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by

C.H. Munro, R.T. Hattersley, A.J. Bonham

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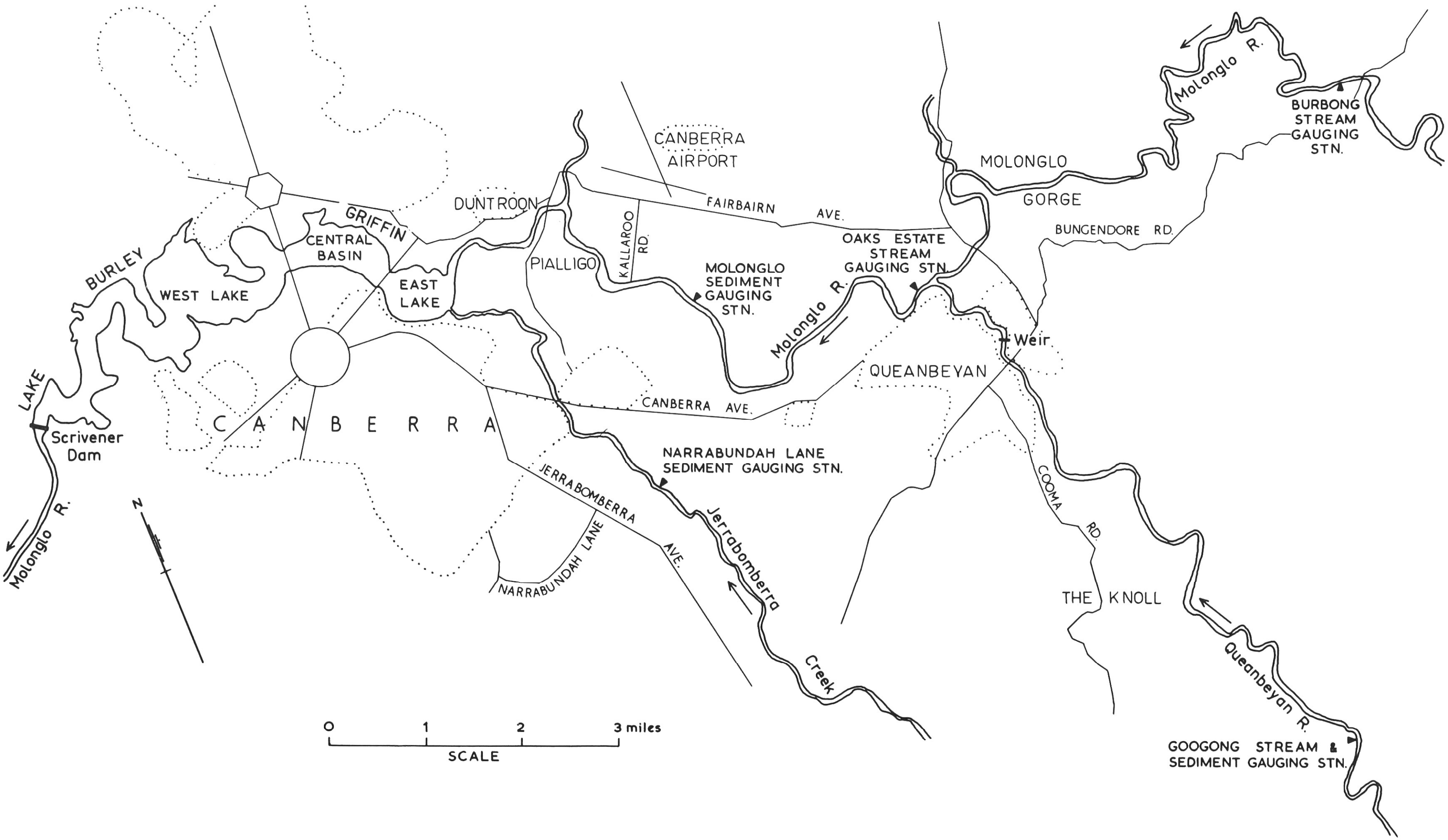

LOCALITY PLAN – LAKE BURLEY GRIFFIN & TRIBUTARY STREAMS

CE-D-7585

University of New South Wales

WATER RESEARCH LABORATORY.

BED SEDIMENT LOAD IN STREAMS TRIBUTARY TO LAKE BURLEY GRIFFIN

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Professor C. H. Munro
Associate Professor R. T. Hattersley
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Preface

The work reported herein was carried out for Maunsell and Partners, Consulting Engineers to the National Capital Development Commission, Canberra, A.C.T. Publication of the report for issue to bona fide research workers is by kind permission of the Commission.

R. T. Hattersley,
Assoc. Professor of Civil Engineering,
Officer-in-Charge.

Summary

This report contains an estimate of the sand bed load of the Molonglo River, the Queanbeyan River and Jerrabomberra Creek which are the principal streams tributary to Lake Burley Griffin at Canberra.

The report first describes the river system and the catchment area. Sediment gauging stations were chosen and the locations are described and discussed. The required data consisted of surveys, backwater curves, bed sample gradings and flow duration curves.

Theoretical relationships are discussed, the modified Einstein method is adopted and estimates of bed load are made.

The possibility is considered of the likelihood of sand deposition in Lake Burley Griffin and measures are suggested for trapping the bed load to prevent it reaching the Lake.

Table of Contents

1. Introduction

This report is the result of part of the work undertaken by Unisearch Ltd. for Maunsell and Partners. The purpose of the investigation was to estimate how serious bed load deposition in Lake Burley Griffin, Canberra, would prove to be in future years.

Two field investigations were carried out on 20th and 21st December 1966 and on 17th and 18th January 1967, and 41 sieve analyses have been made in the Water Research Laboratory of the University of New South Wales and the results of calculations and assessment of the bed load are contained herein.

The descriptions of the rivers, the catchment characteristics and catchment erosion are brief because descriptions are contained in the large number of references dealing with the many other aspects of the Canberra Lakes problem. (See Appendix 1).

Photographic colour slides are available to illustrate the character of the tributary rivers and any evidence of bed sediment movement.

The work was carried out under the supervision of R. T. Hattersley, Associate Professor of Civil Engineering, Officer in Charge, by Mr. A. J. Bonham, Engineer, of the staff of the Water Research Laboratory of the University of New South Wales under the general direction of Professor C. H. Munro, Foundation Professor in Civil Engineering and Head of the Department of Water Engineering.

2. Description of the Contributary Rivers

2.1 Molonglo River

Upstream of its confluence with the Queanbeyan River the Molonglo River has a catchment area of 150,000 acres. The east side of the catchment rises in the Gourock Range of the Great Dividing Range with peaks of 4600 feet above sea level. The catchment is shown in Figure 1.

An important feature of this river is the presence of a sunken valley some 20 miles from Canberra in which most of the bed sediment load is trapped.

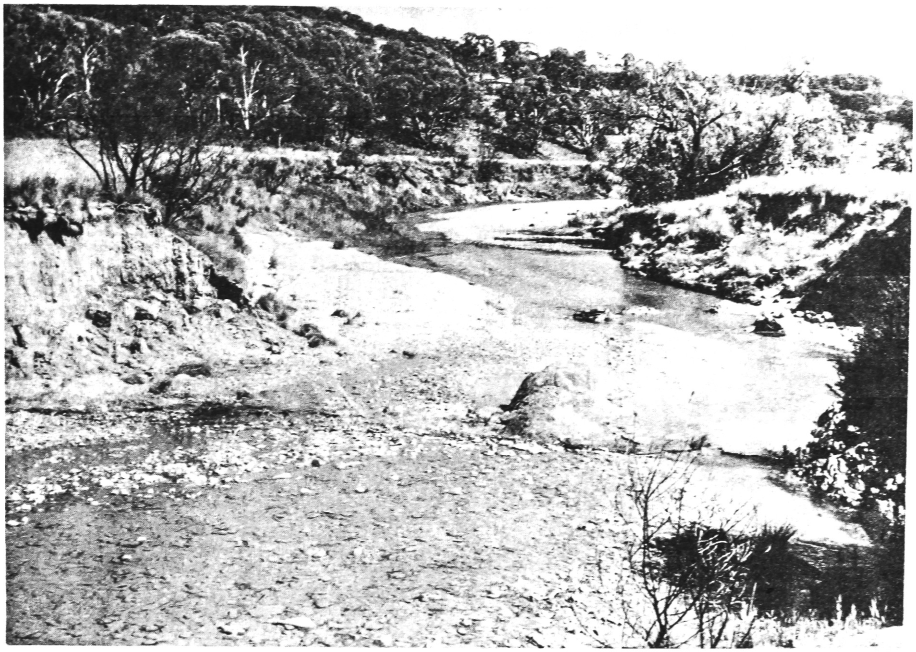
The catchment bears comparison to both adjacent catchments. To the south-west the Queanbeyan River has no significant sunken valley. To the north-east Lake George is a sunken valley. The Lake George catchment is small in relation to the size of the lake so that sufficient sediment has not yet been brought down by the tributary streams to fill in the lake, and there is insufficient discharge to raise the lake level and to force a river outlet.

The reach of the Molonglo River from "Eleven Mile Turn Off" to "Foxlow" meanders through this filled in sunken valley. (See Fig. 1). The Lake George Range of hills extends southwards to cut off this valley on the line of a major geological fault (11). The valley appears to have been a lake and the outlet discharge has cut a gorge, described as the Molonglo Gorge, and gradually lowered the lake level whilst the Molonglo River at the same time was filling up the bed of the lake with sediment. The northern part of the sunken valley is fed by streams from small northern catchment areas resulting in a slower rate of sediment deposition, and in fact a small area of open water still remains. (See Fig. 1).

The Molonglo upstream of the sunken valley is a young river with a heavy bed load and is shown in photograph 1. As described elsewhere (8) extensive erosion and gullying occurs in the tributary streams and catchment and in addition mine waste from the mine at Captains Flat has found its way into the river in large quantities. Most of the sand and silt is deposited at the head of the sunken valley in the "Foxlow" area where hundreds of acres of flood plain were buried under acid sand mine waste when the mine dam failed at the Captains Flat mine in 1941. (See photographs 2 and 3).

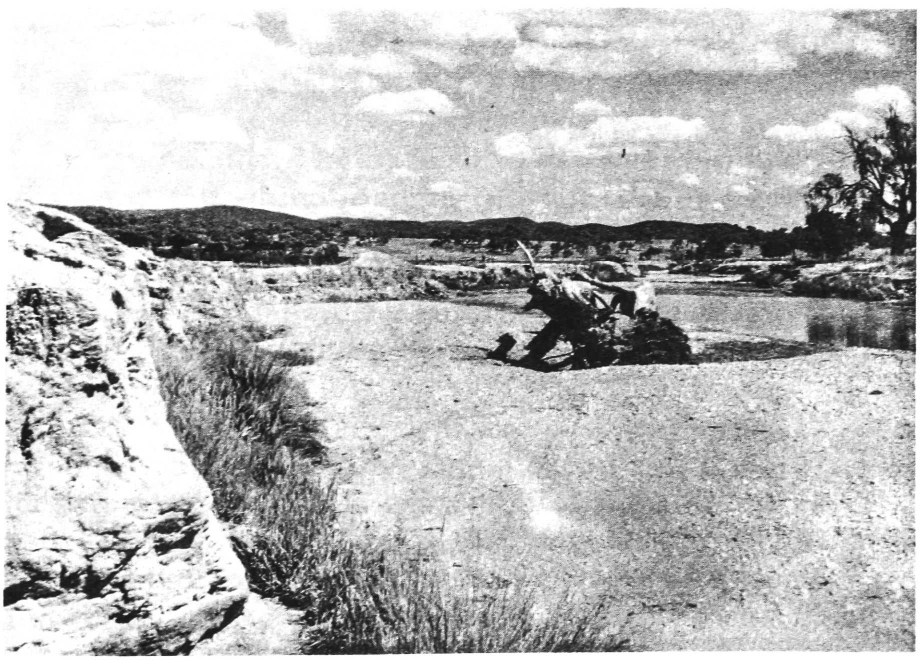
Very little sand appears to work its way right across the sunken valley as far as the road at "Eleven Mile Turn Off" although the suspended silt and clay load is carried through. (See photograph 4). Immediately upstream of "Eleven Mile Turn Off" the river channels are choked with reeds and debris. (See photograph 5). Only very minute deposits and traces of sand are found in the vicinity of Burbong and this probably comes from the many small creeks directly tributary to the gorge. Insufficient bed material was found at Burbong to give an adequate range of samples to establish a bed sediment gauging station. (See photographs 6 and 7).

There is a fan of rock debris at the bottom end of the Molonglo gorge, commencing with a bar of boulders and grading to a scree of



1. Molonglo River upstream of the sunken valley between Foxlow and Captains Flat with heavy bed load (GR. 460115).

2. Molonglo River at Foxlow showing eroded edge of overlying sand mine waste deposit from Captains Flat Mine (GR. 457180).



cobbles followed by pebbles in the last mile before the confluence with the Queanbeyan River.

The final mile to the confluence consists of a meandering stream deeply cut through rock and sandy alluvium with shoal deposits containing coarse and fine sand which have the appearance of age and stability and do not seem to form part of a currently mobile bed system.

The river throughout has the dirty appearance of carrying a good load of clay and silt in suspension during flood flows, and even at very low flows the water sometimes has a noticeable turbidity.

2. 2 Queanbeyan River

The Queanbeyan River catchment area is some 238,000 acres. The river rises to the south-west in the Tinderry Mountains at an average elevation of some 4-5,000 feet. Tinderry rises to 5,307 feet, and Wangrah to 4,348 feet above sea level. To the south east the river rises in the Great Dividing Range, with the Bald Mountain rising to 4,812 feet above sea level. (See Figure 1).

In its lower 15 miles the Queanbeyan is a fast, turbulent, turbid river flowing in deep and rocky valleys and gorges. There is a succession of sandy shoals and a continuous sandy bed with characteristic bars indicating that the river is carrying a copious deep bed load of sand (See photograph 10). There is very little fine sand (median size $>$ 0.7 mm) but the river may well be carrying its full capacity of coarse sand. The sand deposits are covered with a thin veneer of clay and silt which may be fall out from a receding flood and which gives the channel a dirty appearance.

The erosion in the catchment by gullying of tributaries and by bank erosion is sufficiently extensive to provide the river with a full load of bed material.

A weir was constructed about a generation ago at the town of Queanbeyan approximately one mile upstream of the confluence of the Queanbeyan River with the Molonglo River. This weir has completely filled in with coarse sand and the river has aggraded for some considerable distance upstream.

Sand mining operations are in progress in the bed of the river at Googong, The Knoll, and on a smaller scale in the town of Queanbeyan.

2.3 Molonglo River between Canberra and Queanbeyan

Below its confluence with the Queanbeyan River the Molonglo flows through an alluvial channel with rocky outcrops. There are large shoals on the inside bends which are stabilised with vegetation. These are mined for sand on a small scale. The bed consists of gravel and sand which is mostly coarse. Bed deposits are apparently worked after each fresh but are not large enough to enable continuous exploitation.

At Molonglo (point M on Figure 1) the river falls over rocky outcrops and here the river is extensively overgrown by willow trees. (See photographs 8 and 9). Downstream is a straight stable reach through stable sandy banks lined continuously with willows and with the bed alternating from gravel to coarse sand. This section falls within the backwater influence of the Canberra Lakes, with a retention level at 1,825 feet above sea level. The longitudinal section is shown in Figure 24.

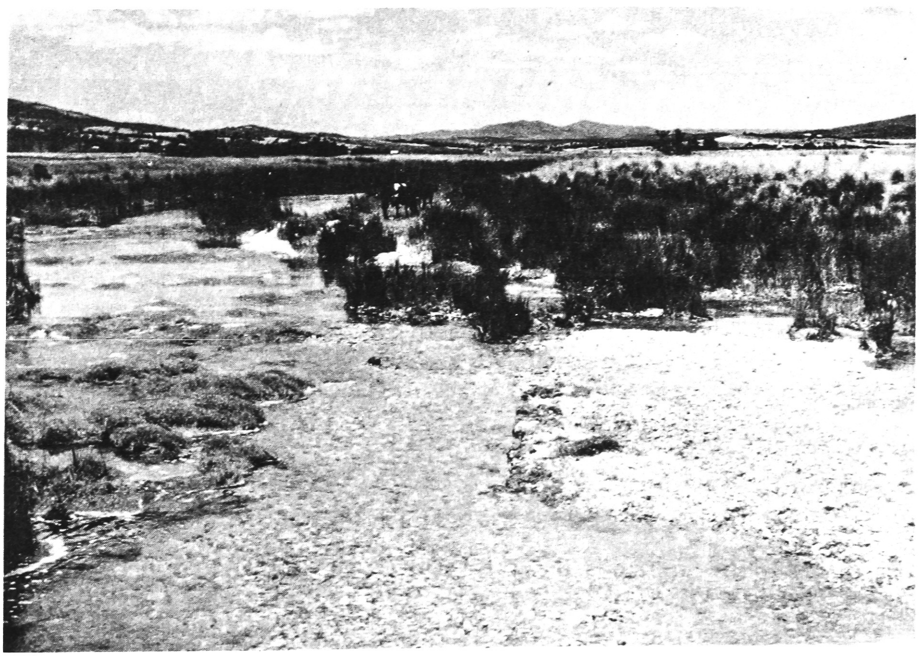
At Pialligo, extensive sand mining operations are in progress in the bed and banks of the river. Excavations and dammings have been made in the bed of the river by the lease holders to trap as much sand as possible. A floating dredge has been built for use in the flood plain or bank flats. The reserves in the bank flats have been estimated to be in the order of 500,000 cubic yards of Sub-Recent origin and 400,000 cubic yards of Contemporary origin (10). These reserves contain extensive pockets of silt and clay alluvium. The sand is washed and the silt and clay washings are settled out in lagoons. The washings are said to comprise 20 pc. of the deposits (2). These bank flat deposits do not form part of the present bed movement of the river.

