PROJECT 24
REPORT 4/1980

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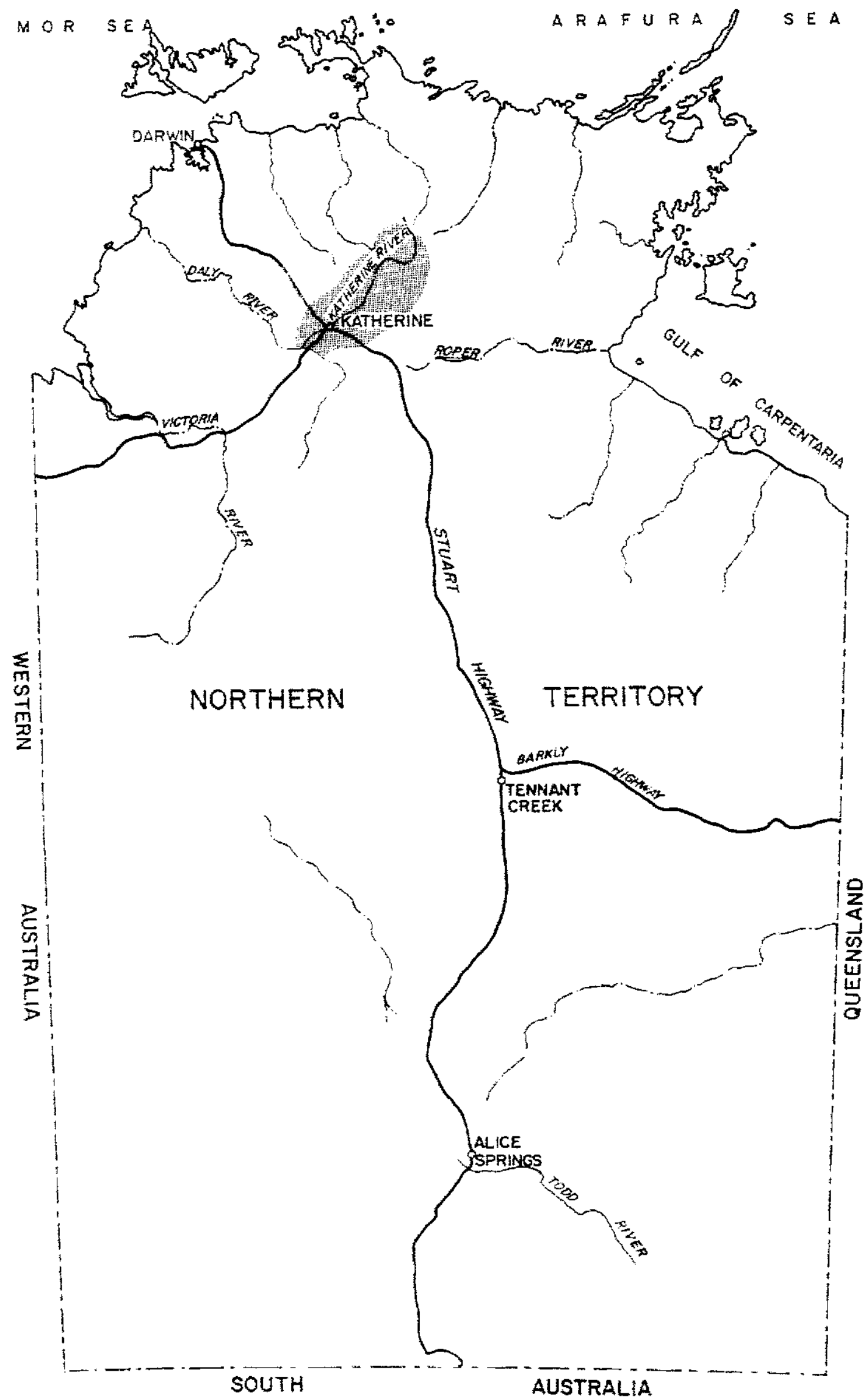
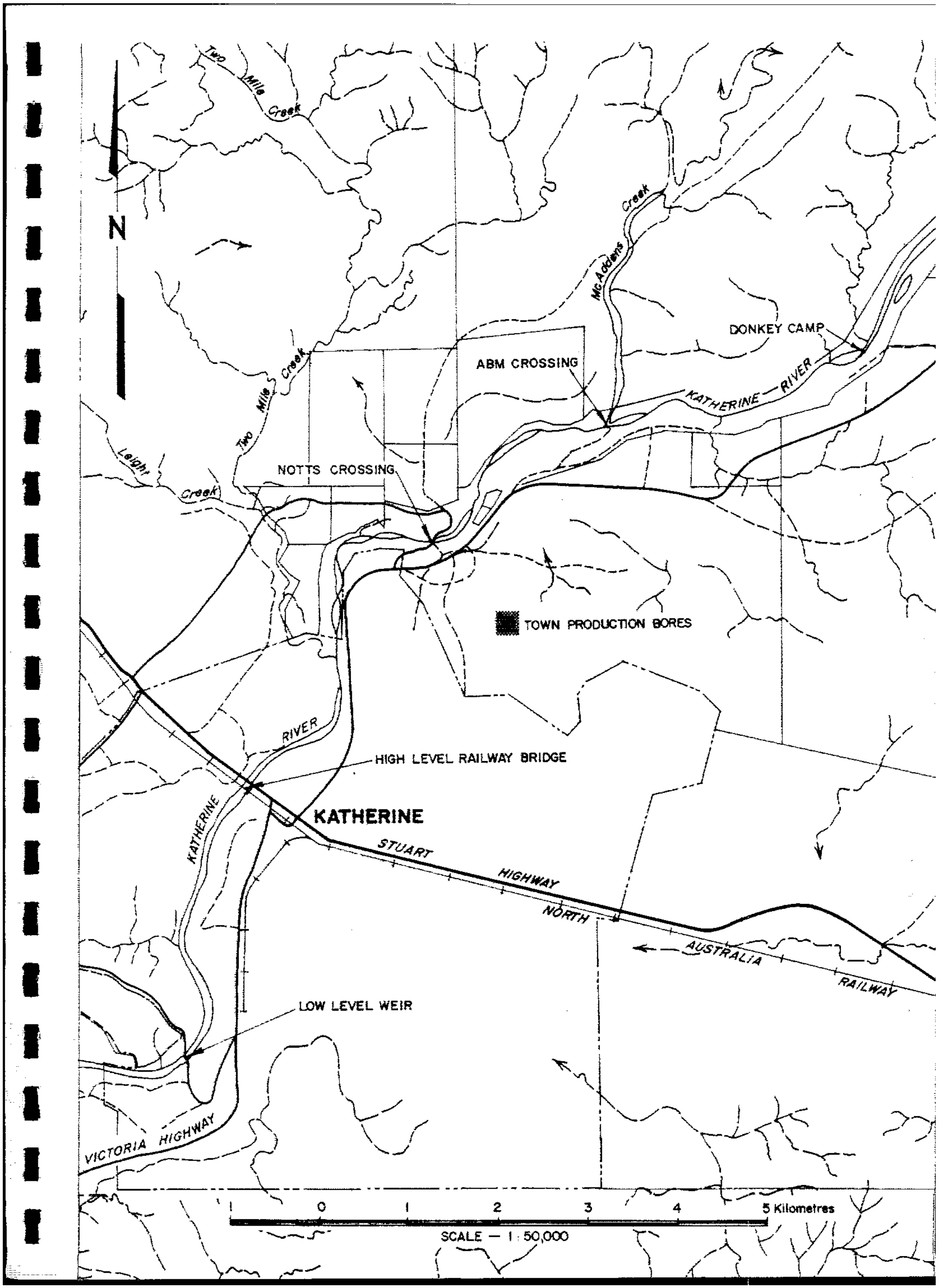


KATHERINE RIVER DEVELOPMENT.


N
Two Mile Creek
Two Mile Creek
Leight Creek
McAdams Creek
DONKEY CAMP
ABM CROSSING
KATHERINE RIVER
NOTTS CROSSING
TOWN PRODUCTION BORES
RIVER
HIGH LEVEL RAILWAY BRIDGE
KATHERINE
KATHERINE
STUART HIGHWAY
NORTH AUSTRALIA RAILWAY
LOW LEVEL WEIR
VICTORIA HIGHWAY
1 0 1 2 3 4 5 Kilometres
SCALE — 1 : 50,000

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KATHERINE RIVER DEVELOPMENT

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KATHERINE RIVER DEVELOPMENT

INTRODUCTION

This report examines hydrological parameters likely to affect the development of the Katherine River at and above the town of Katherine. Broad scale environmental and economic considerations led to a recommendation for development of the next phase of water supply to the town, such development being seen as the major influence in the medium term future of the river. A comparative summary of all water supply options considered suited to the growth of the town of Katherine is presented. In addition to town water supply the irrigation and hydroelectric generating capability of the river is examined at a major damsite (Keckwick) at the N.E. boundary of Katherine Gorge National Park.

CONCLUSIONS

1. Without detailed economic analysis and notwithstanding the development of Keckwick damsite descending priority order of Katherine water supply options is Tindal Limestone water successfully treated by magnetic polarizer, Donkey Camp Pool run of river followed by dam construction at either McAddens Creek or Dorothy Creek sites.

2. Desirable with completion of this report, is a "cost-per-litre" type economic analysis of long term development of the bore supply with treatment, Donkey Camp Pool run of river scheme and McAdden Creek and Dorothy Creek damsites. This would allow real evaluation of supply options for the town of Katherine into the future considering various funding and pricing alternatives, and accounting for broad scale environmental ramifications. Such economic analysis should be of a cost-benefit structure suited to periodic review to account for shifts in economic, technological or socio-political climate and to be reflected in relevant water supply planning policies.

3. Necessary for the completion of a "cost per litre" economic analysis is the establishment of the feasibility of treatment of Tindal limestone water by magnetic polarization.

4. The needs of both the tourist industry and local population for water based recreation require serious consideration, particularly if development of Donkey Camp Pool proceeds. This report provides a suitable data source and starting point for evaluation of the recreation potential of water resources in the Katherine area.

5. Following this report detailed assessment is required of the Keckwick damsite potential for water supply, flood mitigation, energy production, irrigation, recreation and agriculture in a broad regional sense to cover the Daly River basin.

SUMMARY

1. Trend in annual average daily water demand for the town of Katherine is likely to follow the pattern:

1980	-	4,500	cubic	metres	per	day
1985	-	6,000	"	"	"	"
1990	-	8,000	"	"	"	"
1994	-	10,000	"	"	"	"
2000	-	14,000	"	"	"	"

2. Drawing water from Tindal Limestone (the existing groundwater aquifer) yields an approximate volume of 4400 cubic metres per day for each bore, but with a temporary hardness level at around 400 p.p.m. the water deposits heavy scale when heated, resulting in consumer discontent and high maintenance costs for reticulation and water appliance components.

3. No treatment to correct hardness has been provided for the supply. Examination of the suitability of various processes has included domestic and central base exchange softening units, central resin based ion exchange units and cold lime softening plant. Investigation of the feasibility of magnetic polarizer treatment is currently being undertaken. Although this represent the cheapest and most easily adapted treatment solution controlled tests to date have failed to prove the feasibility of this approach. A separate report in this investigation will soon be available.

4. Successful treatment of the bore supply by magnetic polarization represented the lowest cost, least environmentally obtrusive long term water supply to Katherine.

5. Without acceptable treatment of the existing water supply surface sources would be required as investigation within a 20 Km radius of Katherine failed to realise a soft groundwater source alternative to Tindal Limestone.

6. Run of river at 17 Mile Creek, the Low Level and Donkey Camp Pool on the Katherine River, and damsites on McAdden Creek, Dorothy Creek and the Katherine River were studied for yield potential.

7. The most attractive run of river scheme appears to be development of the Donkey Camp Pool. The Low Level site (or any portion of the town reach) is unsuitable due to public health hazard through water recreational use and adjacent commercial activity, as well as late dry season water hardness.

   It is recognised that with diversion the late dry season drawdown and outflow behaviour of Donkey Camp Pool would be significantly affected. Without increased storage capacity the annual drawdown could exceed 3 metres every ten years, with late dry season outflow ceasing six years out of ten. It is considered possible to reduce these effects through the operation of relatively simple and minor control structures on rock bars higher up the river, effectively raising the storage capacity available for offtake. Yield likely from Donkey Camp Pool without upstream work is approximately 10,000 cubic metres per day.

8. The construction of surface storages represents greater development and environmental costs compared to other supply sources. Comparison of damsites on McAddensCreek and Dorothy Creek indicates one site on each of similar merit, with respective daily yields up to 18,000 cubic metres and 15,000 cubic metres. Both sites would deliver to Donkey Camp Pool for the cheapest supply offtake option. While a damsite is identified on 17 Mile Creek, no yield study is presented as its run of river potential outweighed storage development.

9. Keckwick damsite on the Katherine River has potential for water supply, flood mitigation and hydroelectricity generation placing it beyond the scope of development for just town water supply alone. Capable of up to 2 million cubic metres per day continuous regulated flow, 50% reduction in peak flood discharge rates and median continuous average generating capacity of some 8 M.W., the development of the Keckwick reservoir, partially sited inside Katherine Gorge National Park, would require careful, extensive evaluation of all economic and environmental ramifications on a regional development basis encompassing an area through to the Daly River coastal plains.

Some 18,000 hectares of land suitable for irrigation was delineated between Katherine and the Daly-Flora junction representing a median annual water demand of some 320 million cubic metres.

10. Longitudinal section data on the Katherine River was gathered from available contour mapping and ground surveys. Height differences were determined between the Low Level, Notts, A.B.M., Leight Creek and McAddens Creek road crossings and the downstream rock bar on Donkey Camp Pool. Characteristic hydraulic parameters were computed on 52 cross-sections between the Low Level and Maud Creek.

TREND IN WATER DEMAND

A long term view of total water demand for the town of Katherine was sought. The approach used was establishment of long term growth trends for population and per capita consumption. Least squares linear regression analyses established quantitative measures of those trends. Median values for per capita consumption and for the rates of annual increase in per capita consumption were also determined.

DATA

Official census, count and estimate figures for Katherine urban population growth were available as at 1971, 1975 and 1976 from the Bureau of Statistics. The 1976 statement was the latest available for planning purposes and was used for the study. This statement presented data gathered for years 1961, 1966 and 1971-76, plus projections from 1977 to 2001. Population at 1954 was obtained from former Department of Works consumption tables but data source was unknown. Populations for years between given data points were determined by simple linear interpolation. (Fig. 1)

Water consumption patterns were based on pumping totals recorded by water supply operations personnel. Monthly totals covered the period between December 1958 and April 1976. Missing data in this record comprised December 1960 to August 1961 and August 1974 to May 1975. Monthly data was determined from continuous running total metering. Metered annual water consumption for the meatworks was compared with total town use for years 1973-76. In addition to town monthly records, daily consumption rates were available for the periods 22 July - 30 September 1977 and 1 March - 30 June 1978. (Table 1)

HISTORICAL TRENDS

Katherine urban population grew continuously from 1961 to 1976, although the rate of growth showed a reducing pattern; 11.4% per annum between 1961 and 1966, 10.8% from 1966 to 1971 and 5.1% between 1971 and 1976. The longer term predictions gave an average growth rate of around 3.5% from 1976 to 2001. On these predictions Katherine population was expected to rise from 3450 in 1978 to 7750 by the year 2001.

Rising trends in consumption were observed based on analysis of actual per capita consumption data and on analysis of rates of increase in per capita consumption. Through application of linear regression and frequency analysis these growth rate patterns were quantified in terms of trend line slopes and median values, in relation to time and population. It was apparent that not only was per capita consumption increasing with both time and population but it was rising at an ever increasing rate.

Patterns for annual consumption and peak month consumption showed significant shifts in trend at around 1969. Thus the average rates of consumption between 1969 and 1978 were three to four times greater than the long term rates between 1958 and 1978. It was also evident that, while actual rates of consumption were lower, the pattern of Katherine water consumption closely followed that of Darwin. Annual per capita consumption rose from 170 cubic metres in 1958 to 440 cubic metres in 1978. The median consumption rate for that period of record was 190 cubic metres per capita per annum.

Regression analyses on the trends for annual per capita consumption between 1958 and 1978 showed a rate of increase of 9.1 cubic metres per year or 60 cubic metres per 1000 population. Determination of the median for yearly increment in annual per capita consumption between 1958-74 gave 10 cubic metres; the frequency analyses of percentage yearly increment in annual per capita consumption for the same period gave a median of 6%.

The rate of rise in the increase in per capita consumption was examined by regression analyses to quantify the long term trend. This showed that between 1961 and 1974 the average percentage annual increase in annual per capita consumption since 1958 rose at a rate of 0.28% per year. Similarly, between 1963 and 1974 the average percentage annual increase in annual per capita consumption since 1958 rose at a rate of 1.5% per 1000 population. (Figs. 2, 3, 4, 5, 6, 7, 8)

FUTURE TRENDS

The three basic trend patterns considered possible for future consumption levels were:

(i) Zero long term rising trend with patterns conforming to the median consumption for the period of record between 1958 and 1978.

(ii) Zero long term rising trend from 1978 onwards with maintenance of 1978 consumption rates for all future years.

(iii) Positive long term rising trend in annual per capita consumption characterised by:

(a) Extrapolation of regression trends determined for all data.

(b) Extrapolation of median rates of increase determined from all data.

(c) Regression trends determined for all data but applied from 1978 onwards.

(d) Median rates determined from all data but applied from 1978 onwards.

Trends predicted by application of results obtained for rate of increase in annual increase in consumption were unacceptable particularly from about 1990 onwards when average daily per capita consumption in excess of 2.5 cubic metres was predicted. Similarly the pattern given by median annual percentage increase in consumption was considered not suitable for design purposes. The concepts of the consumption pattern in the long term conforming to a median value implied a significant fall in consumption rates and was rejected for planning purposes. For the sake of design predictions, families of demand curves were produced based on positive long term rising trends determined from regression and median value analyses for all data, except as explained above. The continuation of 1978 per capita rates of consumption was presented, along with the increase in rate of increase consumption curve, to provide a comparative framing of the recommended design curves. (Fig. 9)

While trends in peak month total consumption were examined, the relationships between annual average daily and peak daily consumption rates found for 1977/78 data were used for predictions as this was the only daily consumption data available. (Table 2)

The local abattoir provided the most significant single industrial consumption of water. Comparison with total town consumption between 1973 and 1976 showed the meatworks did not warrant separate analysis as a long term component of the future water demand pattern. Considering the cost of town supply water it may well prove far cheaper for the meatworks to develop its own bore supply for water not requiring disinfection and heating. (Table 3)

HYDROLOGIC CONSTRAINTS ON WATER RESOURCE DEVELOPMENT

Examination of hydrologic factors affecting water resource development was limited to statements of quantitative and qualitative parameters pertinent to the options considered available for Katherine. Those options fell into two groups: groundwater and surface water. Groundwater sources were limited to Tindal Limestone, Kombolgie Sandstone and alluvial aquifers. Surface water was investigated for run of river on Seventeen Mile Creek and at the Low Level and Donkey Camp Pool on the Katherine River, plus on stream storage for Katherine River, McAddens Creek and Dorothy Creek.

TINDAL LIMESTONE

The groundwater option was predominated by Tindal Limestone, forming the major aquifer in the north-east Daly Basin. (Fig. 10) Well over half of the bores in the study area draw water from the limestone with reliable yields mostly between 80 and 600 cubic metres per day. (Fig. 11) Yields up to 4000 cubic metres per day had been obtained and only 5% of bores supplied less than 70 cubic metres per day each. Recharge to the limestone catchment above Katherine was estimated as equivalent to more than 800,000 cubic metres per day. The average depth to standing water level was about 20 metres, with 50% of bores having standing water level between 19 and 15 metres below surface. The Tindal Limestone structure was thought to be cavernous with recharge by direct infiltration in the study area. The dominant feature of groundwater from this aquifer was carbonate hardness, characteristically higher than 400 p.p.m. Apart from this temporary hardness parameter the water was satisfactory in all other aspects of chemical quality. (Table 4) No biological testing of aquifer waters had been conducted.

GROUNDWATER STUDY

Other possible groundwater sources in the area included Burrell Creek Formation, Kombolgie Formation, Antrim Plateau Volcanics, Springvale Beds, Jinduckin Formation, Mullamen Beds and Cainozoic Sediments. Excluding those sources likely on previous experience to provide poor quality, variable quantity or low yield supplies the options were narrowed down to fault zones in Kombolgie Formation in the Leight-Two Mile Creek area and on McAddens Creek, plus alluvial silts in the vicinity of the junction of McAddens Creek and the Katherine River. (Fig. 12)

KOMBOLGIE SANDSTONE INVESTIGATION

The Leight-Two Mile Creek area investigation consisted of brief area reconnaissance, geologic mapping and geophysical surveys to locate faults and fractures, followed by drilling. Geophysical techniques consisted of magnetic traverses, resistivity probing and seismic refraction survey. Four rotary bore holes were drilled on the basis of the geophysical interpretations. None of these yielded water and in fact Kombolgie Formation was not intercepted, volcanics being struck at depth 6 metres and continuing to 87 metres depth in one hole. Drill rig access was not available to sandstone outcrop areas North of the investigation area. (Figs. 13, 14)

Access difficulties prevented geophysical investigation on McAddens Creek study area but surface geology revealed a major fault at the interface between Kombolgie Formation and Edith River Volcanics. Two bores intersecting fractured sandstone and interbedded siltstone gave a supply less than 80 cubic metres per day. The second bore yielded over 600 cubic metres per day good quality water from fractures in the volcanics. Although full scale test pumping was not conducted large storage was not anticipated and the area was not considered suitable for borefield development to satisfy town requirements. (Fig. 15)

ALLUVIUM INVESTIGATION

With yields between 250 and 700 cubic metres per day previously obtained from bores in alluvium at Nott's crossing the possibility of groundwater supply from sediments with hydraulic connection to the Katherine River was considered worth investigation, although variability shown by yields less than 40 cubic metres per day for bores on the right bank at A.B.M. crossing was recognized. Examination of aerial photography led to investigation of the area between Donkey Camp Pool outflow and the McAddens Creek junction for alluvium filled channels associated with earlier courses of the Katherine River. Seismic and resistivity results on the right bank, however, proved no buried prior stream channel existed. Two check bores drilled on the geophysical traverse yielded no water in the 7 metre thick surface alluvium layer but encountered a 300 cubic metres per day supply from a vugular zone in volcanics at just over 15 metres depth. This zone did not represent a potential borefield. Five auger holes and three rotary bore holes were drilled on the left bank. Although three of the auger holes encountered low hardness water, all of the bores were dry. (Figs. 16, 17)

SEVENTEEN MILE CREEK RUN OF RIVER

Daily streamflow data was available on Seventeen Mile Creek from November 1962 to August 1976 except for 39 days between February and April in 1968. Rating of the gauging station was not stable. 118 gaugings had been completed between July 1961 and June 1978.

Base flow continued throughout the year at the gauging station. The minimum gauged flow was 6,900 cubic metres per day. The 90 percentile annual minimum daily flow gauged was about 9,000 cubic metres, with the median annual minimum flow rate approximately 20,000 cubic metres per day.

Flow velocities in excess of 1.3 metres per second had been observed during flood gaugings on Seventeen Mile Creek, corresponding to river height at about 117 m.A.H.D. Flow velocities increased with rising river and for the maximum recorded river height of 119 m.A.H.D. a flow approaching 2 metres per second was likely. (Fig. 20, 21 Table 5)

For the 16 sets of gaugings covering both recorder site and Katherine River junction, eleven exhibited a loss in streamflow below the recorder exceeding 2,500 cubic metres per day. The median loss rate for months after June was 4,200 cubic metres per day with gauged flow behaviour varying between 7,500 cubic metres per day gain and 16,700 cubic metres per day loss.

Analyses by Waitt drought curve, mass curve and Alexander's method for reservoir determination was completed. Each analysis supported the expected conclusion that significant rise in yield was possible with relatively minor weir construction.

DONKEY CAMP POOL RUN OF RIVER

With no recorder station on site, flow behaviour for Donkey Camp Pool was examined using recession gauging data to establish correlation with flow at recorder sites upstream. Recession gaugings had been conducted at Donkey Camp Pool inflow and outflow between October 1968 and August 1978. Flow data, on Seventeen Mile Creek, at the Seventeen Mile Creek - Katherine River junction and on Katherine Gorge was available from gauging results and recorder chart analysis. Applying linear regression analysis to this data gave the following relationships defining Donkey Camp Pool flow behaviour :

(a) $Q = .968I - .021$ for $I \leq 2$

(b) $Q = 1.184U - .209$ for $U \leq 1$

(c) $D = 55.6 \log Q + 124.5$ for $Q \leq 0.5$

where Q is Donkey Camp Pool outflow cumecs; I is Donkey Camp inflow cumecs; U is the sum of Seventeen Mile Creek recorder site and Katherine Gorge recorder site cumecs; D is the number of days to nil cumecs outflow from Donkey Camp Pool.

Behaviour analysis for Donkey Camp Pool was conducted for the period 1963 to 1972 on a monthly outflow record based on correlation with Katherine Gorge and Seventeen Mile Creek recorded flows. The behaviour analysis applied to those months when outflow was less than the projected demand for Katherine town water supply at year 1995, of 330,000 cubic metres per month. Pool drawdown behaviour was based on the stage-capacity relationship determined from bed contours found by capacity survey. With a storage of 1.2×10^6 cubic metres below cease to flow level the pool was found capable of meeting the projected demand for the 10 year period studied. The greatest drawdown found was 3.95 metres, with drawdown for all other years lying between 0 and 1.6 metres. Over the 10 years studied, outflow was continuous for 3 of those years, stopped for 1 month once, stopped for 2 months in three years, stopped for 4 months twice and stopped for 6 months once. (Table 6, 14)

LOW LEVEL RUN OF RIVER

Perennial streamflow was known to occur at Katherine Low Level, with minimum daily flow gauged at 60,000 cubic metres. Springs in the town reach of the river had been gauged at rates exceeding 20,000 cubic metres per day, flowing directly from Tindal Limestone in the left bank. Flood flow rates of 0.6 to 1.2 metres per second and 16 metres depth were possible at the Low Level.

Dry season recession flows, originating mainly from limestone springs, showed chemical analysis exhibiting wide range of hardness. During flood flows the water was characterised by high turbidity, colour and biologic loading. (Table 7)

KECKWICK DAM

On stream storage was investigated on the Katherine River and at several sites on its tributaries. Five metre contour mapping at 1:5000 scale was obtained by photogrammetry for Keckwick damsite. A natural saddle spillway at about 200 metres A.H.D. reduced level on the right bank, with a higher saddle at about 240 metres A.H.D. reduced level to the south of the site, was identified from this mapping. (Fig. 22, 23)

A stage/capacity relationship for a reservoir at this site was estimated for 1:100 000 topographic mapping. (Fig. 24) Assuming logarithmic linearity of the relationship between the 20 metres contours available, exponential equations were developed for the stage/capacity curve and subsequently used in behaviour analyses.

Streamflow for the recorder station some 15 km downstream in the gorge was used for analysis of reservoir behaviour. Missing data was synthesized through correlation with flow at the Katherine town gauging station. Frequency analyses were conducted for annual maximum instantaneous flow, monthly maximum instantaneous flow, monthly mean daily flow, monthly total flow and annual total flow for later comparison with river regulation due to operation of the dam.

Behaviour analyses were conducted using monthly flow volumes. Constant supply offtake at 60, 50, 40 and 30 million cubic metres per month were used, with evaporative and other losses assumed constant and equivalent to a rate causing 0.2 metres drop in reservoir level each month. When spill was likely based on monthly data, the behaviour analysis changed to daily inflow/outflow mode until spill ceased. Spillway discharge was determined for a broad crested weir about 90 metres wide. The behaviour analysis thus presented quantitative predictions for reservoir stage on a monthly basis, and stage plus spill discharges on a daily basis for the 1957-1972 record period, for various constant yield situations. (Tables 8, 9, 10, 12)

Hydroelectric generating capacity for uniform, continuous power production at 100% efficiency, (i.e. efficiency factor still to be applied) with tailwater at 160 metres R.L. was determined for the site using constant regulated yield flow rates and stage variations given by the behaviour analyses. (Table 11)

McADDENS CREEK DAMS

From inspection of topographic mapping and aerial photography six potential damsites were identified on McAddens Creek, two on separate branches of the western tributary and four within a 2 km stretch of the eastern tributary in the vicinity of the streamflow recorder station. (Fig. 25) 37 discharge measurements were available from 1963 to 1978 and continuous water level data had been extracted between November 1962 and August 1974 with data missing 25/1 - 17/2/63; 1-21/1/71; 27/2-9/3/71 and 24/1-5/4/74.

Alexander's method for reservoir size determination was used to establish the bases for coarse behaviour analyses using annual inflows determined by reduction of the available McAddens Creek streamflow record in proportion to relative catchment areas, and annual outflow comprising constant levels of evaporation and supply drawoff.

Stage/capacity characteristics were obtained from 1:100 000 topographic mapping. (Figs. 26,27,28,29) Maximum yields obtained by this method were 2.8 x 10^6 cubic metres per year and 3.4 x 10^6 cubic metres per year for the two western sites, while those on the eastern branch were found to range between 4 x 10^6 and 6.8 x 10^6 cubic metres per year.

On the basis of site cross sections obtained from available topographic mapping and assuming an earth/rock fill structure with side slopes 1:2, dam embankment volumes were computed for each site and used, with yield estimates, to provide comparison of sites. This showed sites 5 and 6 as the best for site economics. (Figs. 30,31,32)

Taking these two upper sites as the best for development on McAddens Creek full comparison awaited proof of a suitable natural saddle spillway at the lower site, while geologic appraisal of the fault noted in the groundwater study was probably important for both sites. The sites were in fact only about 300 metres apart and would provide a lake of area 3 square kilometres on a shoreline of 15 km. The lower site, using the adjacent saddle as spillway, required a dam of 24 metres height with crest length of about 165 metres, while the upper site required a dam of similar height but crest length 200 metres. Pipe route distance to the Katherine River was approximately 6 km with static head between 10 and 24 metres depending on reservoir stage. Straight line distance to Drome Hill was 13 km with negligible static head available.

For the 10 years studied in the course behaviour analysis, 3 years had nil flood spill while median yearly spill was 25% of the annual streamflow into the reservoir.

