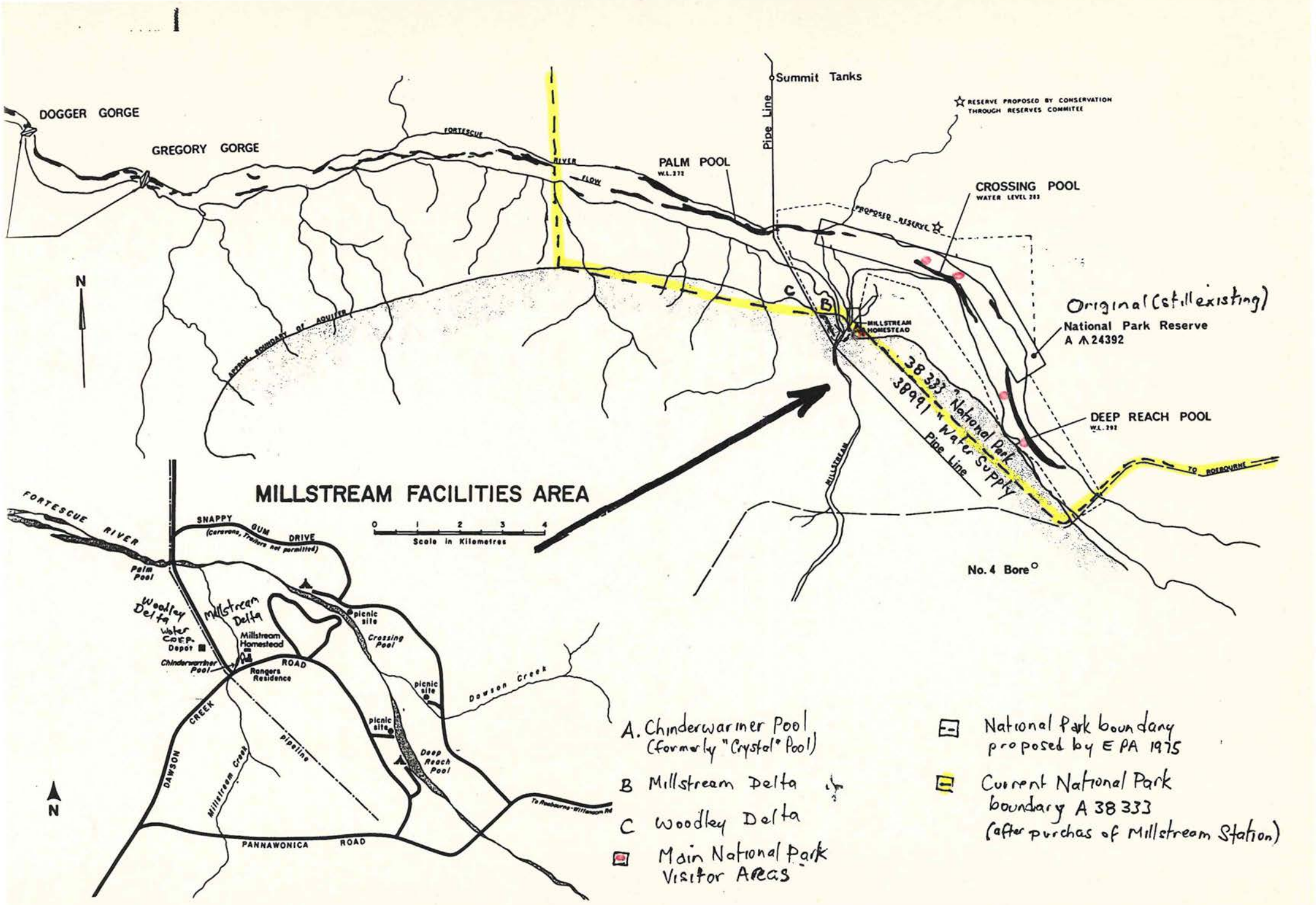
DOGGER GORGE
GREGORY GORGE
FORTESCUE RIVER
FLOW
PALM POOL
W.L. 272
Summit Tanks
Pipe Line
RESERVE PROPOSED BY CONSERVATION THROUGH RESERVES COMMITEE
CROSSING POOL
WATER LEVEL 283
PROPOSED RESERVE
N
APPROX. BOUNDARY OF AQUIFER
C
B
MILLSTREAM HOMESTEAD
Original (still existing)
National Park Reserve
A 24392
38333 ha National Park
38991 ha Water Supply
Pipe Line
DEEP REACH POOL
W.L. 292
TO ROEBOURNE
MILLSTREAM
No. 4 Bore
MILLSTREAM FACILITIES AREA
Scale in Kilometres
0 1 2 3 4
FORTESCUE RIVER
SNAPPY GUM DRIVE
(Caravans, Trailers not permitted)
Palm Pool
Woodley Delta
Millstream Delta
Water Coep. Depot
Millstream Homestead
Chinderwarrner Pool
ROAD
Rangers Residence
picnic site
Crossing Pool
picnic site
picnic site
Dawson Creek
DAWSON CREEK
Millstream Creek
pipeline
Deep Reach Pool
To Roebourne-Wittenoom Rd
PANNAWONICA ROAD
N
A. Chinderwarrner Pool (formerly "Crystal" Pool)
B Millstream Delta
C Woodley Delta
Main National Park Visitor Areas
National Park boundary proposed by EPA 1975
Current National Park boundary A 38333 (after purchas of Millstream Station)

2.0 Introduction

2.1 In June 1995 the former WA Water Authority completed a review and assessment of West Pilbara water supply resources. Water demand in the West Pilbara focuses on the coastal resource processing and shipping area of Roebourne/Wickham/Karratha/Dampier. The equivalent Port Hedland area is serviced by a separate water supply scheme, and inland mining centres also have their own independent water supply schemes. Future development at inland Pilbara centres is not likely to make direct demands on the West Pilbara water supply sources - but the resultant increased processing at the coast will.

2.2 Currently the sole West Pilbara water supply source is the Millstream/Harding Dam conjunctive use scheme. This involves using piped water from the Harding River catchment that is stored behind the Harding Dam, supplemented by the Millstream wellfield when dam storage is low (drought periods) or turbid (fresh recharge periods). Prior to 1985, Millstream was the major source of water for the West Pilbara, and the Harding Dam was commissioned in 1985 to provide the conjunctive scheme. It was originally estimated that Millstream water would only be required for about 20-30% of the time once the Harding Dam was commissioned. However, up to June 1995, Millstream water was required approx. 40% of the time! Heavy draws by the Millstream wellfield take account of Primary Management Area environmental needs (ie. the adjacent Fortescue River pools and marginal delta wetlands) and supplementation schemes have been installed. Abstraction from the Millstream aquifer since development of the wellfield are as follows ($1 \times 10^6 m^3$ = 1 giga litre or GL; GL/y = giga litres per year).

Abstraction from the Millstream Aquifer

YEAR	PRODUCTION ($x10^6 m^3$)	SUPPLEMENTATION ($x10^6 m^3$)	TOTAL ($x10^6 m^3$)
1969	0.05		0.05
1970	1.62		1.62
1971	3.01		3.01
1972	5.86		5.86
1973	7.25		7.25
1974	7.29		7.29
1975	7.86		7.86
1976	8.94		8.94
1977	7.04		7.04
1978	8.67		8.67
1979	9.52		9.52
1980	9.36	0.271	9.631
1981	10.39	2.187	12.577
1982	11.02	4.270	15.290
1983	11.04	4.917	15.957
1984	10.67	3.360	14.030
1985	8.94	0.878	9.818
1986	5.30	0.327	5.627
1987	3.87		3.87
1988	4.39		4.39
1989	6.59		6.59
1990	2.75		2.75
1991	3.39		3.39
1992	2.89		2.89
1993	4.06		4.06
1994	4.88		4.88