2.4 Jerrabomberra Creek

The Jerrabomberra Creek has a catchment area of some 28,800 acres, rising in hills with elevations ranging from 3,400 to 3,900 feet and falling to the plain of the Molonglo River. Jerrabomberra Creek flows directly into the East Basin of Lake Burley Griffin with its retention level of 1,825 feet above sea level and the longitudinal section

3. Molonglo River Flats downstream of Foxlow showing acid sand mine waste from Captains Flat Mine (GR. 456192).

4. Molonglo River halfway through the sunken valley showing some gravel but very little sand (GR. 403276).



is shown in Figure 8. This catchment suffers from extensive gullying of tributary creeks despite the construction of some check dams. The bed of the river is in alluvium in the lower reaches and consists of an almost continuous strip of coarse sand at a gradient of 1/ 400 at Narrabundah Lane. The river banks are vertical on the concave sides of bends and show signs of fast erosion although the recent program of willow planting could help check this in time (8).

Considerable deposits of sand have been located and proved in the bed and banks of the Creek adjacent to Jerrabomberra Avenue (10).

3. Bed Sediment Gauging Stations

3.1 General Comment

A bed sediment gauging station should be in a long straight section of channel, with fairly steep high banks. The straight length of channel should be some 20 times the width or if shorter should have a good approach promoting smooth undisturbed flow. The bed should be fairly flat and deep in sediment and without large dunes and shoals. The stage relationship must be known.

3.2 No Station on the Molonglo River Upstream of Queanbeyan

No suitable location for a sediment gauging point could be found on the Molonglo River upstream of its confluence with the Queanbeyan. There are only small pockets of residual bed material between the confluence and the sunken valley at "Eleven Mile Turn Off". Any bed material that is carried in the bed of the river across the sunken valley when the river is in high flood would carry straight through the Molonglo Gorge. There is insufficient bed material to sample because the carrying capacity of the river is so much greater than the supply of bed sediment. (See photographs 6 and 7).

3.3 Googong Station on the Queanbeyan River (GR279251)

An ideal bed sediment gauging location was chosen upstream of the stream gauging station at Googong (map GR. 279255). (See photograph 9 and the longitudinal sections and cross sections in Figures 6, 20, 21, 22 and 23. The straight reach is only 1,500 feet long but the approach is fairly straight for another 2,000 feet. The bed is deep with coarse sand and fairly flat except for small oblique shallow bars or dunes. The banks are steep and even and not too heavily overgrown. The stream gauging records are available for Googong from March 1912 to December 1965 except for 1925, spring and summer of 1950, autumn and winter of 1957 and several odd months. However, the gauge was drowned out at flows exceeding 560 cusecs from 1912 to 1924 and so the period from 1926 to 1965 was taken which is equivalent to 39 complete years. The stage discharge curve is shown in Figure 19 and the resulting flow duration curve is given in Figure 2. The backwater curves were constructed with confidence for the range of discharges from 500 to 20,000 cusecs from the stream gauging station 4,700 feet downstream. The Mannings "n" values were assessed to be in the range 0.035 to 0.065 using comparative photographs (12).

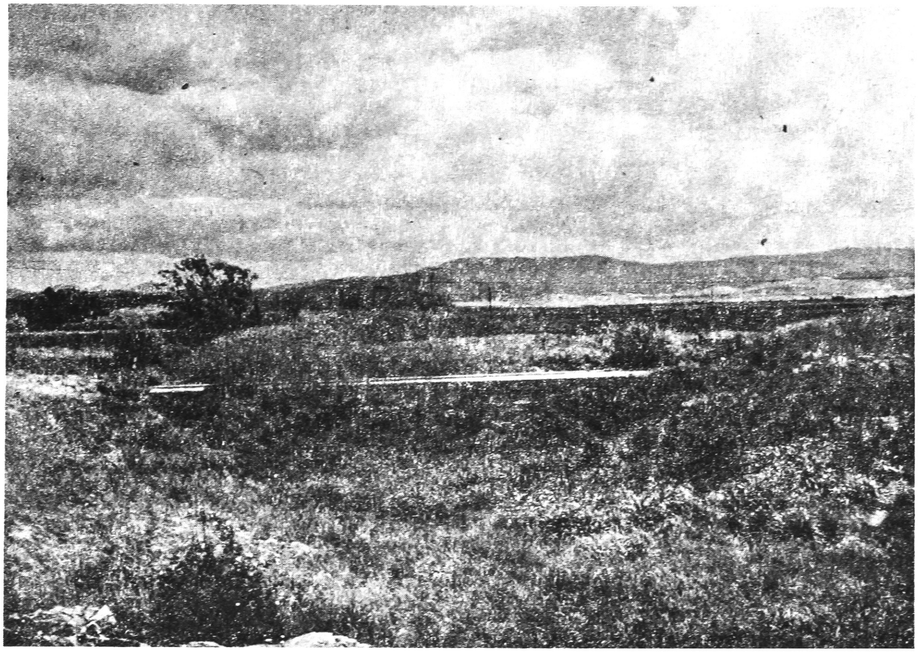
It was assumed that the river temperatures are the same at Googong as at Queanbeyan where the record is available for several years indicating an average annual river temperature of approximately 60°F, for calculating transportation constants.

Bed samples were taken across the 100 feet bed by a laboratory miniature clam shell grab, five samples each representing a 20 ft. wide strip of bed as well as representative samples 100 ft., 200 ft. and 300 ft. upstream. The average D35 grain size was 0.94 mm and the D65 grain size was 1.50 mm from the sieve analysis (See Figure 9). (65 pc. by weight of the grains in the sample have a diameter smaller than the D65 grain size and 35 pc. smaller than the D35 grain size).

The bed sediment discharge was computed over the range of discharges from 200 to 20,000 cusecs, using the Bureau of Reclamation Step Method for the modified Einstein procedure (14). (See Figures 12 and 15). The mean annual bed sediment load was computed to be some 25,000 tons per annum. The significance of this important conclusion is discussed in Section 4.

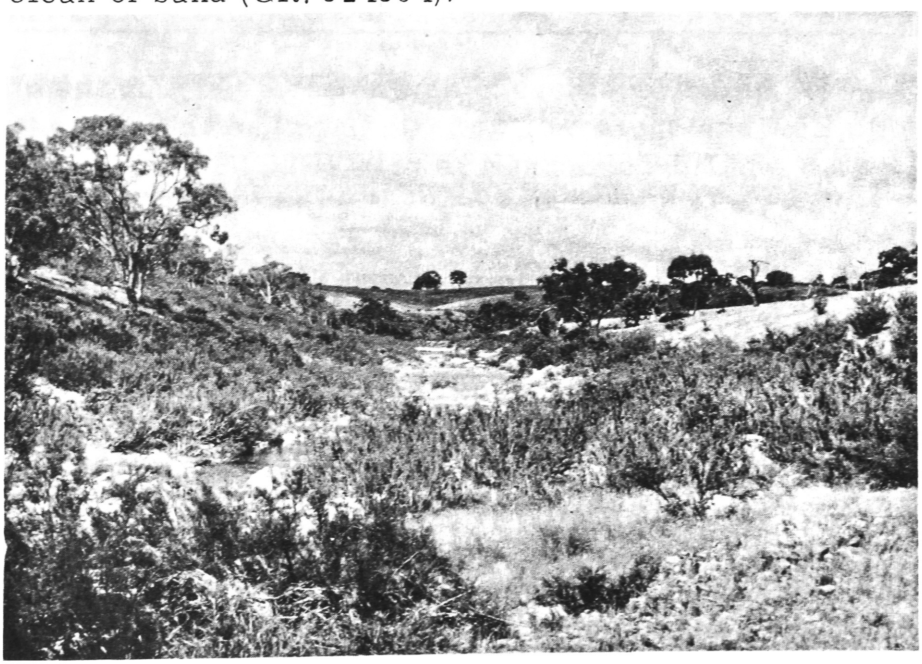
3.4 Molonglo Station on the Molonglo River below the confluence with the Queanbeyan (GR. 200375).

A bed sediment gauging location was chosen at the Commonwealth Department of Works section 5 at Molonglo. (Map GR. 200375). (See photograph 10 and figures 1, 7 and 24). This section of the river is straight for some 3,000 feet and lined with mature willow trees. These trees are evenly spaced giving steady hydraulic characteristics in the reach. The stage discharge relation is known up to 20,000 cusecs for a number of sections in this part of the river giving stage discharge relations and channel slope for section 5 by interpolation. The channel roughness was computed to be:-



5. Molonglo River at Eleven Mile Turn Off viewed up-stream from Molonglo Gorge showing sunken valley with river bed choked with vegetation (GR. 394297).

6. Molonglo River viewed downstream in Molonglo Gorge at Burbong stream gauging station showing bed swept clean of sand (GR. 324364).



Manning's $n = 0.051$ at 10,000 cusecs and
$n = 0.066$ at 1,250 cusecs.

The flow duration curve, Figure 3, refers to Corkhills weir which is now submerged beneath Lake Burley Griffin.

Bed samples were taken by clam shell grab at the quarter points on section line 5 but although coarse sand was found left and centre, a gravel bed was found at the right. However, sand was found 20 ft. and 300 ft. downstream. Additional random samples were taken and approximately half of these showed sand and the others gravel. For the sand the average D65 size was 0.7 mm and the D35 size was 0.55 mm. (See figure 10). It is possible that the sand inflow to this section is less than the transporting capacity of the channel so that the bed has degraded down to the gravel. The ratings may therefore represent the maximum instead of the average load of bed sediment. The average annual river temperature is taken to be 60°F based on a three years record for calculating transportation constants.

The bed sediment discharge was computed over the range from 500 to 20,000 cusecs using the modified Einstein procedure. (See figures 13 and 16). The theoretical stream capacity to transport sand is 21,000 tons per annum in an average year but in practice this capacity will not be reached for the reasons given in Section 4.

3.5 Narrabundah Lane Station on Jerrabomberra Creek (GR. 180346).

The bed sediment gauging location was chosen approximately one mile upstream of the new Narrabundah stream flow gauge and well upstream of a fairly new small rockfill weir at Narrabundah Lane (GR. 181346). (See figures 1 and 8).

In this reach there are no rock outcrops and the valley slope is a smooth curve with a slope of 0.0028 at the gauging site. The bed is uniformly wide and deep, and the bed roughness was judged to be reasonably uniform in the gauging reach. Neglecting the recent influence of the small weir, the bed and valley gradients are parallel and the hydraulic gradients are assumed parallel to these at all stages of flow. Manning's "n" is taken to be 0.030.

Three bed samples of coarse sand were taken in the gauging section, under water by clam shell sampler, and checked by downstream samples for any influence of the weir. The effect of the weir is not yet very marked so that the results of the gaugings should be reliable. The average D65 grain size was 1.4 mm and the D35 size was 0.86 mm. (See figure 11).

The sand in the bed is continuous and deep so that the ratings should represent the actual bed load. The average annual river temperature was taken to be 60°F.

The bed sediment discharge was computed over the range from 3.15 to 6,350 cusecs. (See figures 14 and 17).

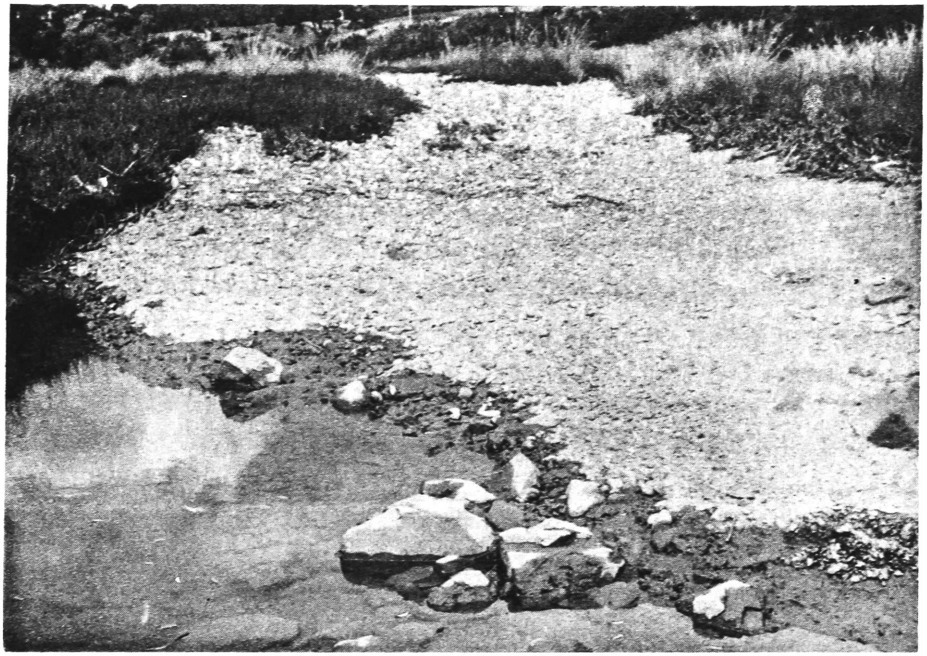
The Narrabundah stream flow gauging station has been in use for only three years but the previous station at "Homestead" had a six year record from 1957 to 1963. The flow duration curve for these six years was compared with a curve for the Queanbeyan over the same 6 year period and with the 39 year period Queanbeyan River flow duration curve. From these a long period flow duration curve was synthesised. (See figures 4 and 5).

The average annual bed sediment load was found to be some 26,000 tons per annum. The reasons for the relatively high sand load are given in Section 4.3.

4. The Probable Bed Load

4.1 Reduced Capacity due to Bank Roughness

The energy slope used in the calculation for bed sediment transportation is the total hydraulic gradient and no allowance has been made for excessive bank roughness. This is especially significant in the Molonglo River below Queanbeyan where at higher flows the willow trees are partly submerged, and produce a bank roughness much greater than the bed roughness. The willows in the Molonglo River have grown up and have stabilised the positions of the banks of the river in very recent times. Also in recent times much of the bed material has been mined upstream in the Queanbeyan area; the bed alternating from sand to gravel indicates that the sand supply is now much reduced. Both changes have been brought about by man in recent years. The sand supply has been reduced by mining and the river sediment transporting capacity has been reduced by the willow trees and very recently also by the backwater effect of the new lake. However, it seems reasonable to argue that the regime of the Molonglo River was evolved to carry much greater bed loads than the present theoretical bed load transporting



7. Molonglo River, Molonglo Gorge, bed material at Burbong showing gravel with a veneer of silt and clay (GR. 324364).

8. Molonglo River at rock bar limit of backwater to Lake Burley Griffin (GR. 202364).

capacity of 21,000 tons per annum. An approximate estimate of the bed load transporting capacity before the lake was filled is 30,000 tons per annum.

The sediment gauging station on the Queanbeyan River at Googong is substantially unaffected by these contemporary changes in topography and sediment load. Although sand mining has very recently commenced upstream of Googong most sand is still mined downstream of the sediment gauging station.

Jerrabomberra Creek is not yet affected by contemporary changes. There is a bank stabilisation programme of planting willow stakes, but they have not yet grown enough to have any significant effect.

4.2 Possible Errors in Estimates of Bed Load at Higher Shear Stresses

Investigations into the transport of solids as bed load have generally been carried out in shallow open flumes. The relationships which have been developed, specifically those of Einstein (13) and of Meyer-Peter and Muller are in fair agreement within the range of the flume data but differ at higher shear stresses. Figure 18 shows the divergence for discharges greater than 400 cusecs in the Jerrabomberra Creek, 8,000 cusecs in the Queanbeyan River and 10,000 cusecs in the Molonglo River, Ning Chien (17) has pointed out that the constants and functions of the sediment transport formulas as determined from the flume studies may have to be modified in applying the formulas to deep rivers. Wilson (16) has carried out investigations at high shear stresses in a pressurized conduit and his best fit line is shown in Figure 18. However, there is no record available of any conclusive investigations in the field in deep rivers similar to the tributaries to Lake Burley Griffin at higher stages.

