POWER AND WATER AUTHORITY
WATER DIRECTORATE

KATHERINE WATER SUPPLY
DONKEY CAMP POOL
YIELD REAPPRAISAL

REPORT 27/1990

T STEWART AND U ZAAR
DARWIN
JULY 1990

001TS
SUMMARY

Since 1982 Katherine has been dependent upon the Donkey Camp Pool as its main water supply source. There are substantial groundwater resources in the region but aquifers close to Katherine produce water with an unacceptable high hardness. Groundwater can be softened and the existing water treatment plant has lime softening facilities but this is a costly process and the preferred source is the Donkey Camp Pool.

Throughout the 1980’s the flow through the Donkey Camp Pool was sufficient to meet urban demand with only minimal drawdown of the pool. The 1980’s were relatively high flow years and a reoccurrence of conditions similar to the 1960’s and early 1970’s together with increasing demand through population growth would result in regular drawdown of the pool. This report reviews the yield available from the Donkey Camp Pool and investigates its augmentation.

For about 70% of years the yield available from the Donkey Camp Pool is in excess of the capacity of the headworks and treatment plant. In these years only a small or in most cases no drawdown of the pool would be experienced in meeting demand.

At the 5% probability level the pool has a safe yield of 3 ML/day and 5 ML/day for a maximum drawdown of 0.5 and 1 metre respectively. These yields are almost equivalent to the minimum yield (independent of probability) that can be provided by the pool and represent a lower limit.

The yield can be improved by allowing for a greater drawdown of the pool than is currently permitted or by increasing the storage available for pumping.

For drawdowns greater than 0.5 metres the yield increase is at the rate of about 2.5 ML/day per metre additional drawdown of the pool. The yield increase from this option is limited by the sill levels of the intake structure.
Storage available for pumping can be increased by constructing a small weir on the Donkey Camp Pool rockbar and interconnecting the upstream pools with Donkey Camp Pool.

A small weir in the height range up to 1.5 metres above the cease to flow of the rockbar increases the yield available in any year by 1.5 Ml/day for a 0.5 metre weir to 5.2 Ml/day for a 1.5 metre weir.

Interconnection of the lower upstream pools with Donkey Camp Pool with a weir has an incremental effect of 0.6 Ml/day.

The minimum yield for a system including a 1.5 metre weir, with interconnection of the lower water holes and a one metre drawdown limit would be 10.1 Ml/day (11.9 Ml/day for 1.7 metre drawdown).

The yield could be further increased by utilising the storage available in the upper upstream pools but this would require the constructional of additional weirs on the higher rockbars and managed releases to the lower pool.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page Nos</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. INTRODUCTION</td>
<td>7</td>
</tr>
<tr>
<td>2. DONKEY CAMP POOL SYSTEM</td>
<td>8</td>
</tr>
<tr>
<td>3. OPTIONS FOR INCREASING YIELD</td>
<td>9</td>
</tr>
<tr>
<td>4. EXISTING WATER SUPPLY SYSTEM PHYSICAL CONSTRAINTS</td>
<td>11</td>
</tr>
<tr>
<td>4.1. Intake Structure</td>
<td>11</td>
</tr>
<tr>
<td>4.2. Pumping Station</td>
<td>11</td>
</tr>
<tr>
<td>4.3. Treatment Plant</td>
<td>12</td>
</tr>
<tr>
<td>5. PREVIOUS YIELD STUDIES</td>
<td>13</td>
</tr>
<tr>
<td>6. FLOW RECORDS</td>
<td>14</td>
</tr>
<tr>
<td>7. POOL LOSSES</td>
<td>16</td>
</tr>
<tr>
<td>8. SURVEY</td>
<td>20</td>
</tr>
<tr>
<td>9. SIMULATION MODEL</td>
<td>21</td>
</tr>
<tr>
<td>10. POOL BEHAVIOUR</td>
<td>23</td>
</tr>
<tr>
<td>11. SIMULATION RESULTS</td>
<td>25</td>
</tr>
<tr>
<td>11.1 Donkey Camp Pool</td>
<td>25</td>
</tr>
<tr>
<td>11.2 Donkey Camp Pool with Weir</td>
<td>25</td>
</tr>
<tr>
<td>11.3 Donkey Camp Pool, Weirs and Upstream Pools</td>
<td>27</td>
</tr>
<tr>
<td>11.4 Inclusion of Pools 5,6 and Maud Waterhole</td>
<td>27</td>
</tr>
<tr>
<td>11.5 Summary</td>
<td>28</td>
</tr>
<tr>
<td>12. FORECASTING POOL BEHAVIOUR</td>
<td>30</td>
</tr>
<tr>
<td>13. DISCUSSION</td>
<td>32</td>
</tr>
<tr>
<td>14. REFERENCES</td>
<td>34</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