DOROTHY CREEK DAMS

Two sites on Dorothy Creek were found suitable for reservoir development from study of topographic mapping and aerial photography. (Fig. 33) With catchment topography and geology similar to McAddens Creek its annual streamflow record was transposed to Dorothy Creek with a simple fractional adjustment based on relative catchment size.

Application of Alexander's method for reconnaissance type assessment of yield and reservoir size was conducted and the results used for a coarse behaviour analysis using annual flows, annual evaporation, constant annual yield and stage/capacity characteristics determined from 1:100 000 topographic mapping. (Figs 34, 35) Yield on the lower site was found to be about 3.4 x 10^6 cubic metres per year for a dam with crest about 25 metres above riverbed and crest length of about 120 metres. The pondage area for this site included an abandoned mining area from which copper, lead, silver and gold had been extracted. The upper site was located in a steep sided, narrow valley in which a dam of length less than 50 metres and height around 20 metres gave yield of about 5.4 x 106 cubic metres per year. This site was upstream of the mining area but it was covered by a mineral lease. No suitable natural spillways were evident for either site. Coarse behaviour analysis indicated nil flood spill from the upper site in the 10 year period of streamflow examined.

Considering the upper site as the better for development the approximate pipe route distance to the Katherine River was 9.2 km with static head of 55 to 75 metres. (Fig 36). Straight-line distance to Drome Hill was 22 km with static head 20 to 40 metres.

Damming at this site would create a lake of 2.5 square kilometres area and 12 km shoreline. No site inspections were conducted on Dorothy Creek.

ENVIRONMENTAL EFFECTS OF WATER SUPPLY DEVELOPMENT

No specific environmentally oriented studies were undertaken but an attempt was made to evaluate the effect on the environment with development of those supply options recognized in the hydrologic review. Construction and operation phases for headworks and reticulation and, where appropriate, broader aspects of environmental impact were considered from a qualitative viewpoint.

TINDAL LIMESTONE GROUNDWATER SUPPLY

Expansion of the existing town supply borefield represented the least environmentally disruptive option for headworks. The construction of additional bores was expected to cause relatively minor disturbance, as did connection to the existing reticulation. Without successful borewater treatment significant, long term, continuous social disruption was expected associated with repair and maintenance works due to scale deposition. Replacement of consumer appliances, a long term source of annoyance among local residents, would have continued to be necessary. With chemical treatment of Tindal Limestone water the need for heavy repair, maintenance and replacement programmes to the reticulation should have been shifted to the central plant, but ecological pressure would depend on the type of treatment.

TINDAL LIMESTONE GROUNDWATER SUPPLY TREATMENT

Previous reports recommended acid regeneration ion exchange softening as the cheapest option. Recognized environmental risk included storage and handling of large quantities of sulphuric acid plus disposal of waste water produced. With evaporation ponds the most likely means of concentrating the high calcium/magnesium content waste prior to final disposal, such ponds could have presented aesthetic disharmony to the riverine landscape while additionally carrying risk of spillage and breaching during flooding. It was noted that the waste product offered possible benefits in conditioning high sodium content soils for agriculture.

An alternative treatment option, magnetic polarization, awaited objective evaluation. This offered least environmental impact, consisting simply of a small "on-line" appliance requiring no operating energy, consuming no materials with minimal maintenance. While the exact details of its action were not known, there appeared to be no measurable change in chemical composition after treatment, merely a reduction in apparent hardness property evidenced by claimed elimination of significant scale deposition.

With the Tindal Limestone outcropping or otherwise occurring at shallow depths in the recharge area above Katherine, and being of cavernous nature, it was considered that biological and chemical contamination from surface sources was quite possible.

SURFACE SUPPLY DEVELOPMENT IMPACT

Development of surface water supplies would impose greater environmental impact than groundwater development. It was recognized that all surface water sources had common environmental components in operational phase presenting largely similar aesthetic and ecological disturbances for pipelines, pumping and treatment works, road access and power supply.

For any surface regulatory scheme the downstream flooding and recession flow behaviour was affected. While wet season flood conditions necessitated careful design and operation of offtake and treatment headworks and perhaps offstream storage to account for flood flow scour, inundation levels and water quality deterioration, it was thought that the recession flow regime would be critical for run of river schemes.

SEVENTEEN MILE CREEK

Continuous spring flow recharge made run of river extraction from Seventeen Mile Creek possible throughout the year. Quantitative hydrogeological knowledge for this area was not available, but with springflow assumed independant of extraction at the proposed site then withdrawal for supply would reduce streamflow available downstream. With the possibility of all late dry season flow in the Katherine River above Nott's Crossing coming from Seventeen Mile Creek this reduction would probably have an effect on river conditions. The impact of providing a crossing on the Katherine River, road access and power supply and headworks structural and operational requirements would be magnified in effect owing to its location within a national park.

DONKEY CAMP POOL

Environmental considerations at Donkey Camp Pool centred on drawdown behaviour due to offtake for supply. Drawdown was expected to affect biota, particularly in the riverbank areas, which may have resulted in changes to water quality and channel stability. Drawdown would also alter outflow from the pool with attendant effects on downstream aquatic ecologies and, above Nott's Crossing, water supply for agricultural or domestic use. It was not considered likely that the mining areas on Maud and Dorothy Creeks could contribute to reduced water quality at Donkey Camp Pool, however tourist accommodation and recreation activities on Katherine River in and outside the national park and possible expansion of agricultural activity on the left bank above the site meant water treatment was a necessity for public supply. Further environmental impact with development of Donkey Camp Pool was possible if public access to the river above the site was restricted, resulting in greater pressure on other recreation areas. Reduction in drawdown at Donkey Camp Pool may have been possible by effectively increasing inflow through flow control structures placed on separate pools further upstream.

DAMS AND RESERVOIRS

Other surface supply options, requiring on stream storage with impoundment structures in addition to pumping, treatment and pipe works represented significant impacts on the environment both during construction and under operation. Worker accommodation, site preparation, access roads, winning of construction materials and site restoration were all recognized factors of environmental importance. Rapid introduction of large bodies of water and extensive shoreline areas subject to wide water level variation would alter the regional environment to far greater extent than either groundwater or run of river development.

KECKWICK DAMSITE

Keckwick damsite offered potential for development of the largest reservoir, the downstream portion of which would be inside the Katherine Gorge National Park. A major dam would entail local quarrying, and road construction from Eva Valley for site access. With major flood mitigation provided by a reservoir on site, altered flow volumes and sediment transport through to the Daly River estuary were expected.

Apart from obvious physical changes to inundation areas and river heights downstream affecting land access, the impact on wetland, riverine and estuarine ecologies would be significant. Continuous dry season river flow would be possible throughout the Katherine River below the site.

With this site suited to hydroelectric development and capable of supplying 180 times the town's water needs there were potential secondary environmental effects related to lowering dependance on fossil fuelled power generation, industrial and agricultural expansion and further development of the tourist industry.

McADDEN CREEK DOROTHY CREEK DAMS AND RESERVOIRS

Lesser damsites located on McAdden Creek and Dorothy Creek offered similar site impact with development, though obviously on reduced scale. With virtually all flow impounded and infrequent spillway operation, development of these sites possible represented as great an impact on local stream hydrology as did Keckwick on the regional scale. Reduction of flood levels below Dorothy Creek damsite may have reduced the potential for mine area dump washings entering Maud Creek and ultimately the Katherine River. Upgrading existing road access would be necessary for development on McAdden Creek, while new access would have to be provided to Dorothy Creek, some 7 km off the gorge road.

WATER SUPPLY DEVELOPMENT

ECONOMICS

There had been no comprehensive review of comparative economics of development of all options for Katherine water supply since the 1970 report of Halpern, Glick and Lewis. Bree conducted a limited economic analysis in 1978 comparing continuation with and treatment of the existing bore supply, development of Donkey Camp Pool and development of Seventeen Mile Creek. The format and method of analysis presented in the earlier report represented the better approach and the findings should have been updated regularly as part of a continuous longterm assessment to aid planning of the Katherine Water Supply. A detailed approach was unfortunately not possible for this study, however some discussion of economic parameters was developed.

Future economic analyses should have been based on a cost benefit framework permitting periodic re-evaluation of components to the analyses. Capital costs, including design, construction and land acquisition, operational costs for materials, labour and services for maintenance of treatment and the reticulation system, and peripheral costs associated with environmental impact at the headworks and downstream as appropriate with surface sources would all have to be evaluated. Quantification of benefits may have included improvement in quality and quantity of municipal, industrial and agricultural water supply, flood mitigation reflected in reduction of municipal and rural damage risk and improvements in recreation and regional land access, establishment of new recreation areas and potential hydroelectric energy production.

It was recognized that benefit costing would be difficult but any start in that direction must ultimately lead to improved planning decision making.

Pricing policy was to sell water at a rate calculated to recover, on a Territory wide basis, the cost of servicing the principal capital repayment with interest, plus meet operational expenses consisting of materials consumed, labour and services and depreciation of system components. The setting of rates for any one year was based on anticipated and known costs and expected consumption levels for that year, with allowance for surplus or deficits from the previous year's receipts. Water payments were recovered totally to consolidated revenue without guarantee that the supply authority had access to those funds for its continuing debt repayment and operational and depreciation expenses associated with provision of water supply.

It was not possible to present detailed economic comparison of supply options in this study. The need for "cost per litre" type analysis, however, was considered of prime importance as an immediate follow-up.

Assuming similar financing arrangements applied to all capital works then ranking according to magnitude of those works gave a simple basis for economic comparison. Similarly, qualitative description of operational features allowed preliminary ranking of alternative schemes. Recognizing that such an approach should only be used to decide how many of the several options possible were deserving of further detailed economic analysis prior to making specific development decisions, ranking of sources for Katherine's future water supply were justified as follows.

GROUNDWATER SUPPLY

Continuation with the existing Tindal Limestone supply with successful treatment for hardness using magnetic polarization represented the least environmentally obtrusive scheme at lowest supply cost to the consumer. It was therefore important to test the real feasibility of this treatment system.

RUN OF RIVER

If Tindal Limestone water could not be successfully treated considering consumer cost and effect on the environment then the next best scheme would be drawn from run of river options. Given that the bore supply was rejected then it was unlikely that the Low Level would be suitable as water quality for late dry season flow was similar to the bore water. With additional biological disinfection required, the danger inherant with close proximity recreational activity and the need for additional pipe and pumping works, the Low Level as an alternative was ranked lower than continuation of the existing bore supply. Of the remaining two run of river schemes Donkey Camp Pool appeared the logical preference to Seventeen Mile Creek. Notwithstanding the sensitive environmental location of the Seventeen Mile Creek site inside a national part, the likely cheapest scheme for its development used Donkey Camp Pool as the reticulation pipeline headworks, with the Katherine River acting as conduit.

Whichever Seventeen Mile Creek scheme was adopted to minimise environmental impact within the national park, hydrologic regime below Donkey Camp was altered to the same extent as caused by its own development, due to the likely role of Seventeen Mile Creek as the sole source of recharge to the Katherine River above Nott's Crossing.

In addition, the Donkey Camp Pool site fitted a broader regional water resource development concept while Seventeen Mile Creek did not. Thus, relatively minor river engineering immediately upstream of Donkey Camp Pool was seen to possibly increase significantly river storage availbale to the pump site, in addition to which the Donkey Camp Pool provided the ideal pump-site for all other recommended surface storage schemes. Potential staging of supply development was therefore available with the Donkey Camp Pool site.

RESERVOIRS

There appeared to be no advantage in immediate development of surface storage sites for Katherine water supply considering the run of river alternatives available. There was no clear economic advantage evident between the best site on McAddens Creek and its counterpart on Dorothy Creek. Both sites allowed gravity piped supply to the Katherine River with subsequent delivery to the town reticulaton from Donkey Camp Pool. Their wider environmental impact due to headworks construction, the high degree of streamflow regulation resulting and the additional cost of development for impoundement and pipelines while still requiring withdrawal from Donkey Camp Pool placed these schemes behind run of river development at Donkey Camp Pool.

The scale of development and multipurpose potential available at Keckwick damsite was so great compared to town water requirement that it could not be considered one of the options for urban supply alone. (Fig. 37)

IRRIGATION POTENTIAL

No broad scale, co-ordinated attempt at irrigation development had been undertaken along the Katherine River. A C.S.I.R.O. research farm had been in operation since 1946 and a larger scale demonstration farm, begun in 1952 by the Northern Territory Administration, had conducted trials of some of the C.S.I.R.O. work. All of this work was directed to dry land agriculture. Minor irrigation had been attempted on isolated farms, pumping from the Katherine River, but no long term extensive scheme had developed.

On the basis of 1:50 000 scale land unit and topographic mapping, three classifications of potentially irrigable land were defined. (Figs. 38, 39) Classification 1 applied to land suited for direct supply from the Katherine River and channel reticulation with flood irrigation water application. Unit 2 land possessed topography dissected to the extent that internal irrigation supply, drainage and farming practice would have precluded flood irrigation and channel supply on anything but a fragmented and small scale. The land areas in category 3 were suitable for flood irrigation methods but their distance from the Katherine River prevented its economic use as supply source. It was considered that irrigation land units 2 and 3 fell outside the scope of this report, being suitable for investigation and development prospects as "keyline" and bore supply irrigation schemes respectively.

The distribution of unit 1 areas and assessment of water demand was then analysed based on the 50 percentile annual and monthly basic crop water requirement. (Figs. 40, 41) The crop water requirement was derived from basic evaporation parameters for the area. The areas and water demands quoted applied to within a 5 km boundary of the river only; unit 1 areas extended across this boundary in many instances and further investigation of the economics of full development of these units was recommended.

Land unit information on the left bank of the river was not available to the 50km radius downstream of Katherine township. From this distance to the Daly River junction there was a significant continuous area of irrigation land unit 1. Continuous land unit information was available along the right bank with the major occurrance of large areas of irrigation land unit 1 occuring within 7km radius of Katherine and from 22 km to 45 km downstream from the town.

Run of river flow as measured at the town only satisfied the full area basic crop water demand during the high rainfall months of February, March, April and May. For the months of January and June approximately 30% of the full area could have been supplied; for all remaining months less than 10% of the full area could have been supplied. In contrast the 50 percentile annual flow was more than three times the 50 percentile annual crop water demand.

Limited examination of the water analysis record at the Low Level Crossing at Katherine (the lowest sampling point on the river) indicated that the natural river waters were chemically suited to irrigation use over their full flow regime.

The Flora River provided a higher base flow than the Katherine at their junction, amounting to in excess of 2.5 cumecs; the Flora may have offered better prospects as source for run of river supply to the significant area of arable land between the right bank of the Flora and the left bank of the Katherine.

YEAR 19..	POPULATION	ANNUAL WATER CONSUMPTION m^3x1000	PEAK MONTH WATER CONSUMPTION m^3x1000	ANNUAL PER CAPITA WATER CONSUMPTION m^3x1000	PEAK MONTH PER CAPITA WATER CONSU CONSUMPTION m^3
58	730	129	20	0.17	27.4
59	770	163	16	0.21	20.8
60	820	155	18	0.19	22.0
61	876	150	20	0.17	22.8
62	1000	172	25	0.17	25.0
63	1120	175	24	0.16	21.4
64	1250	195	27	0.16	21.6
65	1380	230	28	0.17	20.3
66	1506	305	33	0.20	21.9
67	1700	310	39	0.18	22.9
68	1900	340	40	0.18	21.0
69	2110	395	43	0.19	20.4
70	2310	500	54	0.22	23.4
71	2522	502	54	0.20	21.4
72	2800	635	77	0.24	27.5
73	2887	840	93	0.29	32.2
74	3100	877	99	0.28	31.9
75	3200				
76	3300				
77	3350				
78	3450	1518	145	0.44	42.2

TABLE 1 : KATHERINE URBAN POPULATION AND WATER CONSUMPTION

PERIOD	AVERAGE DAILY PER CAPITA CONSUMPTION m^3	% OF ANNUAL AVERAGE DAILY PER CAPITA CONSUMPTION
ANNUAL	1.20	100
PEAK DAY	1.97	164
PEAK WEEK	1.47	122
PEAK MONTH	1.36	113

TABLE 2 : KATHERINE URBAN 1978 PEAK WATER CONSUMPTION RATES

YEAR	ANNUAL WATER CONSUMPTION		MEATWORKS CONSUMPTION AS % OF KATHERINE'S	AVERAGE DAILY WATER CONSUMPTION		MEATWORKS CONSUMPTION AS % OF KATHERINE'S
	MEATWORKS m^3 x 1000	KATHERINE m^3 x 1000		MEATWORKS* m^3 x 1000	KATHERINE m^3 x 1000	
1976/7	18.2	1340	1.4	.099	3.67	2.7
1975/6	43	1190	3.6	.235	3.25	7.2
1974/5	61	1020	6.0	.333	2.80	11.9
1973/4	2.5	870	2.8	.014	2.40	5.8
1972/3	2	840	2.4	.011	2.30	4.8

* ASSUMING SIX MONTH OPERATING PERIOD

TABLE 3 : KATHERINE MEATWORKS WATER CONSUMPTION

PARAMETER	NUMBER OF OBSERVA-TIONS	RANGE OBSERVED	10% ile V	50% ile A L	90% ile U E
pH	21	7-8.3	7.7-7.8	7.3-7.4	7-7.1
TDS mg/l	17	270-450	440-450	380	270-290
TOTAL HARDNESS ($CaCO_3$) mg/l	21	246-438	433-435	416	252-254
Cl mg/l	21	4-18	8-18	6-7	4-5
SO_4 mg/l	19	2-14	13	6-7	2
NO_3 mg/l	19	1, 1x18			
F mg/l	19	.1-.4	.3-.4	.3-.4	.1
Ca mg/l	19	28-104	104	95	45
Mg mg/l	19	34-44	43-44	40-41	34-37
Fe mg/l	19	.1-3.6	1.4	.2	.1

Data for bores R.N. 7807, 6983, 6970, 6961, 6959, 6885, 6884

TABLE 4 : KATHERINE TOWN BORES WATER QUALITY.

PARAMETER	NUMBER OF OBSERVA-TIONS	RANGE OBSERVED	10% ile	50% ile	90% ile
			V A	L U E	
pH	70	5.9-9.2	7.0-7.1	6.5-6.6	6.1-6.2
T.D.S. mg/l	59	14-80	48	34-35	25
TOTAL HARDNESS ($CaCO_3$ mg/l)	70	2-27	9-12	5-6	3-4
Cl mg/l	70	1-8	7-8	6-7	2-3
SO_4 mg/l	59	2-6	5	2	2
NO_3 mg/l	59	1-5	2-3	1-2	1
F mg/l	59	.1-.3	.2-.3	.1-.2	.1
Ca mg/l	59	1-11	3-4	1-2	1-2
Mg mg/l	59	1-2	1-2	1-2	1
Fe mg/l	58	.1-8.0	1.2-1.4	.5-.6	.1-.2

TABLE 5 : SEVENTEEN MILE CREEK WATER QUALITY

YEAR	MINIMUM NATURAL OVER - FLOW $M^3 x 10^6$ MONTH	MINIMUM OVER - FLOW WITH $.33 x 10^6$ M^3/MONTH OFF-TAKE $M^3 x 10^6$/MONTH	DURATION OF NIL OVER - FLOW MONTHS	DRAWDOWN METRES
63	.505	.175	-	-
64	.176	0	2	0.4
65	.090	0	4	1.4
66	0	0	6	4.9*
67	.130	0	4	1.6
68	.210	0	2	0.6
69	.262	0	2	0.2
70	.100	0	2	1.1
71	.504	.174	-	-
72	.448	.118	-	-

* 3.9 if offtake reduced to $.3 \times 10^6$ M^3/month.

Table 6. DONKEY CAMP POOL BEHAVIOUR

PARAMETER	NUMBER OF OBSERVA-TIONS	RANGE OBSERVED	10% ile	50% ile	90% ile
			V	A L U	E
pH	56	5.9-8.5	7.8-7.9	7.0.7.1	6.3-6.4
T.D.S. mg/l	47	14-380	260-310	130	28-30
TOTAL HARDNESS ($CaCO_3$ mg/l)	56	3-368	320-329	126-128	9-13
Cl mg/l	56	2-10	8-9	6-7	3-4
SO_4 mg/l	47	2-11	10-11	4-5	2-2
NO_3 mg/l	47	1-4	2-3	1-2	1-1
F mg/l	47	.1-.3	.2-.3	.1-.2	.1-.1
Ca mg/l	47	1-88	60-69	17	1-2
Mg mg/l	47	1-36	28-32	10-12	1-1.5
Fe mg/l	47	.1-6.4	2.5-2.6	.4	.1-.1

Maximum turbidity observed : 38 A.P.H.A. units

TABLE 7 : KATHERINE LOW LEVEL WATER QUALITY

SPILL R.L M.AHD	REG. FLOW $M^3 x 10^6$ /Month	FAILURE TIME MONTHS	%	NO. OF FAILURES 57/58 - 71/72 OF DURATION MONTHS 2	3	4	5	>5	MAX FAILURE DURATION MONTHS
190	60	26	14	3	-	-	-	2	9
	50	15	8	-	-	-	1	2	8
	40	7	4	1	-	-	1	-	5
	30	0	0	-	-	-	-	-	-
200	60	3	2	1	-	-	-	-	2
	50	0	0	-	-	-	-	-	-
	40	0	0	-	-	-	-	-	-
	30	0	0	-	-	-	-	-	-

For spillway above 210 R.L. and regulated flow 60 x 10^6 m^3/ month and less there were no failures.

TABLE 8 : KECKWICK RESERVOIR PERFORMANCE OVER 15 YEARS

G.S. 814019 FLOW		KECKWICK DAMSITE			
10% ile	50% ile	TOTAL OUTFLOW 10% ile	TOTAL OUTFLOW 50% ile	REG. FLOW	SPILL R.L. M. A.H.D.
MONTHLY MEAN DAILY CUMECS					
0	.64	23	26	23	190
		19	20	19	
		16	18	15	
		13	14	11	
		14	18	23	200
		19	20	19	
		15	16	15	
		12	13	11	
MONTHLY TOTAL $m^3 \times 10^6$					
0	1.6	60	70	60	190
		50	60	50	
		41	43	40	
		30	31	30	
		61	61	60	200
		50	51	50	
		41	43	40	
		31	33	30	
ANNUAL TOTAL $m^3 \times 10^6$					
180	740	730	780	720	190
		640	850	600	
		490	520	480	
		380	460	360	
		740	840	720	190
		610	710	600	
		500	640	480	
		380	540	360	

For spillway at or above 210 M.R.L. and regulated flow $60 \times 10^6 - 30 \times 10^6$ m^3/month there was no spill.

TABLE 9 : KECKWICK RESERVOIR FLOW REGULATION

G.S. 814019 FLOW		KECKWICK DAMSITE		
		OUTFLOW	REG. FLOW CUMECS	SPILL R.L. m A.H.D.
10% ile MONTHLY INST. MAX. CUMECS				
460		54	23	190
		54	19	
		39	15	
		39	11	
		29	23	200
		55	19	
		19	15	
		19	11	
10% ile ANNUAL INST. MAX. CUMECS				
1900		700	23	190
		780	19	
		940	15	
		1050	11	
		110	23	200
		165	19	
		260	15	
		320	11	
MAX. OBSERVED INST. CUMECS				
3160		1320	23	190
		1330	19	
		1340	15	
		1360	11	
		160	23	200
		330	19	
		530	15	
		630	11	

For spillway at or above 210m. R.L. and regulated flow between 23 and 11 cumecs there was no spill.

TABLE 10 : KECKWICK FLOOD MITIGATION

SPILL R.L. m. A.H.D.	REG. FLOW CUMECS	1957/58-1971/72 MONTHLY AVERAGE GENERATING CAPACITY				
		NO. OF FAILURES	RANGE MW	10% ile MW	50% ile MW	90% ile MW
190	23	27	0-7.4	0	5.1	6.6
	19	15	0-6.2	2.9	4.6	5.5
	15	7	0-4.9	2.8	4.0	4.5
	11	-	2-3.7	2.6	3.1	3.4
200	23	7	0-9.2	4.1	7.1	8.8
	19	-	3.7-7.7	4.4	6.2	7.3
	15	-	3.8-6.2	4.2	5.2	5.9
	11	-	3.2-4.7	3.5	4.1	4.5
210	23	-	5.6-11.3	6.9	8.3	10.1
	19	-	5.5-9.4	6.3	7.3	8.6
	15	-	4.9-7.5	5.3	6.1	6.9
	11	-	4.0-5.6	4.3	4.8	5.3
220	23	-	8.5-13.5	8.8	9.9	12.6
	19	-	7.5-11.3	7.8	8.6	10.6
	15	-	6.3-9	6.5	7.0	8.5
	11	-	4.9-6.8	5.1	5.4	6.4

NB: Figure represents hydraulic energy; efficiency factor must be applied to these.

TABLE 11 : KECKWICK DAMSITE HYDROELECTRICITY

PARAMETER	NUMBER OF OBSERVA-TIONS	RANGE OBSERVED	10% ile	50% ile	90% ile
			V	A L U	E
pH	34	4.6-8.3	6.7-6.8	6.3-6.5	5.7
T.D.S. mg/l	23	7-43	40-43	29-30	8-10
TOTAL HARDNESS ($CaCO_3$) mg/l	34	3-26	10-13	6-7	4
Cl mg/l	31	2-8	8	5-6	2-3
SO_4 mg/l	19	2-6	4-6	2-2	2
NO_3 mg/l	21	1-2	1-2	1-2	1-1
F mg/l	21	.1-.2	.1-.2	.1-.2	.1
Ca mg/l	19	1-8	2-8	1-2	1
Mg mg/l	21	1-2	1-2	1-2	1-1
Fe mg/l	21	.1-4.1	2.2-4.1	.5	.1-.2

TABLE 12 : KATHERINE GORGE WATER QUALITY

PARAMETERS	NUMBER OF OBSERVA-TIONS	RANGE OF OBSERVA-TIONS	10% ile	50% ile	90% ile
			V A L U E		
pH	14	6-7.1	6.9-7.1	6.4-6.5	6-6.1
T.D.S. mg/l	3	26, 42, 90			
TOTAL HARD-NESS ($CaCO_3$) mg/l	14	3-38	38	8-9	3-4
Cl mg/l	14	2-6	6	4-5	2-4
SO_4 mg/l	3	3, 2, 2			
NO_3 mg/l	3	2, 1, 1			
F mg/l	2	.1, .1			
Ca mg/l	3	6, 4, 1			
Mg mg/l	3	6, 1, 1			
Fe mg/l	3	1.3, 1.0, .9			

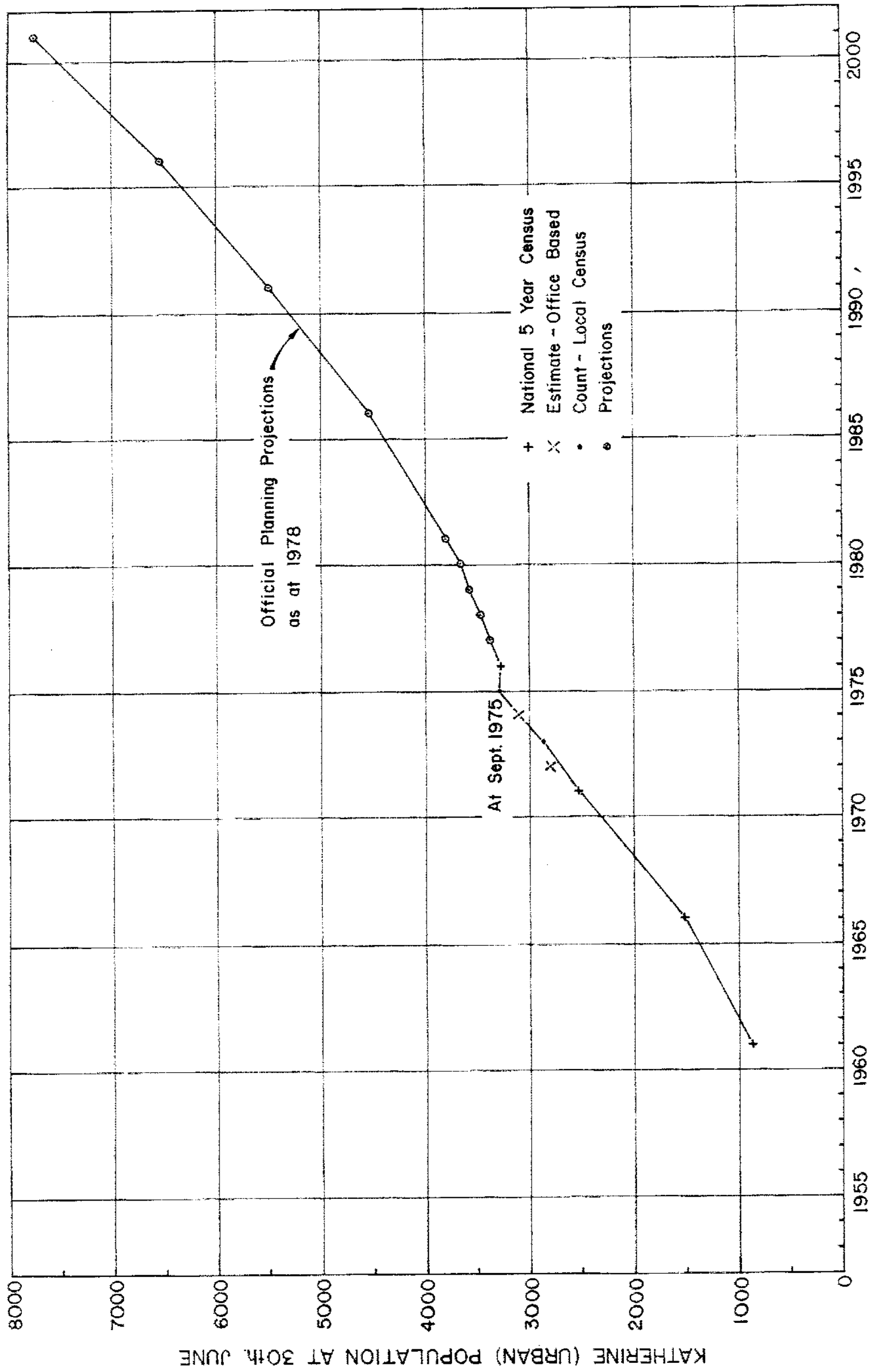
TABLE 13 : McADDEN CREEK WATER QUALITY

PARAMETER	NUMBER OF OBSERVA-TIONS	RANGE OBSERVED	10% ile	50% ile	90% ile
			V A	L U	E
pH	55	5.8-7.7	6.8-6.9	6.5-6.6	6-6.1
T.D.S. mg/l	40	16-31	42-45	32-33	23-25
TOTAL HARDNESS ($CaCO_3$ mg/l)	54	1-16	13-15	7-8	4-5
Cl mg/l	55	2-8	6-7	5-6	3-4
SO_4 mg/l	39	2-6	5	2-3	2-2
NO_3 mg/l	40	1-3	2-3	1-2	1-1
F mg/l	40	.1-.3	.2-.3	.1-.2	.1-.1
Ca mg/l	40	1-4	3	1-2	1-2
Mg mg/l	40	1-2	2	1-2	1-1
Fe mg/l	40	.1-7.7	1.2-1.3	.6-.7	.2-.2