The Einstein function has the theoretical advantage that it is based on a single grain size, and figures 9, 10 and 11 show that Queanbeyan River bed load is remarkably uniform in grain size.

Since the Einstein relationship has been subject to considerable use and general verification in the field in the United States and elsewhere, its present use is considered prudent at this time. At high discharges, the Einstein function represents a low estimate of bed load and at higher stages the bed load may then be 2 to 2.5 times the value calculated by the Einstein procedure. (See figure 18). However, this will not have a very great effect on the average annual bed load due to the short annual duration of the higher stream discharges.

No allowance has been made for the suspended load of coarse sand. It is considered that this load would be a negligible percentage addition to the bed load.

4.3 Estimate of Bed Load

The bed sediment rating curves are shown in Figures 15, 16 and 17, and curves are also given of the percentage of time exceeded against bed sediment load in Figures 12, 13 and 14. The latter curves were integrated to obtain the average annual bed sediment load.

The average annual bed load of the Queanbeyan River at Googong (GR. 279251) is estimated to be 25,000 tons per annum. In a dry year the bed load for that year might be only 10 pc. of this value. In a rare month of prolonged rainfall and high river flows the bed load for that month might exceed the average annual value.

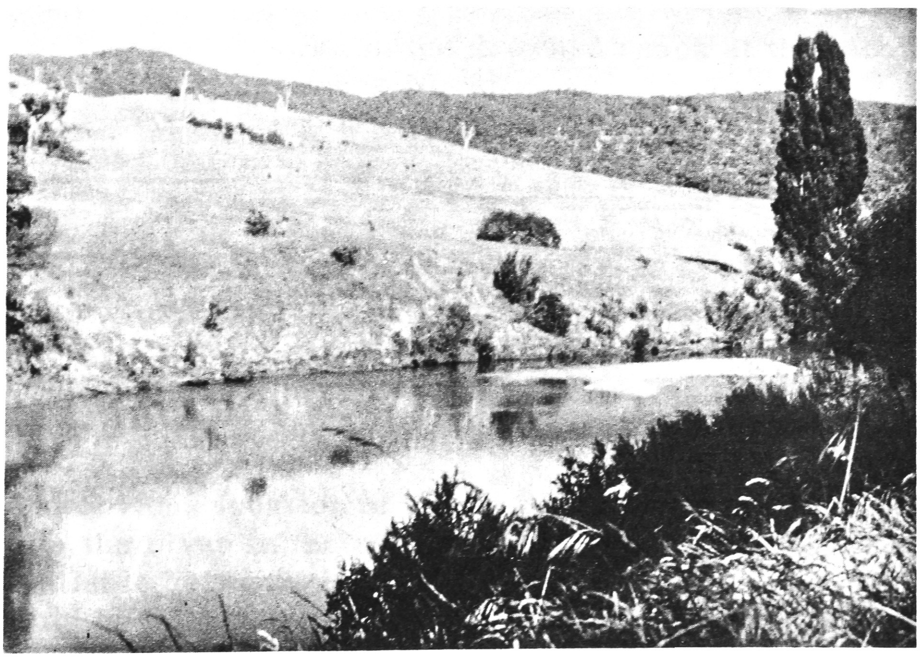
The average annual bed sediment load capacity of the Molonglo River at Molonglo (GR. 200376) is now 21,000 tons per annum neglecting the contemporary effects of the willow trees. However, the bed is starved due to mining operations and any sand movement is intermittent. Before Lake Burley Griffin was filled, the average bed load capacity was in the order of 30,000 tons per annum, but this capacity has been reduced by the backwater effects of the lake over a wide range of discharges.

The average annual discharge of water in the Molonglo River upstream of the confluence at Queanbeyan is less than half of the annual discharge of the Queanbeyan River. No sediment gauging station could be established in the Molonglo River upstream of the confluence because of the lack of sediment in the river bed. The sunken valley traps the bed sediment load from the higher reaches. However, a few thousand tons of bed load per annum may derive from the Molonglo Gorge area and local tributary streams. This would indicate good agreement between the Queanbeyan River and the lower Molonglo River.

The average annual bed sediment load of Jerrabomberra Creek at Narrabundah Lane (GR. 181346) is estimated to be 26,000 tons per annum.

9. Molonglo River at Molonglo sediment gauging station (GR. 200376).

10. Queanbeyan River at Googong sediment gauging station. (GR. 279251).



The bed movement in Jerrabomberra Creek continues to very low discharges. This is because the hydraulic gradient remains the same as the steep valley gradient down to very low discharges. However, in the Queanbeyan River and the Molonglo River the hydraulic gradient flattens out at low discharges in the sandy reaches between rapids and rocky outcrops, with a consequent reduction in bed movement. (See Figures 8, 20 and 24).

4. 4 The Prevention of Sand Deposition in the East Lake

Consideration has been given to what the effect will be if all sand mining were to cease and if no action were taken to prevent sand reaching the lake. The drowned reach between Kallaroo Road at Pialligo, and the East Lake is very deep and this reach would fill up with sand before very much sand reached the lake. There is space for 700, 000 cubic yards of sand and this would fill up in some 25 to 30 years if all sand dredging were to cease. Some of this sand would wash out into the lake if a major flood occurred in this period.

Subsequent stages of silting are hard to predict because future constraints on the river after 30 or 50 years are speculative. If left to nature the river channel would eventually fill with sand and the river would break out into a new channel during the course of some major flood. However, this will be delayed or inhibited if the river were contained between non mobile banks or between levees.

A similar silting would occur in the drowned reach at the mouth of Jerrabomberra Creek. (See figure No. 8).

5. Trapping the Bed Load

5. 1 Molonglo River

A major flood with a peak discharge of 200, 000 cusecs flowing from the Molonglo River into Lake Burley Griffin would possibly transport some 50, 000 to 100, 000 cubic yards of coarse sand sediment in the duration of the flood.

The best and obvious location of a trap would be in the Pialligo area, in the bed of the river in the reaches upstream of Callaro Road. The bed width available between the stable banks would be some 40 yards. Sand could be conveniently trapped to a depth of one yard. The length of river required as a trap would therefore be 2, 500 yards. Allowance must be made for rapids, rock outcrops and other topographical features, as well as any material which has accumulated since the last dredging. Consideration would also be given to the needs of other users and riparian owners. Therefore, all the conveniently available bed between Pialligo and Queanbeyan would probably be required.

It is suggested that arrangements could be made to dredge the bed of the river to remove three feet of sand where this will not prejudice the stability of the banks. For instance a floating dredge could operate between the willow lined banks upstream of Pialligo.

The backwater effect of Lake Burley Griffin now reduces the hydraulic gradient in the reach upstream of Pialligo. This will ensure that the bed load would not transport downstream beyond Pialligo providing the trap is dredged out between freshes.

The sale of the dredged sand would go a long way towards paying for the cost of the dredging and also for the cost of any additional river bank maintenance made necessary by the lowering of the river bed.

Sand mining operators should be encouraged to remove sand from the river bed upstream. The licences to sand mining operators should be regulated and controlled to minimise the risk of damage to banks. The sand mining operations in progress on the Queanbeyan River at Googong, The Knoll and in the town of Queanbeyan are all very useful. Sand deposits upstream of Queanbeyan Weir could be removed with multiple benefit. The Queanbeyan Weir should be dredged empty of sand.

Sand dredging operations between Pialligo and Queanbeyan will almost certainly give rise to some instability of the river banks. This will be reduced if the retention level in the river is kept up to its present level by the provision of low check weirs. These weirs will also assist to trap the sand by reducing the hydraulic gradient and by increasing the depth of flow. However, where possible, check weirs should be located upstream of rocky outcrops to prevent downstream scour. (See photograph 8).

The reaches between Pialligo and Queanbeyan are very close to Canberra. It is envisaged that the works, including dredging and low check weirs, could be made part of a fine scenic and recreational amenity. An access road for the removal of sand would have to be provided on one or other banks of the river, and this road would normally be closed to traffic and serve as a footpath. A higher standard of bank clearing and maintenance including the careful trimming of the very beautiful willow trees in this reach, would assist in the operation of the silt trapping function, and would also assist in the passage of flood waters. (See photograph 9).

5.2 Jerrabomberra Creek

There are serious problems associated with erosion control in the Jerrabomberra catchment. The bed sediment load is very large for such a small catchment.

A major flood in Jerrabomberra Creek flowing into Lake Burley Griffin could possibly transport some 30,000 to 50,000 cubic yards of coarse sand sediment in the duration of the flood. If this flood were to occur the sand load would accumulate in the lower reaches of the creek where the lake backwater curve intersects the steep hydraulic gradient of Jerrabomberra Creek (see Figure 8). A sand trap should be constructed at this location and periodically dredged out, possibly by drag line. At present there is no evidence of much sand from the creek currently reaching the East Lake.

Alternatively, attention could be directed towards stabilising Jerrabomberra Creek by removing the bed load further upstream. The creek is at present in a highly active state of sediment transport but it is in equilibrium and any works would have to be thorough and comprehensive to be effective. At present, the valley slope, bed slope and hydraulic slopes are roughly parallel at all flood stages and the equilibrium is maintained by a sufficient supply of sand. If the supply is cut off in the higher reaches, the bed will degrade and the banks collapse as the channel deepens. This degradation could be checked by the construction of drop structures to reduce the bed gradient and the hydraulic gradient. The treatment might only be effective up to bank full discharge. At high discharges the flood water extending over the flood plain would force the hydraulic gradient to revert to valley gradient, resulting in further bank erosion.

Very careful attention should be given to the effect on the stream channel of reducing the bed load due to silt traps or due to soil conservation measures. The best location for a sand trap is shown in Figure 8.

6. Conclusions

6.1 Average Annual Bed Load Transportation

The estimated average annual bed loads transported by the Queanbeyan, Molonglo and Jerrabomberra streams are respectively 25,000, 21,000 and 26,000 tons.

6.2 Importance of Sand Mining

The existing sand mining operations in the Molonglo and Queanbeyan Rivers are removing all the sand being brought down by these rivers. However, if a major flood occurs, sand may possibly be deposited in the river reach between Kallaroo Road at Pialligo and the lake, and some may even reach the lake. Therefore, it would be desirable to plan the sand mining operations in the most beneficial manner, as for example by dredging out the river reaches upstream of Kallaroo Road to provide space to trap sand brought down by major floods, dredging out the Queanbeyan Weir, and similar measures.

Correspondingly, consideration should be given to removal of sand in Jerrabomberra Creek in the lower reaches.

A co-ordinated supervision of all sand mining operations appears desirable.

6.3 Danger of Sand Deposition in the Lake

Although it is highly desirable to preserve and improve the river systems adjacent to the lake, even if this is not done, sand deposition in the lake itself will be of no significance for half a century or more.

Appendix I - References.

1. "Interim Report on Sediment Load in the Molonglo and Queanbeyan Rivers" Canberra, Commonwealth Department of Works, February 1961.

2. "Lake Burley Griffin - Provision of Bed Load Traps". Director of Works, Commonwealth Department of Works, Canberra, 1963.

3. "Feasibility Report; Use of East Lake Area as a Desilting Basin for the Incoming Water to Lake Burley Griffin" Canberra, Commonwealth Department of Works.

4. "Effect of Sediment from the Queanbeyan - Molonglo River System". Report to the National Capital Development Commission, May 1961, Appendix No. 1.

5. "East Basin and Flood Plain Model Progress Statement No. 1", Canberra, Commonwealth Department of Works, March 1961.

6. "Interim Report on Bed Load in Molonglo River - May 1962" Canberra, Commonwealth Department of Works, 1962.

7. "Preliminary Investigation on Possible Siltation of the Canberra Lakes Scheme and Silt Mitigation Measures". Water Research Laboratory, University of New South Wales 1962.

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9. "East Basin and Flood Plain Model Progress Statement No. 1" Canberra, Commonwealth Department of Works, March 1962.

10. "Sand Gravel Investigation at Sites of Possible Silt Traps along Molonglo River and Jerrabomberra Creek", Canberra, Department National Development, Bureau of Mineral Resources, Geology and Geophysics, May 1962.

11. "Canberra Lakes 'Red' Report". Canberra Commonwealth Department of Works.

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13. "The Bed Load Function for Sediment Transportation in Open Channel Flows" Hans Albert Einstein, Tech. Bulletin No. 1026, U. S. Department of Agriculture, Soil Conservation Service, Washington, D. C. September 1950.

14. "Step Method for Computing Total Sediment Load by the Modified Einstein Procedure" Bureau of Reclamation, U. S. Department of the Interior, July 1955.

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16. "Bed-load Transport at High Shear Stress." by Kenneth C. Wilson, Proc. A. S. C. E. Vol. 92 No. HY6 Nov. 1966.

17. "The Recent Status of Research on Sediment Transport" Chien Ning, Trans A. S. C. E. Vol. 121, 1956.

18. "Derivation of the Regime Equations from Relationships for Pressurised Flow by Use of the Principle of Minimum Energy - Degradation Rate". Arthur Brebner, Kenneth C. Wilson, Proc. I. C. E. Vol. 36, Jan. 1967.

19. "Design of Channels for Supercritical Flow" Proc. I. C. E. Vol. 35 Nov. 1966.

20. "River Improvement and Land Drainage in Australia and New Zealand" H. G. Strom, State Rivers and Water Supply Commission, Melbourne, 1962.

Appendix 2 - Figures.