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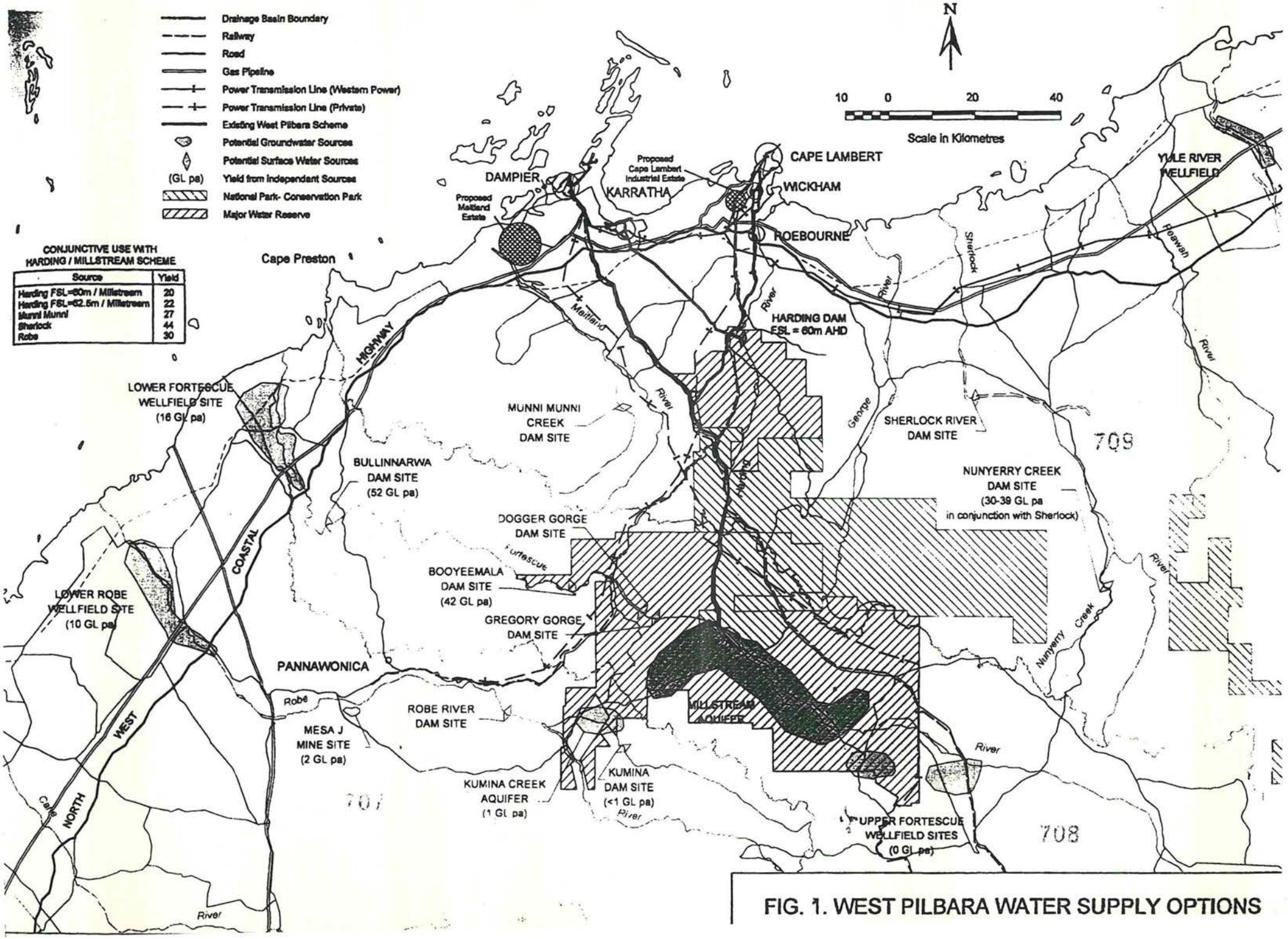

FIG. 1. WEST PILBARA WATER SUPPLY OPTIONS

Current management arrangements of the Prime Management Area at Millstream Area and Millstream Aquifer resulted in a 1992 decision that short-term (<1 year) allowable abstraction from the aquifer could be as high as 9GL/y and long-term (>1 year) allowable abstraction rates could be a lower 6GL/y.

2.3 In 1984, prior to the commissioning of the Harding Dam, the sustainable yield of the conjunctive Millstream/Harding water supply source was determined to be 20GL/y. However, the current yield is about 14GL/y because the Harding Dam water isn't treated and intermittent turbidity reduces usage.

2.4 The current **demand** by West Pilbara towns and industry is 9.2GL/y. Present industry concerns (Hamersley Iron, Robe River, Woodside) are entitled by agreement up to 11GL/y - and with other public consumption provides a potential demand of 15GL/y. Expansion by the three companies is likely in the next few years and this will require the full use of their entitlement and a resultant actual demand of 15GL/y - just beyond the limit of current conjunctive yield potential of the Millstream/Harding source. Additionally, in drought years (when the Millstream Area itself is likely to be under water need pressure), the Millstream Aquifer could be called upon to supply most of the West Pilbara developments water supply demand.

2.5 Other currently proposed additional developments for the West Pilbara could potentially increase demand to more than 30GL/y - double the current yield potential. Even if capital expenditure on water treatment for Harding Dam water was initiated, the increased conjunctive-use yield to 20GL/y would be insufficient to meet this calculated demand. Thus, an additional supply source would need to be developed within the next few years.

2.6 West Pilbara long-term water demand projections of 20 years ago have not been realised (eg. 190GL/y by 1992), it now appears that demand by the year 2000 is likely to be between 12GL/y and 21GL/y - and perhaps as high as 60GL/y by the year 2005. A study of options to progressively enhance existing water supply schemes and to develop new sources has concluded that the following steps should form the basis of a West Pilbara water supply strategy:

- The present 9.2GL/y of untreated water supplied from the Millstream/Harding source can be increased to the capacity of the existing delivery infrastructure (pipeline, etc), which is about 11.5GL/y.

- Delivery of untreated water can be further stepped up to the limit of about 14GL/y by increasing the pipeline capacity.

- The next most economic option for increasing supply is to develop a new wellfield on the lower Fortescue aquifer - increasing yields by a further 16GL/y to 30GL/y. This is a shallow unconfined aquifer near the coast, comprising alluvial sediments forming the Fortescue delta, and is recharged by river flow. Dams on the river upstream of this aquifer are therefore likely to affect the recharge rate.

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- Treat turbid water from the Harding Dam to tap its full potential - to supply a conjunctive yield with Millstream of 20GL/y. This amounts to a further increase of 6.4GL/y providing a total 36.4GL/y capacity for the West Pilbara water supply scheme. However, the present spillway level is lower than originally planned, to maintain a full supply level in the dam that didn't impact on the nearby Robe River railway. Raising the spillway will increase the Millstream/Harding conjunctive use source to a yield of 22.4GL/y and total water development yields to 38.4GL/y. However, railway relocation costs etc may inhibit the viability of this upgrade option. Any improvements to the Harding Dam to provide yields over 14GL/y for the Millstream/Harding conjunctive operation will apparently require additional production wells being provided at Millstream **(reasons are unclear).**

- Once improvements are made to the Harding Dam supply the next most economic option is development of a further wellfield on the lower Robe aquifer - increasing yields by a further 10GL/y to a total of 48GL/y. Like the lower Fortescue, this shallow unconfined aquifer is near the coast and comprises alluvial sediments forming the Robe delta, and is recharged by river flow.

- Previous studies have discounted dams across the Fortescue River at Gregory and Dogger Gorges, immediately below the Millstream Area, because they would flood the area. This was considered to be environmentally unacceptable. However, optional dams have been considered further downstream at Booyeemala and closer to the coast at Bullinarwa. The Booyeemala site has a lower annual yield would be less expensive to construct and possibly have less impact on recharging the lower Fortescue wellfield which is further downstream. A dam at Booyeemala would yield 42GL/y, and lift proposed developed West Pilbara water supply sources to a total yield of 90GL/y. This total capacity is about 50% above the possible demand of 60GL/y that might be reached by 2025.

RECOMMENDED SOURCE DEVELOPMENT STRATEGY
(MEDIUM GROWTH RATE)