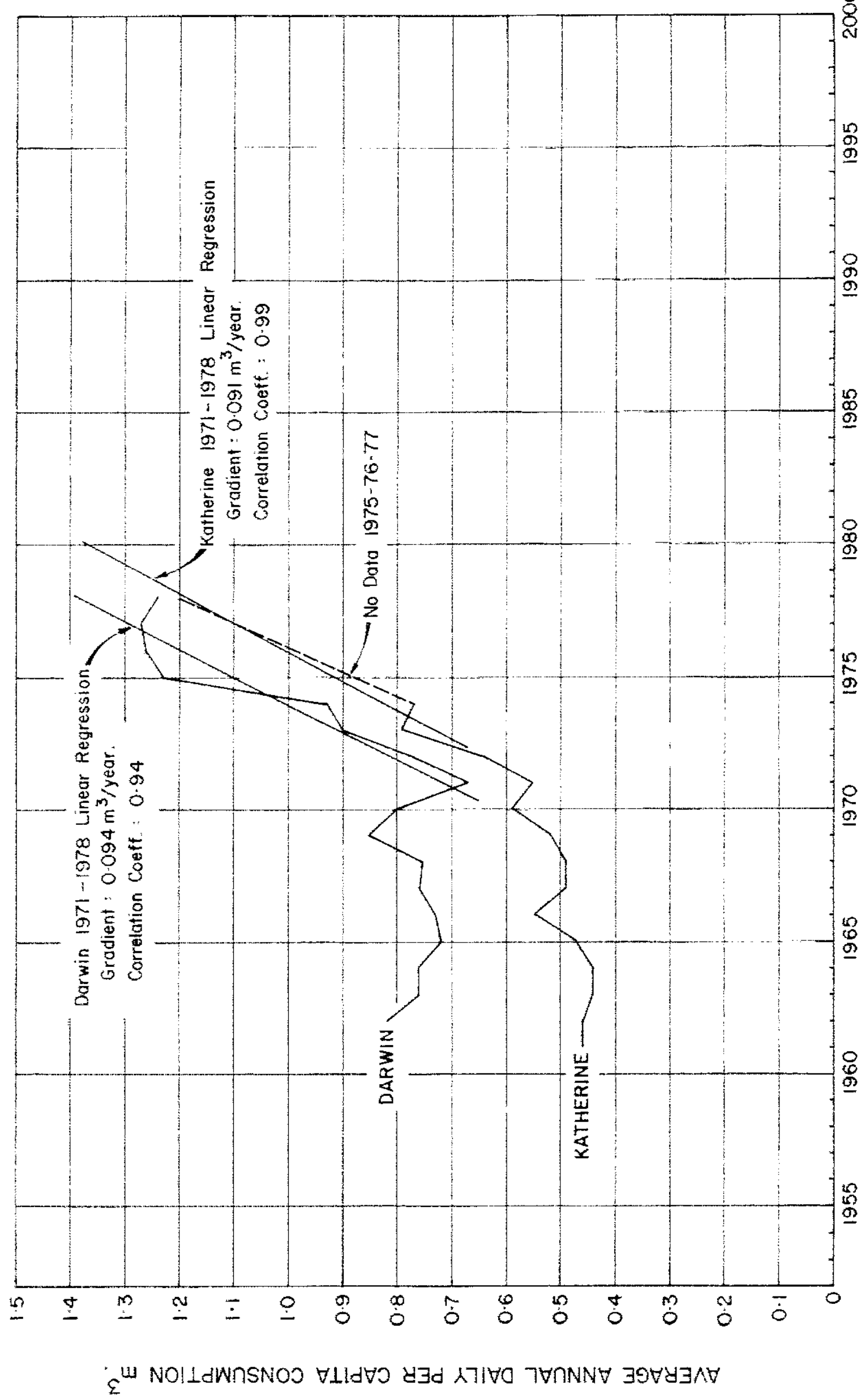
Maximum turbidity : 137 A.P.H.A. units

TABLE 14 _ DONKEY CAMP POOL WATER QUALITY

A. H. CAUDELL, Government Printer of the Northern Territory



KATHERINE RIVER DEVELOPMENT FIG. I.



KATHERINE RIVER DEVELOPMENT FIG. 2.

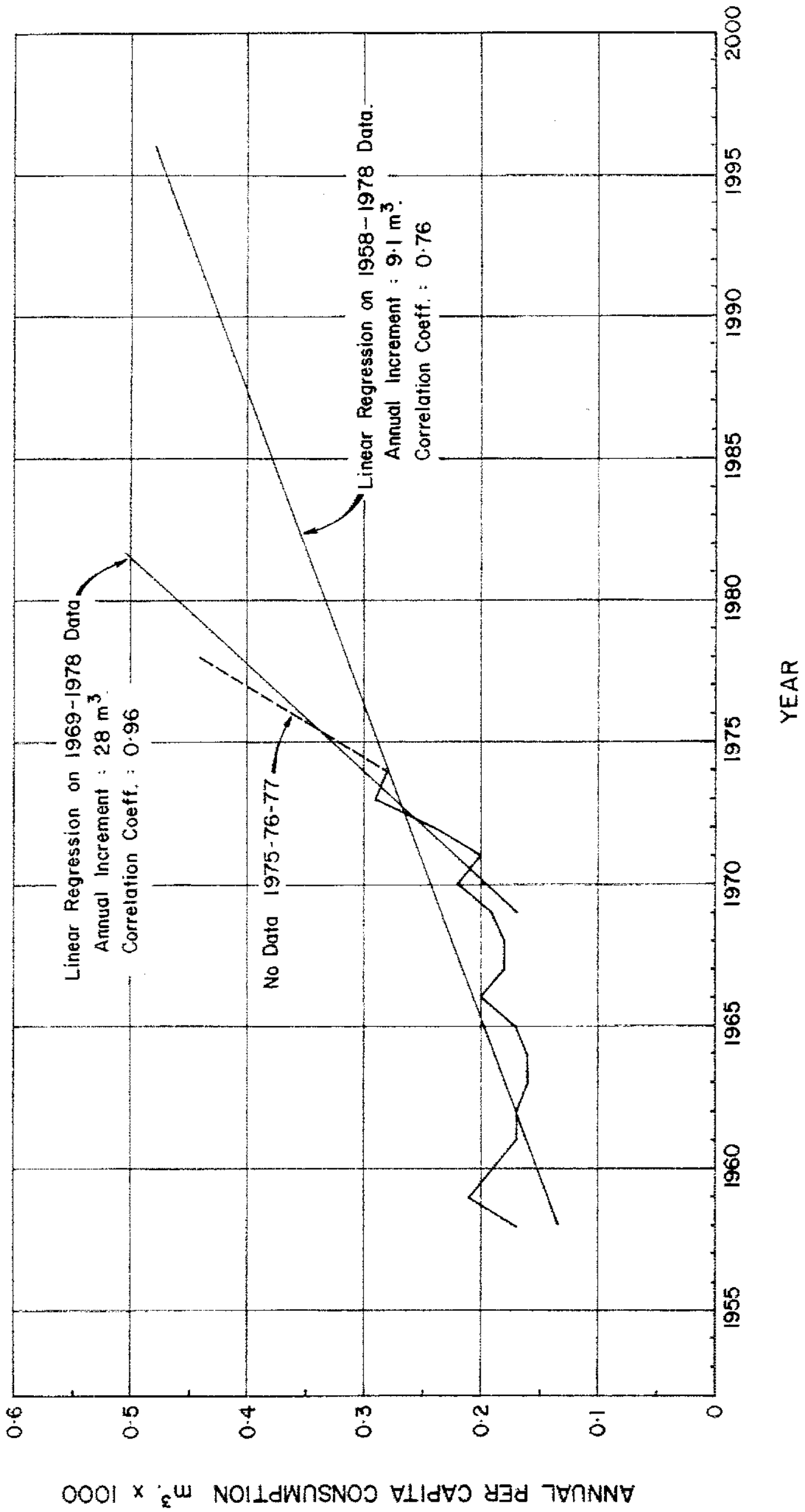


FIG. 3 .
KATHERINE RIVER DEVELOPMENT

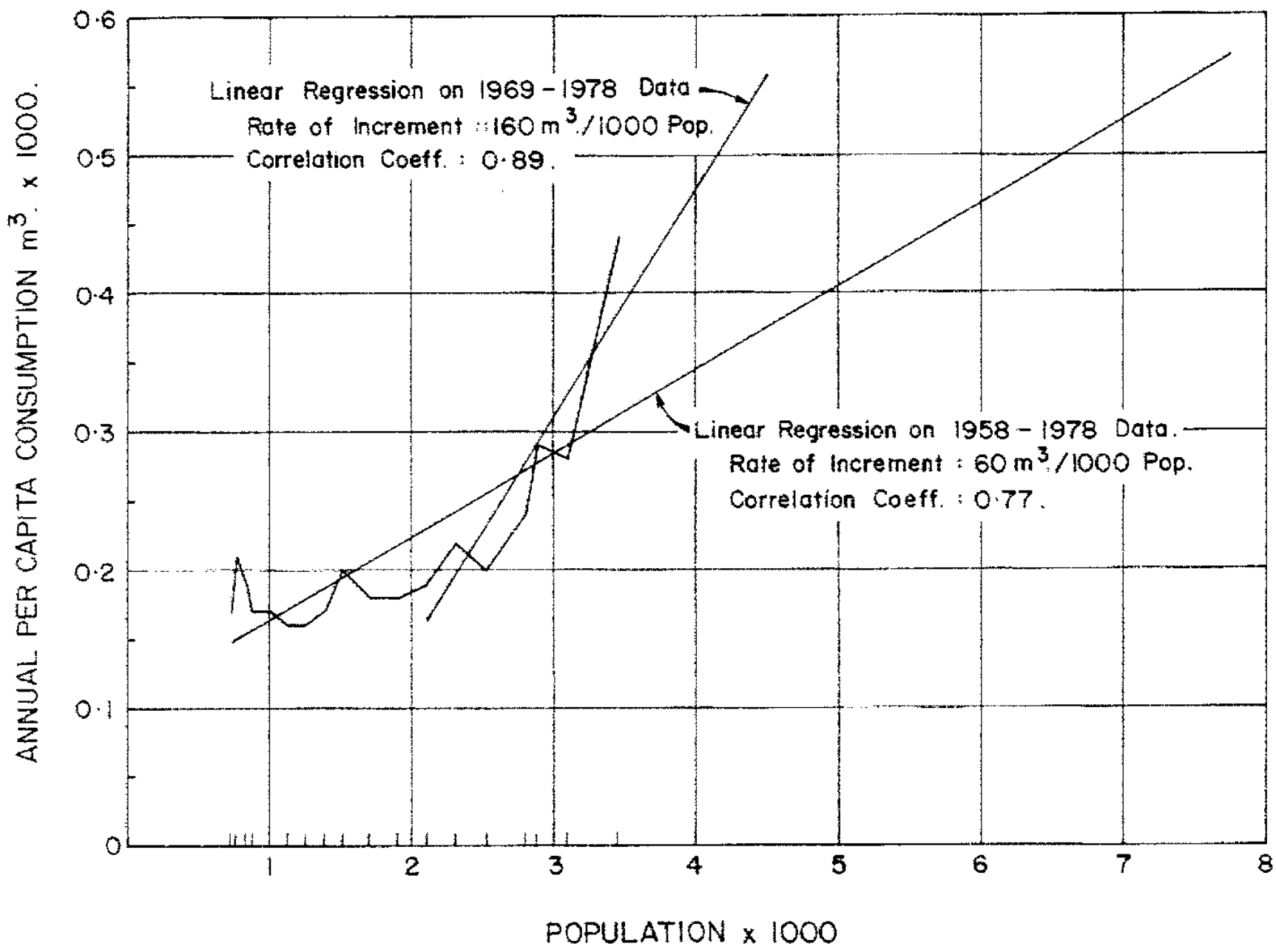
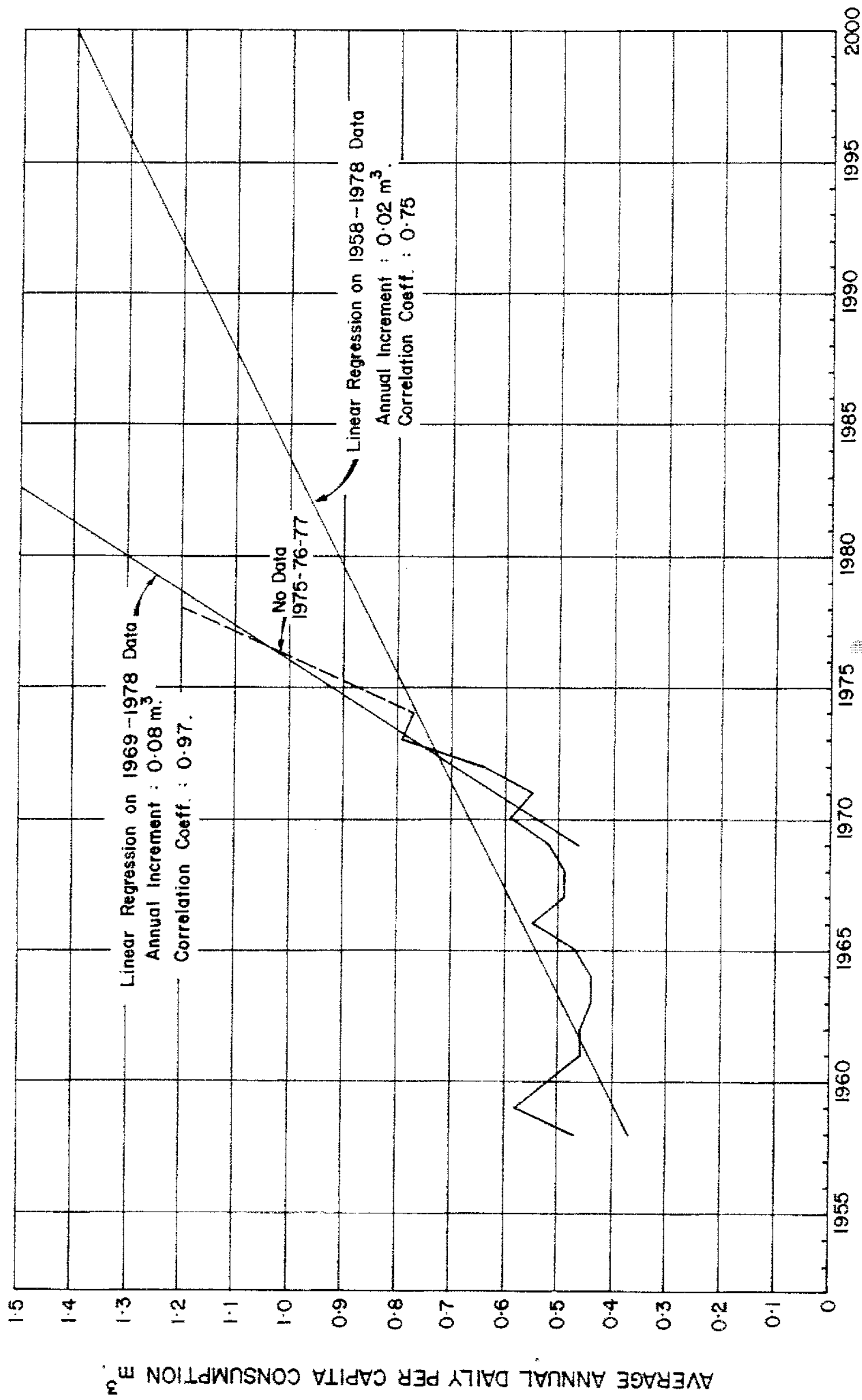