Appendix 3 - Photographs

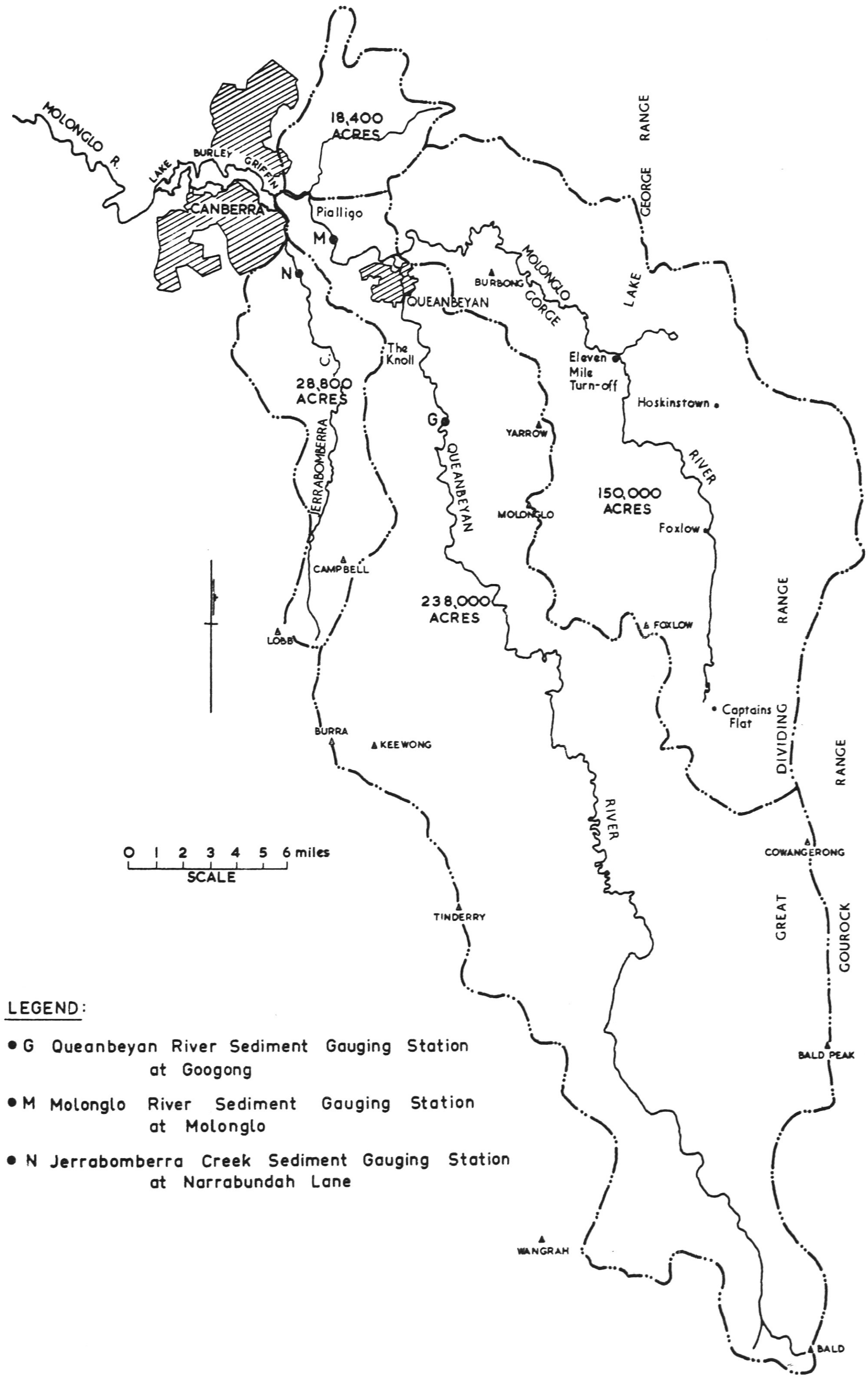


FIGURE 1: CATCHMENT AREAS OF MOLONGLO RIVER AND TRIBUTARIES

CE-C-6937

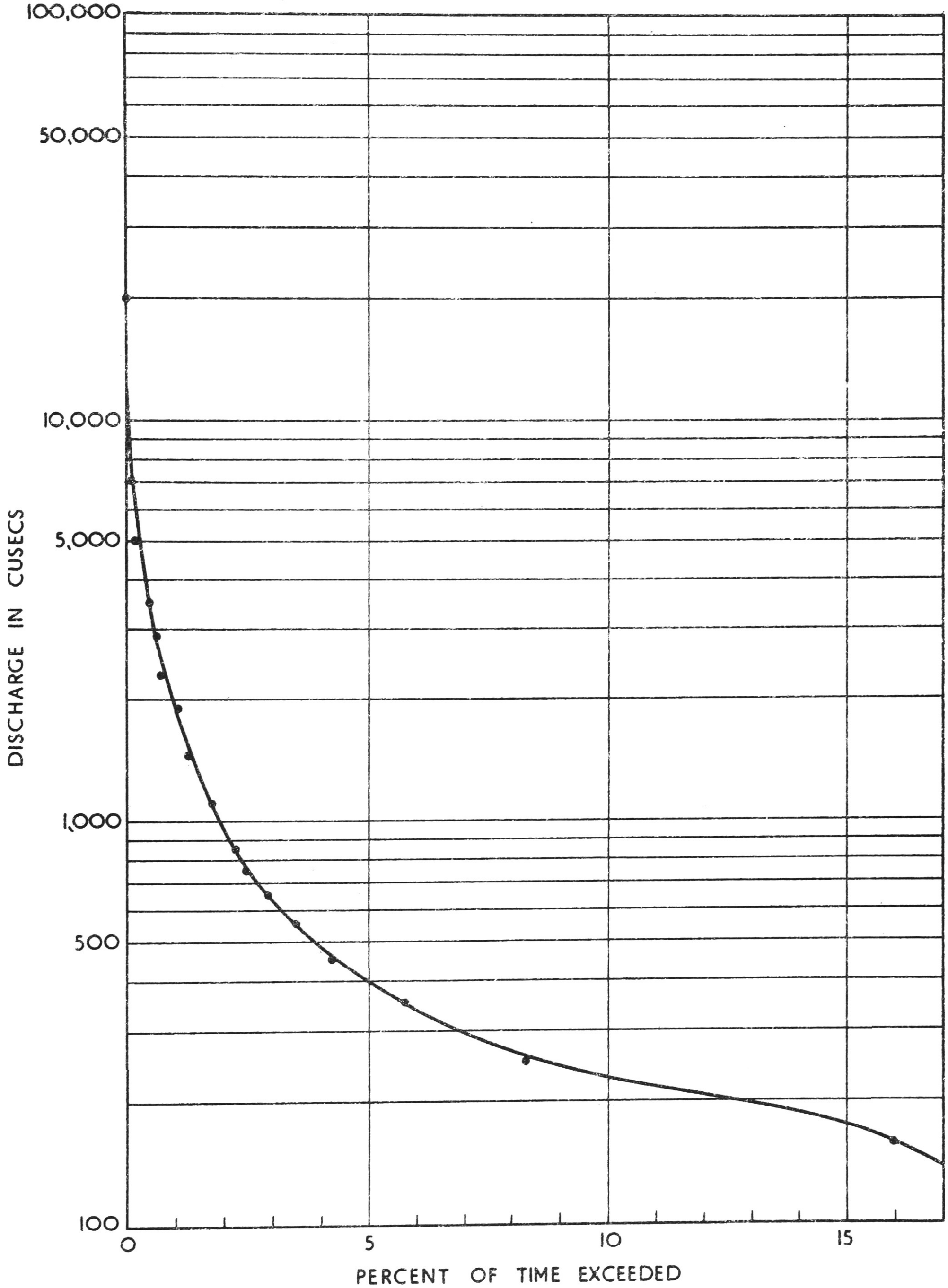


FIGURE 2: FLOW DURATION CURVE

QUEANBEYAN RIVER AT GOOGONG (G.R 279255) (337sq.miles)

CE-E-6927

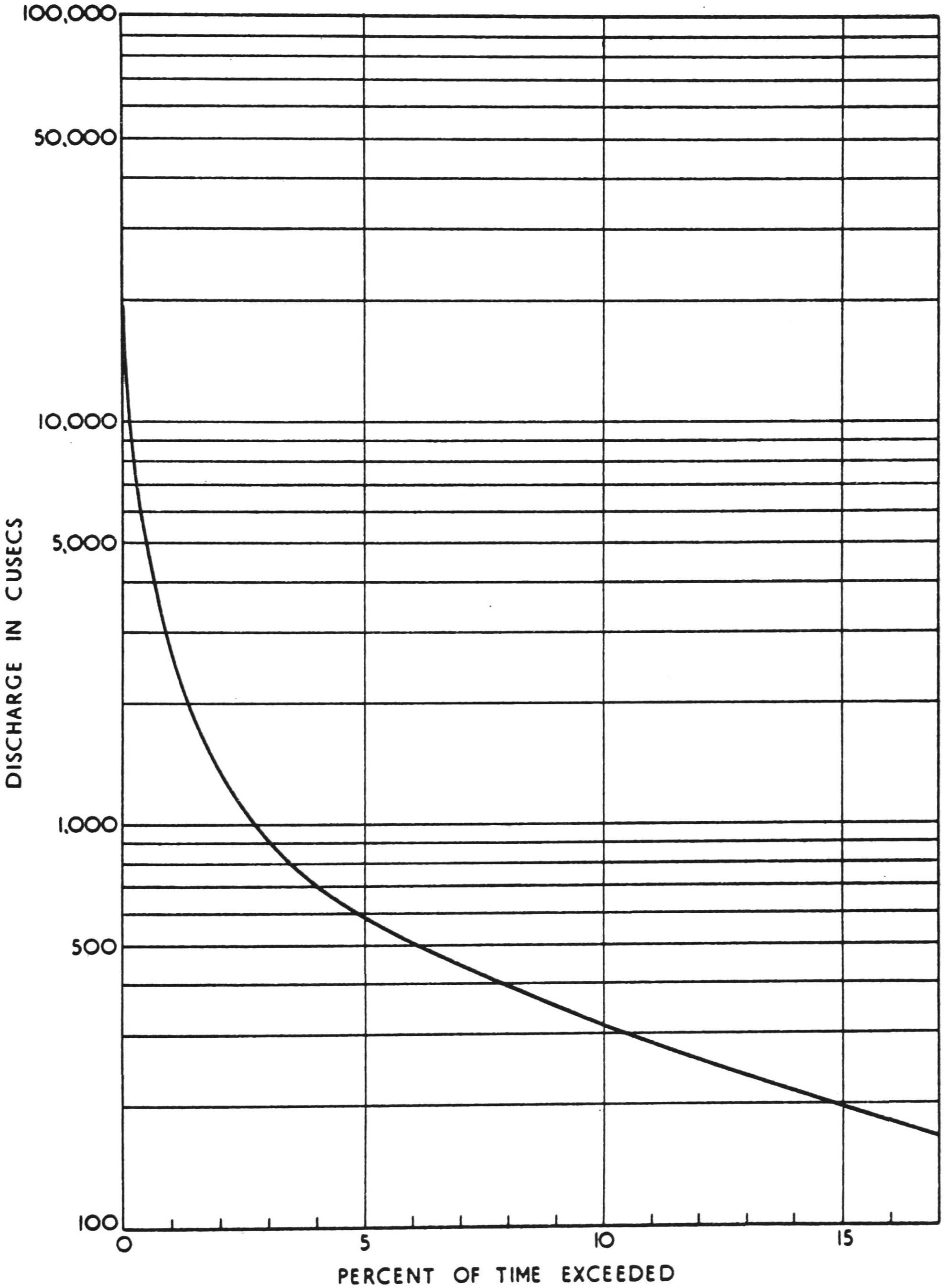


FIGURE 3: FLOW DURATION CURVE

MOLONGLO RIVER AT CORKHILL'S WEIR (G.R 110406)

CE- E - 6928

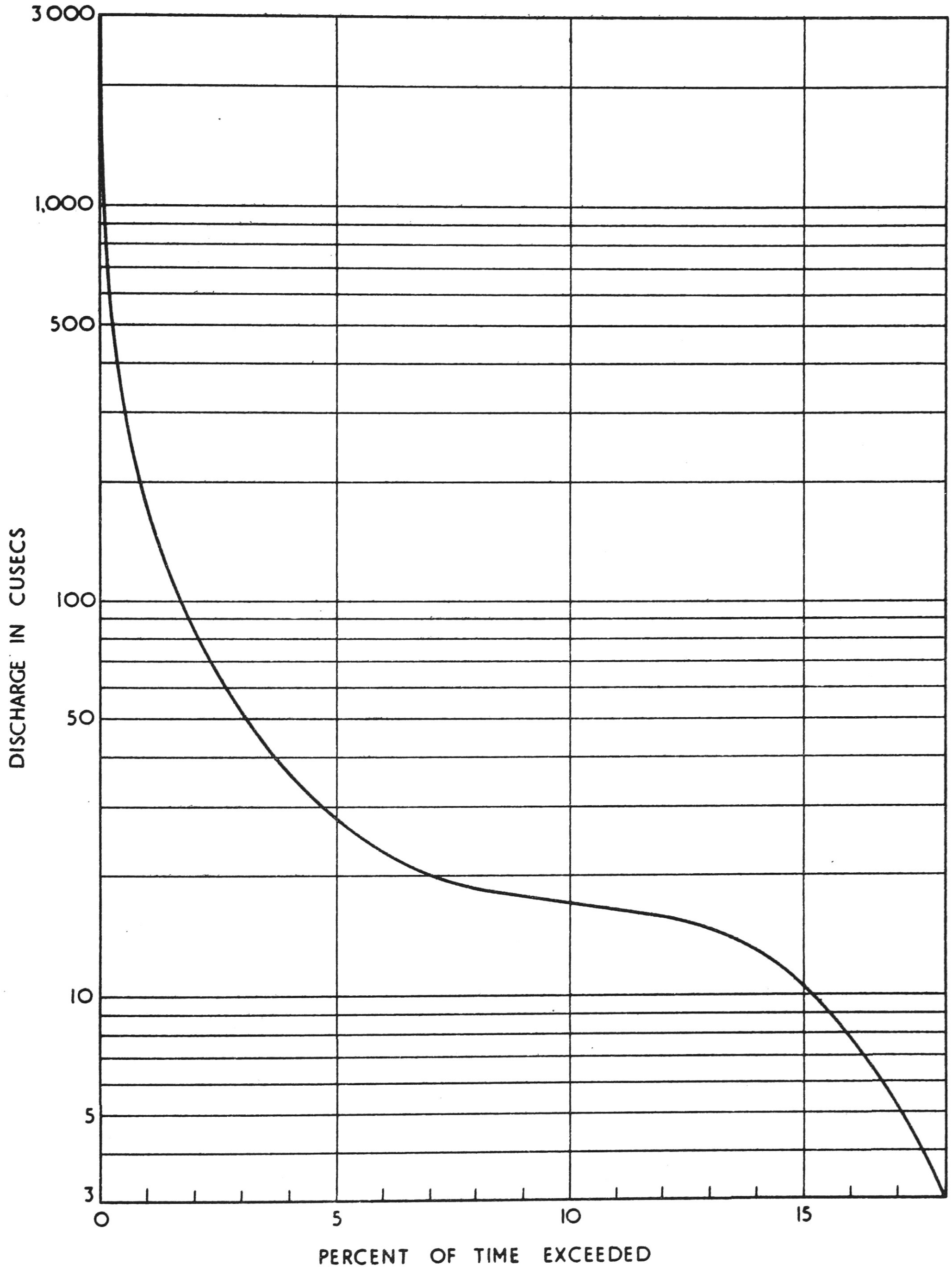


FIGURE 4: FLOW DURATION CURVE

JERRABOMBERRA CREEK AT NARRABUNDAH LANE (G.R 180346)
(44 sq. miles)

CE-E-6929

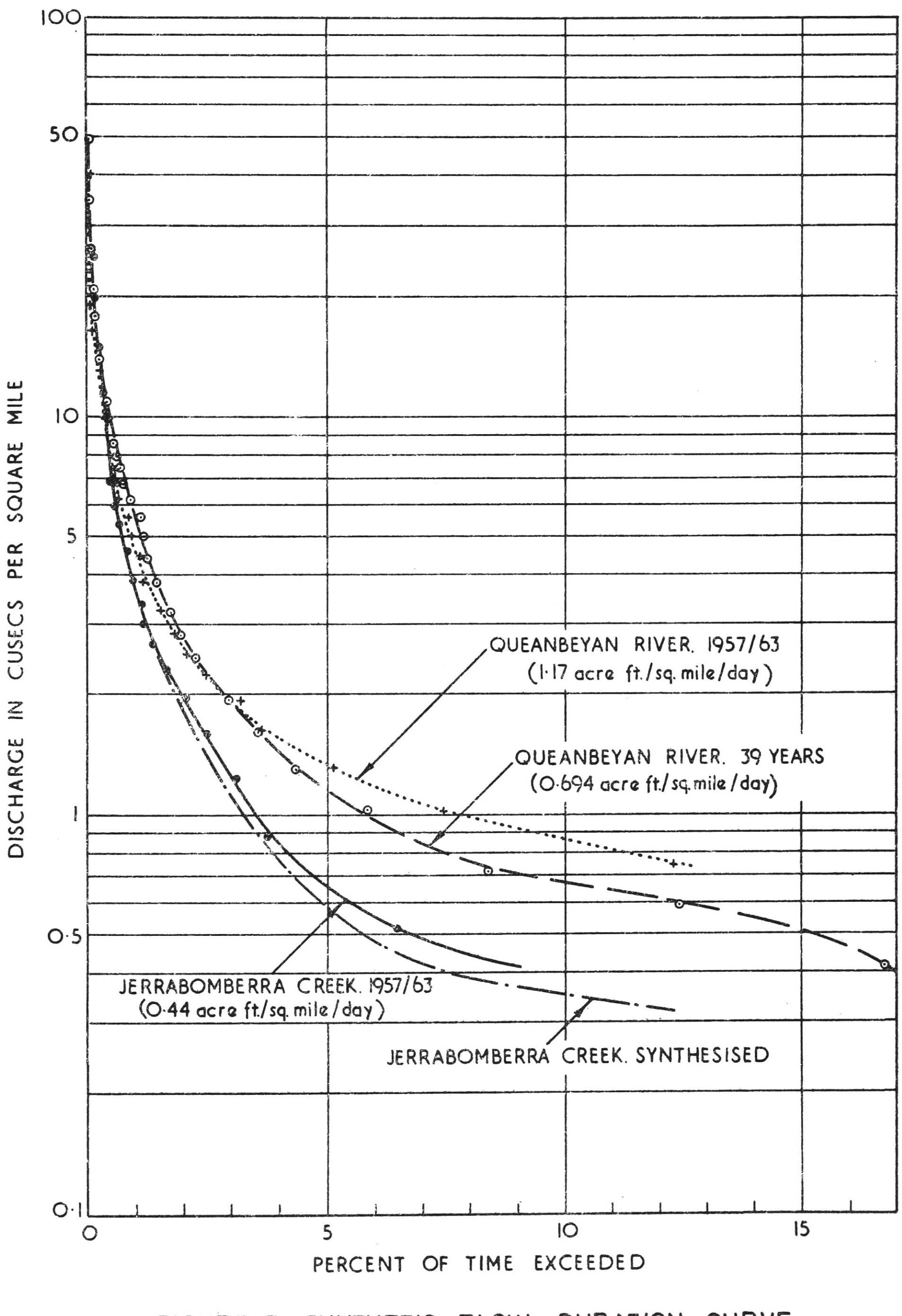


FIGURE 5: SYNTHETIC FLOW DURATION CURVE

QUEANBEYAN RIVER AT GOOGONG (G.R 279255) AND

JERRABOMBERRA CREEK AT "HOMESTEAD" (G.R 203290)