FIGURE 1  LOCATION MAP

2 DONKEY CAMP POOL AND WATERHOLES

3. POOL SYSTEM

4. POOL BEHAVIOUR FOR CONSTANT PUMP RATE

5. KATHERINE WEEKLY WATER DEMAND

6. TIMING OF REFILLING

7. EXISTING POOL DRAWDOWN

8. EXISTING POOL DRAWDOWN PROBABILITY

9. KATHERINE 100 YEARS RAINFALL RECORDS

10. POOL LIMITING CONDITIONS

11. POOL WITH WEIRS - DRAWDOWN OF 0.5 m

12. POOL WITH WEIRS - DRAWDOWN OF 1.0 m

13. MINIMUM WATER LEVELS - 1964

14. MINIMUM WATER LEVELS - 1970

15. MINIMUM WATER LEVELS - 1968

16. MINIMUM WATER LEVELS - 1964 CASES 1 AND 2

17. MINIMUM WATER LEVELS - 1970 CASES 1 AND 2

18. MINIMUM WATER LEVELS - 1968 CASES 1 AND 2
LIST OF FIGURES (cont'd)

19. JUNE - PUMPING RATE RELATIONSHIP

20. JULY - PUMPING RATE RELATIONSHIP

21. AUGUST - PUMPING RATE RELATIONSHIP

22. SEPTEMBER - PUMPING RATE RELATIONSHIP
1. INTRODUCTION

Prior to 1983 Katherine obtained its water supply from two bores near the town storage tank with pumping from the Tindall Limestone Formation. The water from these bores was of good quality except for the high hardness (hardness of about 400 ppm caused almost entirely by calcium bicarbonate).

In 1982 a surface water system consisting of intake structure, pumping station, pipeline and treatment plant was constructed with Donkey Camp Pool as the source.

In 1987 the town bores were reactivated to provide a blend of bore water and river water to neutralise the low pH of the river water and still provide a supply with an acceptable level of hardness. A lime softening plant has also been installed to reduce hardness in the bore water supply so that a higher blending rate can be used during periods of high demand. However, treatment of the bore water by softening is costly and the preferred supply is a Donkey Camp unsoftened bore water blend.

In 1989, Gutteridge, Haskins and Davey Pty Ltd (GHD 1989) reviewed the total system and recommended modification to ensure a continuing supply in the short term (i.e. the next 15 years) to Katherine. However, GHD’s recommendations were based on a preliminary analysis of yield for a variety of storage options and these yield figures are now considered unreliable.

This study reports on a reappraisal of the yield of the Donkey Camp Pool and on the options available to increase the Donkey Camp Pool storage and utilise storage available in the pools upstream of Donkey Camp.
2. DONKEY CAMP POOL SYSTEM

Donkey Camp Pool is a natural pool in the Katherine River formed by a rockbar about 6 km upstream of the town of Katherine (Figure 1). The pool extends upstream for a distance of about 6 kilometres where it is terminated by a second rockbar. Upstream of the Donkey Camp Pool is a series of waterholes separated by rockbars (Figure 2).

Flow through the pools is mainly from the combined contributions of the Katherine River and Seventeen Mile Creek. During the annual dry season (June to November) flow in the Katherine River at the Gorge (GS 814019) normally ceases and the inflow to the pools is only from the recession of Seventeen Mile Creek.

Britten (1985) found that the groundwater discharge into Seventeen Mile Creek during the dry season was largely a function of the previous annual rainfall as the groundwater source, cretaceous sediments, did not have sufficient storage capacity to provide a marked buffering effect against dry years.

Since pumping from Donkey Camp Pool commenced in 1983, there have been no problems experienced in meeting the demand and to date drawdown of the pool has not been necessary. However, the 1980’s were relatively wet years and with the increasing demand a reoccurrence of the flow condition of the 1960’s and early 1970’s would result in substantial drawdown of the pool.
3. OPTIONS AVAILABLE FOR INCREASING YIELD

The yield that can be obtained from the Donkey Camp Pool system is related to the inflow to the pool and the storage volume that can be extracted.

In the past, extraction volume has been limited by an operating rule imposed by the Katherine Water Supply Advisory Committee. Initially, this rule limited the maximum drawdown of the Donkey Camp Pool to 0.5 metres below the cease to flow level of the pool. Recently, the limit has been relaxed and now drawdown up to one metre is allowable. To date this operating criteria has never had to be implemented.

The yield of the pool could be increased by drawing on the storage below the 1 metre limitation or by increasing the storage.

Available storage can be increased by the construction of a weir at the Donkey Camp outlet rockbar (Rockbar 1), by tapping into the storage in the upstream pools or by a combination of both.

A small weir in the range of 0.5 to 1.5 metres high would increase the available storage in the Donkey Camp Pool and also make storage in pools 1, 2, 3 and 4 available (see Figure 3). However, the storage available from these upstream pools is limited by the cease to flow levels of the separating rockbars. The storage below cease to flow level of the upstream pools could be utilised if the pools were interconnected through the rockbars either by a cut or a control structure.

Also, additional storage is available in pools 5, 6 and Maud Creek Pool. The pools have cease to flow levels higher than 1.8 metres above the cease to flow level of Donkey Camp rockbar and their storage could not be used by simple interconnection with the lower pool. These pools could be used by having controlled releases through a structure in their rockbars and only operated to refill the lower pools during periods of high drawdown.
Alternatively, a series of weirs could be constructed on all rockbars and the system operated as a cascade. The combinations of the system are many and this report considers the following options:

- Drawdowns of Donkey Camp Pool exceeding the 1 metre limit.
- Weirs in the range of 0.5 to 1.5 metres high on the Donkey Camp rockbar.
- Weirs in the range of 0.5 to 1.5 metres high on the Donkey Camp rockbar with interconnection of the lower pools (pool 1, 2, 3 and 4).
- Weirs on Donkey Camp rockbar with interconnection of lower pool and transfers from the upper pools (pools 5, 6 and Maud Creek).
4. EXISTING WATER SUPPLY SYSTEM PHYSICAL CONSTRAINTS

Within the existing water supply system there are a number of physical constraints that limit the quantity of water that can be extracted from Donkey Camp Pool. These constrains are discussed below.