FIG. 4.
KATHERINE RIVER DEVELOPMENT



KATHERINE RIVER DEVELOPMENT FIG. 5

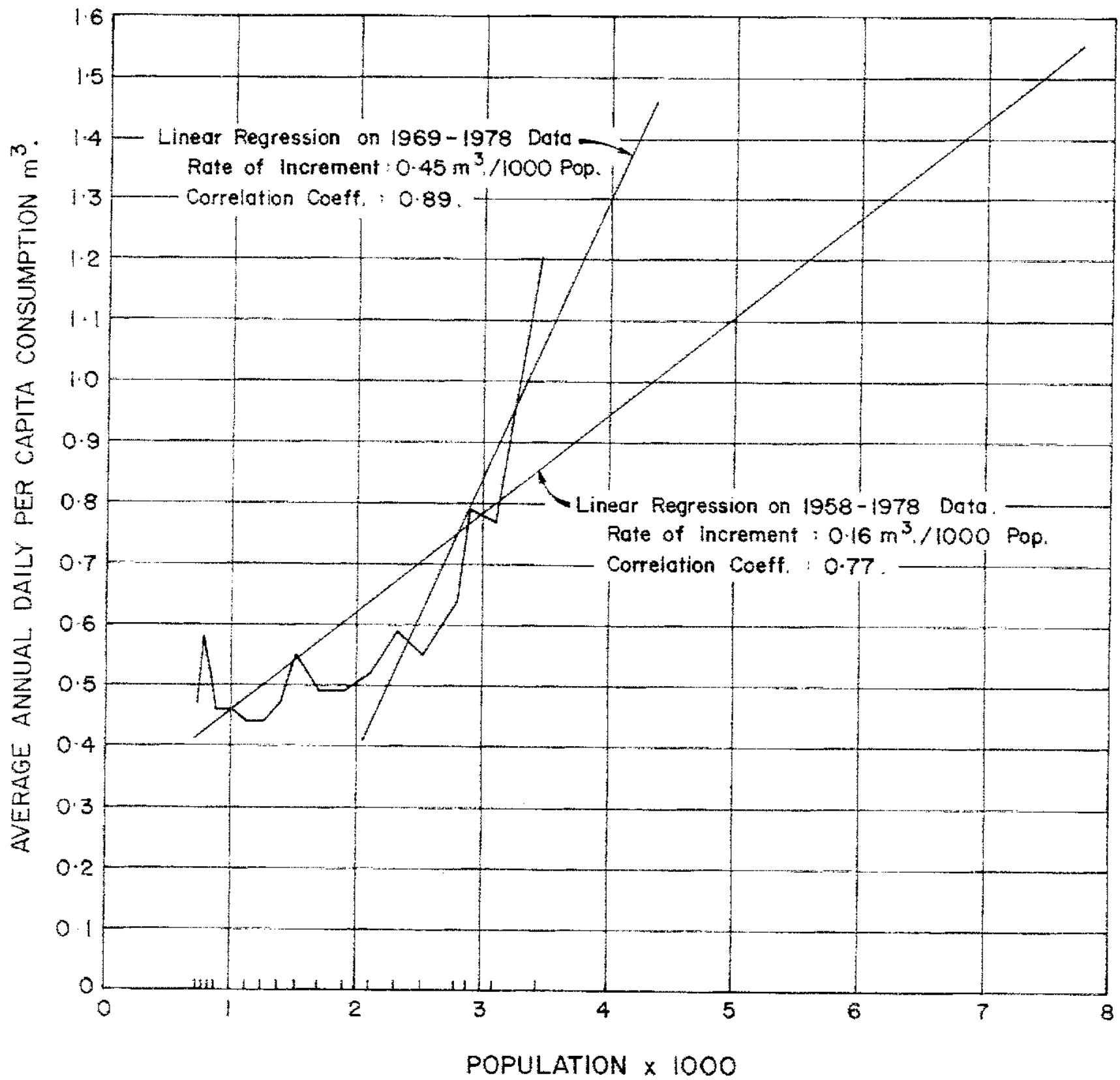


FIG. 6 .
KATHERINE RIVER DEVELOPMENT

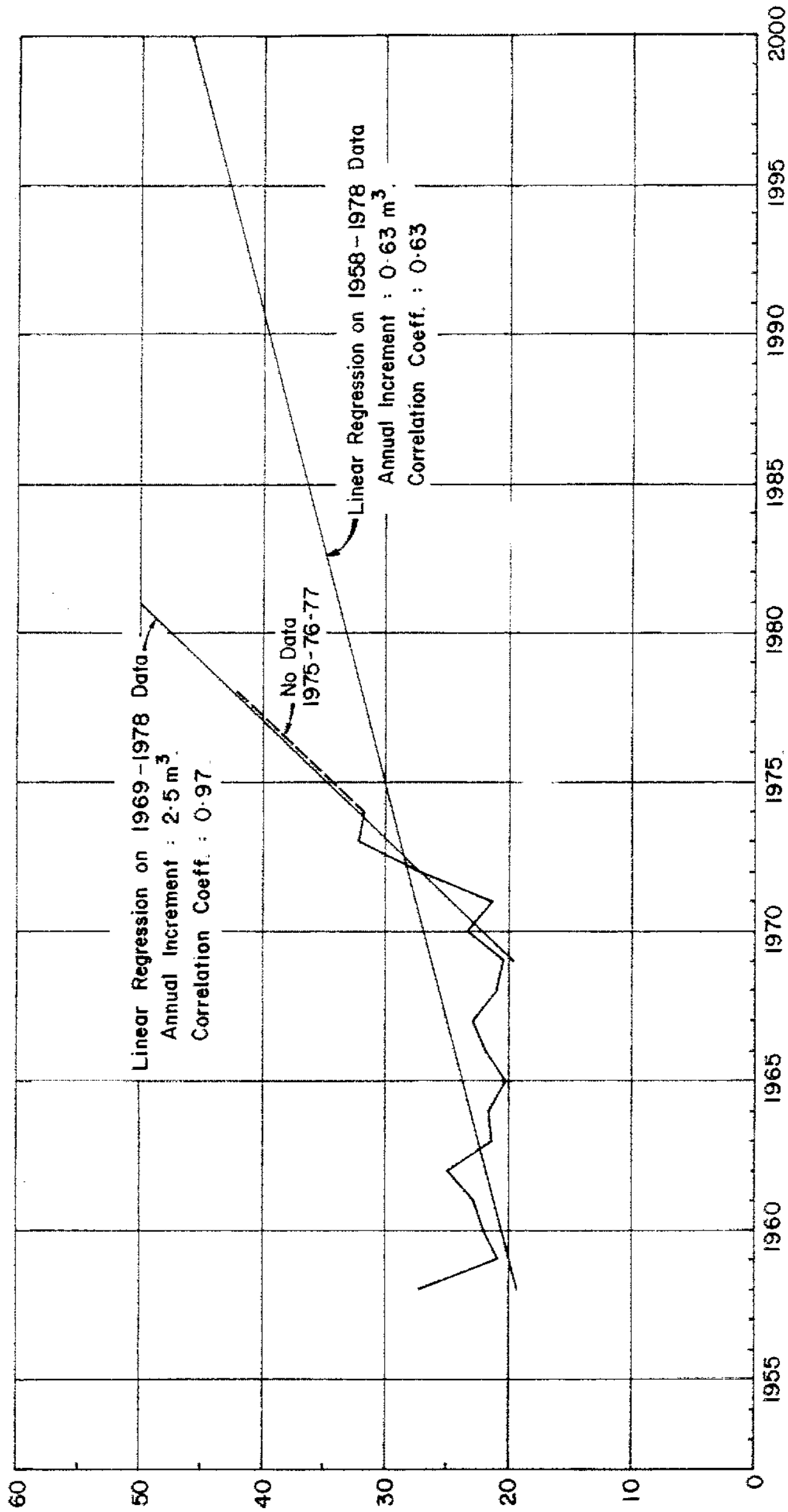


FIG. 7 .
KATHERINE RIVER DEVELOPMENT

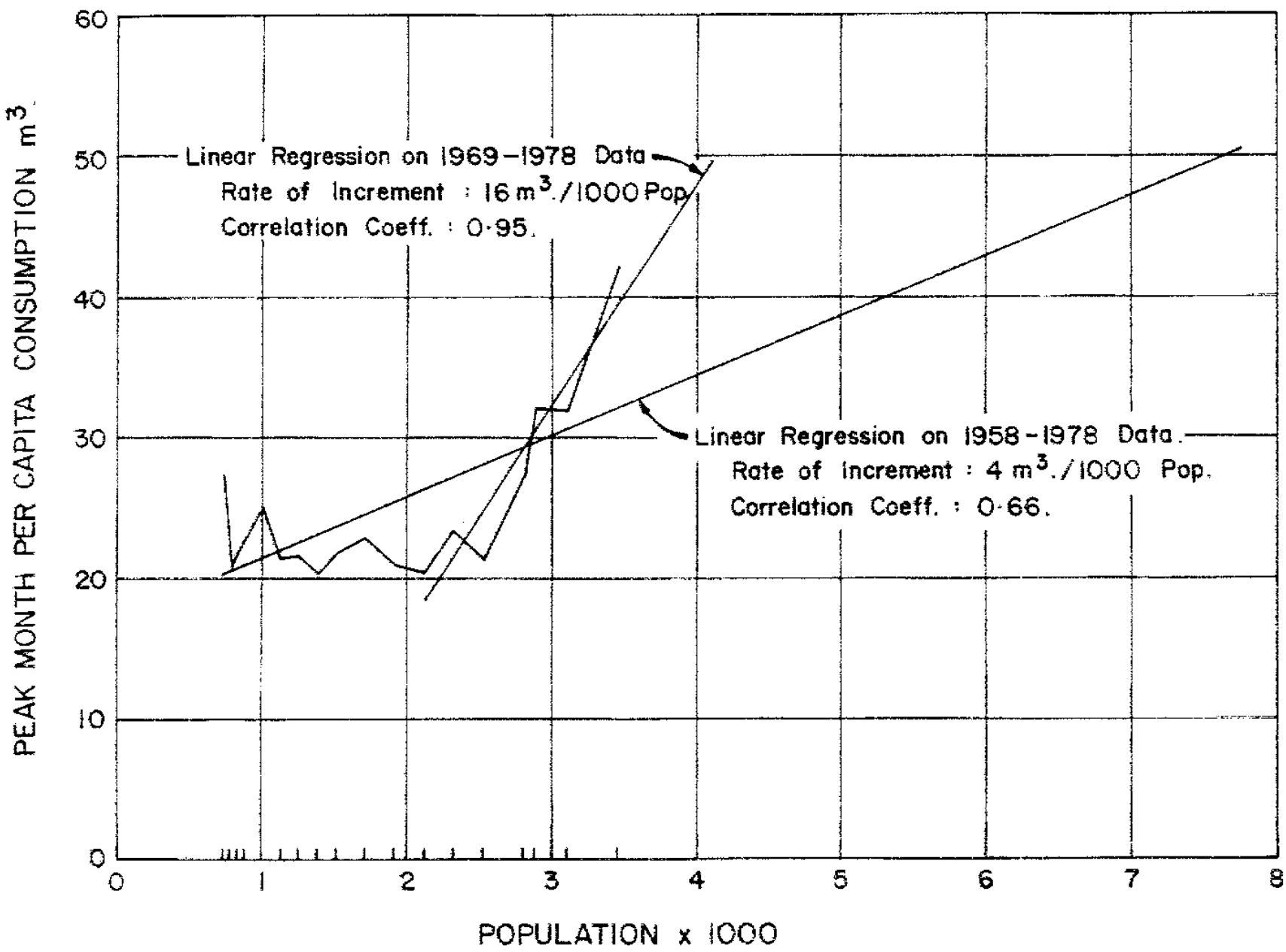


FIG. 8.
KATHERINE RIVER DEVELOPMENT

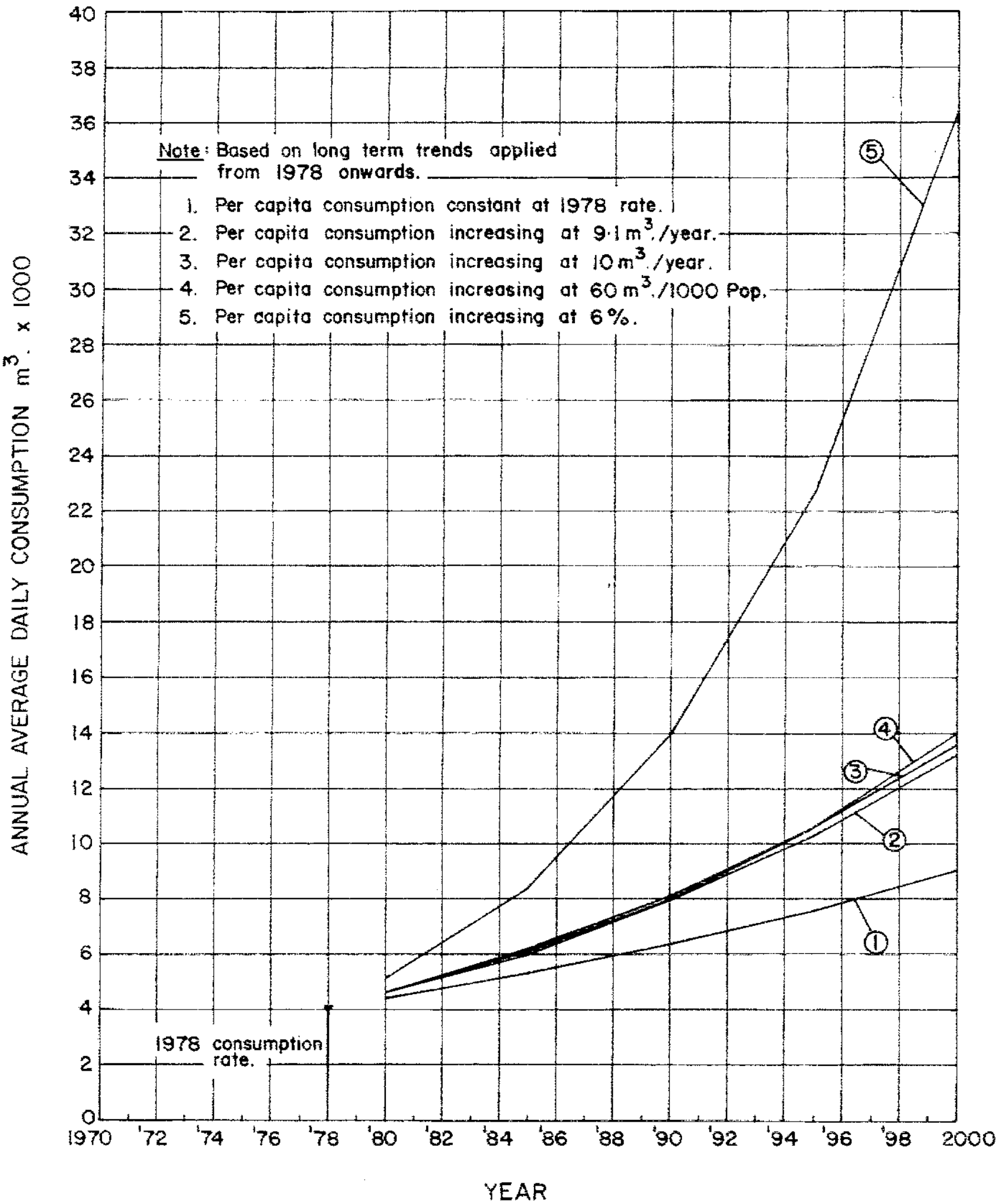
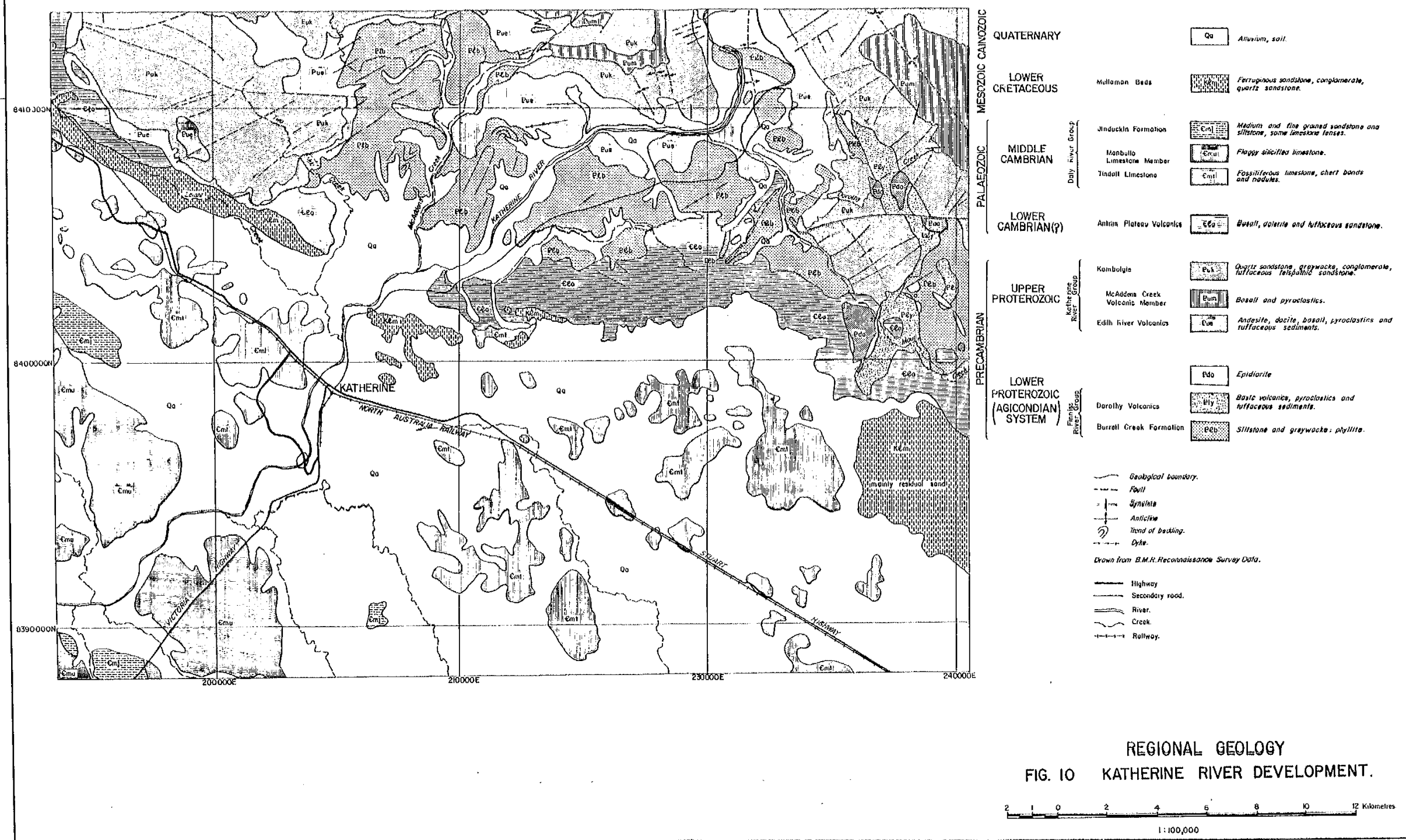


FIG. 9.
KATHERINE RIVER DEVELOPMENT

KATHERINE REGIONAL GEOLOGY.



REGIONAL GEOLOGY

FIG. 10 KATHERINE RIVER DEVELOPMENT.

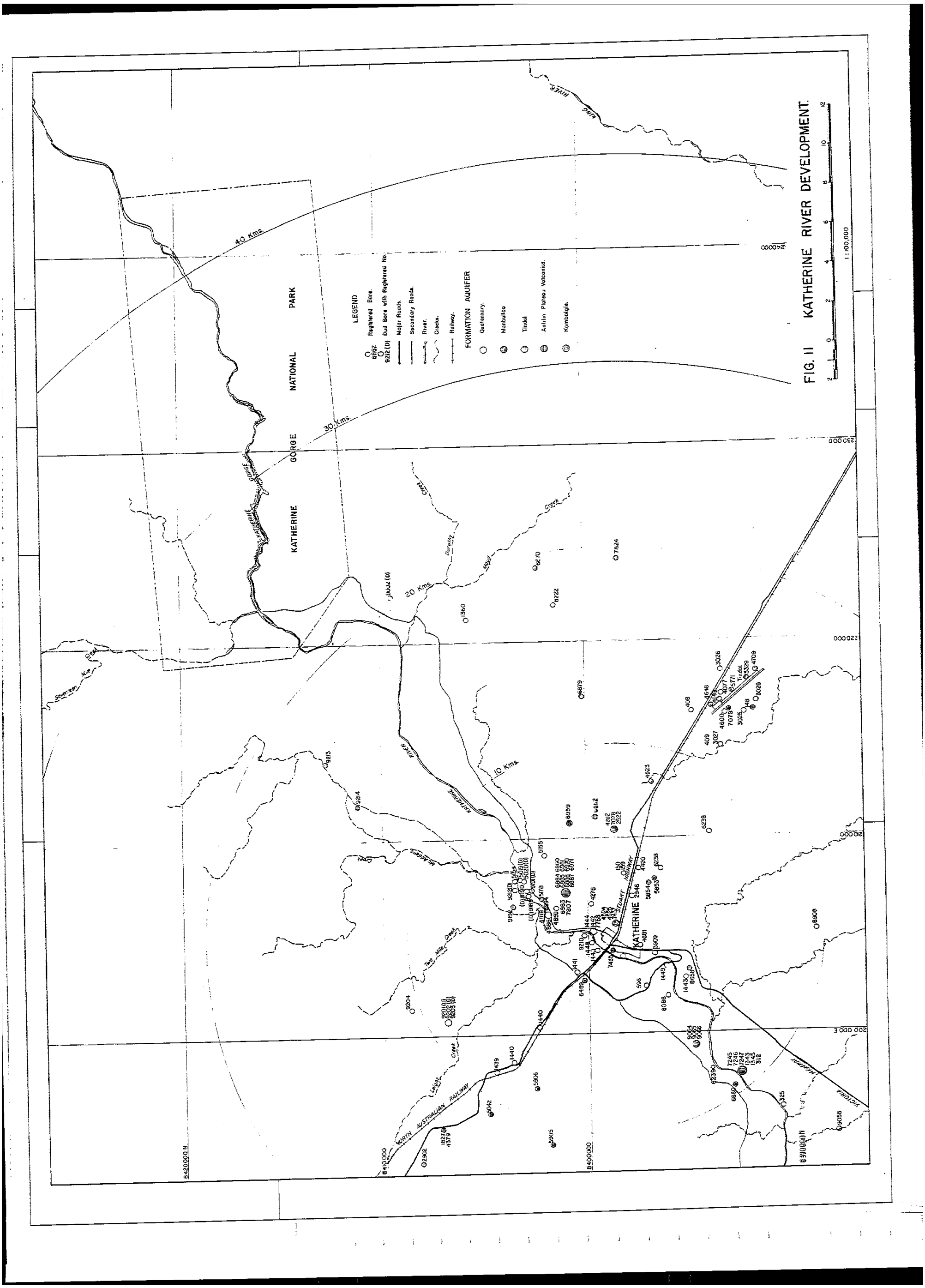
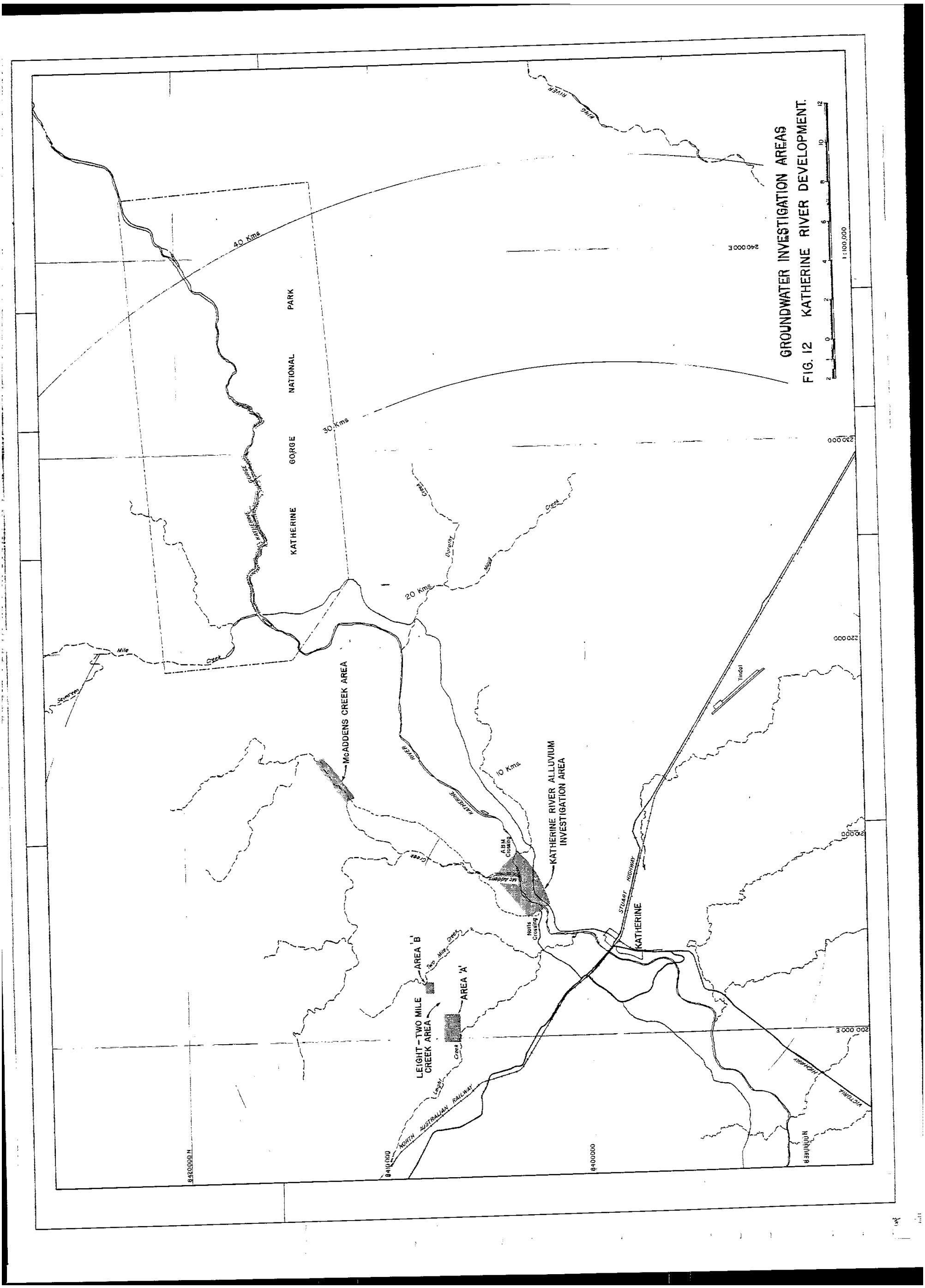
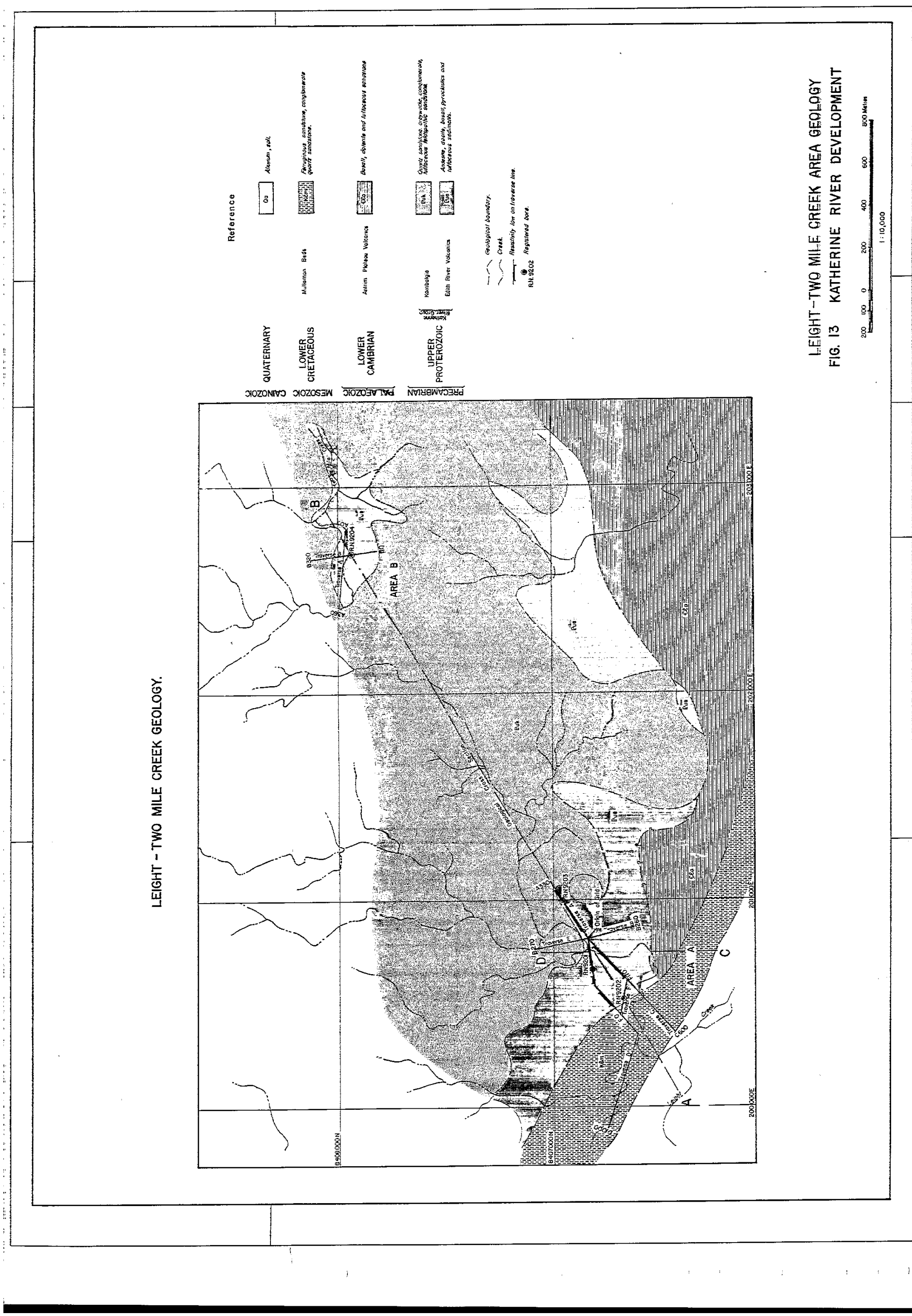


FIG. 11 KATHERINE RIVER DEVELOPMENT.
1:100,000
LEGEND
Registered Bore.
Dud Bore with Registered No.
Major Roads.
Secondary Roads.
River.
Creeks.
Railway.
FORMATION AQUIFER
Quaternary.
Manbulloo
Tindal
Antrim Plateau Volcanics.
Kombolgie.
KATHERINE GORGE NATIONAL PARK
KATHERINE
KATHERINE RIVER
MAIN RIVER
40 Kms.
30 Kms.
20 Kms.
10 Kms.
NORTH AUSTRALIAN RAILWAY
STUART HIGHWAY
VICTORIA HIGHWAY
Two Mile Creek
Seventeen Mile Creek
Legaty Creek
McAdams Creek
Dorothy Creek
Moyle Creek
8420000 N
8410000
8400000
8390000 N
200 000 E
220000
230000


GROUNDWATER INVESTIGATION AREAS
FIG. 12 KATHERINE RIVER DEVELOPMENT.
1:100,000
KATHERINE GORGE NATIONAL PARK
40 Kms
30 Kms
20 Kms
10 Kms
McADDENS CREEK AREA
KATHERINE RIVER ALLUVIUM INVESTIGATION AREA
LEIGHT – TWO MILE CREEK AREA
AREA 'A'
AREA 'B'
KATHERINE
STUART HIGHWAY
VICTORIA HIGHWAY
NORTH AUSTRALIAN RAILWAY
Tindal
240000E
230000
220000
210000
200000E
8420000N
8410000
8400000
NORTHERN


LEIGHT - TWO MILE CREEK GEOLOGY.
Reference
CAINOZOIC
QUATERNARY
Qa
Alluvium, soil.
MESOZOIC
LOWER CRETACEOUS
Mullaman Beds
Ferruginous sandstone, conglomerate quartz sandstone.
PALAEOZOIC
LOWER CAMBRIAN
Antrim Plateau Volcanics
Basalt, diabase and tuffaceous sediments
PRECAMBRIAN
UPPER PROTEROZOIC
Kombolgie
Quartz sandstone, greywacke, conglomerate, tuffaceous feldspathic sandstone.
Edith River Volcanics
Andesite, dacite, basalt, pyroclastics and tuffaceous sediments.
Geological boundary.
Creek.
Reasonably low on traverse line.
RN 9202
Registered bore.
LEIGHT-TWO MILE CREEK AREA GEOLOGY
FIG. 13 KATHERINE RIVER DEVELOPMENT
200 100 0 200 400 600 800 Metres
1:10,000
AREA A
AREA B
AREA C
AREA D
B320
B260
RN 9203
RN 9204
RN 9202
RN 9201
Two Mile Creek
Leight Creek
Tuggeranong Creek
Katherine River
Origin of Bird
Cross Section
200 000E
201 000E
202 000E
203 000E
8480000N
8470000N