CE-E-6930

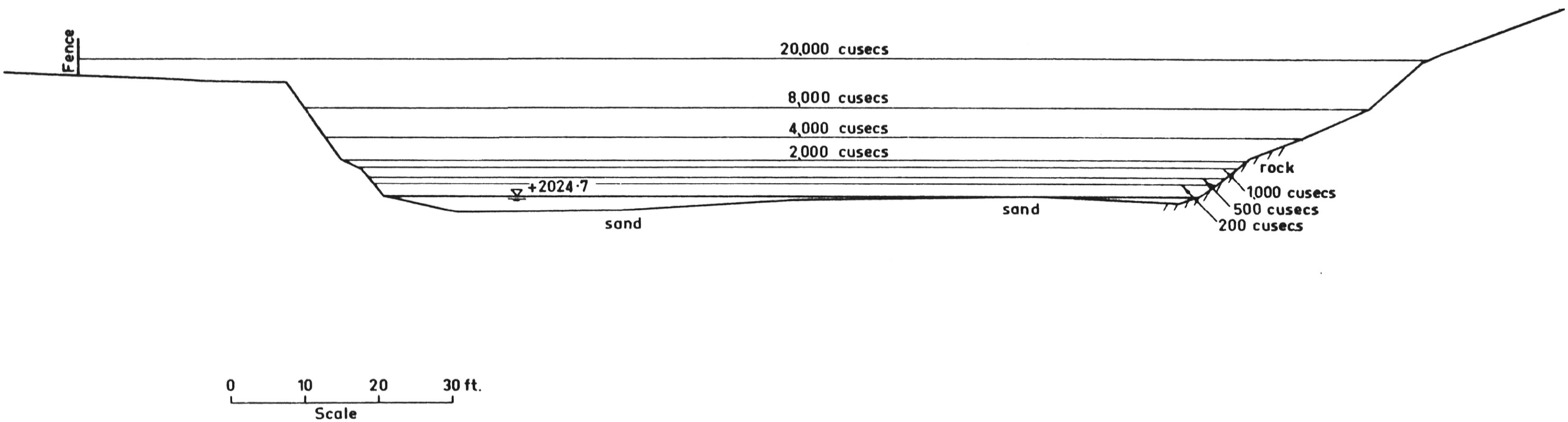


FIGURE 6: CROSS SECTION OF QUEANBEYAN RIVER AT GOOGONG SEDIMENT GAUGING STATION (G.R 279251)

CE-C-6926

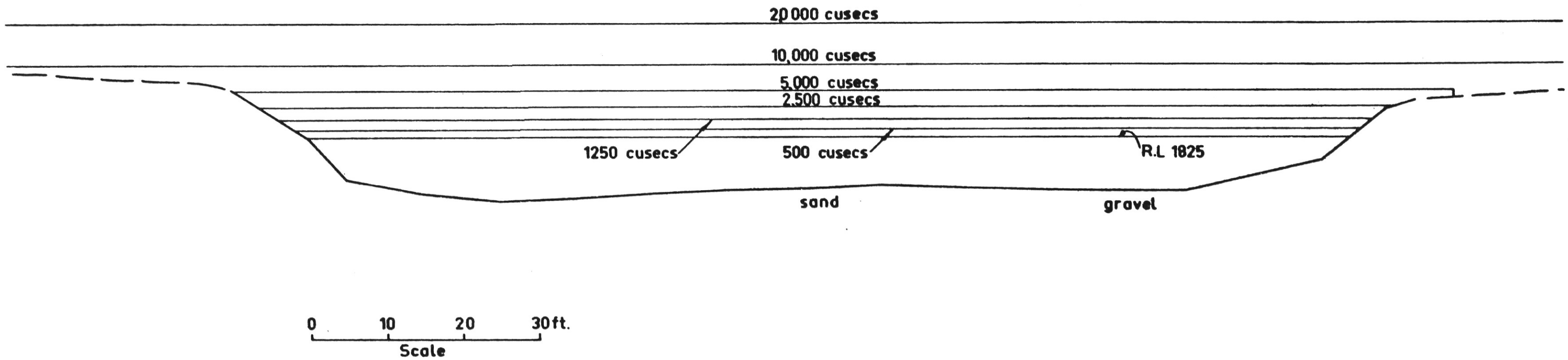
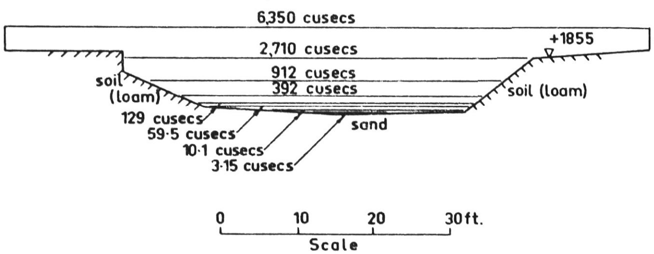
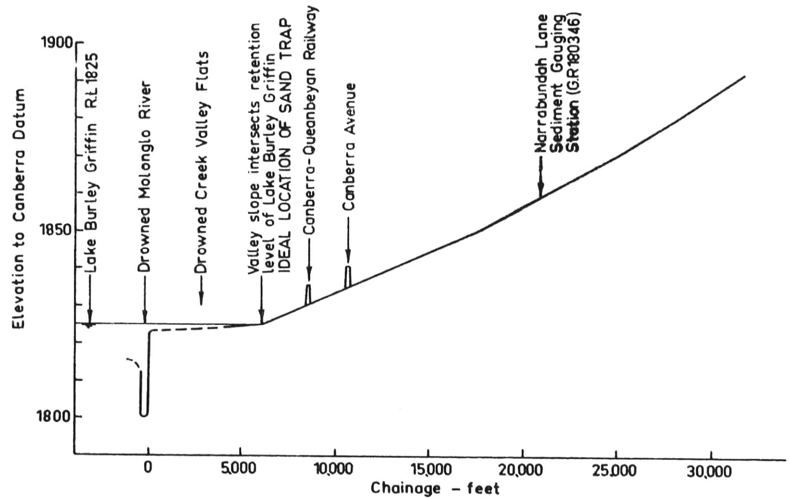


FIGURE 7: CROSS SECTION OF MOLONGLO RIVER AT MOLONGLO SEDIMENT GAUGING STATION (G.R 200376)

CE-C-6932



CROSS SECTION



LONGITUDINAL SECTION OF VALLEY SLOPE

FIGURE 8: JERRABOMBERRA CREEK AT NARRABUNDAH LANE (G.R 180346)

CE-C-6933

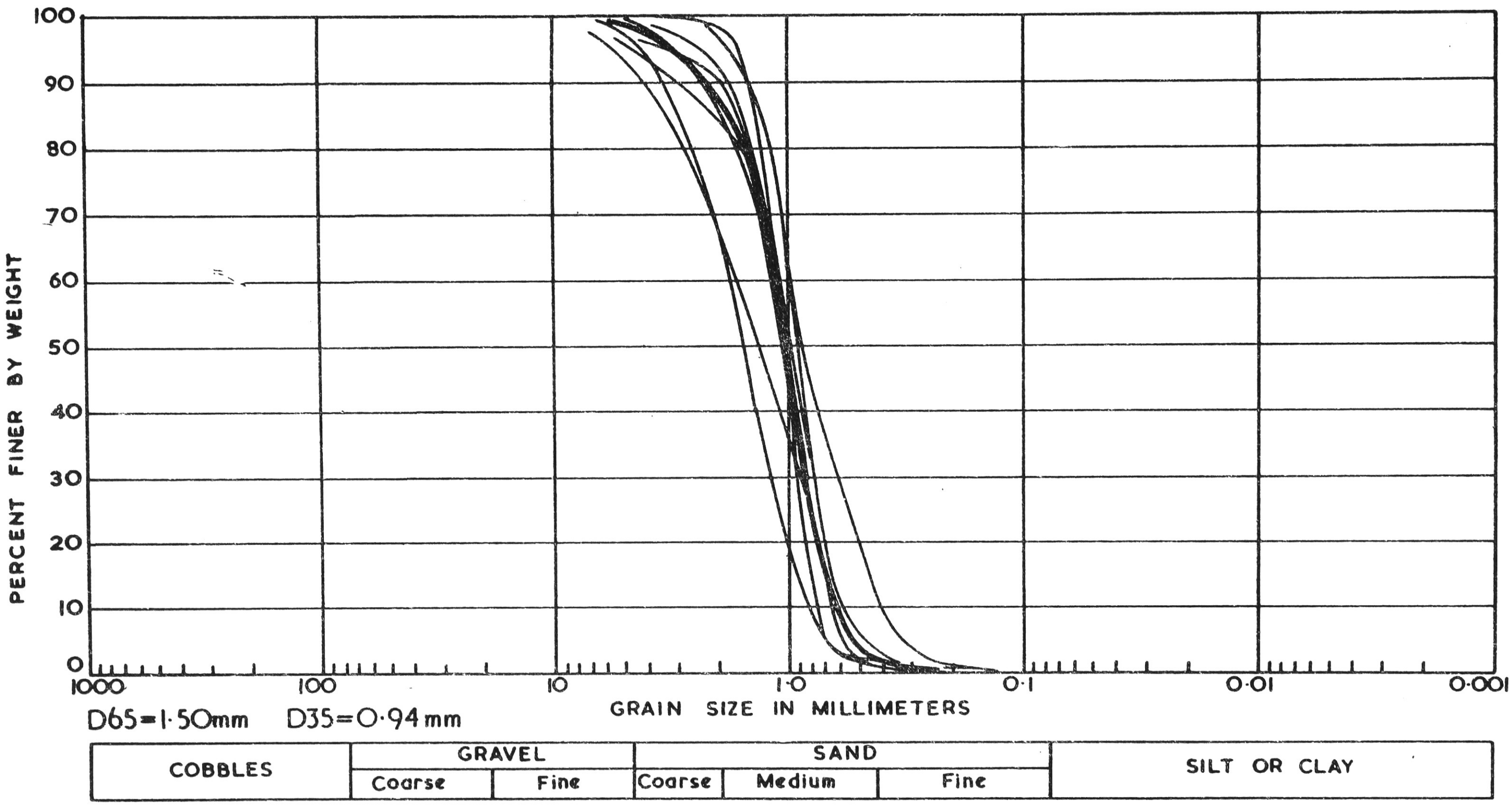


FIGURE 9: QUEANBEYAN RIVER AT GOOGONG (G.R 279251)

BED SEDIMENT COMPOSITE GRADING CURVE

CE-E-6934

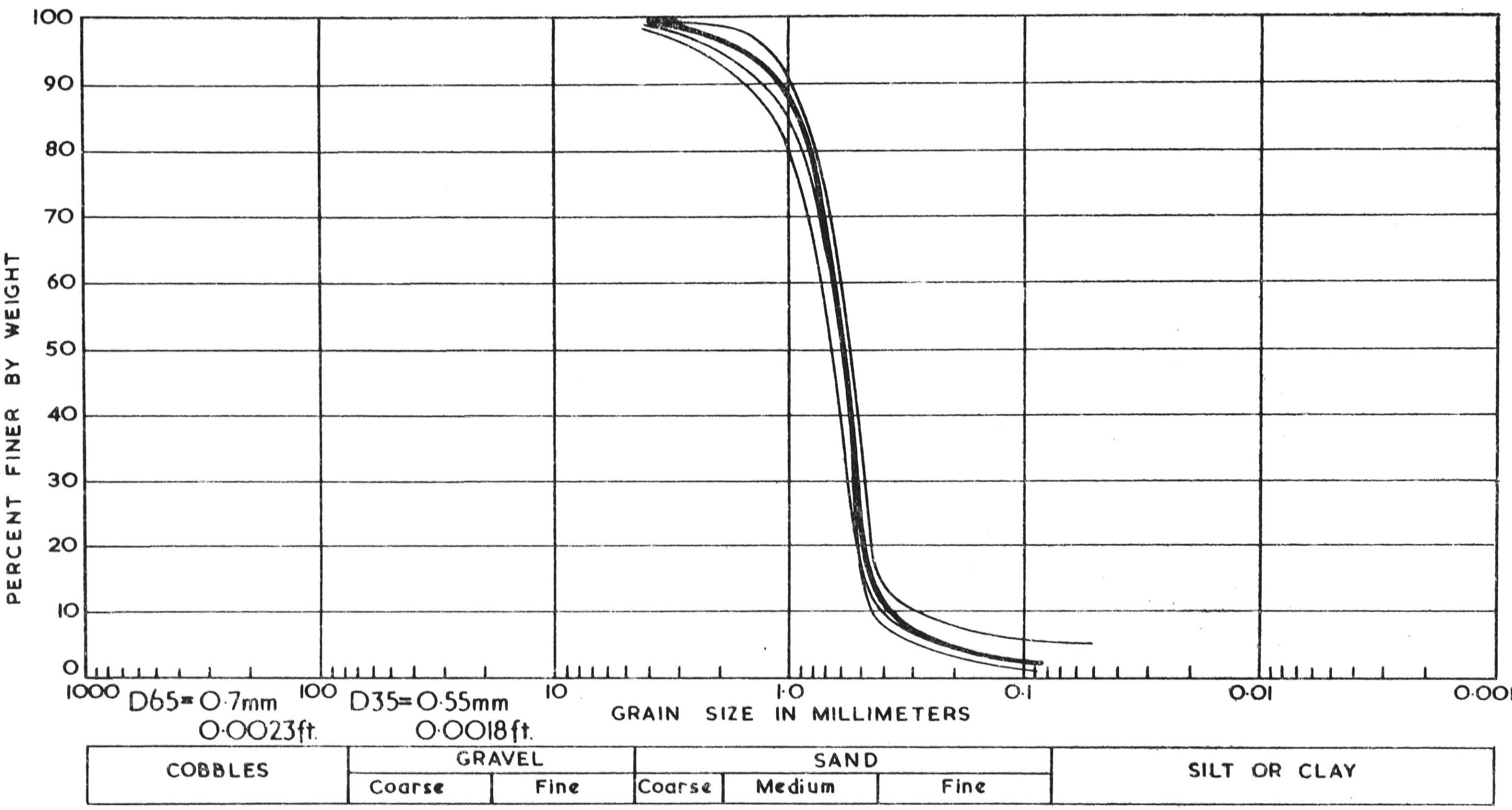
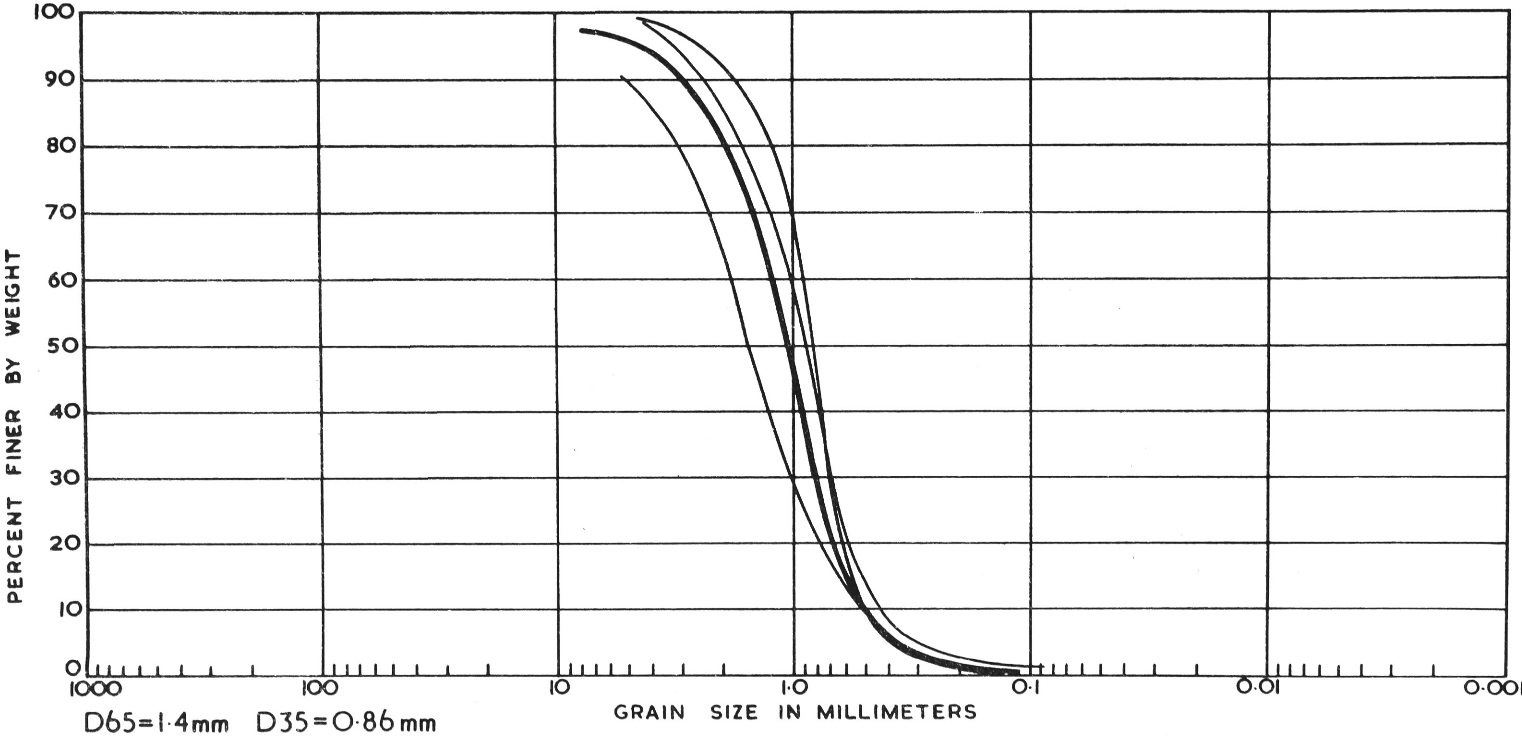