4.1 Intake Structure

The intake structure is a reinforced concrete structure located upstream of the Donkey Camp Pool rockbar. The constraints placed on the system are the crest levels of the internal weirs which limit the maximum drawdown that can be achieved in the pool. These levels (survey of October 1989) are:

- Sill level of outer trash rack opening - RL 93.81 AHD (about 2.0 m below cease to flow level of the pool RL 95.8 AHD).
- Crest level of internal weir RL 94.14 AHD (about 1.7 m below cease to flow level of the pool).

One option available to increase the yield of the pool is to lower the crest level of the internal weir to that of the sill level of the trash rack. This would allow for increased drawdown of the pool.

4.2 Pumping Station

From the intake structure to the treatment works the system is controlled by the capacity of the pumps. At present modifications are being carried out on the pumping arrangement (GHD 1989) and the plant's capacity is given in Table 1.
### TABLE 1

**PUMPING PLANT CAPACITY**

<table>
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<tr>
<th>RIVER LEVEL</th>
<th>RIVER LEVEL</th>
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<tr>
<td>m AND Above CTF</td>
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<td><strong>EXISTING PUMPS</strong></td>
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<tr>
<td>97.2</td>
<td>1.4 m</td>
<td>L/sec</td>
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<tr>
<td></td>
<td></td>
<td>(Ml/day)</td>
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<tr>
<td></td>
<td></td>
<td>107</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9.2)</td>
</tr>
<tr>
<td>96.2</td>
<td>0.4 m</td>
<td>L/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Ml/day)</td>
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<tr>
<td></td>
<td></td>
<td>103</td>
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<tr>
<td></td>
<td></td>
<td>(8.9)</td>
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<tr>
<td>95.2</td>
<td>-0.6 m</td>
<td>L/sec</td>
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<tr>
<td></td>
<td></td>
<td>(Ml/day)</td>
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<tr>
<td></td>
<td></td>
<td>99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(8.6)</td>
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<tr>
<td>94.2</td>
<td>-1.6 m</td>
<td>L/sec</td>
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<tr>
<td></td>
<td></td>
<td>(Ml/day)</td>
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<td></td>
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<td>95</td>
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<tr>
<td><strong>MODIFIED PUMPS</strong></td>
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<td>L/sec</td>
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<td></td>
<td></td>
<td>(Ml/day)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>108</td>
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<tr>
<td></td>
<td></td>
<td>(9.3)</td>
</tr>
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</table>

(Source GHD 1989 modified for CTF 95.8)

#### 4.3 Treatment Plant

During the dry season the filters are the controlling units of the treatment plant. The filters have a maximum capacity of 140 L/sec or 11.9 Ml/day. At present ground water can be blended with Donkey Camp water at a blend ratio of 20% producing water with a total hardness of 100 mg/L. The maximum output of blended water is 15.4 Ml/day.

With the addition of extra blending pumps a blend ratio of 33% could be obtained producing a maximum output of blended water of 17.8 Ml/day at 140 mg/L hardness.
5. PREVIOUS YIELD STUDIES

Smith (1980) identified the Donkey Camp Pool as a potential source for the water supply of Katherine. He estimated, based on the historical record of 1963 to 1972, that a supply of 330,000 cubic metres per month (11 Ml/day) could be supplied from the Pool. For the period of analysis this yield would result in a maximum drawdown of the pool of 3.95 metres in one year and a drawdown between 0 and 1.6 metres for the other years.

Marlow (1983) reappraised the yield based on the limitations imposed by the intake structure and the operating criterion set by the Katherine Water Supply Advisory Committee. In the first case a maximum drawdown of 1.6 metres below cease to flow level was determined based on the crest level of the weir within the intake structures and in the second the Committee's recommended drawdown limit of 0.5 metres imposed to avoid any possible environmental effects of drawing down the pool.

For a failure criterion of one failure in twenty years of the drawdown exceeding 0.5 metres, Marlow estimated the yield at 3.4 Ml/day and for a drawdown of 1.67 metres a yield of 9 Ml/day.

Marlow concluded that the "yield can be increased by utilising the reach upstream from Donkey Camp Outflow. This can be done with the use of weirs, regulation of flow through rockbars or a combination of both."

However, before the increase in yield for these improvements could be assessed a survey of the pools upstream of Donkey Camp Pool to determine storage capacity and an investigation of losses from the pool were recommended.
6. FLOW RECORDS

Continuous streamflow records from 1954 are available for the Katherine River at the Gorge (GS 814019) and since 1962 for Seventeen Mile Creek at Waterfall View (GS 814159). For the Donkey Camp Pool there are only recession gauging for the outflow (GS 814012) and inflow (GS 814027).