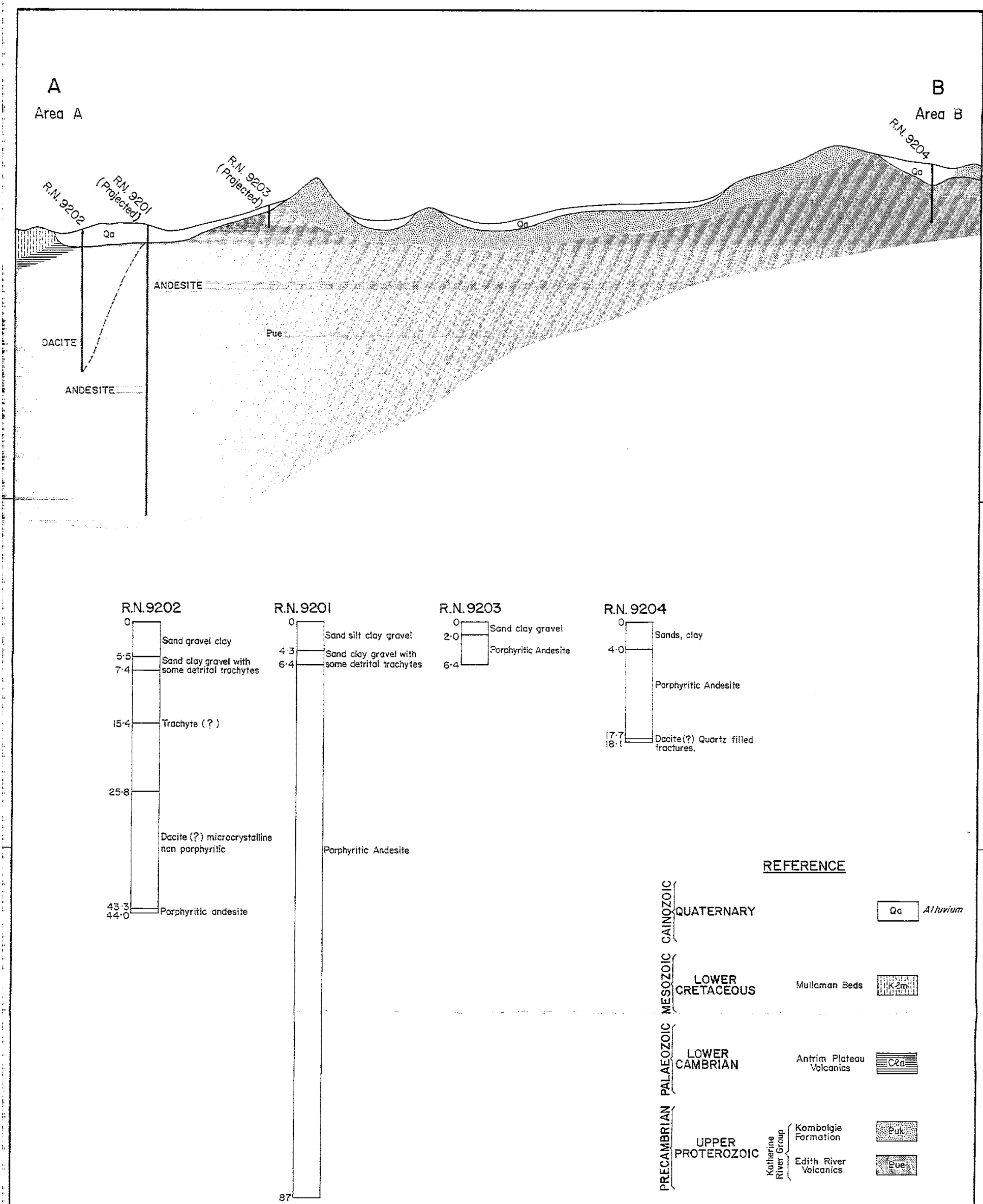


FIG. 14
KATHERINE RIVER DEVELOPMENT

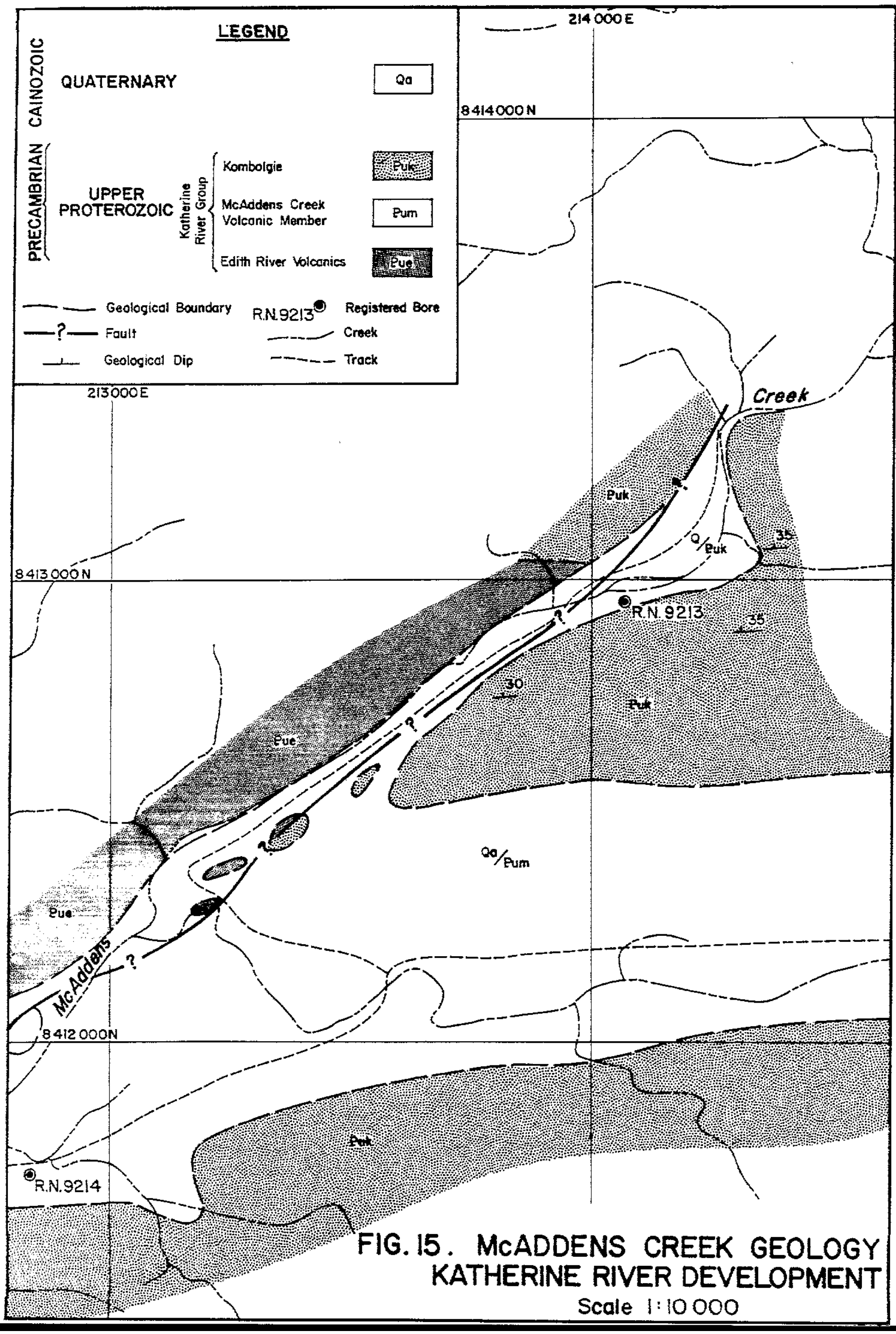
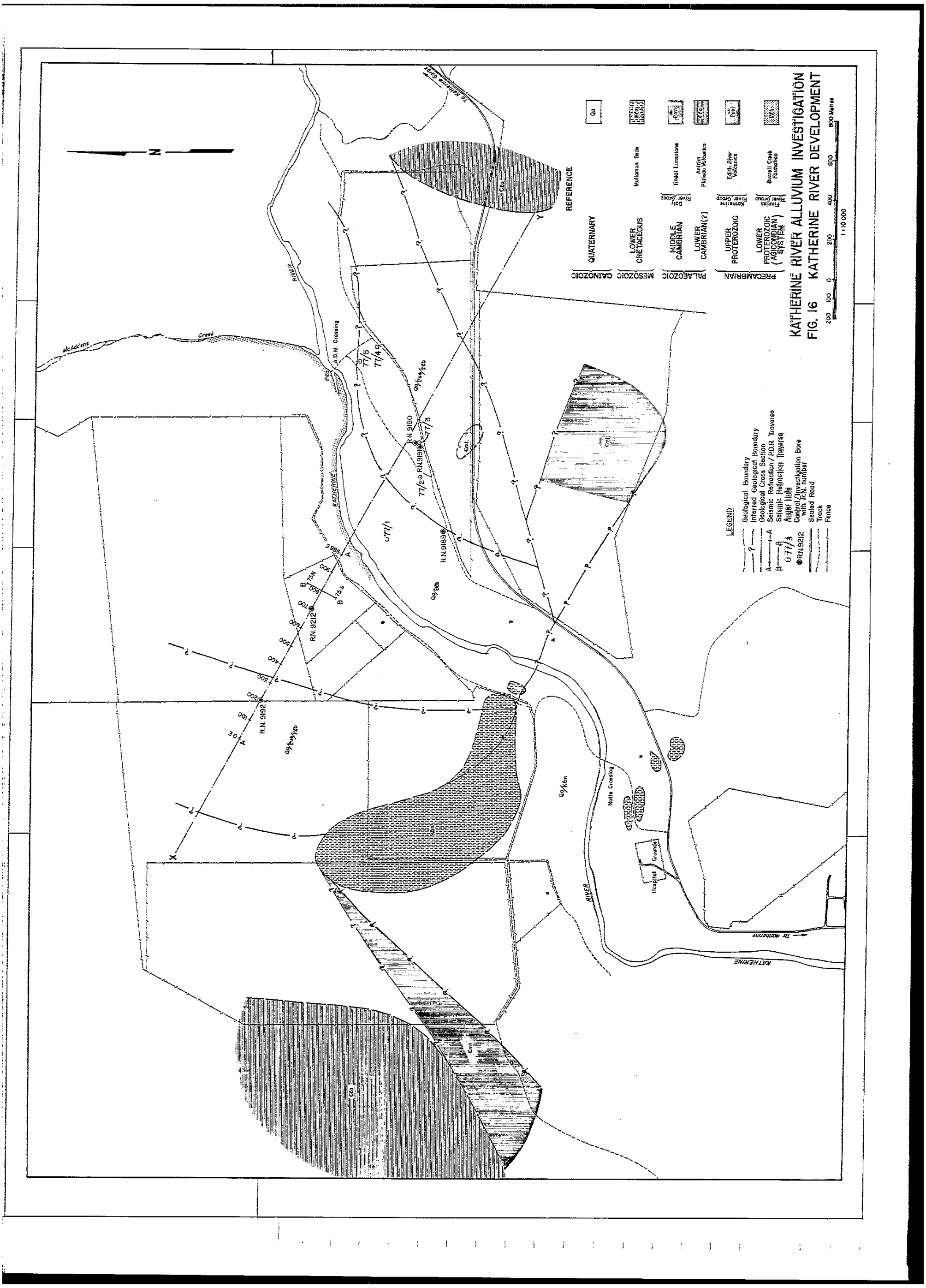
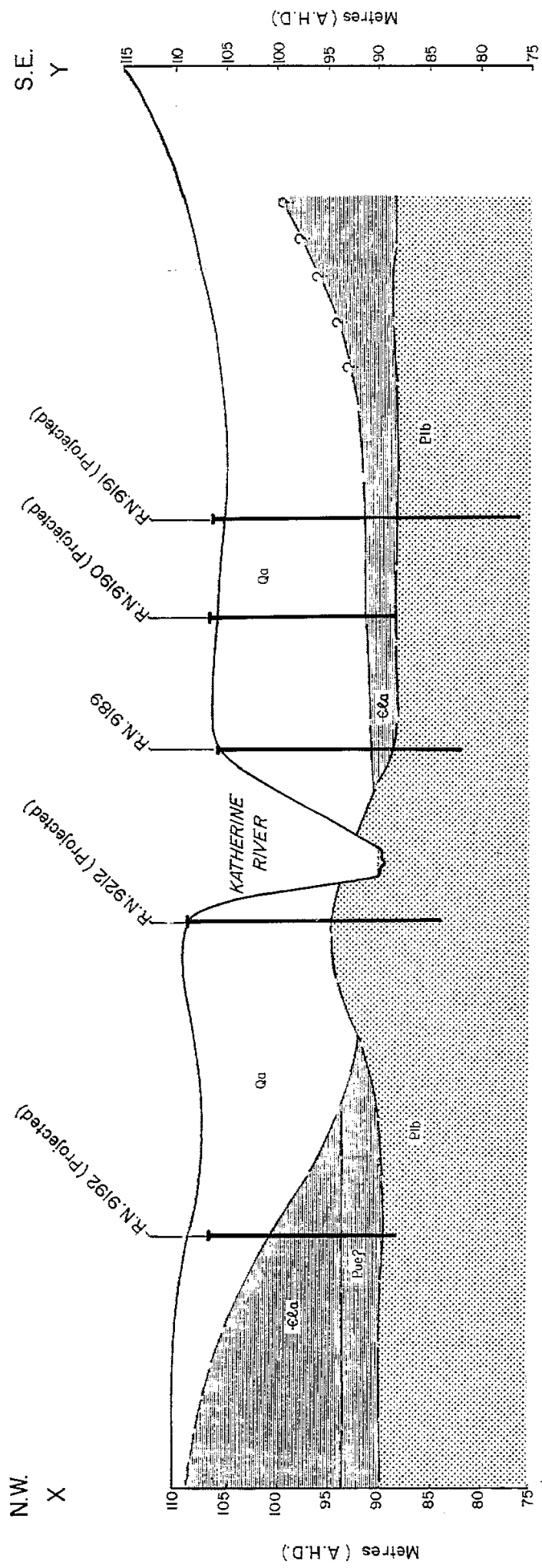
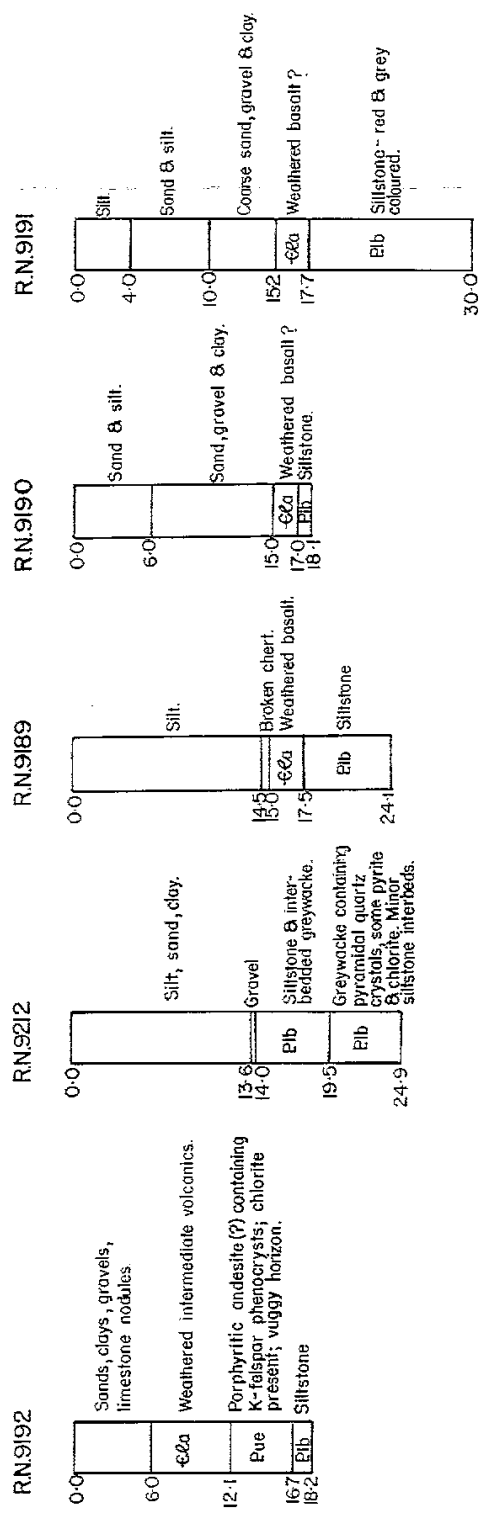
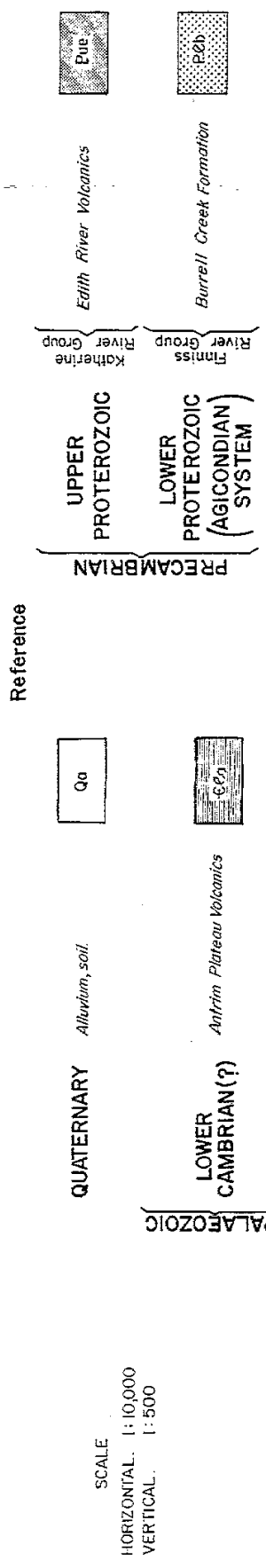


FIG. 15. McADDENS CREEK GEOLOGY
KATHERINE RIVER DEVELOPMENT
Scale 1:10 000

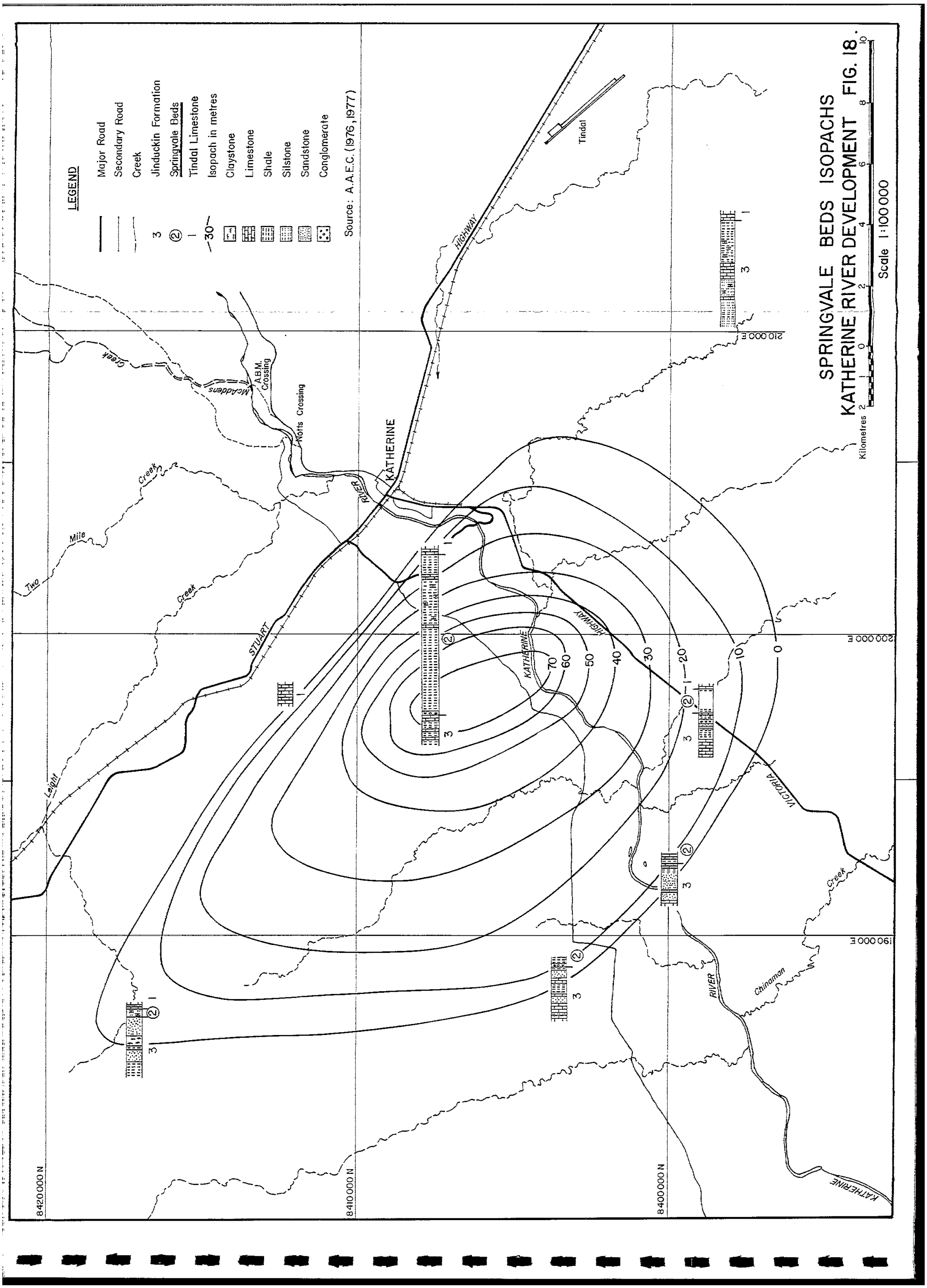

KATHERINE RIVER ALLUVIUM INVESTIGATION
FIG. 16 KATHERINE RIVER DEVELOPMENT
1:10 000
200 100 0 200 400 600 800 Metres
REFERENCE
CAINOZOIC
QUATERNARY
Qa
MESOZOIC
LOWER CRETACEOUS
Mullaman Beds
PALAEOZOIC
MIDDLE CAMBRIAN
Dry River Group
Tindal Limestone
LOWER CAMBRIAN(?)
Antrim Plateau Volcanics
PRECAMBRIAN
UPPER PROTEROZOIC
Katherine River Group
Edith River Volcanics
LOWER PROTEROZOIC (AGICONDIAN SYSTEM)
Finniss River Group
Burrell Creek Formation
LEGEND
Geological Boundary
Inferred Geological Boundary
Geological Cross Section
Seismic Refraction / P.D.R. Traverse
Seismic Refraction Traverse
Auger Hole
Control/Investigation Bore with R.N. number
Sealed Road
Track
Fence
N
KATHERINE RIVER
McAdams Creek
A.B.M. Crossing
To Katherine Gorge
Notts Crossing
Hospital
Grounds
R.N. 9192
R.N. 9212
R.N. 9189
R.N. 9190
R.N. 9191
77/1
77/2
77/3
77/4
77/5
Qa
Emt

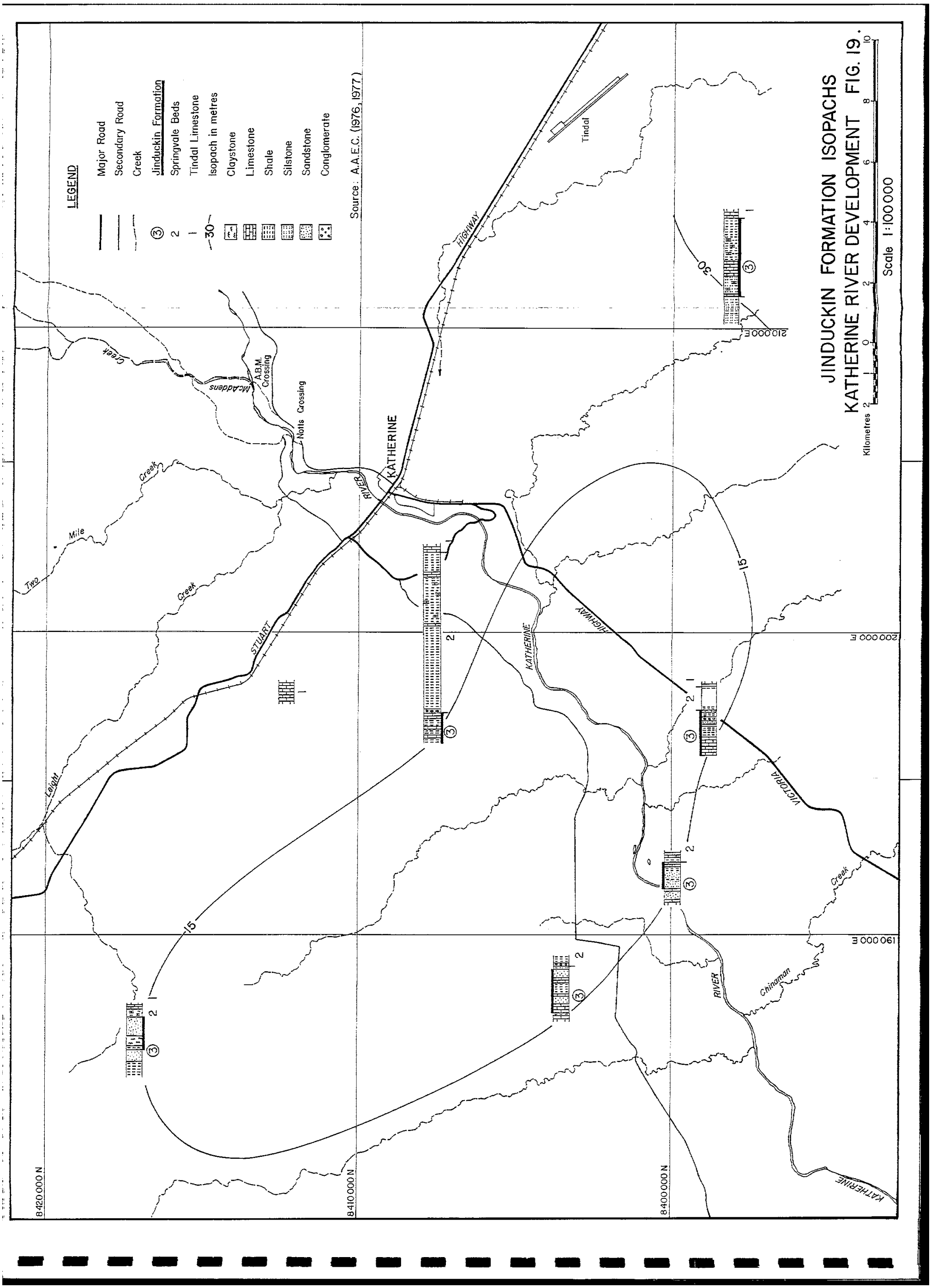


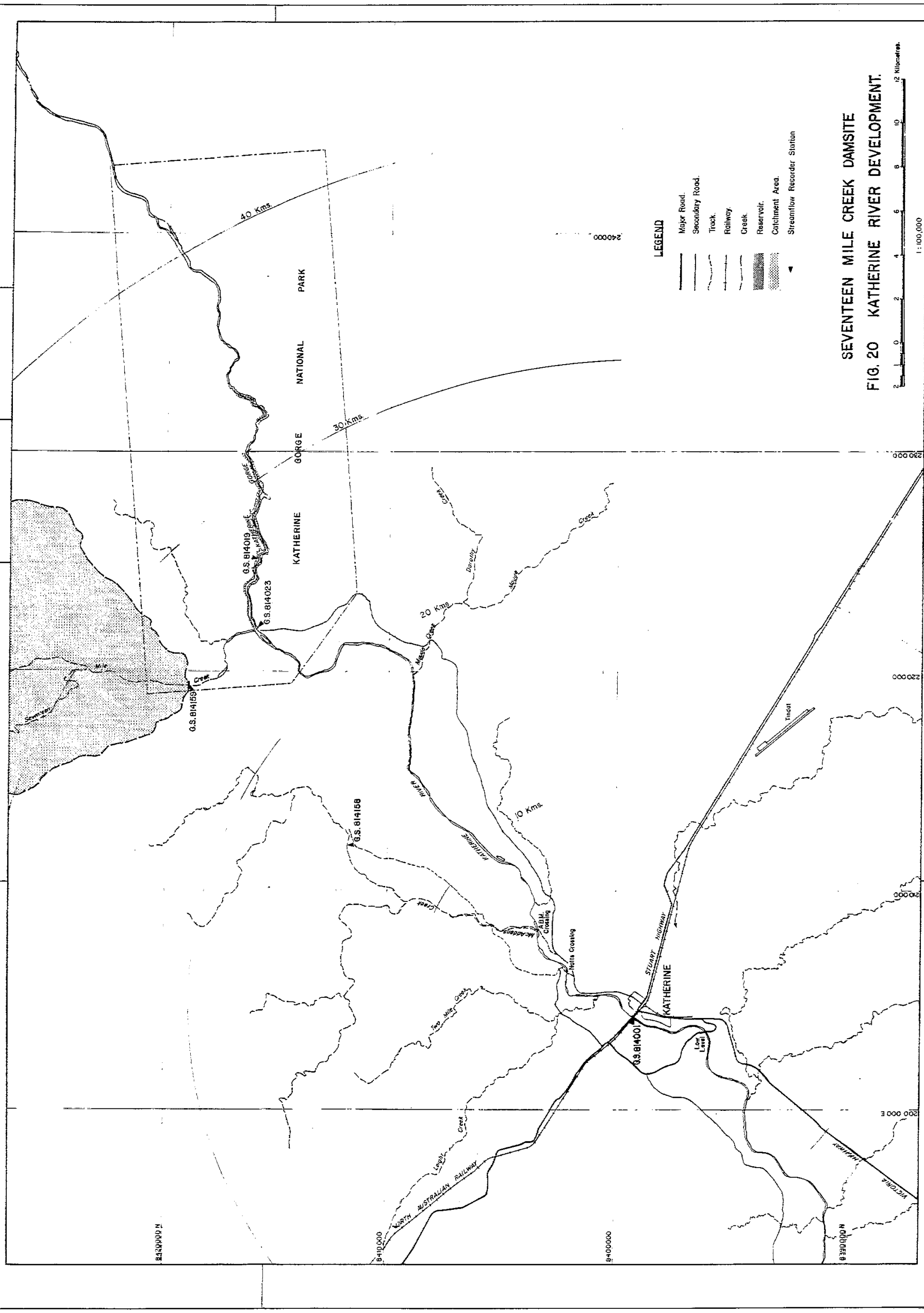


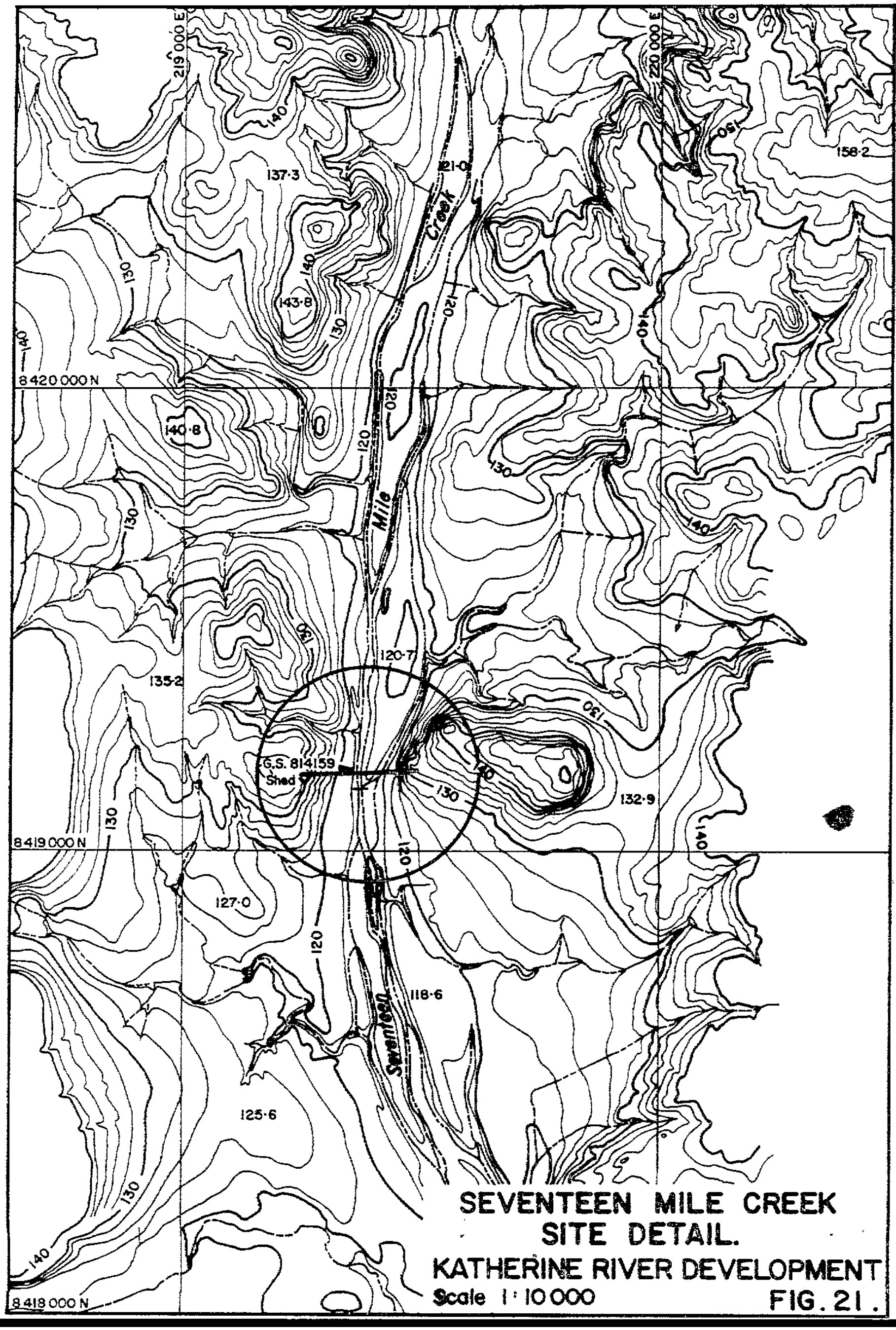


KATHERINE RIVER DEVELOPMENT. FIG. 7.


LEGEND
Major Road
Secondary Road
Creek
Jinduckin Formation
Springvale Beds
Tindal Limestone
Isopach in metres
Claystone
Limestone
Shale
Siltstone
Sandstone
Conglomerate
Source: A.A.E.C. (1976, 1977)
SPRINGVALE BEDS ISOPACHS
KATHERINE RIVER DEVELOPMENT FIG. 18.
Scale 1:100 000
Kilometres
Tindal
HIGHWAY
KATHERINE
RIVER
STUART
VICTORIA
Two Mile Creek
Leight Creek
McAdams Creek
A.B.M. Crossing
Notts Crossing
Chinaman Creek
70
60
50
40
30
20
10
0
8420 000 N
8410 000 N
8400 000 N
190 000 E
200 000 E
210 000 E


LEGEND
Major Road
Secondary Road
Creek
Jinduckin Formation
Springvale Beds
Tindal Limestone
Isopach in metres
Claystone
Limestone
Shale
Siltstone
Sandstone
Conglomerate
Source: A.A.E.C. (1976, 1977)
JINDUCKIN FORMATION ISOPACHS
KATHERINE RIVER DEVELOPMENT FIG. 19.
Kilometres 2 1 0 2 4 6 8 10
Scale 1:100000
Tindal
HIGHWAY
KATHERINE
RIVER
STUART
HIGHWAY
KATHERINE
VICTORIA
Notts Crossing
A.B.M. Crossing
McAddens
Creek
Two Mile Creek
Leight
Creek
Chinaman
RIVER
KATHERINE
210000E
200000E
190000E
8420000N
8410000N
8400000N
30
15
15


SEVENTEEN MILE CREEK DAMSITE
FIG. 20 KATHERINE RIVER DEVELOPMENT.
1:100,000
LEGEND
Major Road.
Secondary Road.
Track.
Railway.
Creek.
Reservoir.
Catchment Area.
Streamflow Recorder Station
40 Kms
30 Kms
20 Kms
10 Kms
KATHERINE GORGE NATIONAL PARK
G.S. 814019
G.S. 814023
G.S. 814159
G.S. 814158
G.S. 814001
KATHERINE
Tindal
Notts Crossing
A.B.M. Crossing
STUART HIGHWAY
NORTH AUSTRALIAN RAILWAY
VICTORIA HIGHWAY
Seventeen Mile Creek
Two Mile Creek
Leopold Creek
Katherine River
Low Level
8420000 N
8410000
8400000
8390000 N
200 000 E
220 000
240000



SEVENTEEN MILE CREEK
SITE DETAIL.
KATHERINE RIVER DEVELOPMENT
Scale 1:10 000
FIG. 21.

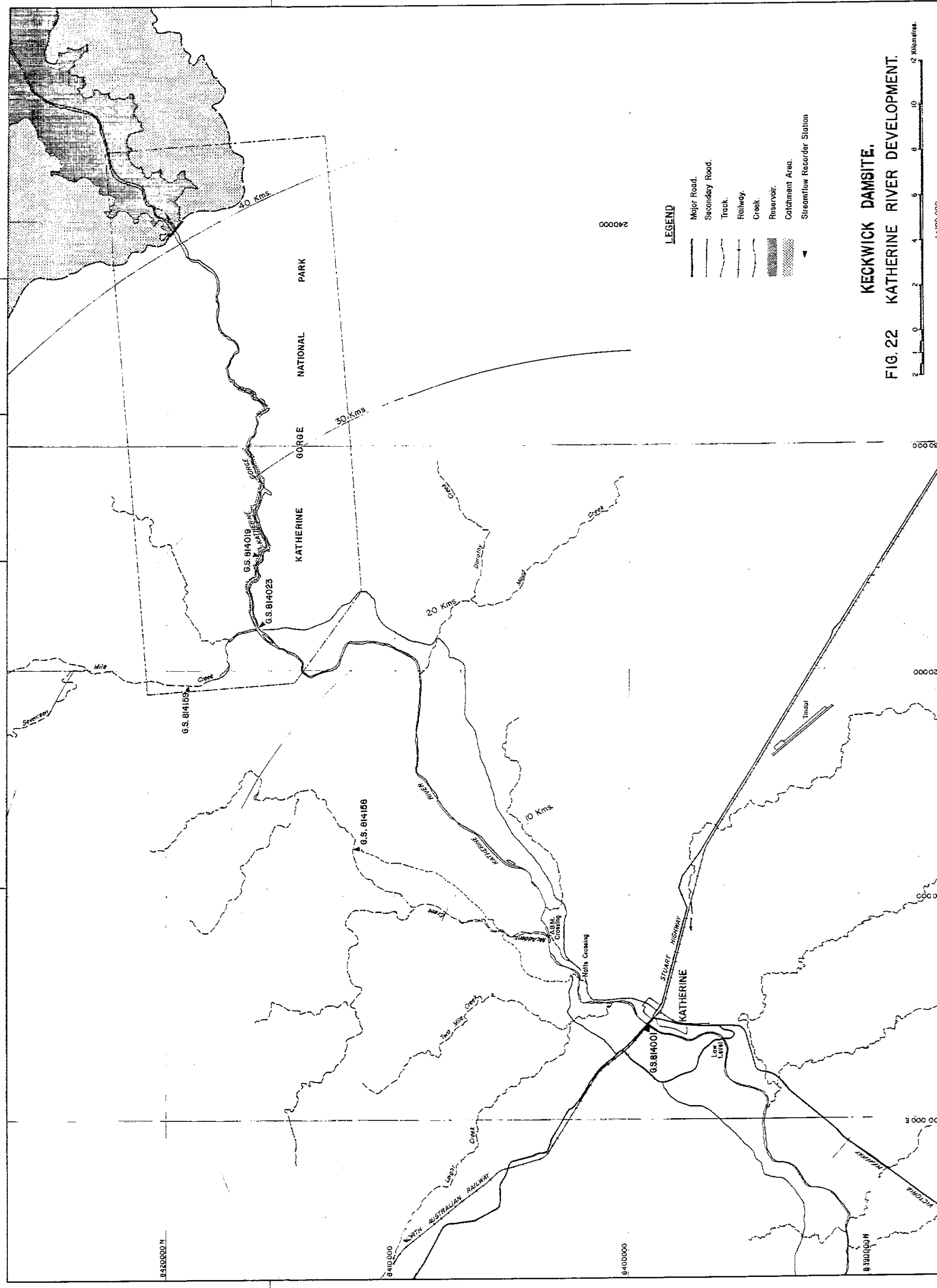
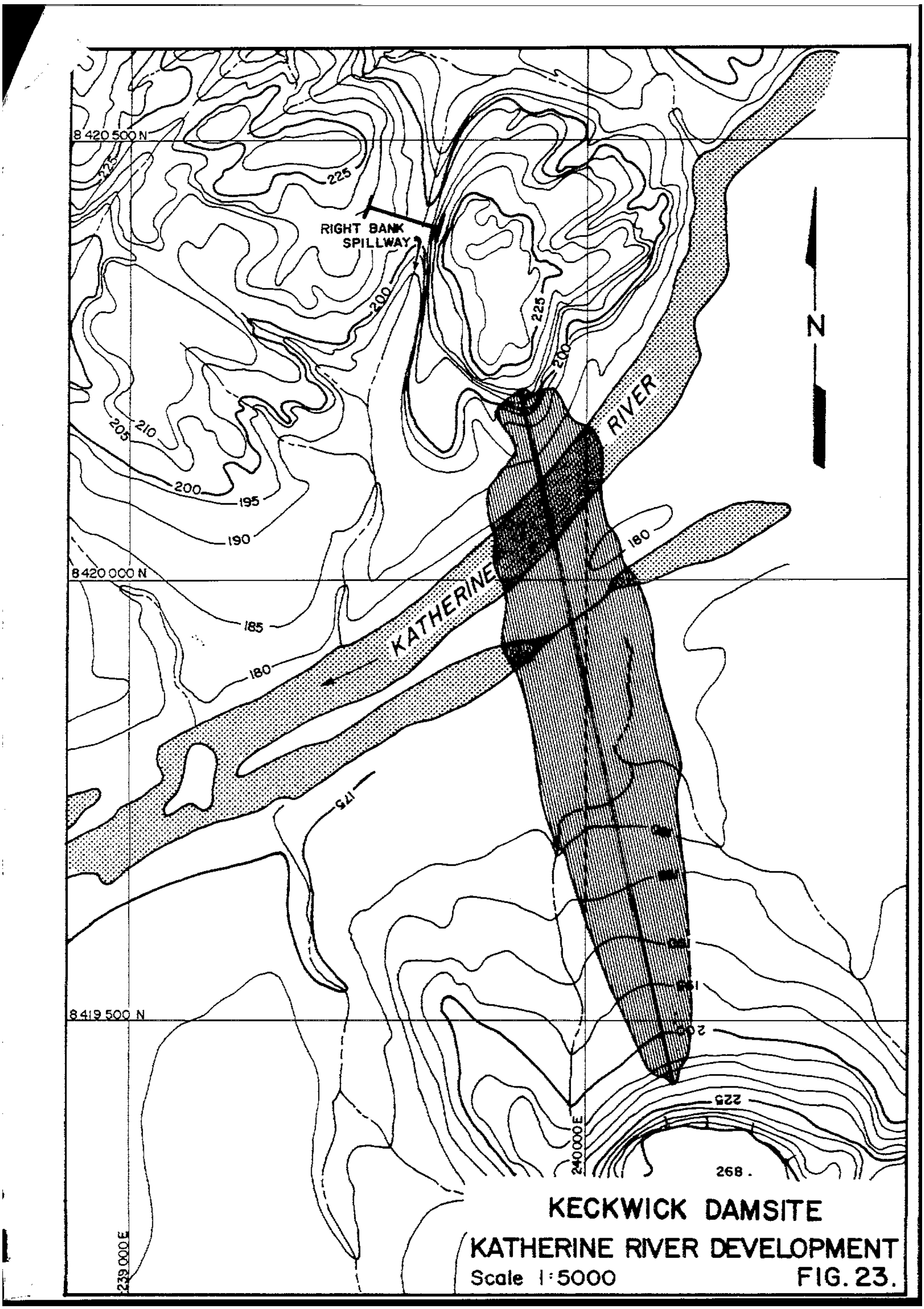


FIG. 22 KECKWICK DAMSITE.
KATHERINE RIVER DEVELOPMENT.