FIGURE 10: MOLONGLO RIVER AT MOLONGLO (G.R 200375)

BED SEDIMENT COMPOSITE GRADING CURVE

CE-E-6935



D65=1·4mm D35=0·86mm

COBBLES	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

FIGURE II: JERRABOMBERRA CREEK - NARRABUNDAH LANE (G.R 180346)

BED SEDIMENT COMPOSITE GRADING CURVE

CE-E-6936

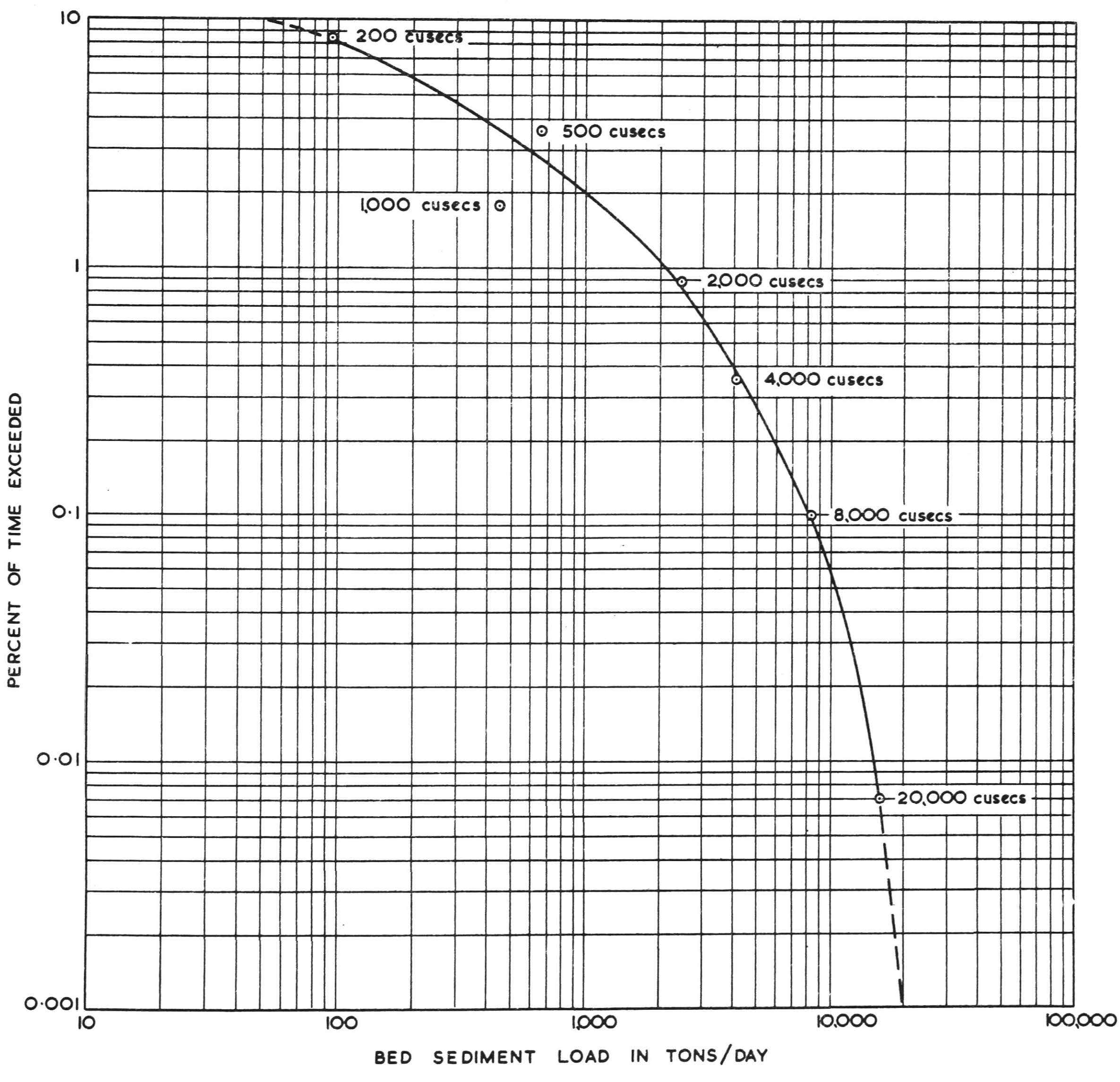


FIGURE 12: TIME EXCEEDED/ BED SEDIMENT CURVE
QUEANBEYAN RIVER AT GOOGONG

CE-D-6938

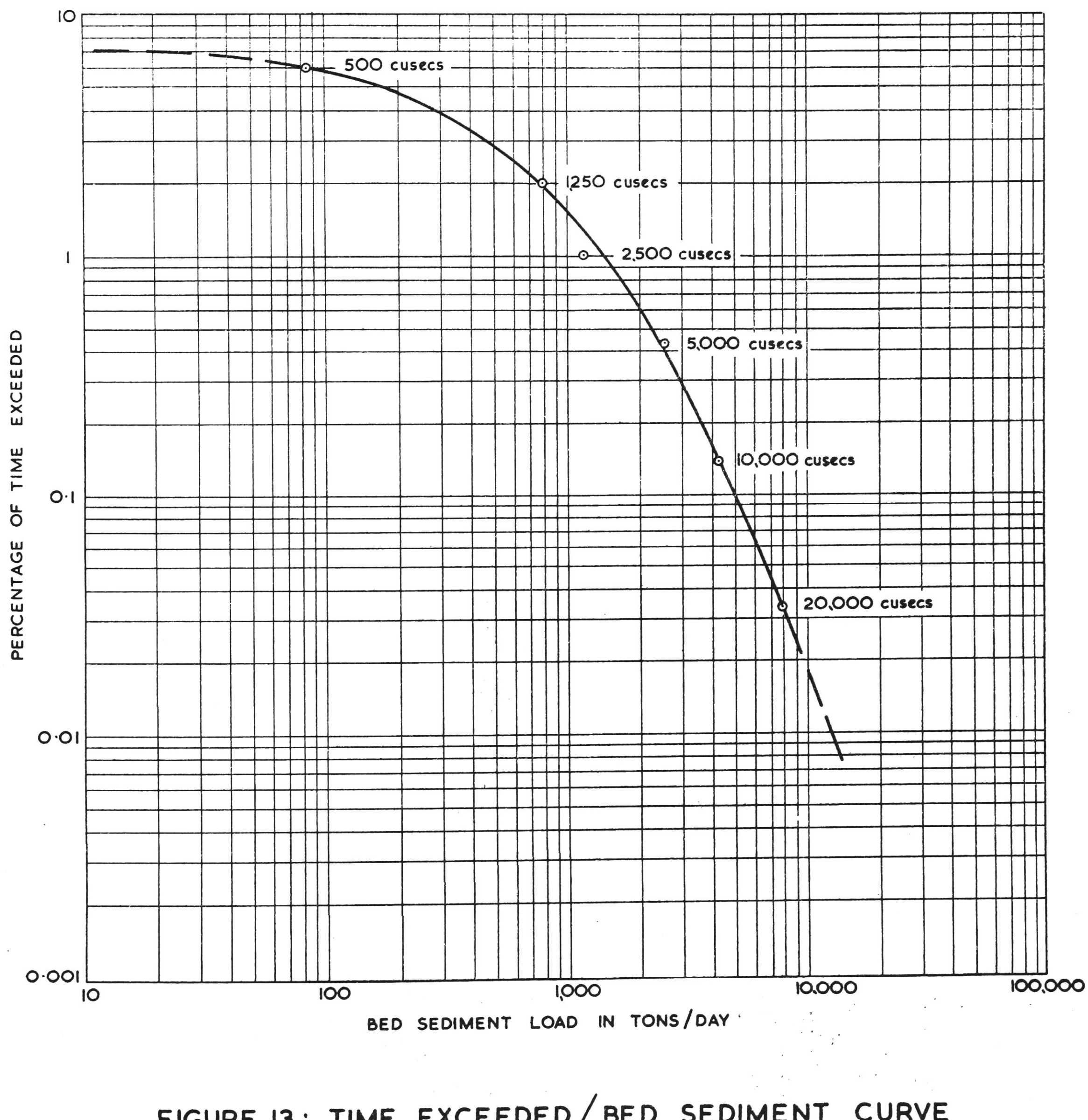


FIGURE 13: TIME EXCEEDED/BED SEDIMENT CURVE
MOLONGLO RIVER AT MOLONGLO

CE-D-6939

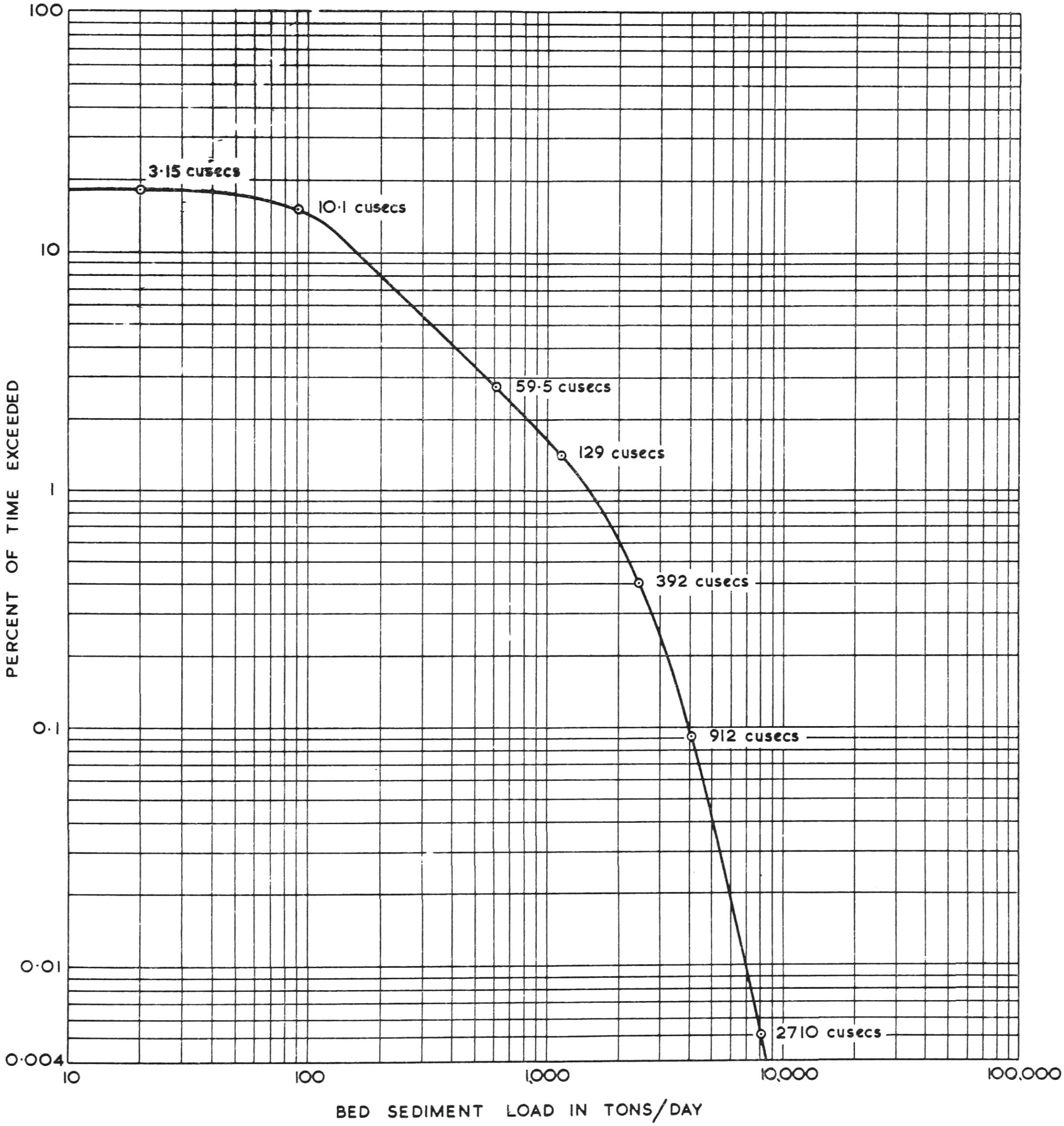


FIGURE 14: TIME EXCEEDED / BED SEDIMENT CURVE

JERRABOMBERRA CREEK AT NARRABUNDAH LANE. G.R 180346