To overcome the lack of continuous records at the Donkey Camp Pool site both Smith (1980) and Marlow (1983) related the flows at Donkey Camp Pool with the flow at Seventeen Mile Creek and the Katherine Gorge. The relationships obtained were:

SMITH

\[ Q = 0.968I - 0.021 \] ............................................. (1)
\[ Q = 1.184U - 0.209 \] ............................................. (2)
\[ I^* = 1.223U - 0.194 \] ............................................. (3)

(*equation 3 is a combination of equation 1 and 2).

MARLOW

\[ I = 1.03Q_{17} - 0.15 \] ............................................. (4)

Where

\[ Q \] = outflow from Donkey Camp Pool
\[ I \] = Inflow to Donkey Camp Pool
\[ U \] = Flow at the Gorge plus flow at Seventeen Mile Creek
\[ Q_{17} \] = Flow at Seventeen Mile Creek

Within the range of 0 to 0.3 m³/sec flow at Seventeen Mile Creek, equations (3) and (4) differ by a maximum of only + 0.01 m³/sec for the inflow into Donkey Camp Pool. For flows above 0.3 m³/sec the results in using the equations diverge. However, for estimating safe yield the critical inflows are in the range of up to 0.3 m³/sec where Smith and Marlow's equations produce equivalent results.
Additional gaugings made after the above equations were developed are insufficient to warrant a refinement of the equations.

As Marlow's equation does not account for any contribution of flow from the Gorge, its use results in drawdown of the pool occurring earlier in the dry season and an over estimation of maximum drawdown. As Smith's equation allows for Gorge flow and thereby overcomes problems associated with Marlow's equation, it was adopted for this study.
7. POOL LOSSES

The major sources of losses from the pools are seepage and evapotranspiration. Britten (1985) investigated seepage losses from the pool and found:-

- the physical features of the aquifer only allowed an insignificant throughflow;
- the standing water level in the investigation bores were above the baseflow level of the river indicating groundwater flow to the river rather than recharge;
- the chemical quality of the groundwater indicating a source other than river water;

and concluded that seepage losses from the Donkey Camp Pool were not significant.

Evapotranspiration loss however is significant but its measurement is extremely difficult. Reliable measurement can only be obtained from very accurate long term continuous measurement of inputs (inflow) and outputs (spills and pumping) preferably during a period of drawdown of the pool. This type of data is not available for the pool and unlikely to be available in the future. Generalised evaporation data is available from the Bureau of Meteorology (1988) and for the site the monthly evaporation during the dry season is shown in Table 2.
<table>
<thead>
<tr>
<th>MONTH</th>
<th>PAN EVAPORATION*</th>
<th>OPEN WATER**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm/month</td>
<td>mm/day</td>
</tr>
<tr>
<td>June</td>
<td>200</td>
<td>6.7</td>
</tr>
<tr>
<td>July</td>
<td>225</td>
<td>7.3</td>
</tr>
<tr>
<td>August</td>
<td>250</td>
<td>8.1</td>
</tr>
<tr>
<td>September</td>
<td>300</td>
<td>10.0</td>
</tr>
<tr>
<td>October</td>
<td>310</td>
<td>10.0</td>
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<tr>
<td>November</td>
<td>300</td>
<td>10.0</td>
</tr>
<tr>
<td>December</td>
<td>275</td>
<td>8.9</td>
</tr>
<tr>
<td>Average June-Dec</td>
<td>-</td>
<td>8.7</td>
</tr>
</tbody>
</table>

* SOURCE: Bureau of Meteorology Climatic Atlas of Australia
April 1988

** Devised from pan evaporation allowing 7% increase for bird guard screen and a 0.7 pan coefficient.
The open water estimates of evaporation shown in Table 2 are for standardised exposures and extensive deep water bodies. The Donkey Camp Pool system consists of narrow, shallow water bodies partly shaded from direct solar radiation and sheltered from the wind and thus it would be expected that the monthly evaporation would be substantially less than the values shown in Table 1.

Marlow (1983) adopted a value of loss rate of 0.034 m³/sec which based on the surface area of the Donkey Camp pool is equivalent to an evaporation rate of 7.35 mm/day. This figure was obtained from limited inflow and outflow measurements which showed a wide range of loss rates. The difficulty with Marlow's method is the data, as most of the measurements were taken at a time of day when evaporation would have been at a maximum. Also, within a day and from day to day the evaporation rate can show wide variation similar to the range reported. However, for analysis of the pool behaviour average data is needed and this is difficult to determine from limited instantaneous readings.

To overcome this problem, this study uses equation (2) of Section 6 where outflow of Donkey Camp Pool is related to the flow at Seventeen Mile and the Gorge. With an outflow relationship, losses due to evaporation and seepage have been accounted for and do not have to be directly estimated. At the cease to flow condition, equation (2) provides for losses of about 0.022 m³/sec equivalent to 5.5 mm/day. This loss rate is the same as the loss rate obtained from the only measured occurrence when the pool ceased to flow and equal to the loss rate found by Britten (1985) for the cease to flow condition. The rate also appears reasonable when compared to the open water evaporation rates (Table 2).

Concern was expressed in previous studies (Marlow and Britten) of the apparent relationship of losses to stream flow and Britten has stated that "this is difficult to explain, as a loss which is a constant proportion of the flow does not fit any model of either evapotranspiration losses or infiltration and seepage into groundwater." In the analysis of pool yield, streamflows in the range of 0 to 0.3 m³/sec are of importance.
and this range of streamflows produce almost a constant loss rate when applied to the inflow/outflow equation (1). Therefore, although the apparent relationship of streamflow to losses is interesting, it is not of any significance to this analysis.
8. SURVEY

A depth capacity relationship for Donkey Camp Pool was established from survey carried out in 1969 (Marlow 1983).