8 420 500 N
8 420 000 N
8 419 500 N
239 000 E
240 000 E
RIGHT BANK
SPILLWAY
KATHERINE
RIVER
N
225
200
210
205
195
190
185
180
175
268.
KECKWICK DAMSITE
KATHERINE RIVER DEVELOPMENT
Scale 1:5000
FIG. 23.

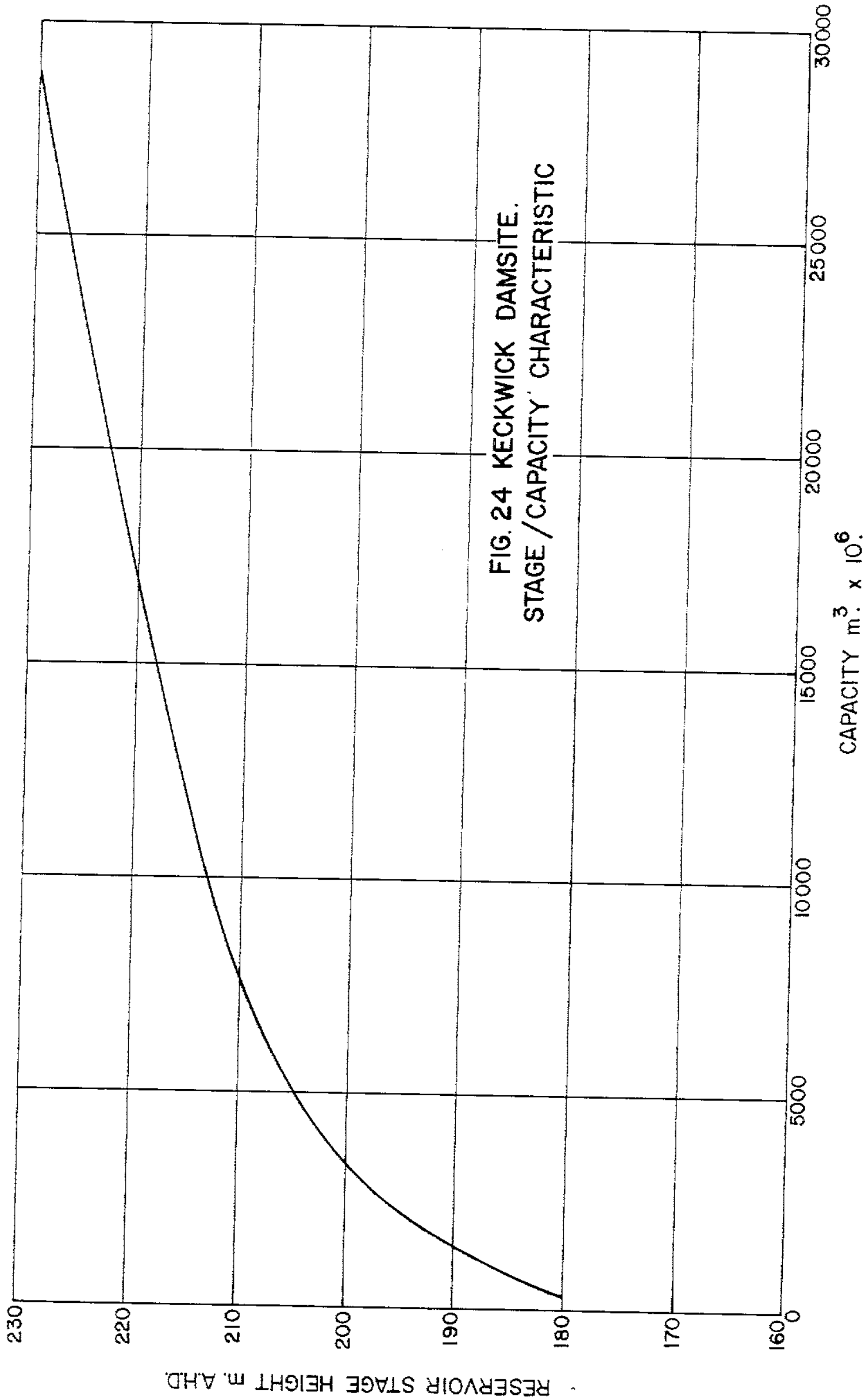
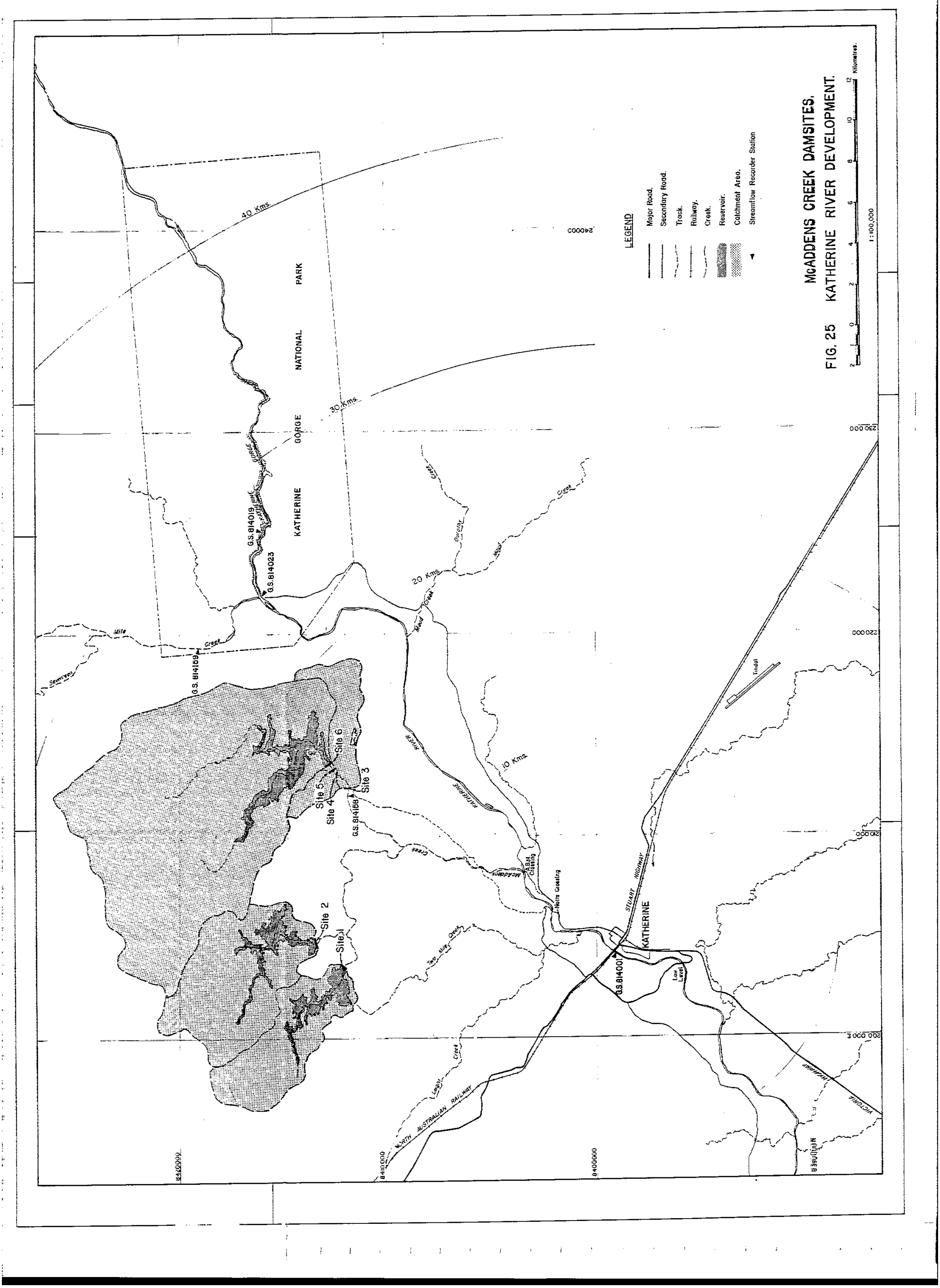
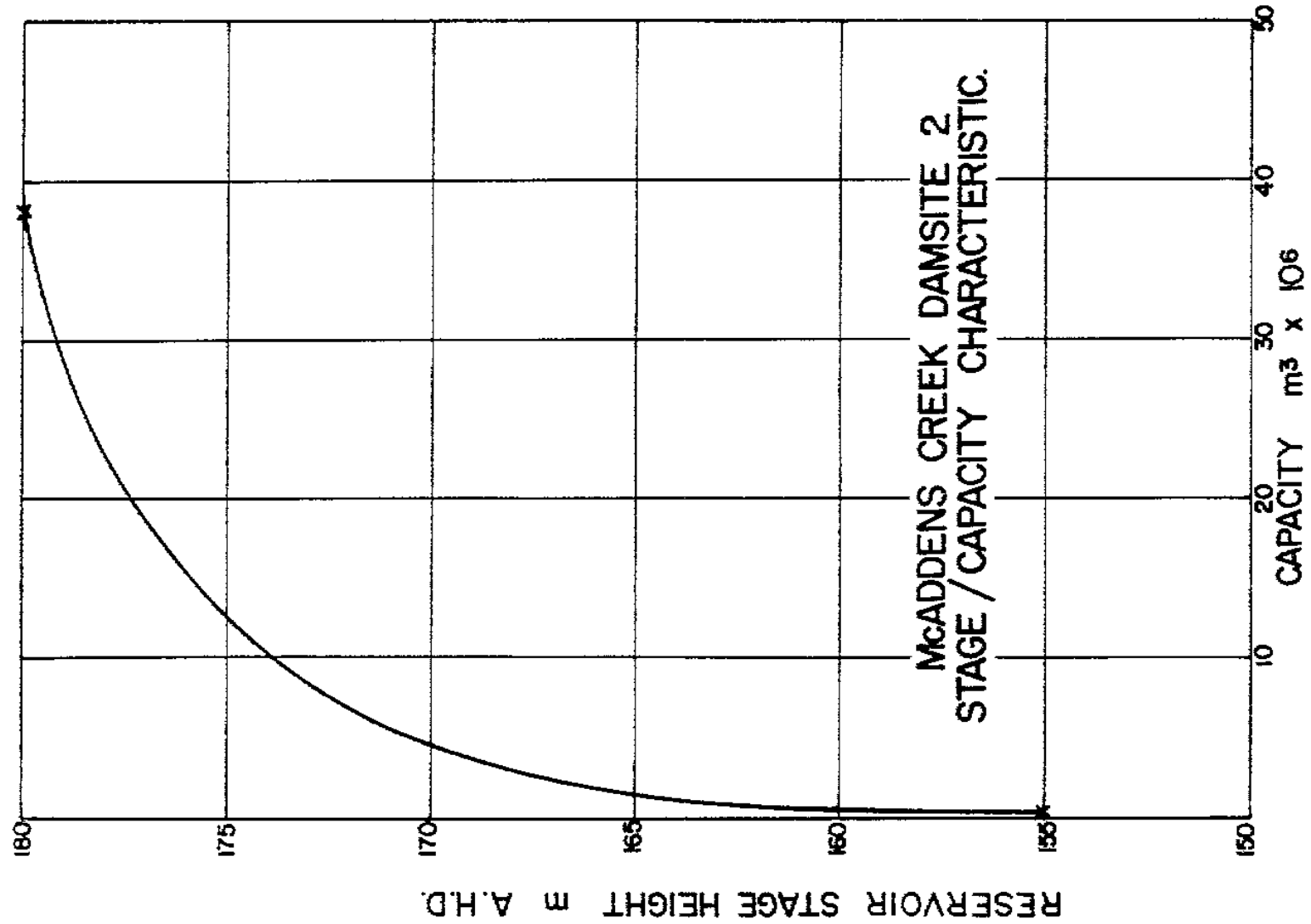


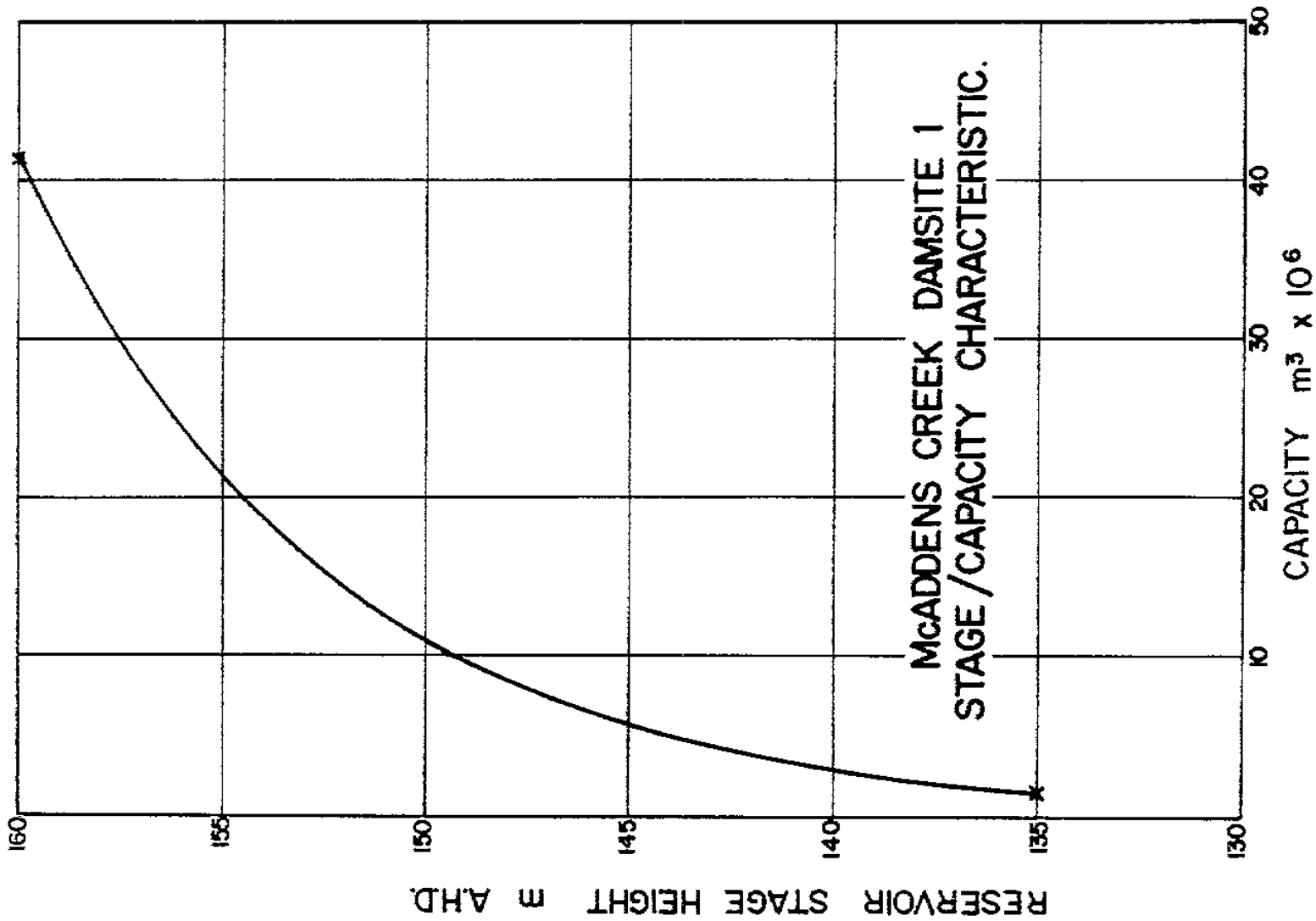
FIG. 24 KECKWICK DAMSITE.
STAGE /CAPACITY' CHARACTERISTIC

KATHERINE RIVER DEVELOPMENT. FIG. 24

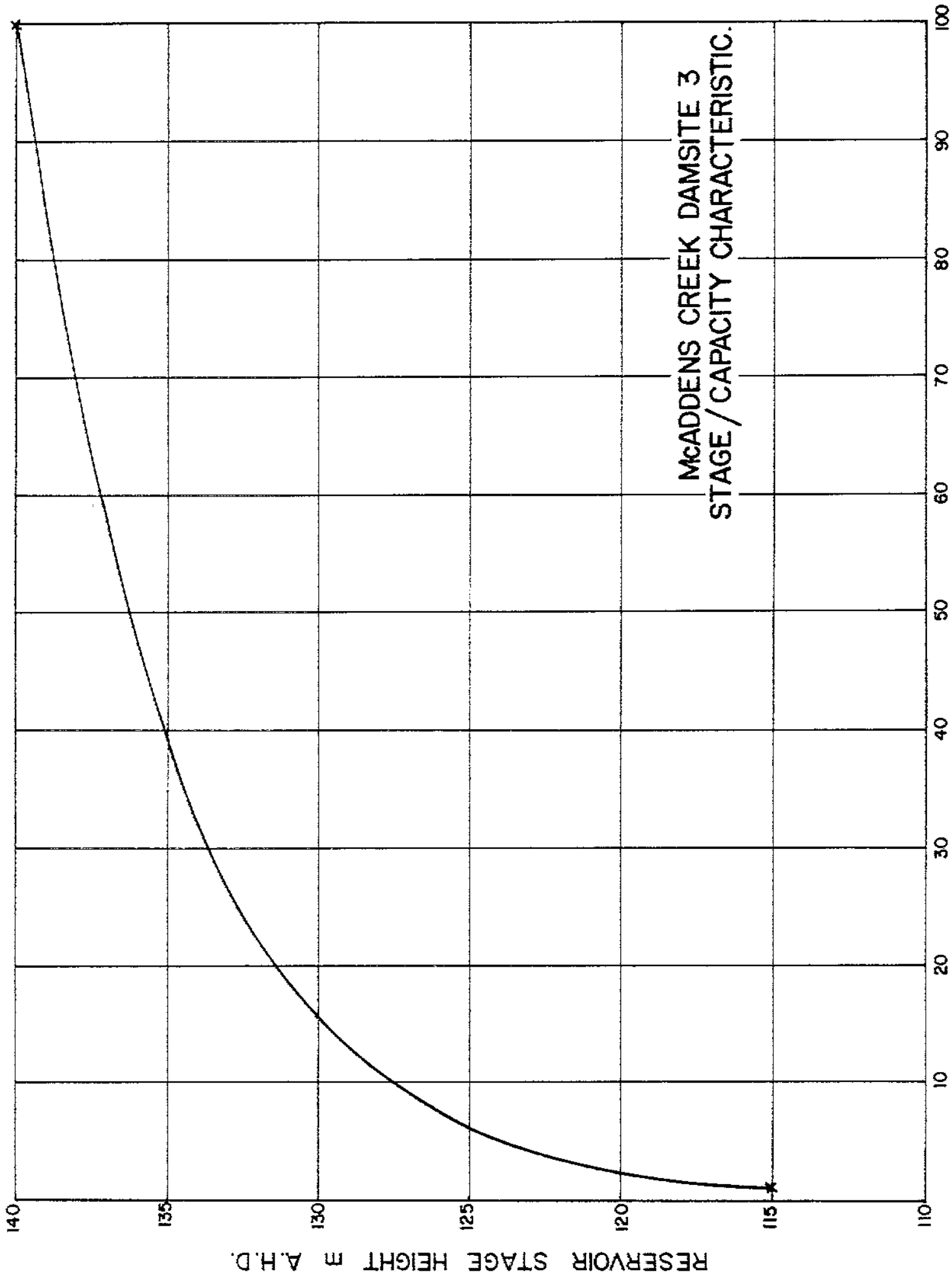

McADDENS CREEK DAMSITES.
FIG. 25 KATHERINE RIVER DEVELOPMENT.
1:100,000
Kilometres.
LEGEND
Major Road.
Secondary Road.
Track.
Railway.
Creek.
Reservoir.
Catchment Area.
Streamflow Recorder Station
KATHERINE GORGE NATIONAL PARK
40 Kms.
30 Kms.
20 Kms.
10 Kms.
G.S. 814019
G.S. 814023
G.S. 814159
G.S. 814168
G.S. 814001
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
KATHERINE
Tindal
STUART HIGHWAY
VICTORIA HIGHWAY
NORTH AUSTRALIAN RAILWAY
Katherine River
Mule Creek
Seventeen Mile Creek
Two Mile Creek
Mead Creek
Dry Creek
Gorge Creek
Low Level
Nolts Crossing
R.B.M. Crossing
8410000
8400000
8390000
200 000 E
220 000
230 000



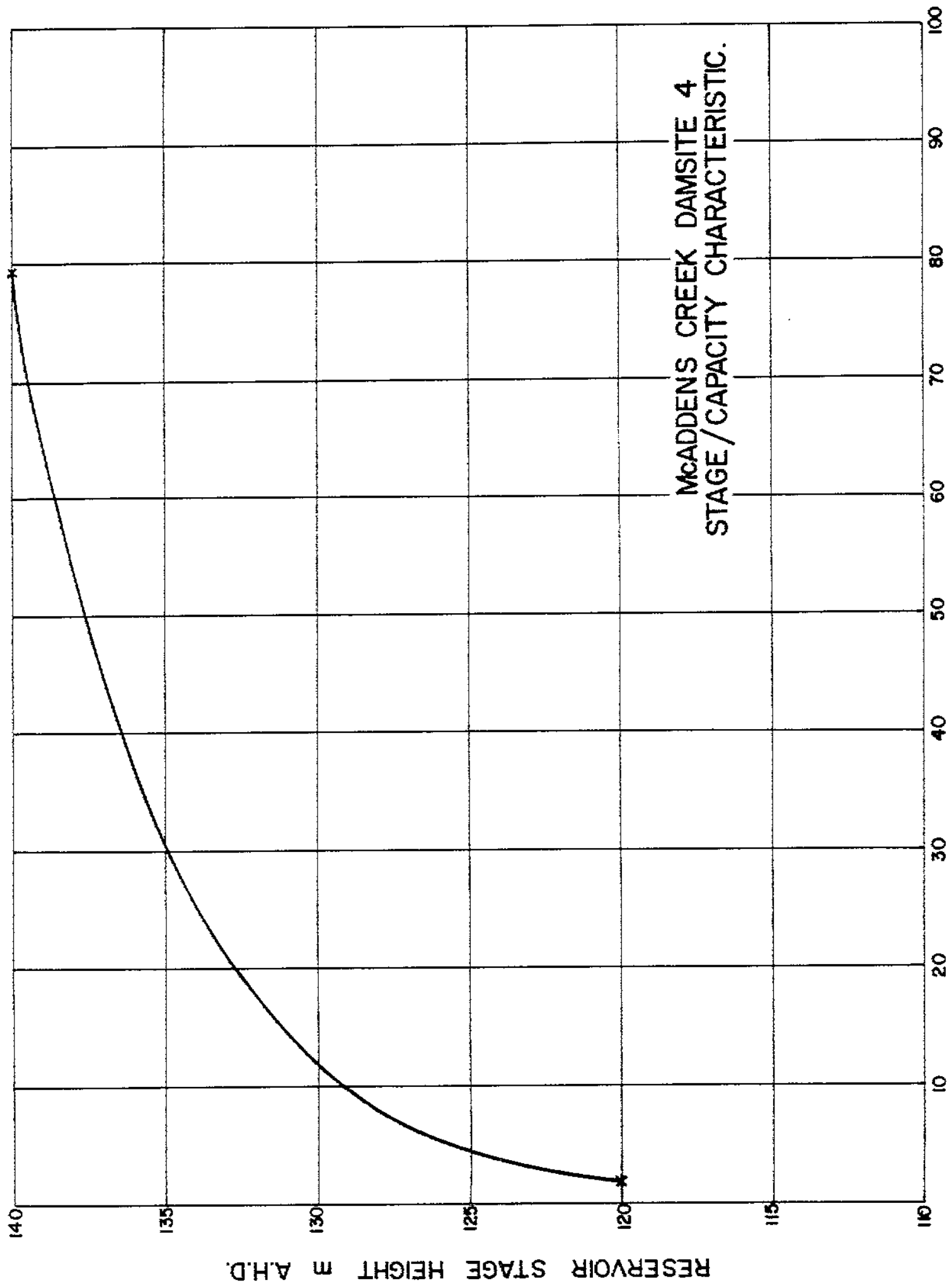
KATHERINE RIVER DEVELOPMENT. FIG. 26.



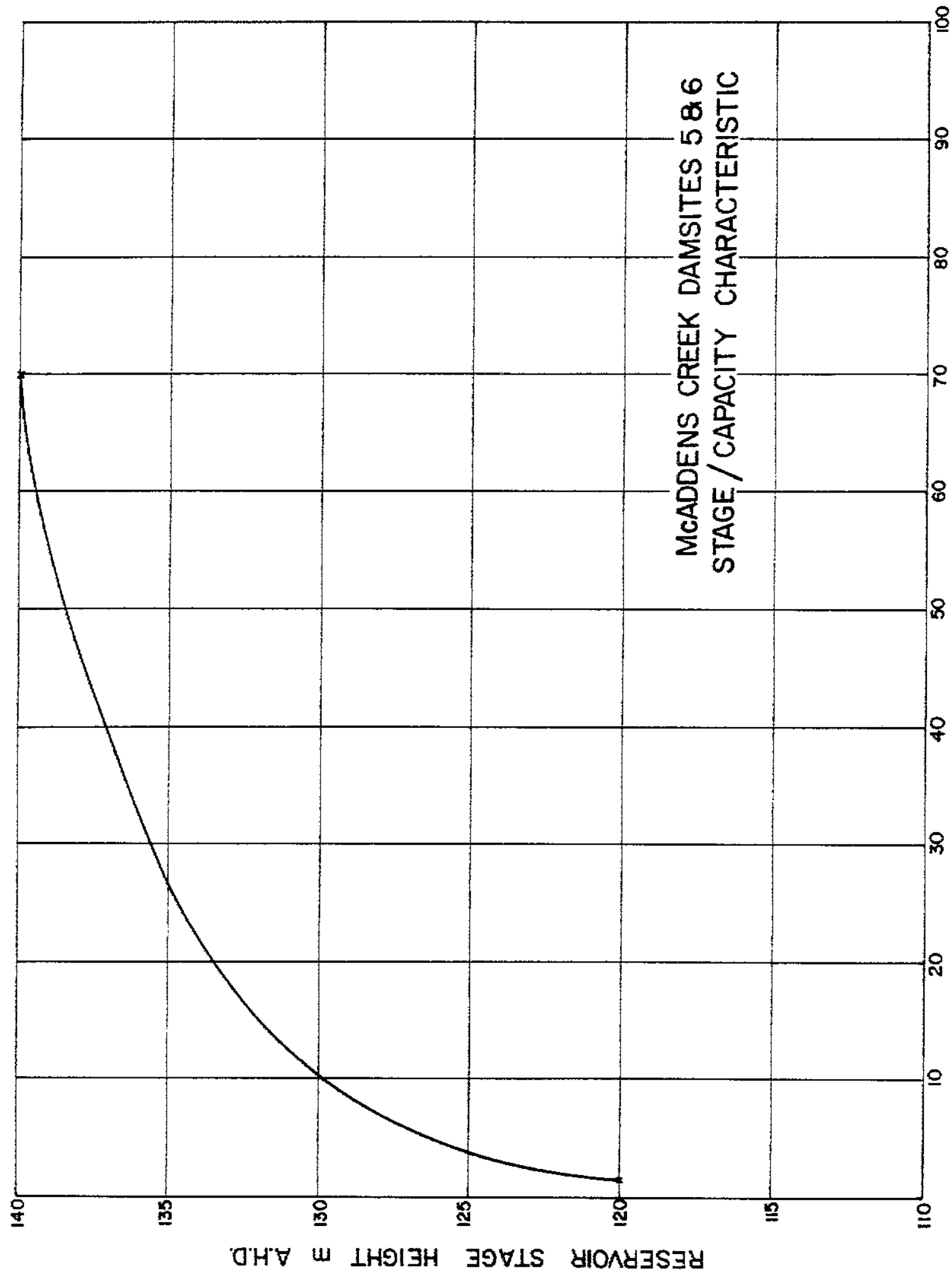
McADDENS' CREEK DAMSITES 1 & 2.
RESERVOIR CHARACTERISTIC.
KATHERINE RIVER DEVELOPMENT. FIG. 26.