CE-D-6940

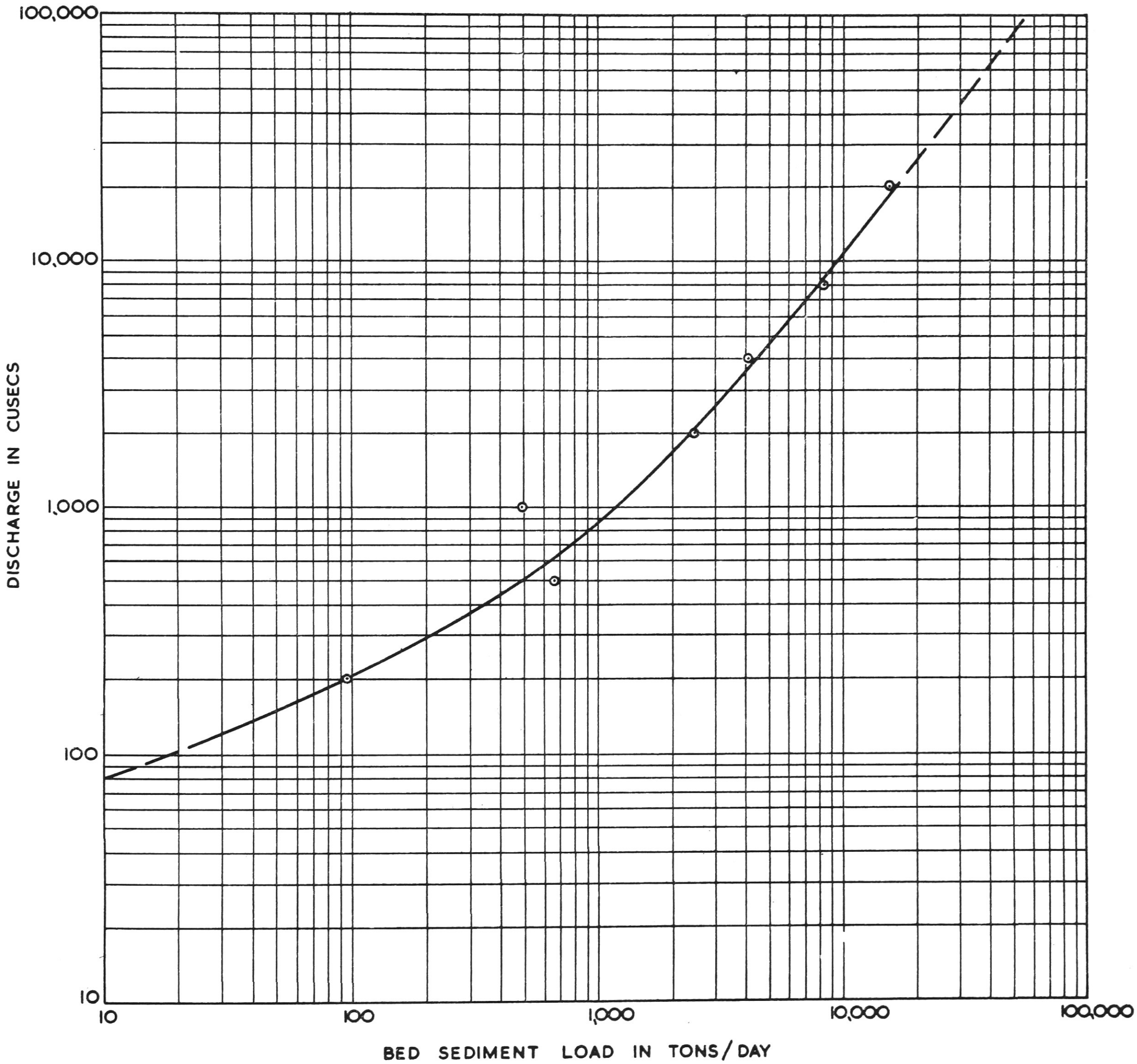


FIGURE 15: BED SEDIMENT RATING CURVE

QUEANBEYAN RIVER AT GOOGONG

CE-D-6941

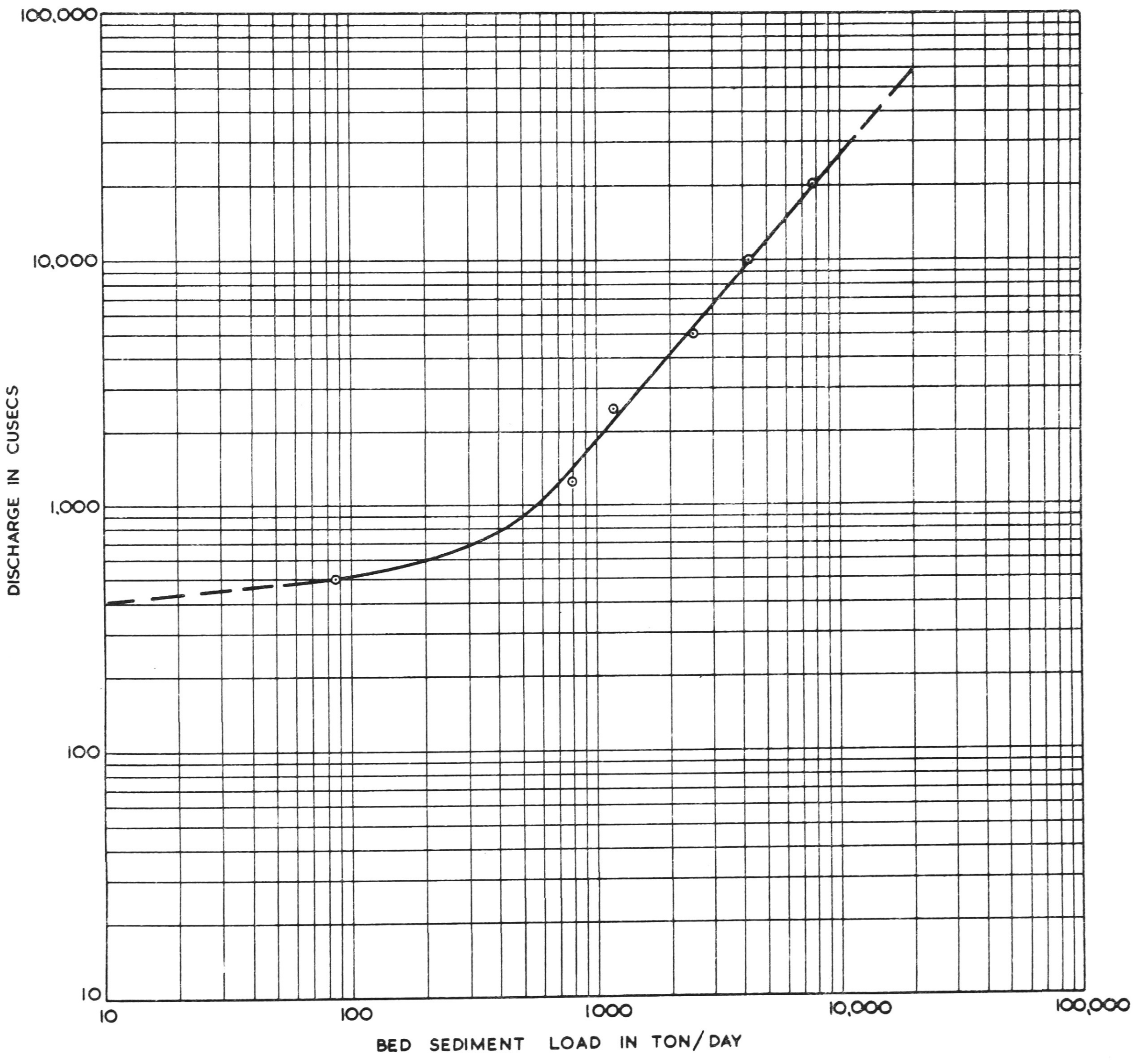


FIGURE 16: BED SEDIMENT RATING CURVE

MOLONGLO RIVER AT MOLONGLO

CE-D-6942

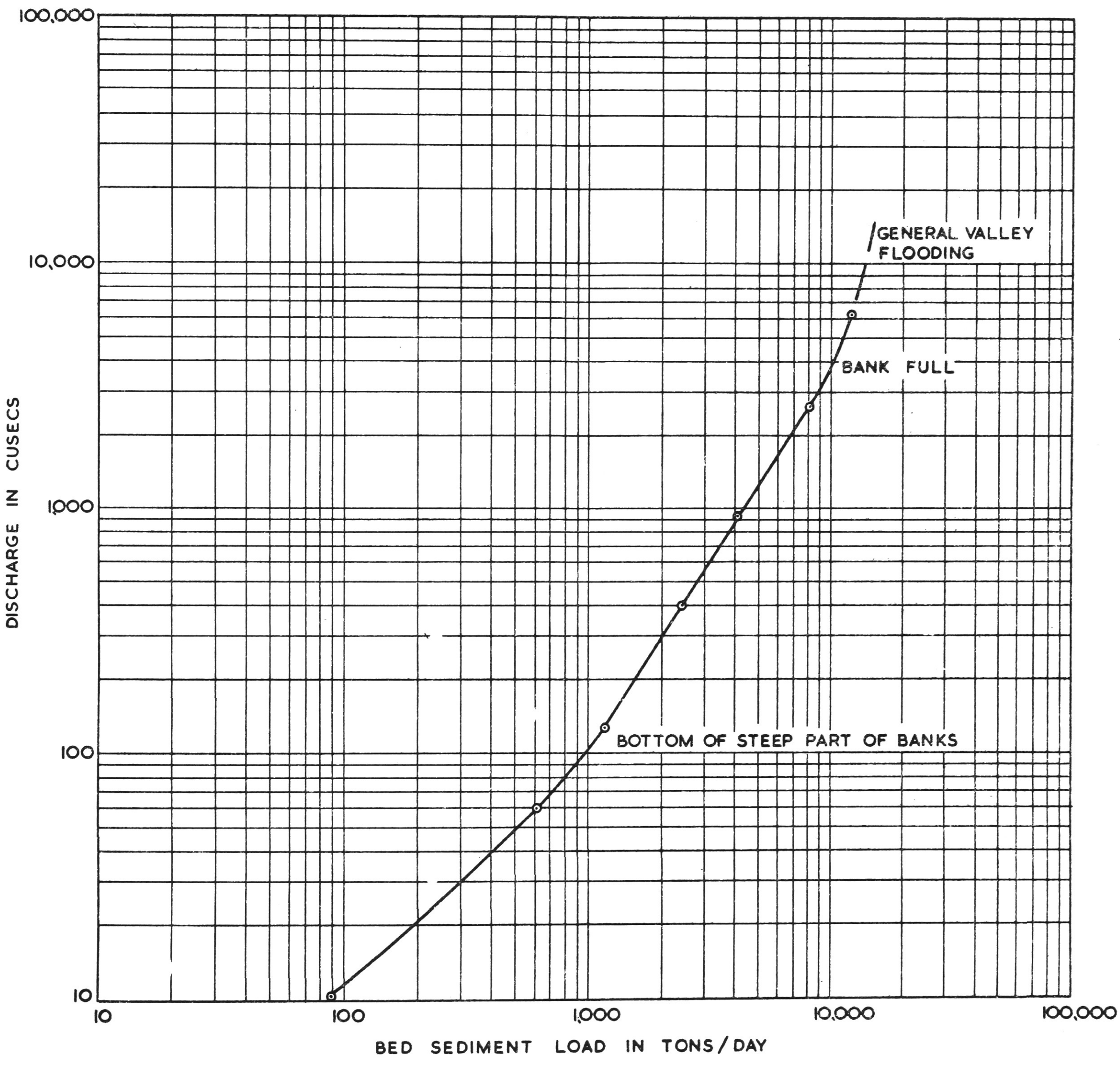


FIGURE 17: BED SEDIMENT RATING CURVE

JERRABOMBERRA CREEK AT NARRABUNDAH LANE. G.R 180346

CE-D-6943

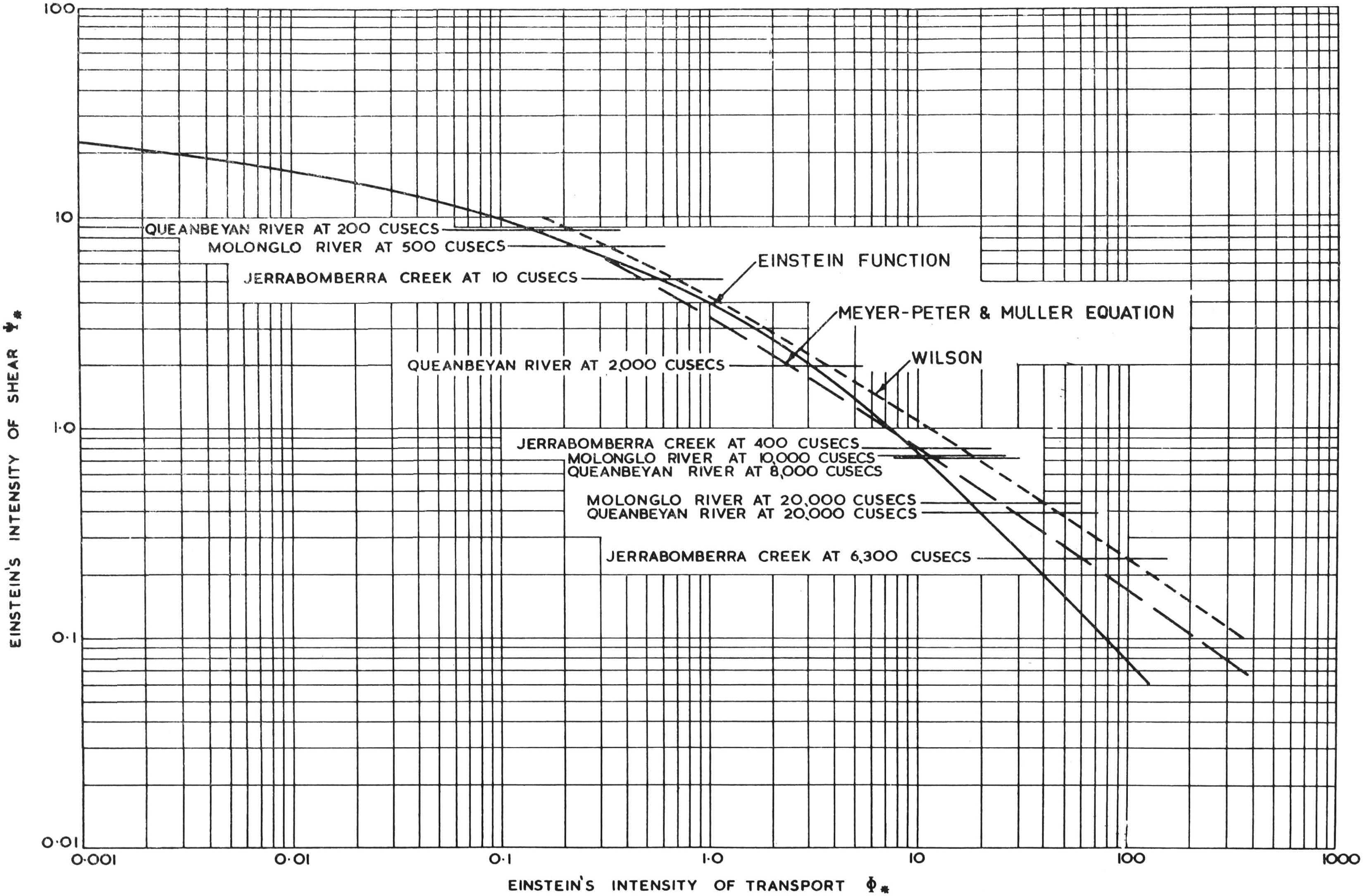


FIGURE 18: EINSTEIN'S INTENSITY OF SHEAR / INTENSITY OF TRANSPORT CURVE

CE-D-6944

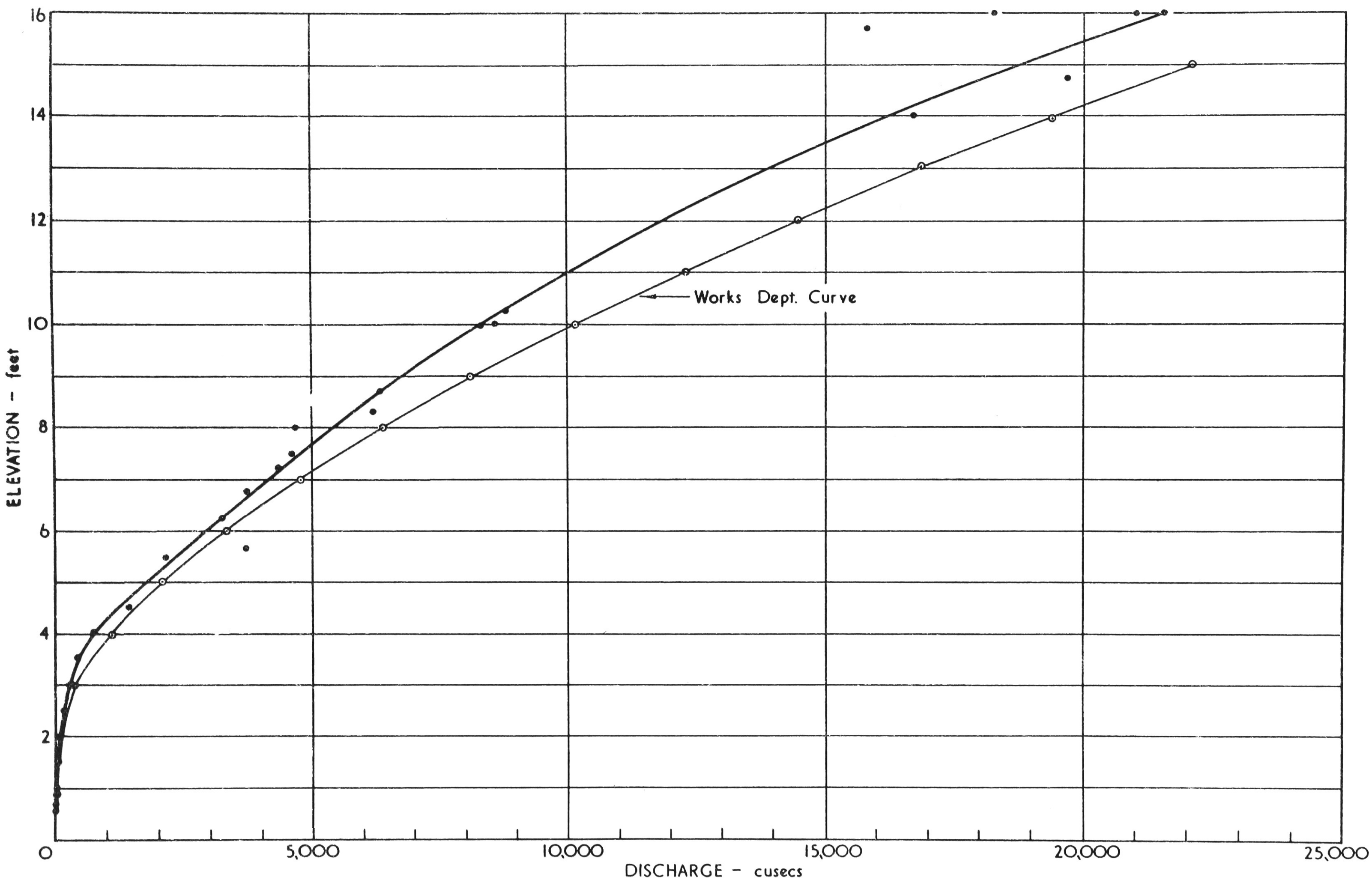


FIGURE 19: QUEANBEYAN RIVER - GOOGONG STAGE-DISCHARGE CURVE (RIVER GAUGING STATION)