In 1990 survey by the Department of Lands and Housing produced:

- Contour plans of the pools upstream of Donkey Camp Pool
- Contour plans of the rockbars separating the pools (including Donkey Camp Pool outlet rockbar)
- Capacity listings of each pool
- Longitudinal sections of each rockbar (including Donkey Camp Pool)
- Cease to flow levels for each rockbar

This survey was sufficient to establish storage capacity relationships for each of the upstream pools (reported by Zaar 1990).
9. SIMULATION MODEL

The simulation model used in this analysis is described by Zaar (1990) and uses a daily step to determine the storage available at any time period. The equation used was:

\[ S_i = S_{i-1} + I_i - P \]

where \( S_i \) = Storage volume in the pool at time \( i \)

\( S_{i-1} \) = Storage volume in the pool at time \( i - 1 \)

\( I_i \) = inflow into the pool at time \( i \) (this allows for pool losses as discussed in Section 7)

\( P \) = pumping rate

The drawdown of the pool is a function of storage volume with a generalised relationship of:

\[ \text{Drawdown} = a - b S_i \]

where \( a \) & \( b \) are constants depending upon the case being considered. The constants \( a \) and \( b \) were determined from the pool capacity surveys (see Zaar 1990). In some cases considered, a family of curves were used to allow for the contribution of upstream pools.

The pumping rate in all cases was constant for the full analysis period of June to December. In practice the pumping rate would vary to satisfy the varying demand (Figure 5). During period of substantial drawdown, the drawdown occurs at the same time as maximum demand (ie September/October) so that this limitation would not have a significant effect on the results but in all cases would overestimate the maximum drawdown slightly due to lower pumping rates in August and November.

No constraints were placed on the pumping rate or maximum drawdown. As discussed in Section 4, the existing intake structure, pumping station and treatment works all have physical constraints.
limitations on the quantity of water that can be handled. These limitations were not incorporated in the model as most items of existing plant could be modified or duplicated if the yield was available.

In the past the Katherine Water Supply Advisory Committee limited the maximum drawdown that would be allowed to half a metre. Recently this limitation has been increased by the Committee to one metre drawdown. This limitation was not imposed on the model and the analysis allowed for drawdown exceeding one metre. As the limit was arbitrarily set the results of the analysis will provide information for the Committee to review the drawdown limit (either upwards, downwards or removal).

The cases considered were as follows:

(a) The existing system with pumping from Donkey Camp Pool only.

(b) Pumping from Donkey Camp Pool (neglecting any storage available from upstream pools) with weirs at the Donkey Camp Pool rockbar (weir heights considered 0.5 m, 1.0 m and 1.5 m).

(c) As for (b) but including storage available from the upstream pools (1,2,3 and 4) above their cease to flow level.

(d) As for (c) but including storage down to 1 metre below cease to flow level of the pools allowing drawdown in the upstream pools.

(e) As for (d) but full depth interconnection of upstream pools (1,2 and 3).

(f) As for (e) but with provision for tapping into pools 5,6 and Maud Creek Waterhole.
10. POOL BEHAVIOUR

Irrespective of any construction at the pools to increase yield, the behaviour of the pool with pumping follows a regular pattern.

Figure 4 shows the typical behaviour pattern of the pool with a constant pumping rate. Initially at the start of the dry season the water level in the pool is above the cease to flow level of the rockbar or of any future weir. In years of high inflow into the pool, this state can continue through to the next wet season without any drawdown of the pool. This was the case for most of the 1980's.

For years of low inflow a state is reached, during August and September where there is a transition period from the spilling state to a state of continuous drawdown. In this period the water level fluctuates by a few centimetres about the cease to flow level. The duration of this period depends upon the magnitude of the pumping rate in relation to the inflow. For periods of moderate inflow this periods can extend through to the next wet season. For periods of low flow the transition period can be short or non existent.

When the pumping rate exceeds the inflow there is a period of continuous drawdown. This normally commences towards the end of August or beginning of September. This drawdown continues until there is inflow following the start of the next wet season. Once inflow occurs the pool fills very rapidly (ie within a few days).

The maximum drawdown is very much dependent upon the timing of the first inflows of the wet season. For drawdown of the order of 1 metre, the drawdown rate of the pool is of the order of 0.02 metres per day so a delay of say 5 days in the commencement of the wet season inflow could increase the maximum drawdown by 0.1 metres. This would not create a problem in most years as
this would occur during a period of rapid decline in demand, the demand declines from a peak at the end of October to about 60% of the peak at the end of November (see Figure 5) and the final drawdown could be controlled by reducing the pumping rate.

From the simulation of the pool behaviour for drawdown in the range of 0.5 to 1 metre the probability of time of filling of the pool following the start of the wet season has been determined and plotted on Figure 6.
11. SIMULATION RESULTS

11.1 Existing Pool

The behaviour of the Donkey Camp Pool in its existing state and with a range of pumping rates was simulated for the period 1963-1986.