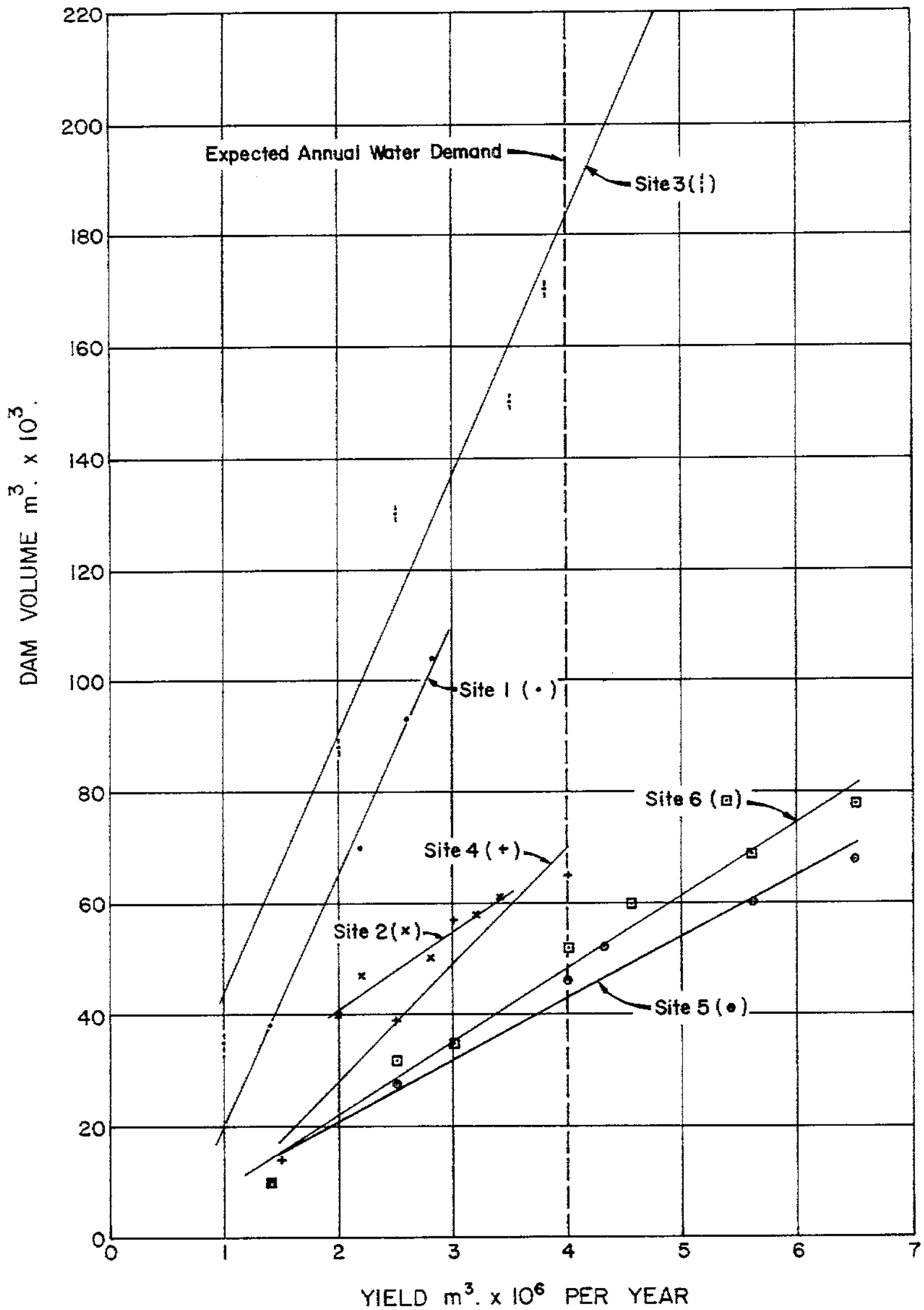
KATHERINE RIVER DEVELOPMENT FIG. 27.



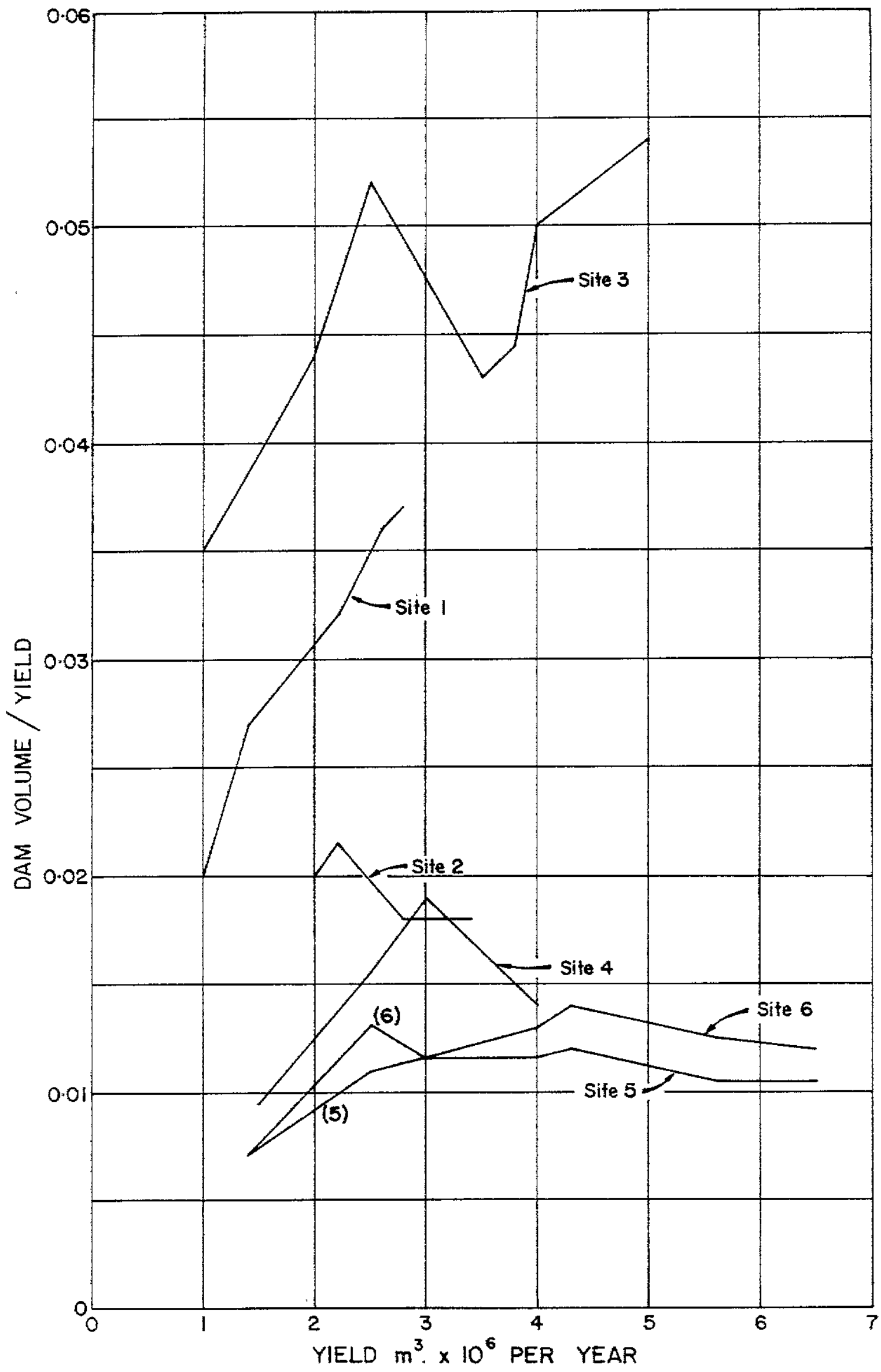
KATHERINE RIVER DEVELOPMENT FIG. 28.



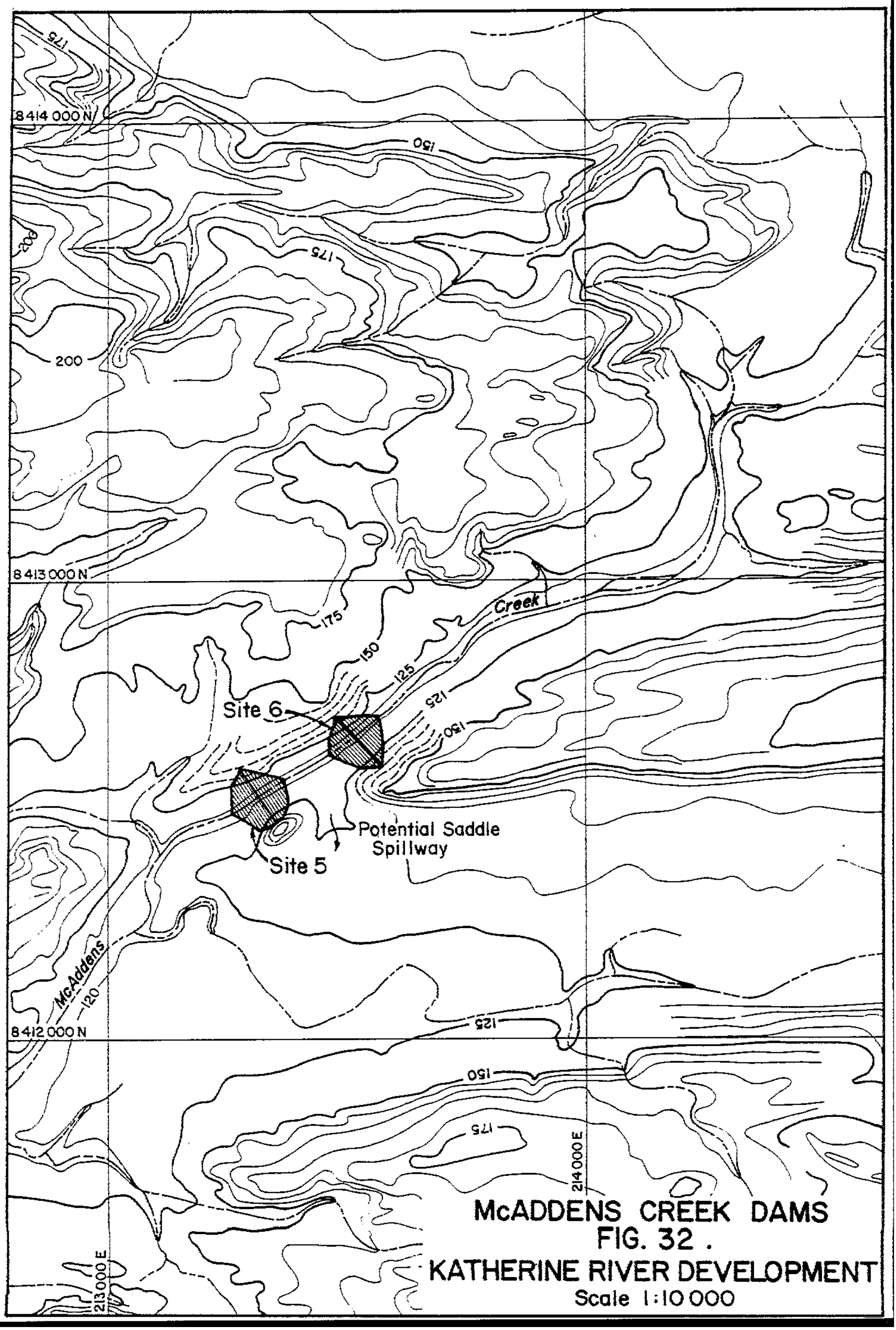
KATHERINE RIVER DEVELOPMENT FIG. 29.



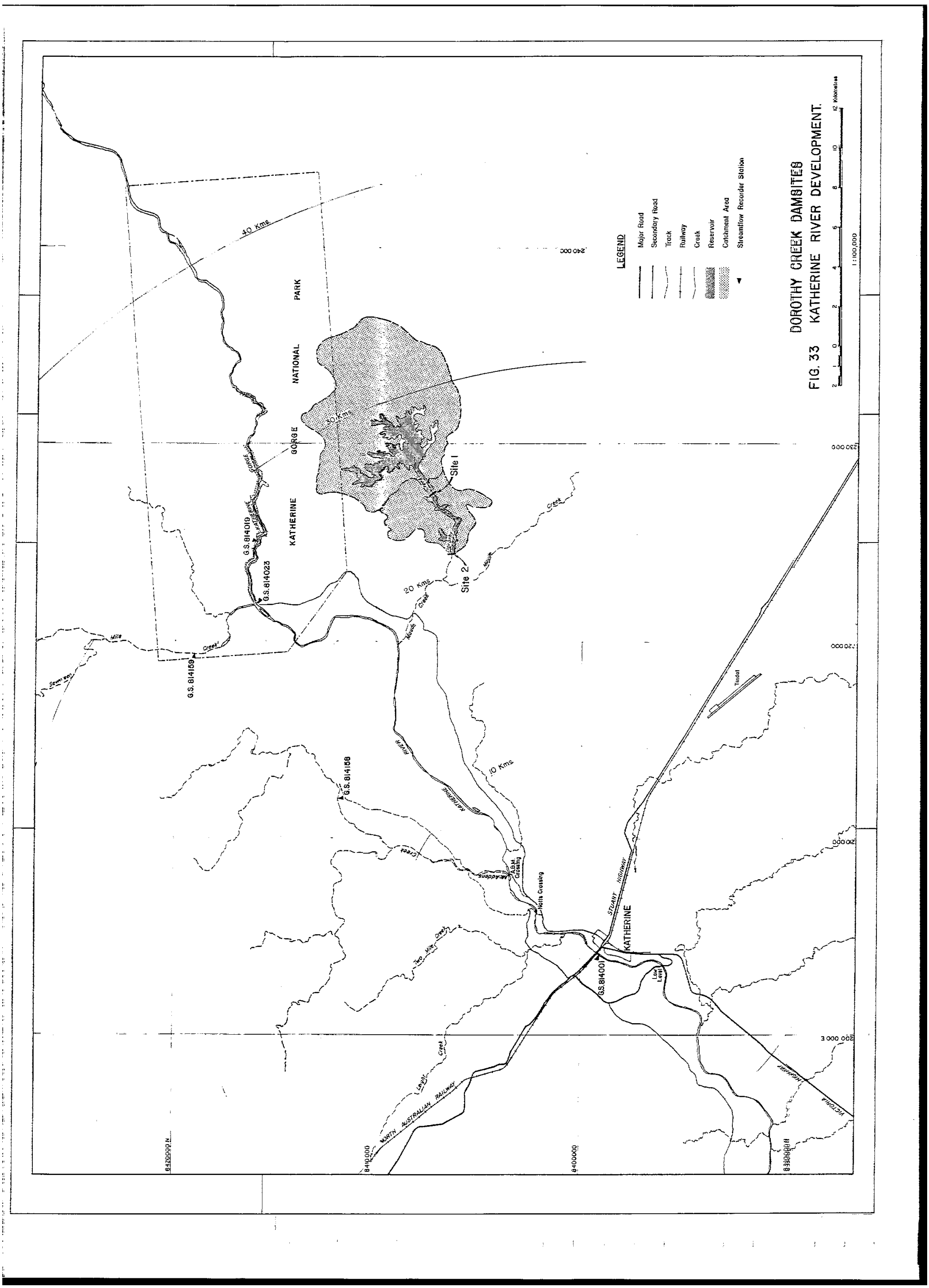
McADDENS CREEK DAMSITES COMPARISON
KATHERINE RIVER DEVELOPMENT FIG. 30.

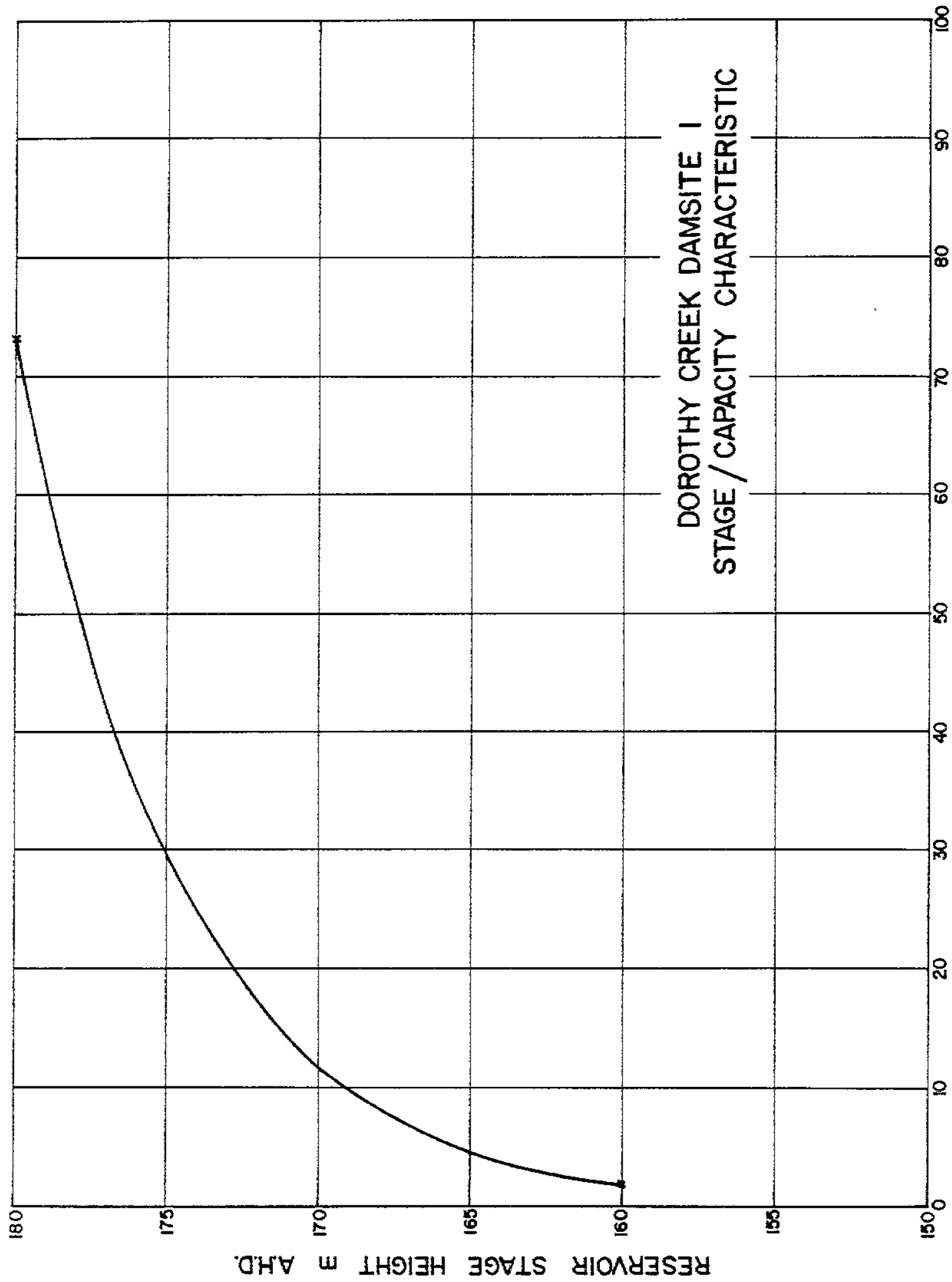


McADDENS CREEK DAMSITES ECONOMICS
KATHERINE RIVER DEVELOPMENT FIG. 31.

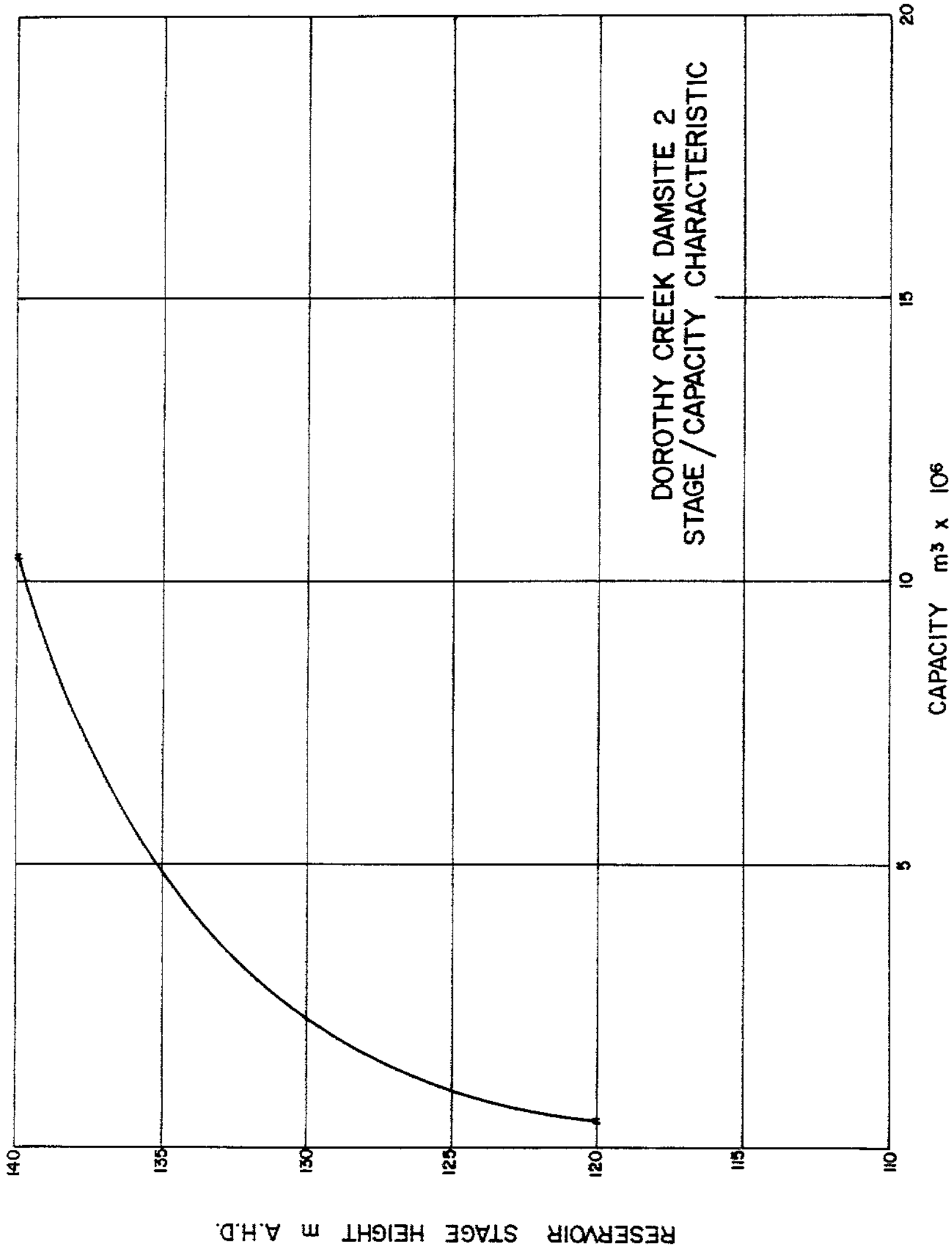


McADDENS CREEK DAMS
FIG. 32.
KATHERINE RIVER DEVELOPMENT
Scale 1:10 000

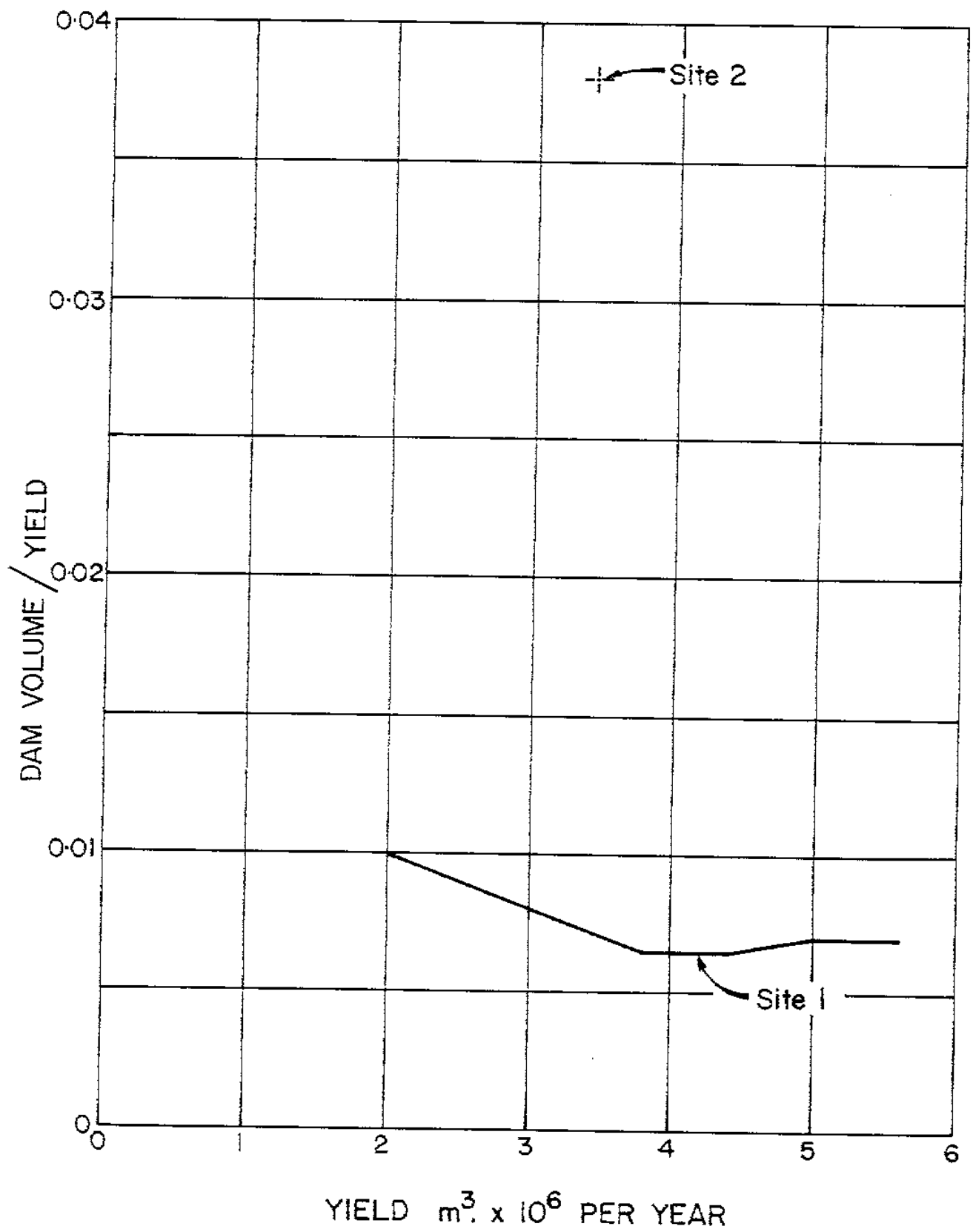

DOROTHY CREEK DAMSITES
KATHERINE RIVER DEVELOPMENT
FIG. 33
1:100,000
LEGEND
Major Road
Secondary Road
Track
Railway
Creek
Reservoir
Catchment Area
Streamflow Recorder Station
NATIONAL PARK
KATHERINE GORGE
Site 1
Site 2
40 Kms.
30 Kms.
20 Kms.
10 Kms.
G.S. 814019
G.S. 814023
G.S. 814159
G.S. 814156
G.S. 814001
KATHERINE
Tindal
Mills Crossing
A.B.M. Crossing
NORTH AUSTRALIAN RAILWAY
STUART HIGHWAY
VICTORIA HIGHWAY
8420000 N
8410000
8400000
8390000 N
200 000 E



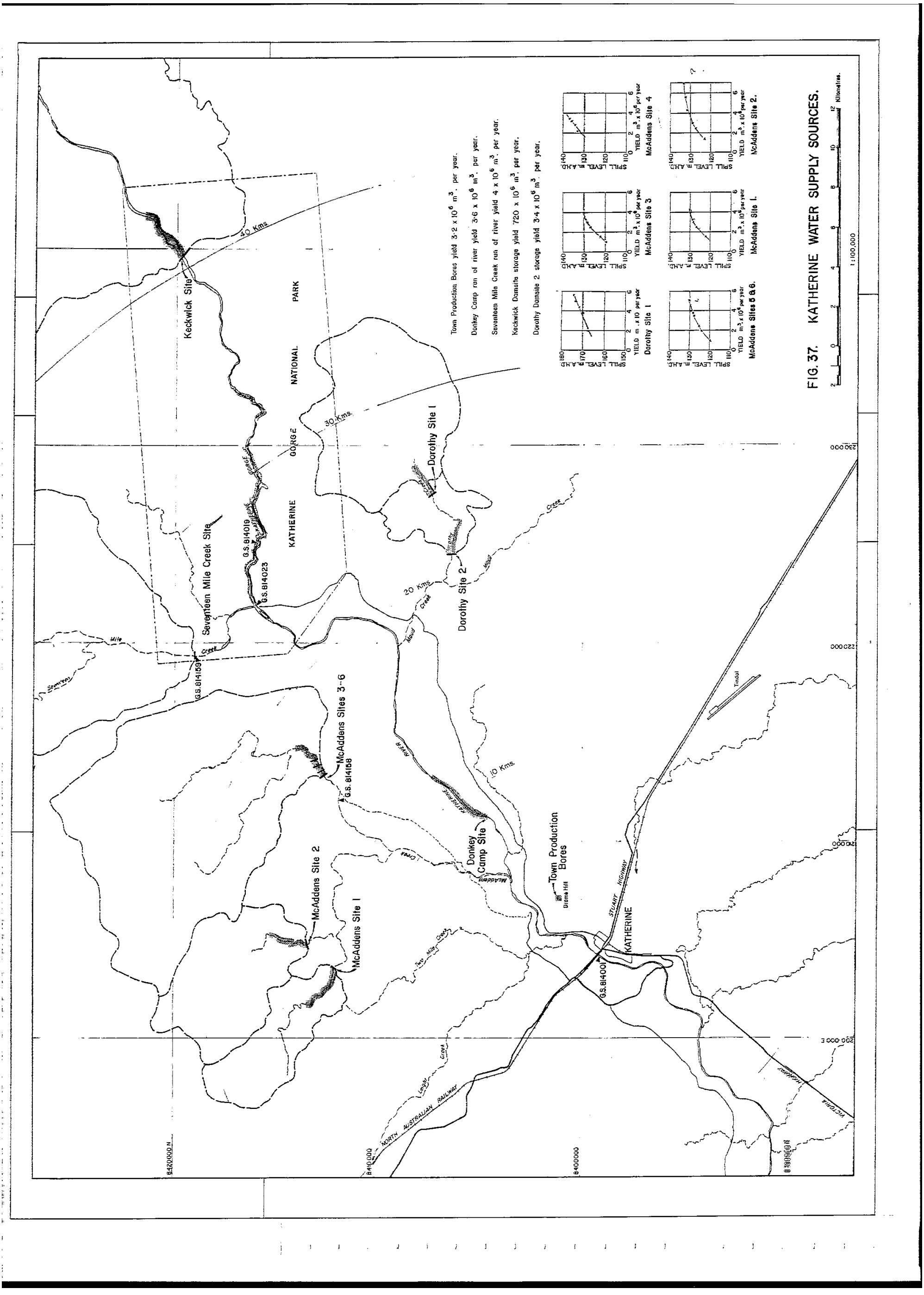
KATHERINE RIVER DEVELOPMENT FIG. 34.