CE-E-6945

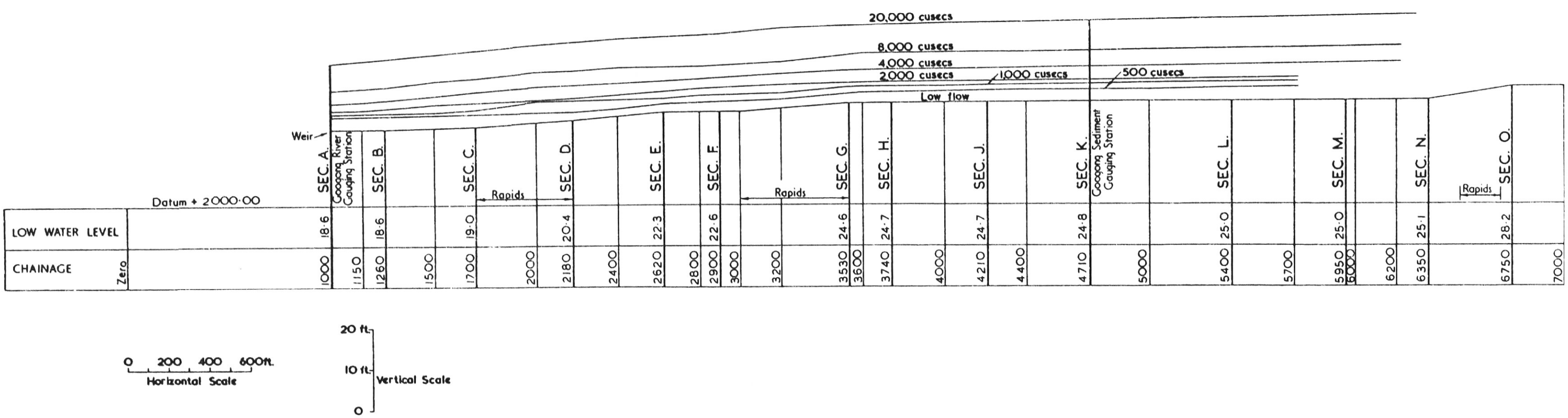


FIGURE 20: LONGITUDINAL SECTION - QUEANBEYAN RIVER AT GOOGONG BETWEEN RIVER AND SEDIMENT GAUGING STATIONS

CE-B-6946

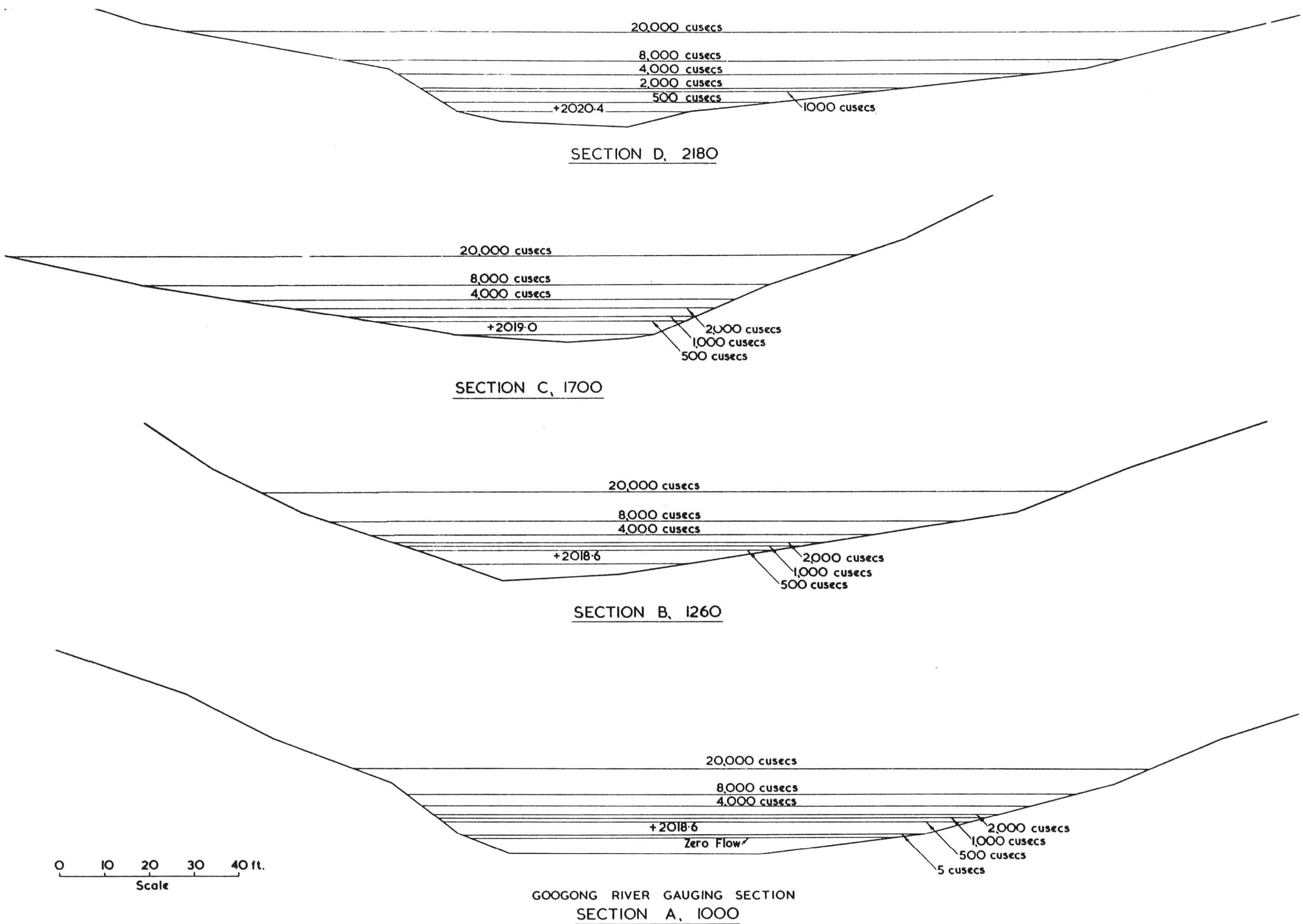


FIGURE 21: CROSS SECTIONS A–D – QUEANBEYAN RIVER AT GOOGONG

CE-B-6947

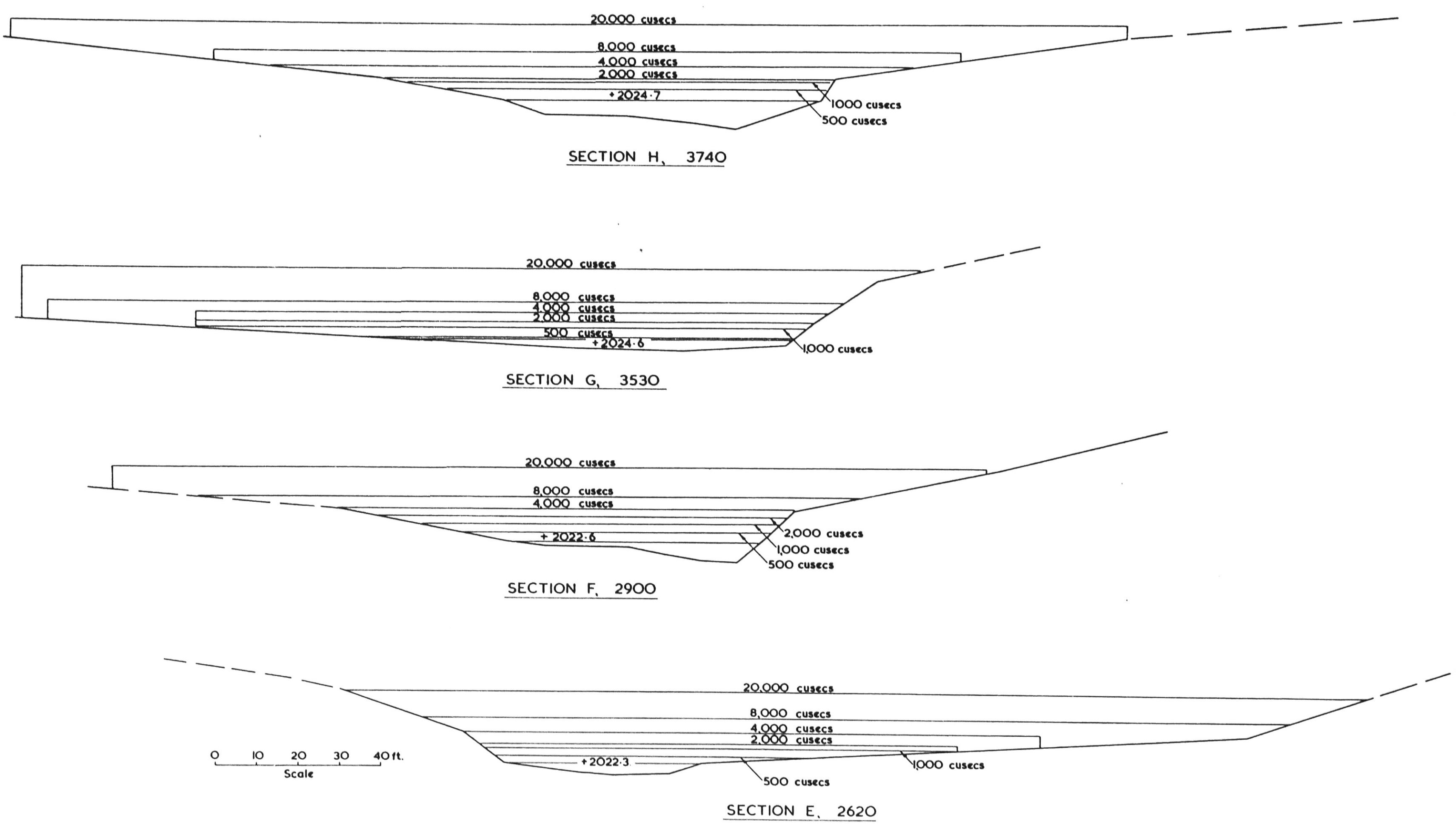


FIGURE 22: CROSS SECTIONS E-H – QUEANBEYAN RIVER AT GOOGONG

CE-B-6948

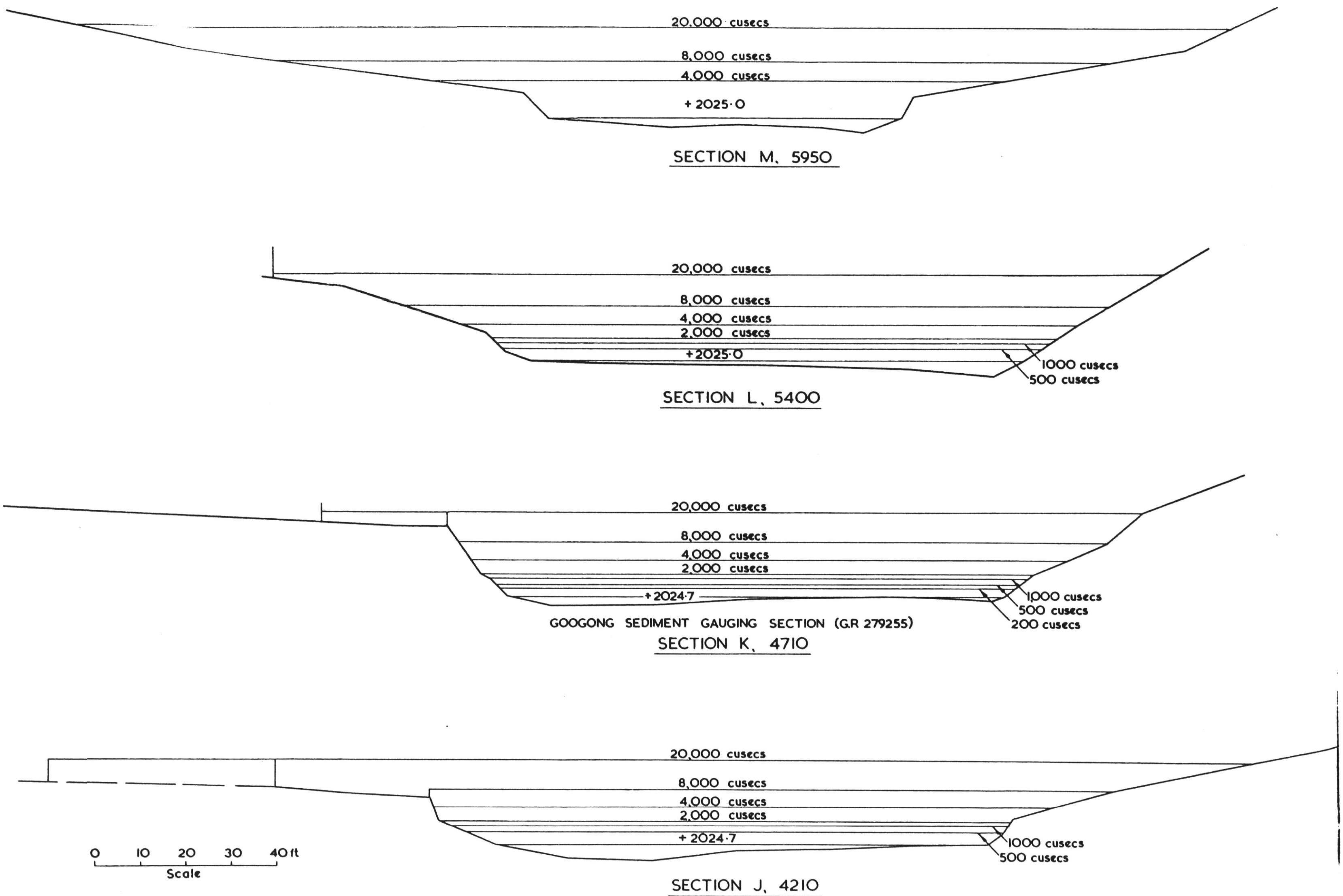


FIGURE 23: CROSS SECTIONS J-M – QUEANBEYAN RIVER AT GOOGONG

CE-B-6949

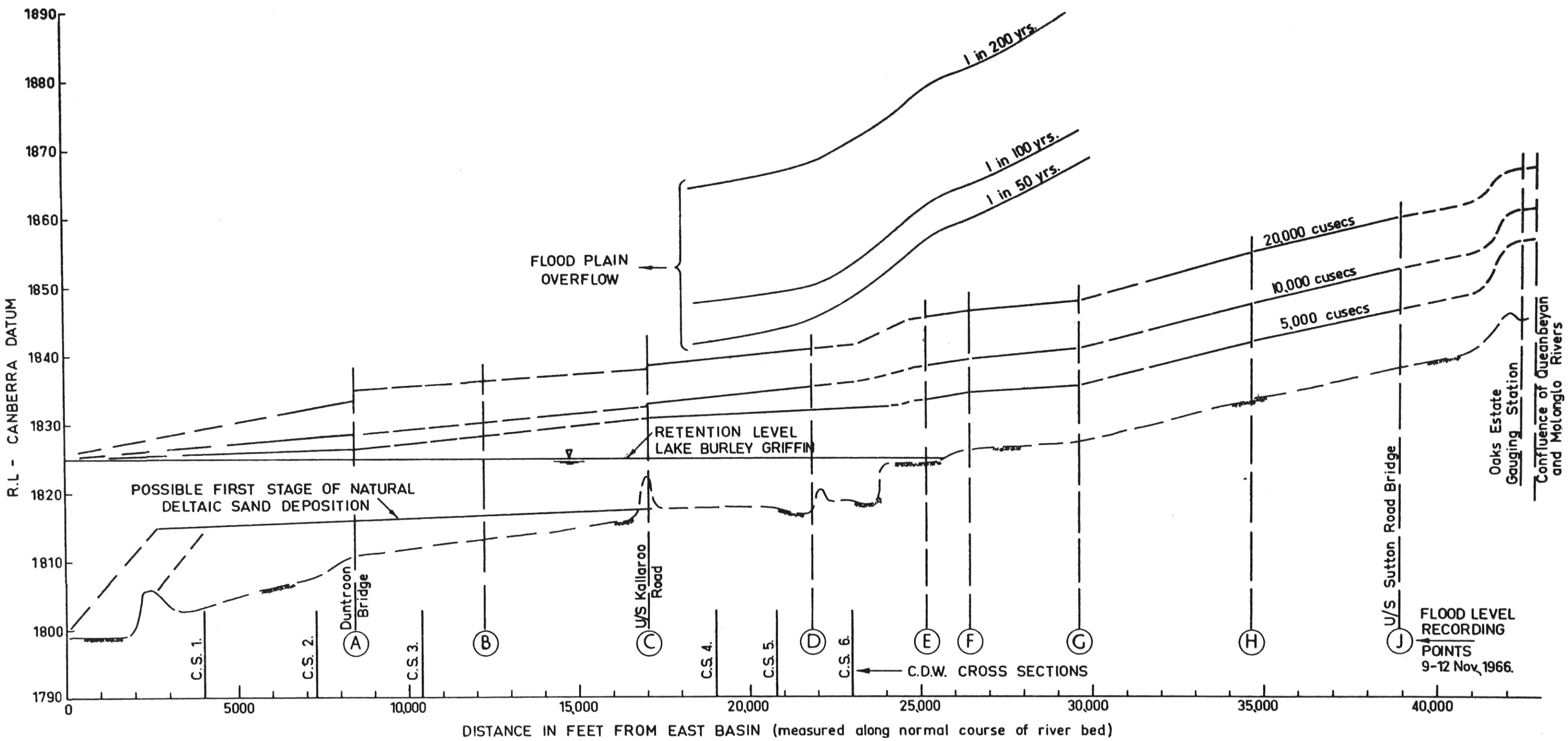


FIGURE 24: LONGITUDINAL SECTION - MOLONGLO RIVER. QUEANBEYAN CONFLUENCE TO CANBERRA

CE- B-6950