The maximum drawdown of the pool obtained for these simulations is shown in Figure 7. For pumping rates of up to 20 Ml/day no drawdown of the pool was experienced in the years 1974 to 1985 inclusive.

The results showed four groupings. The first was for 1964 and 1965 where low pumping rates produced large drawdowns. An intermediate group including 1967, 1970 and 1972 where moderate pumping rates produce drawdown of the pool. A third group including 1963, 1966, 1968, 1971 and 1973 where high pumping rates were needed to produce drawdown and the final group where pumping rates outside the range considered were necessary to produce little or no drawdown. For illustrative purposes in the remainder of this report the 1964, 1968 and 1970 situations are shown as representative of groups 1, 2 and 3 respectively.

For all years, pumping rates have been determined to produce maximum drawdowns of the pool of 0.5 metres and 1.0 metres. From this the probability of drawdown of the pool has been determined (Figure 8) as shown in Table 3.

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>EXISTING POOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of drawdown</td>
<td>Pumping Rate (Ml/day) for maximum drawdown</td>
</tr>
<tr>
<td>Percentage of years</td>
<td>0.5 m</td>
</tr>
<tr>
<td>Drawdown will be less than maximum for pumping rate</td>
<td>3.0</td>
</tr>
<tr>
<td>95</td>
<td>4.8</td>
</tr>
<tr>
<td>90</td>
<td>8.2</td>
</tr>
<tr>
<td>80</td>
<td>22.0</td>
</tr>
<tr>
<td>50</td>
<td>001TS</td>
</tr>
</tbody>
</table>
Consideration has been given to the possibility that the short historical record is not representative of the long term inflows to the pool. Rainfall records for Katherine (Figure 9) show that there were periods of low rainfall prior to 1963 and as the baseflows from Seventeen Mile Creek are related to rainfall it is possible that the yield estimates at low probabilities could be in error.

A situation where there is no inflow to the pool during the dry season and the drawdown is only a function of losses and pumping defines a limiting condition. To reach the same maximum drawdown in any year the pumping rate must be higher than the limiting condition.

For the historical record, 1964 and 1965 had the smallest inflow and the lowest pumping rate for any level of drawdown. In 1964, a pumping rate of 4.5 Ml/day was necessary to produce a drawdown of 1.0 metres. As shown in Figure 10 this pumping rate is approaching the limit condition of the pool with only a very low equivalent net inflow.

In effect this limiting condition modifies the shape of the frequency curve so that in the low probability area the slope of curve is horizontal. The point of discontinuity of the curve would probably be somewhere near the conditions for the 1964 dry season so that the lowest yield that could be obtained irrespective of probability is of the order of 4.5 Ml/day for a 1 metre drawdown.

11.2 Donkey Camp Pool with Weir

Figures 11 and 12 show the increase in yield that could be obtained from constructing a low weir at rockbar 1 (Donkey Camp rockbar) and thereby increasing the storage capacity of the pool. These simulations did not allow for any contribution from the upstream pools. Allowance for these pools is detailed in the next section.
The effect of a weir is to increase the available yield in all years by a rate of about 3 Ml/day per metre height of weir. This rate applied for all levels of maximum drawdown.

11.3 Donkey Camp Pool Weir and Upstream Pools

The above case neglected any influence of the upstream pools. This would be the case for a weir up to about 0.5 metres high but for weirs above 0.5 metres high there is a small volume of storage contributed by pools 1, 2, 3 and 4 (Figure 3). The effect of including these pools in the analysis is that a higher yield can be obtained and this increase varies from zero for a 0.5 metre weir to 0.7 Ml/day for a 1.5 metre weir (Figures 13, 14 and 15).

The available storage can be further increased by interconnecting the rockbars between pools by means of a cut. Cuts that allow for up to one metre drawdown in the upper pools (1, 2, 3 and 4) would provide an increased yield of 0.5 Ml/day. Full connection of the pools to their bed level would only provide a further 0.2 Ml/day but this would only apply in cases where the maximum drawdown exceeded about 0.7 metres.

11.4 Inclusion of Pools 5, 6 and Maud Waterhole

The cease to flow level of the rockbars of pools 6, 7 and Maud Waterhole is above the level of impoundment for any weirs considered previously. This does not allow simple connection by means of cuts from these upstream pools to the lower pools. However, storage from these pools can be used by means of controlled releases from the upstream pools to the lower pools when drawdown of the lower pools has provided sufficient storage space to avoid spilling.

There are many possibilities in utilising these upper pools and Figures 15, 16 and 17 illustrates two cases:–

Case 1 a release producing a drawdown of 0.5 metres from the pools when the drawdown in Donkey Camp Pool has reached a level of 0.5 metres.
Case 2 as per Case 1, but with additional storage in the upper pools provided by a 0.5 metre weir.

In Case 1 an increase in yield (over the greatest yield that could be obtained from the lower pools i.e. weirs and full depth interconnection of the pools) of 0.4 Ml/day could be achieved and in Case 2 an increase in yield of 0.9 Ml/day. However, these yield increases only apply for situations where the lower pools are drawn down over 0.5 metres.

11.5 Summary

Table 4 summarises the above results on an incremental basis for the various improvements.