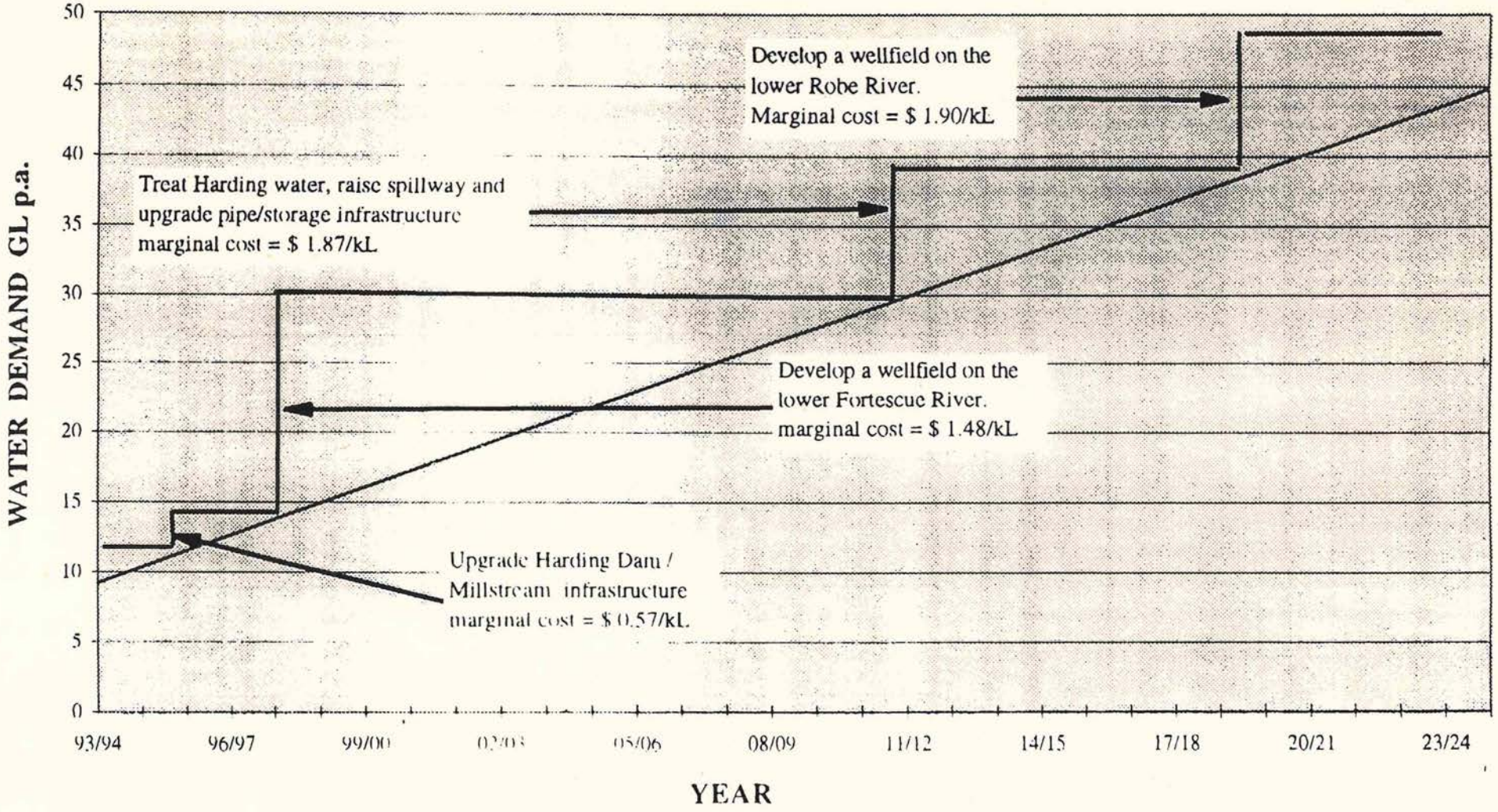
Staged Source Development	Water Available from WP (GL p.a.)	Increase in Water Available (GL p.a.)	Capital Cost ($ M's)	Annuity Cost ($ M's p.a.)
Harding Dam / Millstream - current demand	9.2	N.A.		
1. Harding Dam / Millstream upgrade pipe/storage infrastructure	14	5	30	0.4
2. Develop lower Fortescue wellfield.	30	16	143	2.1
3. Harding Dam / Millstream treat water from Harding Dam and raise spillway (Does not include the cost to relocate or stabilise Robe River's railway line)	38	8	160	1.0
4. Develop lower Robe wellfield	48	10	160	1.4
5. Dam on the Fortescue River at Booyeemala.	90	42	300	3.4

Note: 1. Capital costs are expended over the initial development phase (i.e. 2-4 years).

2. The annuity cost considers upgrading, replacement, operating and maintenance costs expended each year, up to 2025.

RECOMMENDED SOURCE DEVELOPMENT STRATEGY

MEDIUM GROWTH SCENARIO



WP222

3.0 Management of the Millstream Water Resource

3.1 A large iron-ore mining and export industry commenced in the Pilbara Region in the 1960's. Two companies, Hamersley Iron and Robe River, have their port and related infrastructure in the West Pilbara area of Roebourne/Wickham/Karratha/ Dampier, and created a demand for water. A wellfield was consequently developed on the Millstream Aquifer by the former Public Works Department (PWD) and groundwater abstraction commenced in 1968-69, as the first phase in the development of the West Pilbara Water Supply Scheme.

3.2 Development of the Millstream Aquifer was the most economical and quickest of several water resource development options available at the time. Environmental protection legislation wasn't enacted until 1971 and there was no environmental assessment of this initial development of the Millstream Aquifer. However, as a consequence of this development, ecological interest was shown in the Fortescue River pools of the Millstream Area and a biological survey was undertaken by the former Department of Fisheries and Fauna in 1969. At the time, the aquifer and associated wellfield development, and the river pools were part of the Millstream pastoral lease. A small national park over the river pools was subsequently declared in .

3.3 The Millstream Aquifer acts as a large reservoir of groundwater, and is largely recharged from rainfall, run-off from the adjacent Hamersley Range, and flooding of the adjacent Fortescue River. Its estimated water storage volume is 1 700 GL, with a recharge rate of 16.8GL/y. Thus, if environmental needs were ignored, the sustainable yield from the aquifer is about 16GL/y. In the 1970's a major study was made of the Pilbara's potential for industrial processing of its produced raw materials and other feedstock, and projected future water demands for the West Pilbara were of the order of 190GL/y by 1992. As a consequence the identification and evaluation of potential Pilbara water sources has been a continuing work.

3.4 Initially, it was proposed to construct a storage dam below the Fortescue pools of the Prime Management Area, at Gregory or Dogger Gorges. However, environmental protection legislation by then existed in the State and the PWD was obliged to commission an environmental assessment of these proposals. The resultant 1978 report reinforced the biological and social values of the Millstream Area and the State Government decided against dams at sites on the Fortescue River that would flood the river pools at Millstream. Instead, it opted for a storage dam on the Harding River, closer to the West Pilbara demand centres. An environmental assessment of this proposal was made and the EPA considered the impacts to be acceptable. However, it was recognised that at times the Harding Dam could not meet West Pilbara water demands due to low storage levels, and in some periods the shortfall would be met from the Millstream Aquifer. It was recognised that this conjunctive use would therefore need a management program for the Millstream Aquifer, to ensure that environmental demands of the Millstream Area could also be met. Recommendations by the EPA in 1982 supported these concepts.

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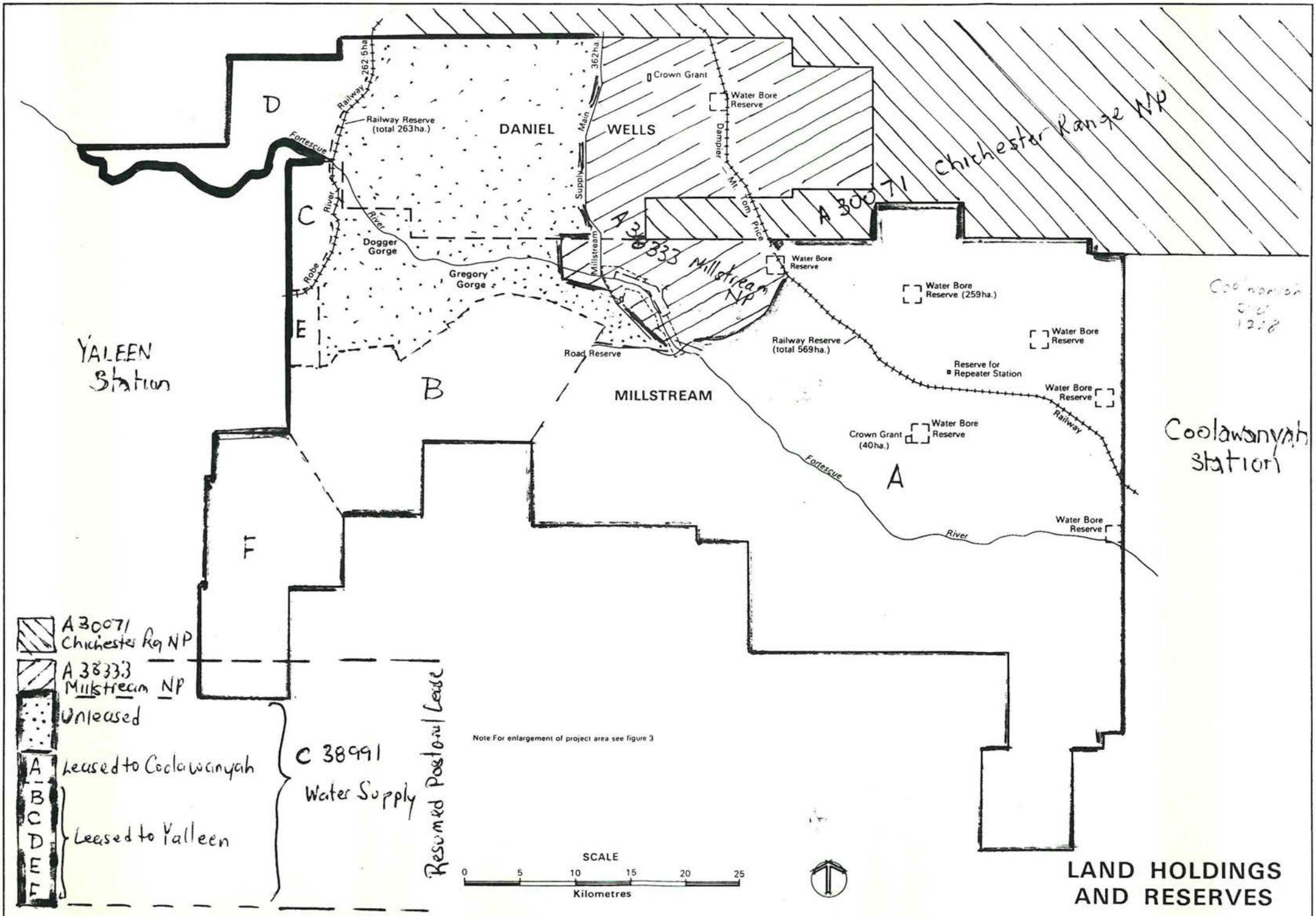
DANIEL WELLS
YALEEN Station
MILLSTREAM
Coolawanyah station
Crown Grant
Water Bore Reserve
Railway Reserve (total 263ha.)
Railway Reserve (total 569ha.)
Road Reserve
Reserve for Repeater Station
Crown Grant (40ha.)
Water Bore Reserve (259ha.)
Dogger Gorge
Gregory Gorge
Fortescue River
Robe River
Millstream
Main Supply
Dampier
Mt Tom Price
Railway
262.5ha
362ha
A 30071 Chichester Range NP
A 38333 Millstream NP
A
B
C
D
E
F
A 30071 Chichester Rg NP
A 38333 Millstream NP
Unleased
Leased to Coolawanyah
Leased to Yalleen
C 38991 Water Supply
Resumed Pastoral Lease
Note: For enlargement of project area see figure 3
SCALE
0 5 10 15 20 25
Kilometres
LAND HOLDINGS AND RESERVES