KATHERINE RIVER DEVELOPMENT FIG. 35.



DOROTHY CREEK DAMSITES COMPARISON
KATHERINE RIVER DEVELOPMENT FIG.36.


Town Production Bores yield 3·2 x 10^6 m^3. per year.
Donkey Camp run of river yield 3·6 x 10^6 m^3. per year.
Seventeen Mile Creek run of river yield 4 x 10^6 m^3. per year.
Keckwick Damsite storage yield 720 x 10^6 m^3. per year.
Dorothy Damsite 2 storage yield 3·4 x 10^6 m^3. per year.
Dorothy Site 1
McAddens Site 5 & 6.
McAddens Site 3
McAddens Site 1.
McAddens Site 4
McAddens Site 2.
SPILL LEVEL m. A.H.D.
YIELD m^3. x 10^6 per year
FIG. 37. KATHERINE WATER SUPPLY SOURCES.
1:100,000
Kilometres.
Keckwick Site
40 Kms.
NATIONAL PARK
30 Kms.
GORGE
KATHERINE
G.S. 814019
G.S. 814023
Seventeen Mile Creek Site
G.S. 814159
Seventeen Mile Creek
McAddens Sites 3-6
G.S. 814158
McAddens Site 2
McAddens Site 1
Two Mile Creek
Dorothy Site 1
Dorothy Site 2
Mould Creek
20 Kms.
10 Kms.
Donkey Camp Site
McAddens Creek
Town Production Bores
Diorite Hill
STUART HIGHWAY
KATHERINE
G.S. 814001
Tindal
Length Creek
NORTH AUSTRALIAN RAILWAY
VICTORIA HIGHWAY
8420000 N
8410000
8400000
8390000 N
220 000 E

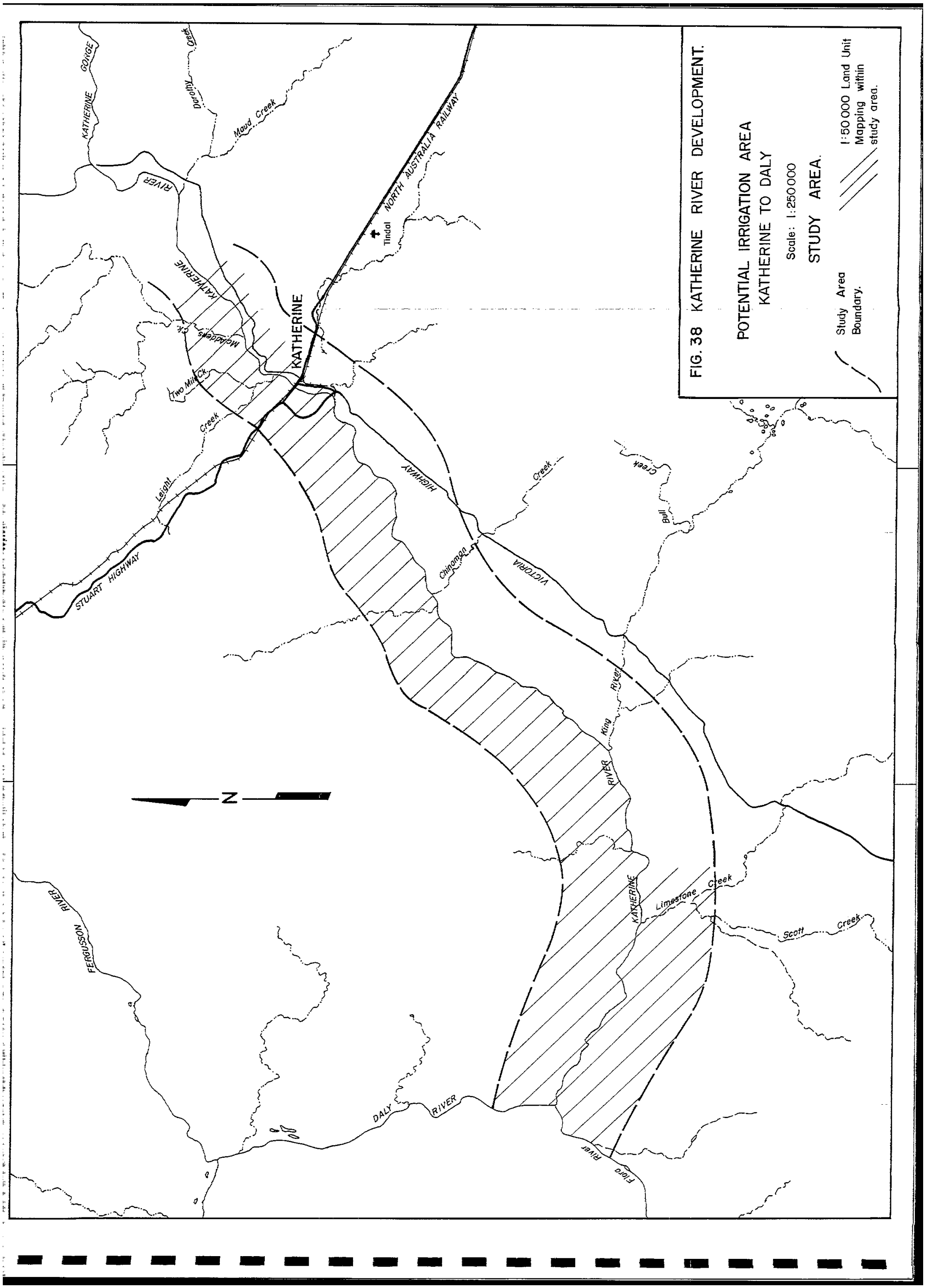
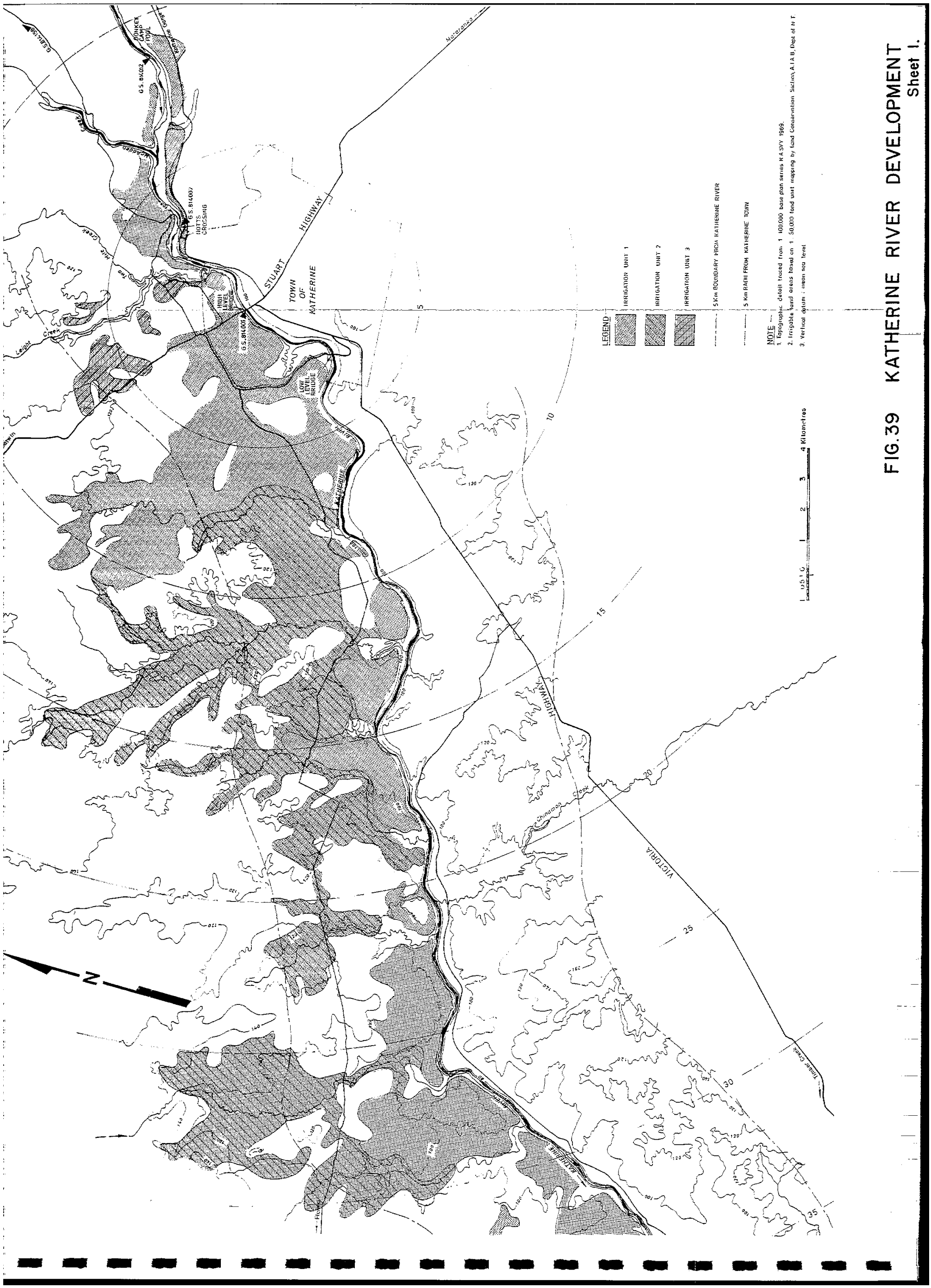


FIG. 38 KATHERINE RIVER DEVELOPMENT.
POTENTIAL IRRIGATION AREA
KATHERINE TO DALY
Scale: 1:250000
STUDY AREA.
Study Area Boundary.
1:50000 Land Unit Mapping within study area.
KATHERINE GORGE
RIVER
Doolin Creek
Mound Creek
NORTH AUSTRALIA RAILWAY
Tindal
KATHERINE
KATHERINE
McFadden's Ck.
Two Mile Ck.
Creek
Leight
STUART HIGHWAY
HIGHWAY
Creek
Bull Creek
Chinaman
VICTORIA
King River
RIVER
N
KATHERINE
Limestone Creek
Scott Creek
RIVER
FERGUSSON
DALY RIVER
Flora River


KATHERINE RIVER DEVELOPMENT
Sheet I.
FIG. 39
LEGEND
IRRIGATION UNIT 1
IRRIGATION UNIT 2
IRRIGATION UNIT 3
5 Km BOUNDARY FROM KATHERINE RIVER
5 Km RADII FROM KATHERINE TOWN
NOTE
1. Topographic detail traced from 1 100,000 base plan series R A SVY 1969.
2. Irrigable land areas based on 1 50,000 land unit mapping by land Conservation Section, A I A B, Dept of N T.
3. Vertical datum - mean sea level
0.5 1 0 1 2 3 4 Kilometres
STUART HIGHWAY
TOWN OF KATHERINE
HIGH LEVEL BRIDGE
LOW LEVEL BRIDGE
G S. 814001
G S. 814002
G S. 814003
HOTTS CROSSING
DONKEY CAMP ROAD
Katherine Gorge
Katherine River
Leight Creek
Two Mile Creek
Chinaman Creek
Tiger Creek
VICTORIA HIGHWAY
Katherine
Flora River
Katherine
N
5
10
15
20
25
30
35

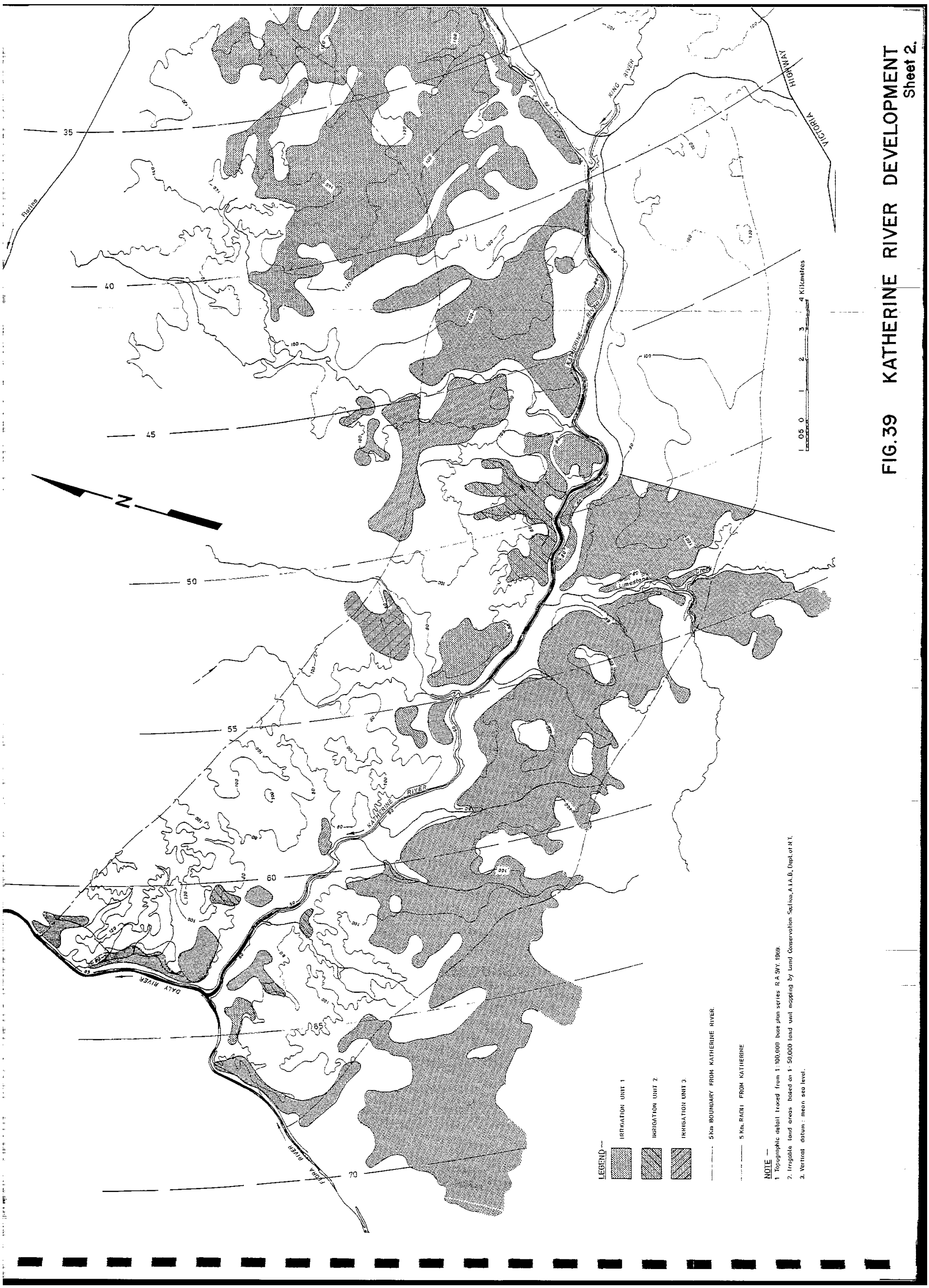
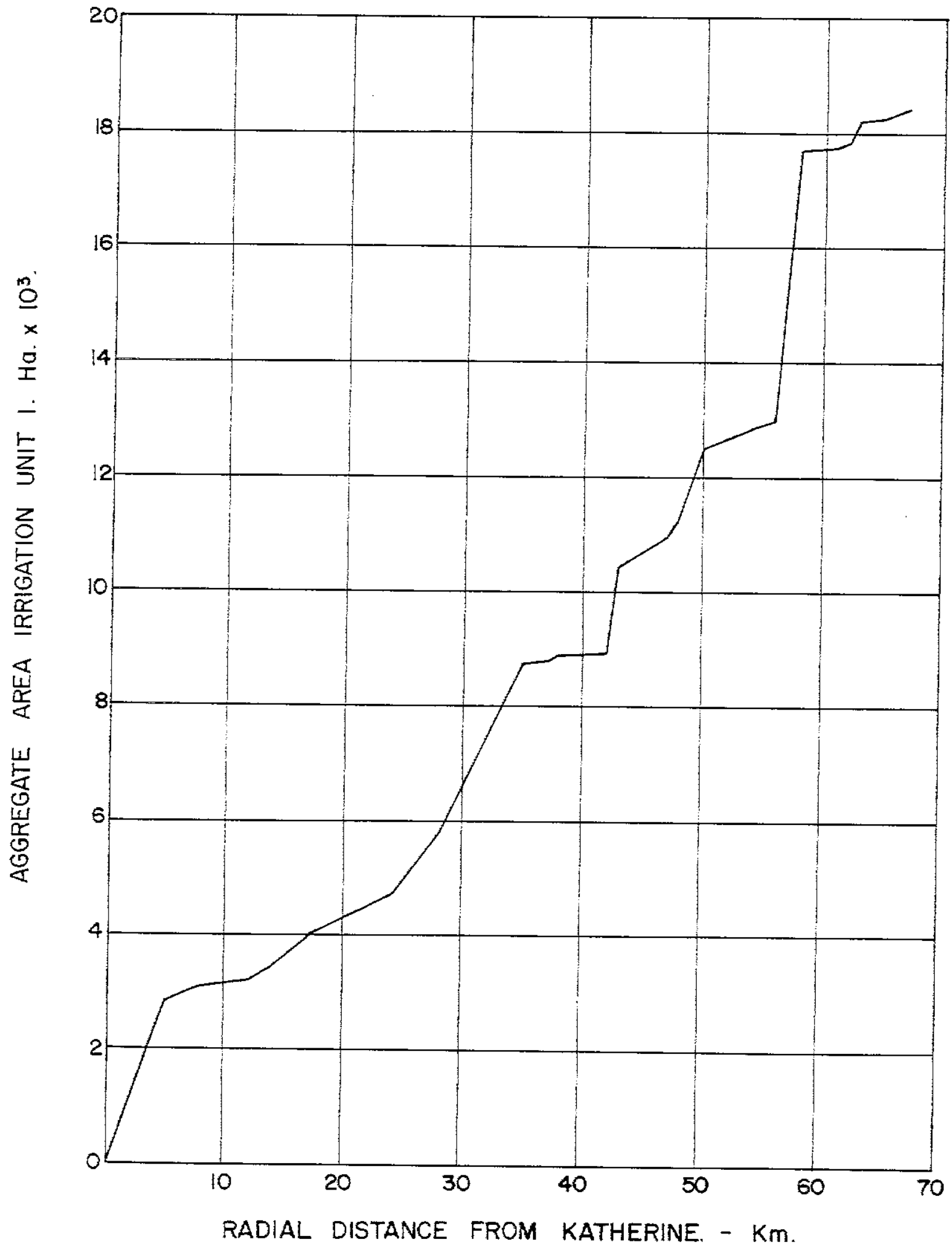
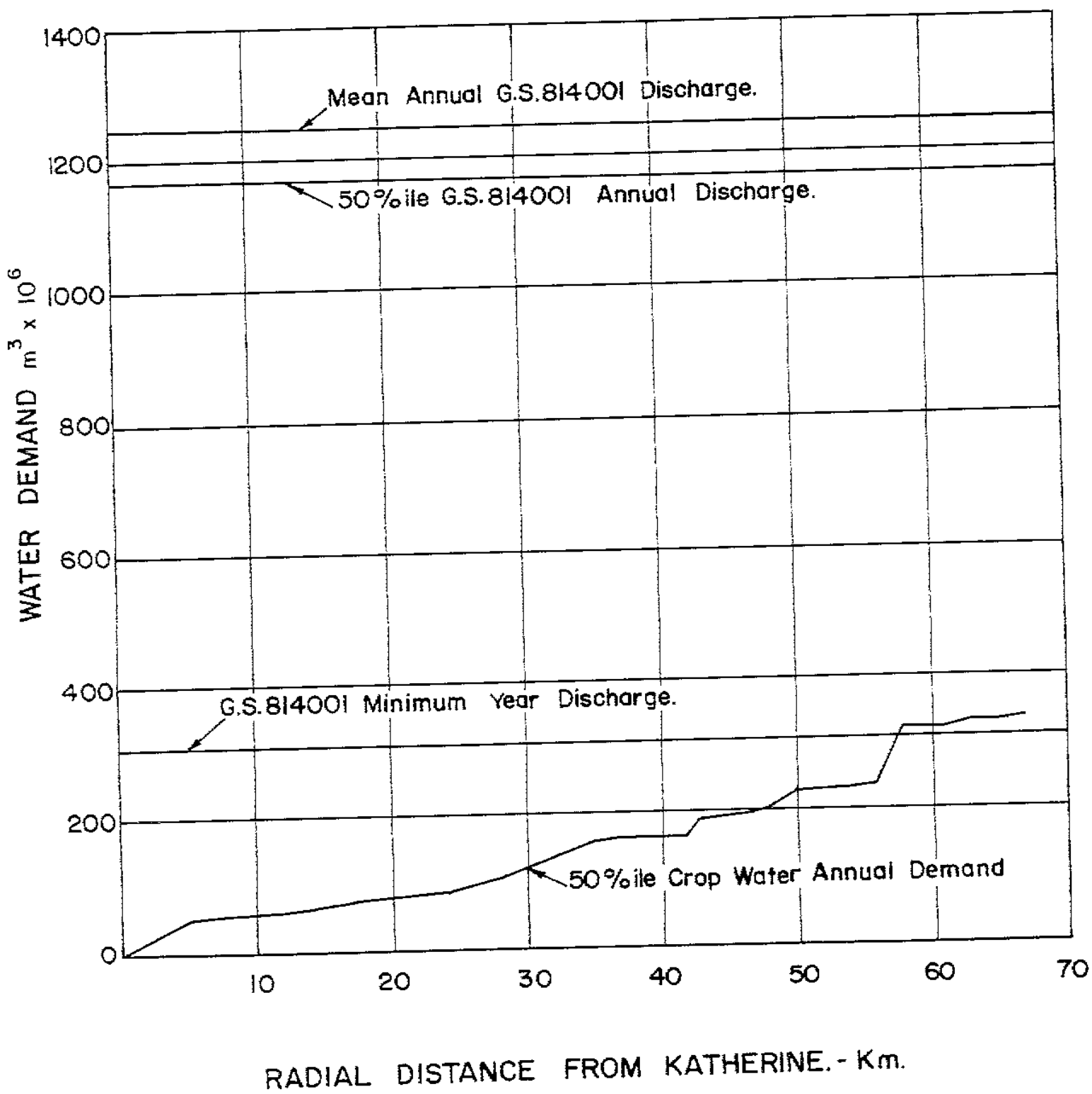


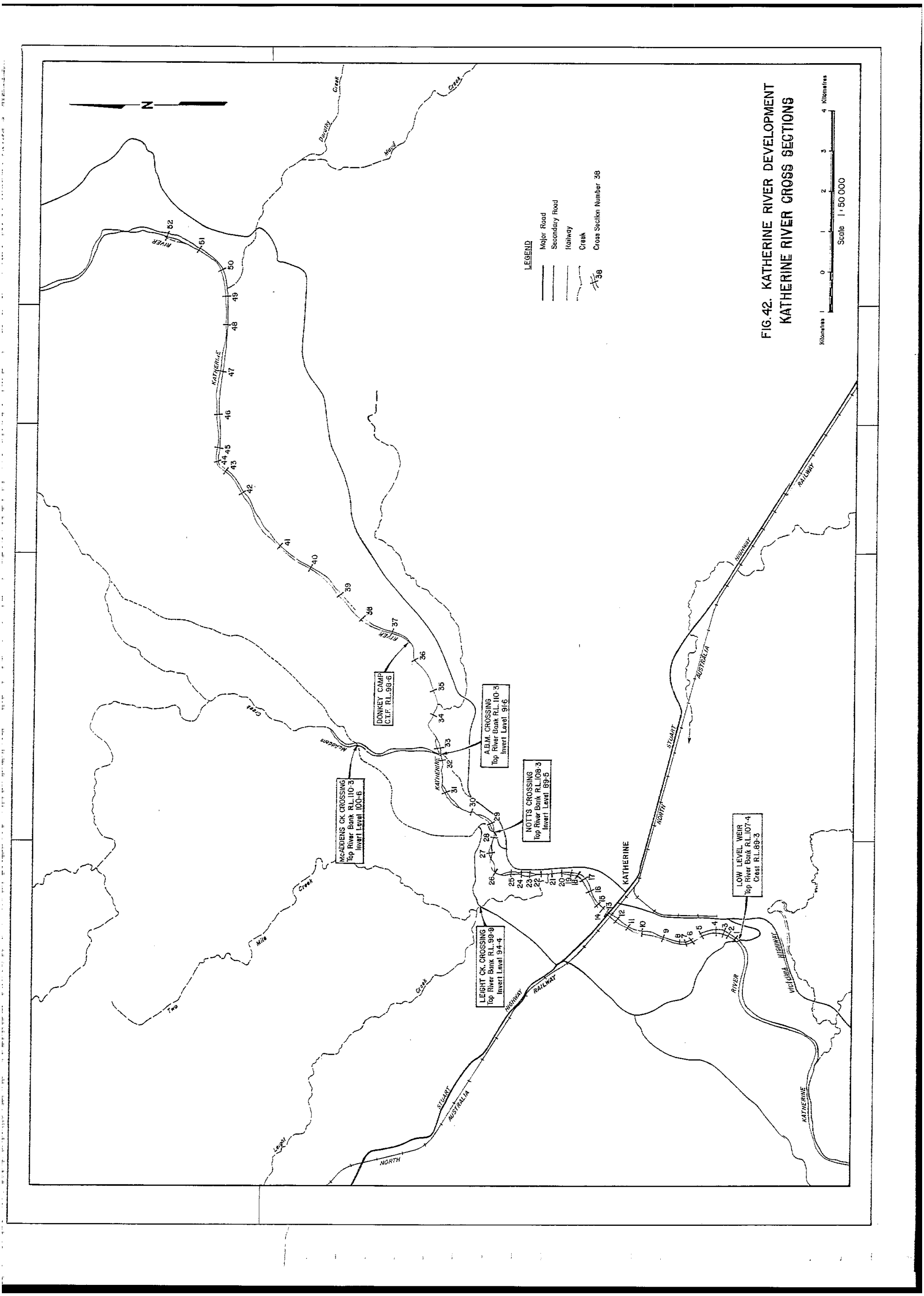
FIG. 39 KATHERINE RIVER DEVELOPMENT
Sheet 2.
N
35
40
45
50
55
60
65
70
Florina
KING RIVER
VICTORIA HIGHWAY
KATHERINE RIVER
Limestone Creek
DALY RIVER
FLORA RIVER
0 0.5 1 2 3 4 Kilometres
LEGEND —
IRRIGATION UNIT 1
IRRIGATION UNIT 2
IRRIGATION UNIT 3
5Km BOUNDARY FROM KATHERINE RIVER.
5 Km. RADII FROM KATHERINE
NOTE —
1 Topographic detail traced from 1:100,000 base plan series R A SYY. 1969.
2. Irrigable land areas based on 1:50,000 land unit mapping by Land Conservation Section, A.I.A.B., Dept. of N.T.
3. Vertical datum: mean sea level.



KATHERINE RIVER DEVELOPMENT. FIG. 40.



KATHERINE RIVER DEVELOPMENT. FIG.41 .


N
LEGEND
Major Road
Secondary Road
Railway
Creek
Cross Section Number 38
Scale 1:50 000
Kilometres
FIG. 42. KATHERINE RIVER DEVELOPMENT
KATHERINE RIVER CROSS SECTIONS
DONKEY CAMP
C.T.F. R.L. 98·6
A.B.M. CROSSING
Top River Bank R.L. 110·3
Invert Level 91·6
NOTTS CROSSING
Top River Bank R.L. 108·3
Invert Level 89·5
McADDENS CK. CROSSING
Top River Bank R.L. 110·3
Invert Level 100·6
LEIGHT CK. CROSSING
Top River Bank R.L. 99·9
Invert Level 94·4
LOW LEVEL WEIR
Top River Bank R.L. 107·4
Crest R.L. 89·3
KATHERINE
KATHERINE RIVER
Two Mile Creek
Leight Creek
McAddens Creek
Donkey Creek
Hard Creek
NORTH AUSTRALIA RAILWAY
STUART HIGHWAY
VICTORIA HIGHWAY