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>AVAILABLE YIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donkey Camp Pool</td>
<td>Depends upon year and maximum drawdown allowed</td>
</tr>
<tr>
<td>PLUS</td>
<td></td>
</tr>
<tr>
<td>Weir on Rockbar 1</td>
<td>3 Ml/day per metre height of weir</td>
</tr>
<tr>
<td>PLUS</td>
<td></td>
</tr>
<tr>
<td>Upstream pools (1-4)</td>
<td>Ranges from 0 for 0.5 m weir to 0.7 Ml/day for 1.5 m weir</td>
</tr>
<tr>
<td>PLUS</td>
<td></td>
</tr>
<tr>
<td>Interconnection of pools to allow up to 1 m drawdown</td>
<td>0.6 Ml/day</td>
</tr>
<tr>
<td>PLUS</td>
<td></td>
</tr>
<tr>
<td>Interconnection of pools to bed level</td>
<td>0.2 Ml/day (if drawdown allowed to exceed 0.7 m).</td>
</tr>
</tbody>
</table>

001TS
Increase in yield from the incorporation of pools 6, 7 and Maud Creek Waterhole into the scheme depends on the construction of weirs and the allowable drawdown in these pools. However, the storage available from these pools is only useful after significant drawdown of the Donkey Camp Pool.
12. FORECASTING POOL BEHAVIOUR

Accurate forecasting of the behaviour of the pool and the selection of a safe pumping rate for any year is difficult because of the number of variables involved. One major difficulty is the variability of the timing of the refilling of the pool in the following wet season. This refilling can occur anytime during November (see Figure 6) and has a major impact on the final drawdown of the pool.

However, an indicative guide for selecting a safe pumping rate could be prepared for the operation of the system. Such a guide would depend upon the final configuration of works carried out and could be refined as additional data is collected on actual system performance.

Figures 19 to 22 have been prepared from data generated from the simulation runs. The figures only relate to the pool in its existing state without any weir but other relationships could easily be developed for any system configuration.

The curves relate the pumping rate needed to achieve a drawdown of 0.7 metres on the 1 November to the flow at Seventeen Mile Creek on the 1 June, July, August and September. The 0.7 metres drawdown on the 1 November was selected as it generally resulted in a maximum drawdown of 1 metre later in November.

The envelope curve shown on the figures is the minimum pumping rate for the 0.7 m drawdown and in most years a lower drawdown would be obtained for the pumping rate calculated. The scatter of the results on the figures reduces further into the dry season and reasonable estimates can be made in September just before the start of the period of highest demand.

It is possible to further develop this so that a simple model for operation of the system could be developed. The recession flow of Seventeen Mile Creek can be reasonably predicted as the monthly flows during the dry season are correlated as shown in Table 5.
<table>
<thead>
<tr>
<th></th>
<th>JULY</th>
<th>AUGUST</th>
<th>SEPTEMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUNE</td>
<td>0.965</td>
<td>0.910</td>
<td>0.886</td>
</tr>
<tr>
<td>JULY</td>
<td>1</td>
<td>0.934</td>
<td>0.891</td>
</tr>
<tr>
<td>AUGUST</td>
<td>-</td>
<td>1</td>
<td>0.976</td>
</tr>
</tbody>
</table>

Seventeen Mile Creek inflows could be used until reliable pool inflow data is available which when combined with estimated pumping rates on a weekly or monthly basis would allow reasonable estimates of pool drawdown to be obtained.
13. DISCUSSION

In most years (about 70%), the flow in the Katherine River at the Donkey Camp Pool is more than adequate to match the current capacity of the headworks and treatment plant without drawdown of the pool below its cease to flow level. In these years the system operates as a run of the river scheme.

For about 30% of the year it is necessary to draw upon the storage capacity of the pool to satisfy demand. This results in the drawdown of the pool below the cease to flow level of the Donkey Camp rockbar. The maximum drawdown in the pool is a function of the pumping rate, net inflow to the pool and the time of refilling of the pool in the following wet season.

At the 5% probability level the yield of the pool for a maximum drawdown of 0.5 and 1 metre is 3 Ml/day and 5 Ml/day respectively. These yields also represent the limiting condition of the pool where it acts as a single storage without inflow and they can be taken as the minimum yield of the pool.

The yield of the pool can be increased by allowing for drawdowns greater than 1 metre. The existing intake structure would allow a drawdown of almost 1.7 metres and with modification of the internal weir this could be extended to two metres. The effect of increasing the drawdown limit is to increase the yield by a rate of 2.5 Ml/day for each additional metre of drawdown. For example, the minimum yield for one metre drawdown is 5 Ml/day if the drawdown was allowed to reach the internal weir level (94.14 AHD) the yield would be 6.75 Ml/day (5 + 0.7 x 2.5).

A weir on the Donkey Camp rockbar would provide additional storage and an increased yield as shown in Table 6.

The case of a 1.5 metre weir with 1.7 m drawdown gives a minimum yield approaching the total pumping capacity of the pumping station (12.4 Ml/day with modifications carried out to pumps sec 4.2) and the capacity of the filters.
TABLE 6

<table>
<thead>
<tr>
<th>Weir Height</th>
<th>Drawdown Limit</th>
<th>Minimum Yield Weir</th>
<th>Ml/day Weir + Upper Pools*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 m</td>
<td>1.0 m</td>
<td>6.5</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>1.7 m</td>
<td>8.3</td>
<td>8.9</td>
</tr>
<tr>
<td>1.5 m</td>
<td>1.0 m</td>
<td>9.5</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>1.7 m</td>
<td>11.3</td>
<td>11.9</td>
</tr>
</tbody>
</table>

(*interconnected to provide 1 m drawdown in upper pools).