3.5 The quantity of water from the Millstream Aquifer to maintain the adjacent pools and associated vegetation (ie. local 'environmental demand') is considered to be 12GL/y, leaving a balance of 4.8GL/y over the estimated annual recharge rate for aquifer storage. Until the Harding Dam was commissioned in 1985, abstraction from the aquifer steadily increased to a peak of 16GL/y - exceeding 5GL/y over a period of 16 consecutive years. Since 1987, the draw has generally been maintained below 5GL/y. The PWD proposed that by artificially maintaining spring flow in the Millstream Area through a water supplementation scheme, the conjunctive Millstream/Harding source yield would be 21.8GL/y.

3.6 In 1982 the State Government resumed the Millstream pastoral lease to protect the West Pilbara water supply, preserve indigenous flora and fauna, and to expand the national park. Part of the former lease was incorporated into the Millstream National Park (reserve 38333) and the expansion linked it to the nearby Chichester Range National park (reserve 30071), to now form a single national park. The remainder of the former lease became reserve 38991 vested in WAWA for the purpose of " Water Supply ". While most of this new reserve has been leased back to adjoining pastoral stations by the Water Authority, the Millstream wellfield in the Prime Management Area remains unleased.

3.7 In 1984, the former PWD commissioned consultants Dames & Moore to prepare a Millstream Water Management Program. This addressed the provision of a management group; established monitoring needs; and established procedures for determining the level of supplementary environmental water demand, and provided proposals for supplying water to various components of the environment. The 1984 water management plan also suggested procedures for modifying the management plan in the light of operational experience, and addressed reporting and review mechanisms. For a number of reasons it became necessary to review the 1984 management plan, and the current 1992 Millstream Environmental Management Program is the result. In the meantime the former PWD had been broken up and a new agency, the Water Authority of Western Australia (WAWA), became responsible for managing the West Pilbara Water Supply Scheme.

3.8 Under the 1984 management programme, two inter-departmental committees were established to co-ordinate its implementation. Under the 1992 Millstream Environmental Management Program (EMP), these have been retained. Both committees had representatives from WAWA, CALM and the EPA, with one based in Perth and the other in the Pilbara (Karratha). The Karratha-based Millstream Management Committee (MMC) has the following functions:

- co-ordination and control of the EMP
- review of the monitoring data
- modification/adoption of the EMP
- receipt and reviewing of the annual reports from the WAWA management officer (assisted by the CALM management officer)

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- preparation of triennial reports to the Perth-based Review Committee
- reviewing future development proposals for the Millstream Area
- advising the Review Committee of any breaches of the management criteria or other adverse changes in the environment.

3.9 Annual reports to the MMC cover the 12 month period October-September are to be submitted by the end of each December, with the Committee itself meeting in the following February-March. These reports provide an update on a wide range of issues, including monitoring results of several important items. The first triennial report to the Review Committee under the 1992 EMP was produced in 1994, and it was this report that raised the issue of current headward erosion at the Millstream pools.

3.10 Environmental management under the EMP basically involves the following general objective:

> *to maintain sufficient quality, distribution, variation and quantity of water in the Millstream Area, and to support ecological processes and the essential natural values of the Millstream Area.*

The EMP is applicable to the *Millstream Area*, which is defined as areas of the former Millstream Station are vested in State Government agencies (reserve 38991 for " water supply "; and reserve 38333, Millstream NP) and currently remain under their management (ie. areas not leased back for grazing). It includes the Millstream *Prime Management Area* which basically comprises the Fortescue River pools that are within the national park, and the adjacent Millstream wellfield which remains an unleased part of reserve 38991. Management of other areas of the national park and management of issues at Millstream not related to water are addressed by CALM. Management of the remainder of reserve 38991 that is leased to adjoining pastoral stations.

3.11 At Millstream, the lower Fortescue River has cut into an old river valley, and has a steeper gradient below Deep Reach Pool (which is in the 'old' river valley). The upper pool, Deep Reach rests on the outside lip of the Millstream Aquifer and is directly fed water from the aquifer. The other pools are in the newer river valley, which has been cut below the older valley level, and each pool is at a level lower than its upstream neighbour - Crossing Pool, Palm Pool, Livistona Pool, respectively. The system of lower pools is fed from water overflowing from Deep Reach and down the river channels from pool to pool. Marginal springs maintain some side creeks that also flow into the system, particularly near the former Millstream homestead. Here, overflow from Chinderwariner Pool (formerly known as Crystal Pool) has created damp areas known as the Millstream and Woodley Deltas.

3.12 The Fortescue River pools are therefore an integrated system with water flow generated largely from spring discharge into Deep Reach Pool, and supplemented by flows from Chinderwariner Pool (near the former Millstream homestead) via the Millstream Delta. Both Deep Reach and Crossing Pools have aesthetic and recreational values and the total pool system with its interconnecting channels and fringing forest have an overall ecological value as an oasis in an arid landscape.

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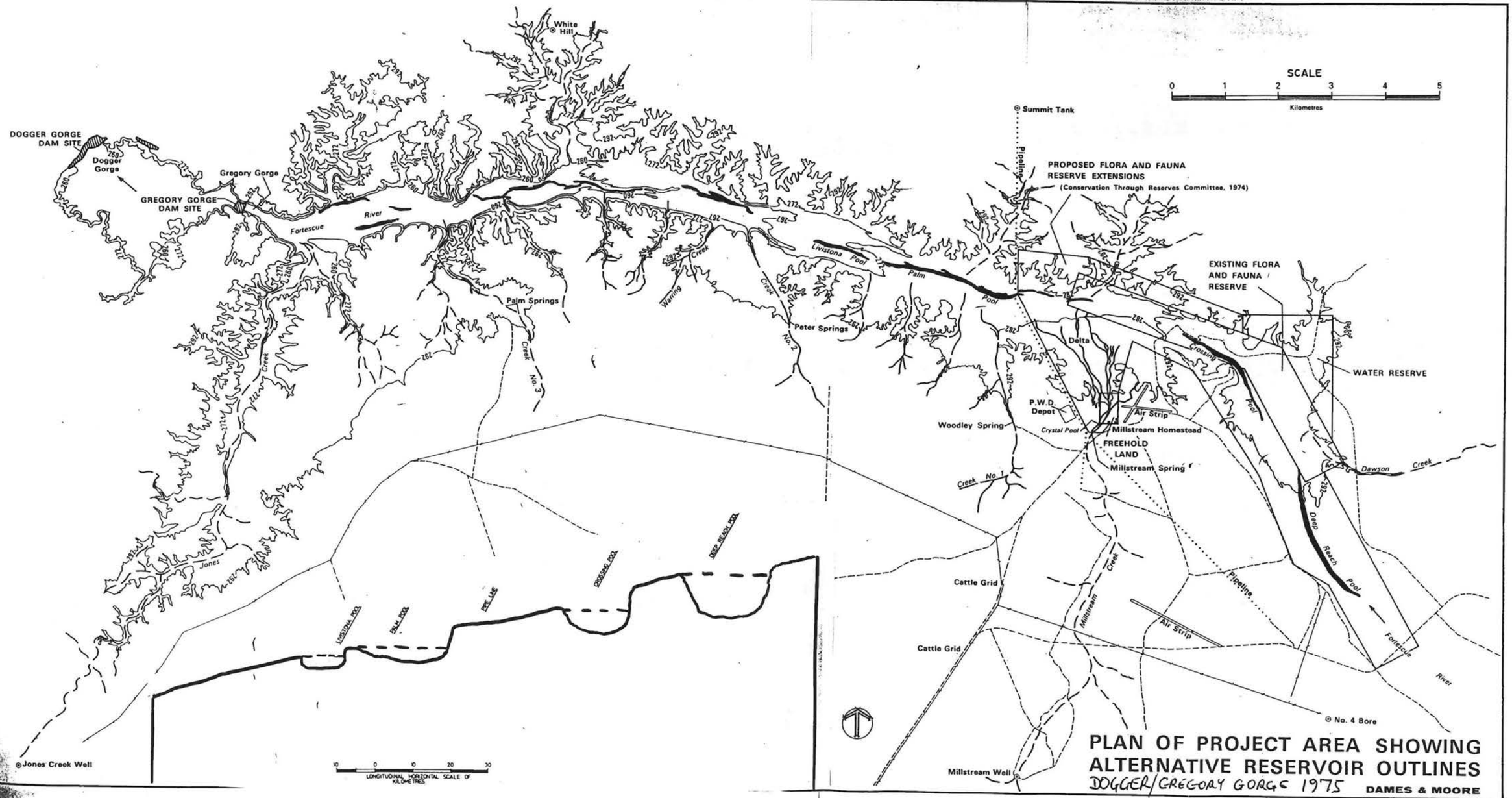


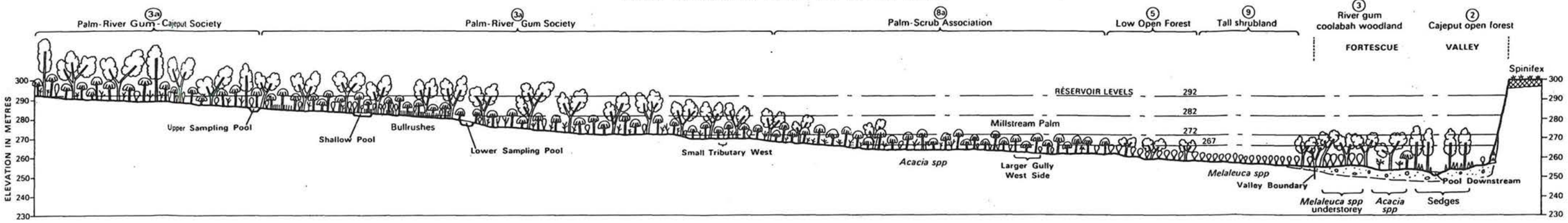
PLAN OF PROJECT AREA SHOWING ALTERNATIVE RESERVOIR OUTLINES

DOGGER/GREGORY GORGE 1975

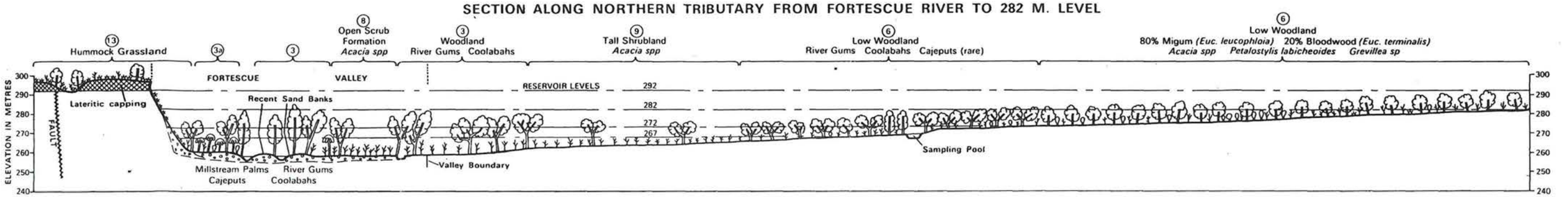
DAMES & MOORE

FIGURE 3

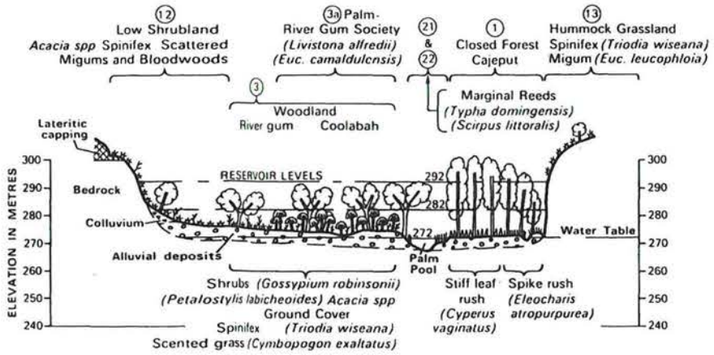
SECTION ALONG SOUTHERN TRIBUTARY (CREEK NO. 3) FROM FORTESCUE RIVER TO 292 M. LEVEL



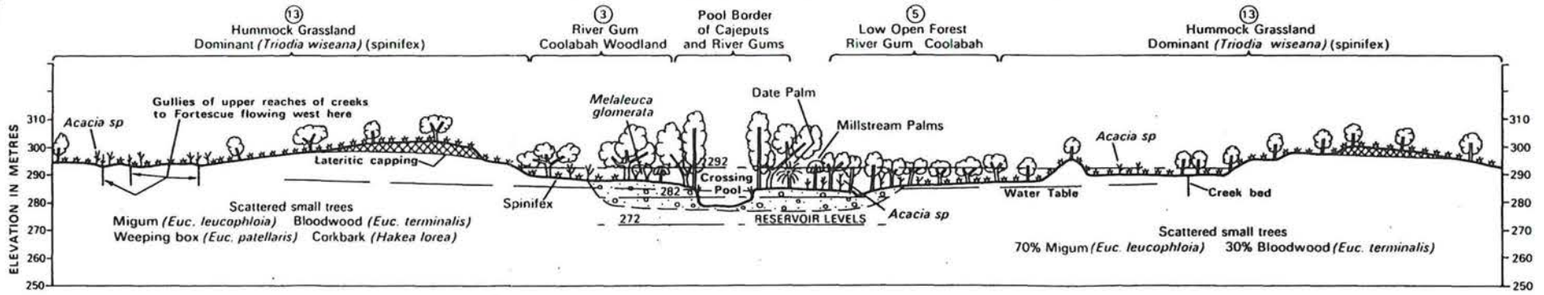
SECTION ALONG NORTHERN TRIBUTARY FROM FORTESCUE RIVER TO 282 M. LEVEL



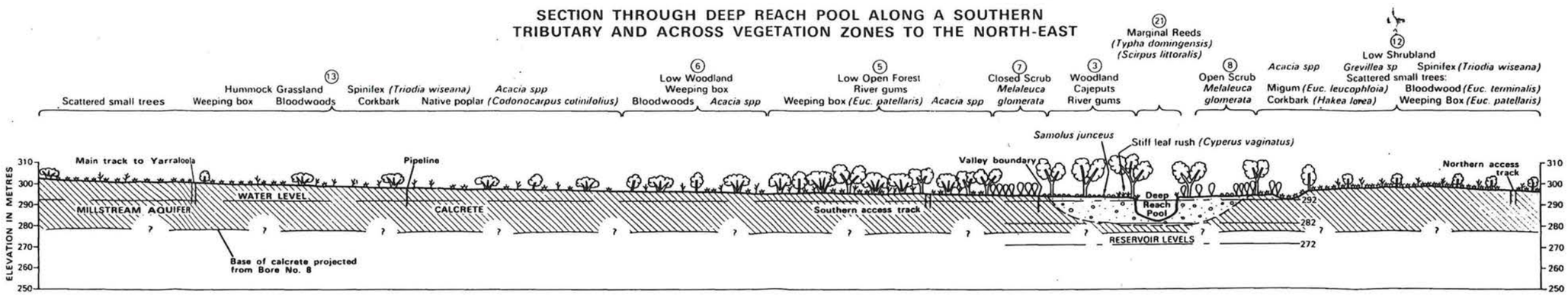
SECTION THROUGH PALM POOL LOOKING DOWNSTREAM



SECTION THROUGH CROSSING POOL LOOKING DOWNSTREAM



SECTION THROUGH DEEP REACH POOL ALONG A SOUTHERN TRIBUTARY AND ACROSS VEGETATION ZONES TO THE NORTH-EAST



NOTES

Vertical scale is exaggerat
Representation of plants i

HORIZONTAL SCALE

0 100 200 300 400 500

Metres

VEGETATION TRANSECTS OF MILLSTREAM-FORTESCUE SYSTEM

Provision of the Deep Reach Supplementation Scheme was commissioned in 1984 and completed in 1986. However, it has not had to be used for ecosystem maintenance as yet, as the Harding Dam water supply came on stream at this time.