It must be remembered that these yields are lower limits and in 95% of years yields exceeding these values are available eg for a 1.5 metre weir with one metre maximum drawdown the yield available from the pool would exceed the capacity of the pumping station and treatment works in over 90% of years.

There is scope for further augmenting the supply by using the storage in the upper pools ie those upstream of rockbar 6. To use these pools weirs on rockbars 6 and 8 would be required and their operation would be more complex than the simple arrangement of a weir on Donkey Camp Pool.

As adequate yield can be obtained by the construction of a modest weir on Donkey Camp Pool no benefit at this stage would be obtained from treatment to the upstream pools. However, if in the future the capacity of the pumping and treatment plant is increased works could be carried out on these upstream pools to provide a substantial yield increase.

Following the construction of any works it is possible to develop a reasonable operational model to predict drawdown of the pool. Such a model would assist in deciding on safe pumping rates throughout the dry season.
14. REFERENCES


BUREAU OF METEOROLOGY (1988) - Climatic Atlas of Australia


Fig. 3

BED LEVEL

<table>
<thead>
<tr>
<th>POOL</th>
<th>Donkey Camp</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Maud Ck</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEASE TO FLOW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEVEL (A.H.D)</td>
<td>91.1</td>
<td>93.0</td>
<td>93.4</td>
<td>93.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISTANCE u/s of RB1 (Km)</td>
<td>96.8</td>
<td>96.3</td>
<td>96.0</td>
<td>96.5</td>
<td>96.8</td>
<td>96.0</td>
<td>98.7</td>
<td>98.8</td>
</tr>
<tr>
<td>0</td>
<td>6.10</td>
<td>7.24</td>
<td>8.10</td>
<td>8.69</td>
<td>8.88</td>
<td>10.26</td>
<td>11.45</td>
<td>13.45</td>
</tr>
</tbody>
</table>
Fig. 4

**DONKEY CAMP POOL BEHAVIOUR FOR CONSTANT PUMPING RATE**

- **Period of Max Water Demand**
- **Cease to Flow Level of Weir or Rockbar**
- **Time of Start of Drawdown** depends on inflow and pumping rate
- **DRAWDOWN**
- **Flow Over Rockbar**
- **Transition Period** between spill and drawdown
- **Period of Continuous Drawdown**
- **Maximum Drawdown**
- **Rapid Filling of Pool** following Oct/Nov rains
- *Depends upon inflow to pool*
Fig. 5

KATHERINE WEEKLY WATER DEMAND

(SOURCE G.H.D. 1989)
Fig. 6

TIMING OF REFILLING

PROBABILITY THAT REFILLING HAS COMMENCED

NOVEMBER
Fig. 7

DONKEY CAMP EXISTING POOL DRAWDOWN SIMULATIONS
Fig. 8

PUMPING RATE ML/day

PROBABILITY DRAWDOWN WILL BE LESS THAN

EXISTING POOL DRAWDOWN PROBABILITY
KATHERINE 100 YEARS RAINFALL RECORDS

SOURCE: CLARK 1987 (Status Report on Katherine water source augmentation
Northern Territory Water Authority, February 1987)
Fig. 10

DONKEY CAMP POOL LIMITING CONDITIONS
* PUMPING RATE FOR 0.5m DRAWDOWN BELOW C.T.F. OF ROCKBAR

DONKEY CAMP POOL WITH WEIRS
- DRAWDOWN OF 0.5m

Fig. 11
Fig. 12

PUMPING RATE FOR 1.0m
DRAWDOWN BELOW C.T.F. OF ROCKBAR

DONKEY CAMP POOL WITH WEIRS
- DRAWDOWN OF 1.0m
Fig. 13

MINIMUM WATER LEVELS FOR VARIOUS PUMP RATES.

YEAR 1964

- Donkey Camp Pool
- Including upstream pools 1, 2, 3 and 4
- Including upstream pools with cuts allowing 1m drawdown
- With full connection of upstream pools 1, 2 and 3
MINIMUM WATER LEVELS FOR VARIOUS PUMP RATES.
YEAR 1970

Fig. 14
MINIMUM WATER LEVELS FOR VARIOUS PUMP RATES.
YEAR 1968

Fig. 15
MINIMUM WATER LEVELS FOR VARIOUS PUMP RATES. CASES 1 and 2.
YEAR 1964

Fig. 16
MINIMUM WATER LEVELS FOR VARIOUS PUMP RATES. CASES 1 and 2.

YEAR 1970

Fig. 17
MINIMUM WATER LEVELS FOR VARIOUS PUMP RATES. CASES 1 and 2.
YEAR 1968

Fig. 18
Fig. 19

Flow at 17 Mile Creek ML/day on 1st June

Pumping rate for Donkey Camp

For drawdown of 0.7m on November 1st

Flow Rate Relationship
Fig. 20
Fig. 22

FLOW AT 17 MILE CREEK ML/day ON 1st SEPTEMBER

PUMPING RATE FOR DONKEY CAMP FOR DRAWDOWN OF 0.7m ON NOVEMBER 1st

Fig. 22