3.13 Since commissioning the Harding Dam, however, considerable water quality problems have been experienced, restricting the use of that source. Originally, it had been estimated the Millstream water would only be required for about 20-30% of the time as part of a conjunctive use scheme - but it has been required to contribute to the West Pilbara Water Supply Scheme for over 40% of the time. Nevertheless, the conjunctive use of both sources has reduced the requirement for Millstream water - but this will rise as water demands increase unless and until other regional water resources are developed. Under the 1992 EMP the specific management objectives for the Fortescue River pools and the Deep Reach Supplementation Scheme are:

- to maintain Deep Reach Pool above its cease-to-flow level and maintain flow in the main distributing channels between Deep Reach and Crossing Pool.

- to maintain Crossing Pool above its cease-to-flow level and maintain flow down each of the main distributary channels to Palm Pool.

- to maintain Palm Pool above its cease-to-flow level, with sufficient out-flow to meet the requirements of Livistona Pool.

- to maintain discharge from Livistona Pool between April and October, with the level being allowed to decline by 0.5m below the cease-to-flow level from November to March.

3.14 The delta areas are important both ecologically and aesthetically and surface flow through them supports large areas of wetland with aquatic microphytes, sedges and fringing Cajuput (northern paperbark) and River Gum forest. Together these provide habitat for a variety of dependent small fish, dragon flies, birds and reptiles. The surface flows from the delta areas also contributes to water levels in the downstream Fortescue pools (Palm Pool, etc). During the late 1970's, areas of the normally damp deltas dried out and resulted in Cajuput deaths and general vegetation thinning. These observations resulted in the PWD in 1982 establishing bores for the Chinderwariner Supplementation Scheme. The delta environments have been modified since the area was occupied by Europeans and will probably be restored under an active CALM program if adequate resources are provided. Under the 1992 EMP, the specific objectives of the Supplementation Scheme are:

- to maintain Chinderwariner Pool (near the former Millstream Station Homestead) at an aesthetic level and which will maintain a strong flow through outlet channels.

- to maintain flow into the delta distributaries to maintain the current area of wetland, and

.../11.

- to maintain at least one small flow into the Fortescue River.

3.15 Downstream from Livistona Pool are Gregory Gorge, Palm Spring and Palm String Pool which are currently outside of the Millstream National Park. The spring occurs in Palm Creek where the bed of the creek has intersected the water table, and provides a continuous flow in the creek downstream to the Fortescue River. It has become an important groundwater level monitoring site.

3.16 There are a range of non-water supply management issues covered by the EMP, the two most significant ones being river erosion and weed control. Several weed species have been displacing endemic terrestrial and aquatic species in the Millstream area. Some of the exotic plants were deliberately introduced around the station Homestead and have now spread through the delta. CALM has an active control program but there are resource constraints on top of physical and ecological constraints associated with the delta wetland. On the matter of erosion, the EMP's objectives are to strike a balance between allowing natural river and stream scouring processes to proceed and intervening where it is desirable to maintain the aesthetic and recreational values of pools where these are threatened. Given these objectives, the management criteria for erosion along the Fortescue River system at Millstream are:

- to maintain pool levels close to those currently occurring at Deep Reach and Crossing Pools by actively managing erosion where it would otherwise result in alterations to those pool levels,

- to maintain open water in Palm and Livistona Pools but, providing this and other management criteria can be met, undertake no management of erosion at the lower end of these pools and to allow the pool levels to fluctuate accordingly. Correspondingly, the cease to flow levels at Palm and Livistona Pools will vary in response to erosion events,

- to ensure that erosion of distributary channels between Deep Reach and Crossing Pools, Crossing Pool and Palm Pool, and Palm Pool and Livistona Pool does not prevent flow between the pools, but otherwise allow erosion to occur; and

- in the event of major floods or other erosion events which significantly alter the morphology of the Fortescue Pools, to allow any erosion features to persist unless in the opinion of the Millstream Management Committee action should be taken;

and for Chinderwariner Pool is:

- to maintain pool levels and flow discharge regimes close to those currently occurring at Chinderwariner Pool by actively managing erosion where it would otherwise result in alterations to those pool levels or flow characteristics.

.../12.

4.0 Millstream Environmental Water Requirement Study

4.1 The Fortescue River above Deep Reach Pool drains an area of 44 300 km^2, with its headwaters in the Ophthalmia, eastern Hamersley and Chichester Ranges. However, the catchment area east of about Wittenoom does not contribute flow into the lower part of the Fortescue River under normal circumstances - and the effective catchment which includes Millstream is about 13 800 km^2. Above Millstream, the Fortescue flows through a broad valley between the northern escarpment (Hamersley Escarpment) of the Hamersley Range and the volcanic rocks of the Chichester Range. This valley is incised through a large thickness of gently dipping Wittenoom Dolomite which overlays resistant Marramamba Iron Formation.

4.2 Within the ancient valley in the vicinity of Millstream is the calcrete Millstream Aquifer, basically formed of Millstream Dolomite. This is probably an old lake deposit, and arcs southward to follow the old valley that links with Robe River drainage. Older secondary deposits of iron stone (Robe Pisolite) occur in the ancient valley under much of the Millstream Dolomite. Some of the characteristics of the aquifer are tabulated below:

Table 2: Some Characteristics of the Millstream Aquifer (Derived from Dames and Moore, 1974)

Areal extent of dolomite outcrop	540 km^2
Areal extent of dolomite aquifer	1,000 km^2
Depth of water-table below surface	5 - 25 m
Thickness of water bearing strata (maximum)	26 m
Estimated volume in storage	1,700 x 10^6 m^3
Estimated storage per metre thickness in the upper part of the aquifer	100 x 10^6 m^3
Estimated annual natural recharge	16.8 x 10^6 m^3
Estimated annual environmental demand (vegetation and pool requirements)	12 x 10^6 m^3
Estimated short term aquifer yield*	10 x 10^6 m^3

* Based on historical data and environmental considerations.

4.3 At Millstream, the Fortescue River's course flows alongside northern flank of the aquifer before the aquifer arcs southward. Natural discharge from the aquifer in the vicinity of Millstream involve springs within Deep Reach Pool (estimated at 11GL/y) and Chinderwariner Pool (3.8GL/y). Of the estimated 15GL/y discharged from these two pools, about 12GL/y is believed to be lost by evapotranspiration along the river course and associated Millstream/Woodley Delta. There is groundwater flow between the aquifer and the river and additional groundwater discharge by transpiration, in small springs west of Chinderwariner Pool and into underlying rock formations between Millstream and the Robe River.

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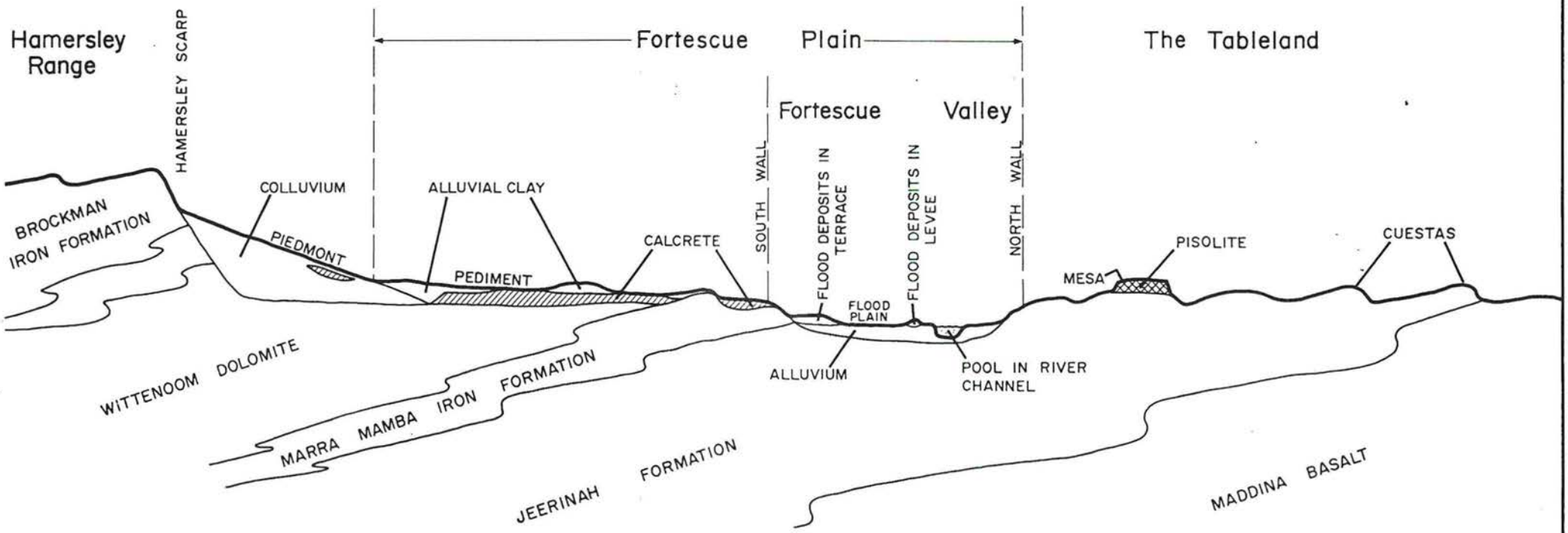
DIAGRAMMATIC PROFILE ACROSS FORTESCUE RIVER VALLEY
DOWN STREAM OF DEEP REACH POOL



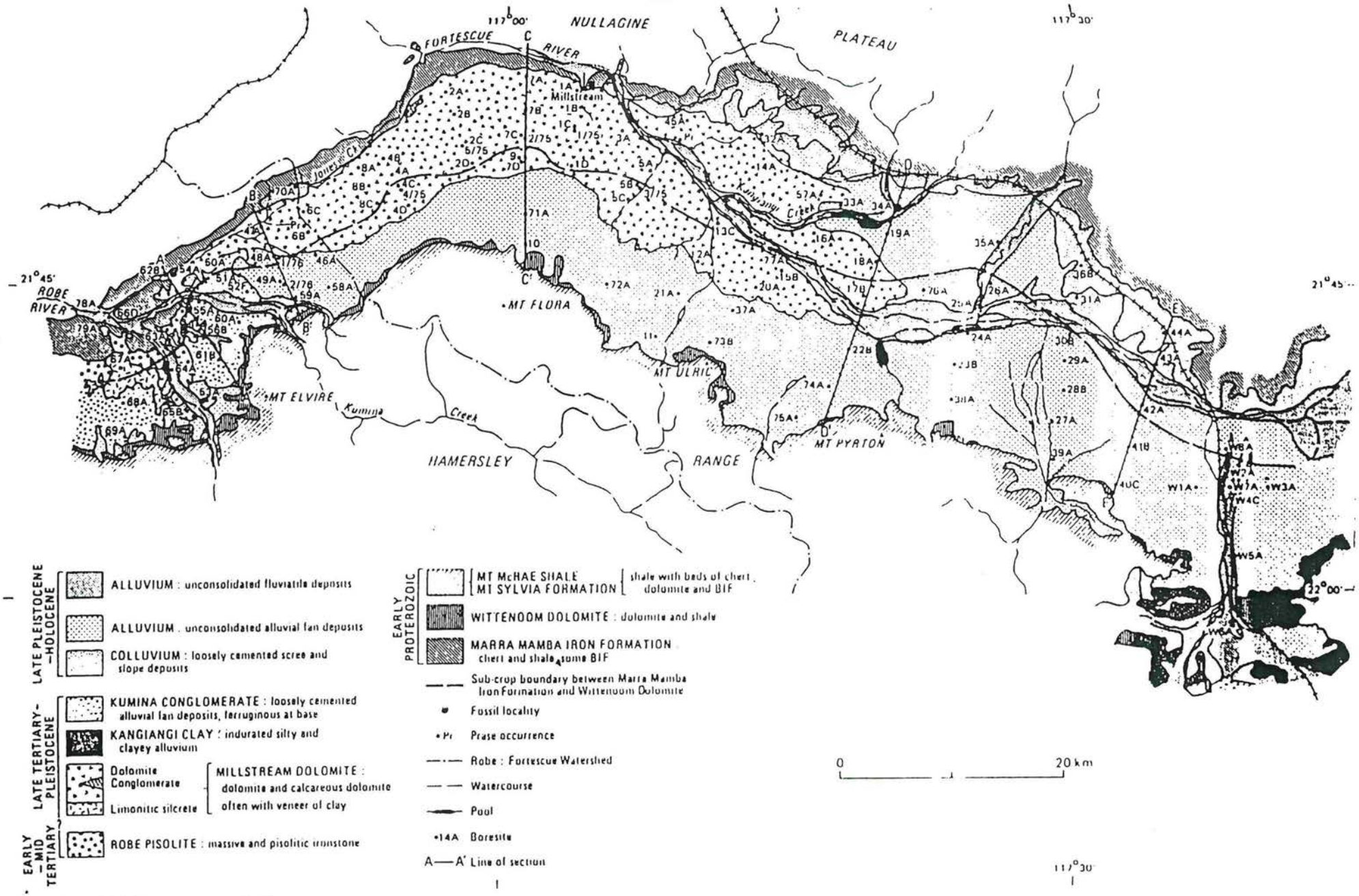
NOTE: Not to scale

RELATIONSHIPS BETWEEN LAND FORMS AND GEOLOGY (Diagrammatic)

GEOLOGICAL SUCCESSION IN MILLSTREAM AREA

	Unit	Thickness (m)	Description	Associated Land Forms
	Alluvium (Qr)	Up to 3	Cobbles, gravels and sands, uncemented.	River beds.
	Colluvium (Qg)	Up to 16	Boulders, cobbles and gravels in matrix of silty sand. Cemented in parts. Grain size decreases with distance from mountains.	Piedmont slopes and outwash fans flanking Hamersley and Chichester Ranges.
	Flood Deposits (Ql)	Up to 4	Cobbles, gravels and silty sands.	Levees, terraces and sand bars within flood plain.
	Alluvial Clay (Qpl)	Up to 16	Sandy clay and clayey sand, highly expansive with gilgais; cemented calcareous horizon present in places.	Pediment - gently sloping plain between the outwash fans and the main river valleys.
	Calcrete (Qkp,Qk)	Up to 10	Cemented calcareous soil horizon, siliceous in part.	Associated with alluvial soils on pediment.
	Pisolite (Tp)	Up to 16	Pisolitic limonite, goethite and hematite.	Capping on mesas.
HAMERSLEY GROUP	WITTENOOM DOLOMITE (Phd)	150	Dolerite with interbedded cherts and calcareous shales.	Underlies alluvial pediment and calcrete of Fortescue River.
HAMERSLEY GROUP	MARRA MAMBA IRON FORMATION	6 - 16	Interbedded chert, jaspilite and shale. Commonly weathered, limonitic.	Rubbly outcrop on low hills and south wall of Fortescue Valley.
FORTESCUE GROUP JEERINAH FORMATION	Roy Hill Shale Member (Pfjo)	30	Carbonaceous shale, (bleached white weathered exposures).	Low relief areas. Underlies Fortescue Valley at Millsteam.
FORTESCUE GROUP JEERINAH FORMATION	Warrie Member (Pfjw)	60	Interbedded chert, shale and jaspilite.	Cuestas to north of Fortescue valley. Forms cliffs along part of north wall of Fortescue Valley.
FORTESCUE GROUP JEERINAH FORMATION	Woodiana Sandstone Member (Pfjd)	16	Interbedded quartzite, siltstone chert and shale.	Forms scarps and cuestas on Tableland to north of Fortescue Valley.
	MADDINA BASALT (Pfm)	650	Basalts and intermediate lavas with some interbedded sediments. Commonly overlain by highly expansive residual clays.	Extensive undulating plains of Tableland. Some cliffs in gorge areas, e.g. Dogger Gorge.

Surface Geology and Bore Locations



(from Barnett & Commander, 1985)

4.4 Recharge of the aquifer occurs by direct infiltration of rainfall, leakage from streams flowing across the aquifer surface from the Hamersley Range, and leakage from the Fortescue River which flows across the eastern part of aquifer above Deep Reach Pool. Groundwater flow within the aquifer is generally from south and east to the north and west, with a large area of low hydraulic gradient in the north-central part of the aquifer. This is the focal point of the wellfield in which production bores are located.

4.5 The principal impact of groundwater abstraction via the wellfield is a lowering of the groundwater level in the surrounding area. In the Millstream Area, the maintenance of the Fortescue River pools, Chinderwariner Pool, and the associate wetlands, is dependent upon springflow which is linked to the Mean Aquifer Level (MAL). MAL is defined as the average groundwater level in a number of monitoring bores in the area of very low hydraulic gradient. From 1976 to 1983, MAL generally declined as a result of heavy pumping and very small river flows. During this period there was a general decline in the water level of Deep Reach Pool. However, erosion and sedimentation of the Pool's outflow channel can also affect pool level fall and rise. Small changes of the MAL will also affect discharges to Chinderwariner Pool and therefore flow in the streams which run through the Millstream Delta from this pool.

4.6 The Millstream Delta and adjoining Woodley Delta support import habitats and specific management of the delta area is therefore very important. Soils in the delta area consist of fine-grained calcareous silt and alluvium, and groundwater is derived both from flow from the adjacent Millstream Dolomite to the Fortescue River, and leakage from the delta channels emanated from Chinderwariner Pool. Soil in the leakage areas is saturated while between the channels groundwater levels are deeper (2-4m). Soil conditions evidently support significant upward movement of water from the deeper water table to the soil surface or plant roots. Thus, water discharge at Chinderwariner Pool and into the channel distribution system is important to vegetation adjacent to the pool and the top half of the delta area where the diverging channels are closer together. Further away, more of the delta vegetation is dependent upon groundwater that directly flows from the dolomite to the river, and most of the delta area (and most of the vegetation) is close to the Fortescue River.

4.7 In December 1995, a Millstream Environmental Water Requirements Study (commissioned by WAWA) was completed by Welker Environmental Consultancy and associated consultants. The Water Authority had sought a study of the water requirements of Millstream vegetation, in particular Cajuput, River Red Gum, Coolabah and Millstream Palms - to gain a better understanding of the impact of groundwater abstraction on this vegetation. Advice was also requested on the impact of four potential groundwater abstraction scenarios supplied by WAWA; amendments to the existing monitoring program covered by the EMP; and potential mitigation measures. A copy of the study report's Executive Summary is at Appendix A.

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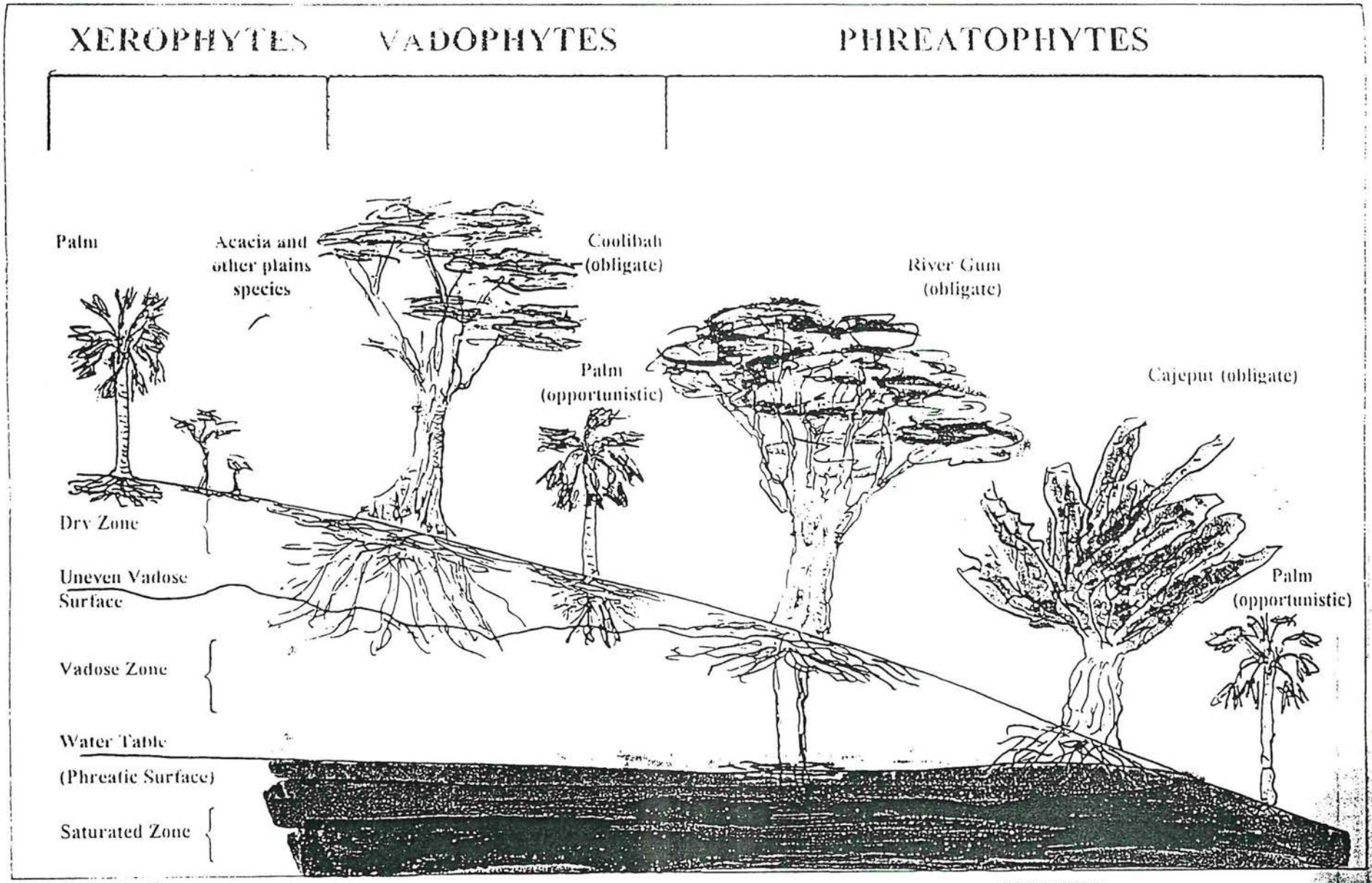

MUIR ENVIRONMENTAL

FIGURE 5
SOIL-WATER PROFILE AND
DISTRIBUTION OF PLANT TYPES

4.8 The principal trees in the Millstream Area were classified in regard to their association with water needs and studied in relation to water access. The Millstream Palm is a typical exeromorphic species with adaptations to prevent water loss and to also take advantage of water when it is available. It is thought that generally the species is tolerant of water stress. Coolabah appears to be vadophytic in that its root system tends to be in the vadose zone of the soil which lies above the watertable, where free water is minimal and the soil is effectively dry in terms of the ability of plants to extract water. Water rises from the water table by capillary action to replenish this zone. It is considered that Coolabah is relatively tolerant to drought but would experience moisture stress if the watertable fell so low that the vadose zone was no longer accessible. River Red Gum and Cajuput are obligate phreatophytes drawing water directly from the watertable. Because of their dependence on water, they can be expected to be relatively intolerant of drought. While the River Red Gum is deep rooted, the Cajuput has no tap root and depends upon adventitious roots which directly tap the shallow watertable and has difficultly in adapting to the even short periods of (a few weeks) dry conditions. However, River Red Gums appear to be able to adapt to dry periods if the impacts were not too sudden or too severe.

4.9 The study concluded that the Fortescue River course downstream from Deep Reach Pool, and the associated Millstream/Woodley Delta area, are dynamic systems with evidence of changing channels over periods of several hundred years. These elements may not be stable for long periods of time. This seems to contrast with the Deep Reach Pool environs (associated with the more ancient river valley) which are relatively stable. While declining groundwater levels would have minimal impact on creek vegetation around the edges of the river and around Deep Reach Pool, the vegetation around Chinderwariner Pool and the Millstream Delta channels would be more sensitive to declining water levels. However, the vegetation/soil and groundwater relationships on the delta are complex and impacts are likely to vary from place to place. Vegetation in river bed and around the pools of the Fortescue River are dependent upon water outflow from Deep Reach Pool and water availability influenced by channel scouring and siltation.

4.10 The four potential Millstream groundwater abstraction rates posed by the Water Authority for impact consideration were:

14 GL/y	-	equates to current <u>combined</u> yield of the Harding Dam and Millstream Aquifer. (see para 2.3).
20.5 GL/y	-	equates to the calculated sustainable yield of the combined Harding Dam and Millstream Aquifer. (see para 2.4).
22.5 GL/y	-	equates to the conjunctive yield if the Harding Dam spillway was also raised (para 2.6).
42 GL/y		

.../15.

While all scenarios assumed supplementation of Deep Reach and Chinderwariner Pools, it was concluded that impacts (while varying) would be substantial. The greatest impacts would occur where the most groundwater is abstracted at the highest rate and widespread deaths of Cajuput, Millstream Palms and River Red Gums may be anticipated in affected areas. However, a number of mitigating measures were also suggested.

4.11 The study concluded with proposals for improved monitoring and a suggestion that investigations were needed to gain a better understanding of the Millstream ecosystem, and to better evaluate the impacts of groundwater abstraction on Millstream vegetation. It also suggested a more holistic and integrated approach to the management of the Millstream resource is required to meet the public demand for water and the requirements of the Millstream vegetation.