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SALINE RIVER DIVERSION STUDIES
TONE AND KENT RIVERS.
GEOLOGICAL INVESTIGATION

by

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ABSTRACT

The possible hydrogeological impact of a diversion structure to transport saline water from the Tone River to the Frankland River has been investigated, together with a preliminary study of the engineering geology aspects associated with its design. A brief study of geological conditions likely to influence the design of a diversion structure from the Kent River has also been made.

The likely effects of three hypothetical conveyance systems - open channel, sealed channel and pipeline, have been discussed. At this stage of the investigation it appears that, in terms of the hydrogeological requirements, a sealed channel or pipeline are the most suitable methods for transporting saline water across wet land country.

A more detailed study is recommended, including drilling and seismic traverses to investigate the hydrogeology and subsurface sediments of the area.

INTRODUCTION

Clearing control legislation imposed upon the Warren and Kent Rivers Water Reserves has led to the proposal that saline headwaters from the Tone and Kent Rivers be diverted to the Frankland River.

The Public Works Department expects that the works will consist of some form of diversion structure and conveyance system, either a pipeline or channel. The Geological Survey was requested to undertake an engineering and hydrogeological appraisal of the region, and to provide assistance with drawing up the terms of reference for an environmental and social investigation, which may be required during the later phases of the project.

PREVIOUS WORK

Application for a coal mining lease for the purpose of peat mining by Cladium Mining Pty Ltd prompted an investigation of the water quality in the Lake Muir area (Hydrogeology Rept 2003). Since April 1977, water samples were collected at three monthly intervals from Byenup, Toordit-Gurrup and Poorginup Lagoons. In order to calculate salt storage in these lagoons, staff gauges were installed in March 1978 and a bathymetric survey is ongoing.

Calculation of salt storage (Na Cl) for Toordit Gurrup and Byenup Lagoons for the period 16.1.79. to 17.1.80. (Fig. 6) suggests that salt storage was increasing in both lagoons until December 1979. However, the storage values obtained for January 1980 are less than those of the previous January. Since the record only covers a twelve month period, it is impossible, at the present time, to make a meaningful comment on the trend of salt storage in these lagoons.

As part of the Saline River Diversion Study, a bore census was carried out towards the end of 1979 and early 1980. This involved visiting farming properties throughout the area to obtain details of bores and wells located on the properties. Water samples were tested for total dissolved solids (TDS) using a Phillips portable conductivity meter, PW 9504/00, and as a check on field salinity measurements, selected samples were submitted to the Government Chemical Laboratories for analysis. Where possible, water from lakes and swamps throughout the area was tested. Where dams intersected groundwater, samples were also collected. However, in many cases, the relationship between the dam and the surrounding groundwater was not always certain. Other field work carried out included an orientation survey and monitoring of the existing staff gauges.

GENERAL DESCRIPTION

The study area is located 60 km east of Manjimup, and covers an area of approximately 1600 km^2 (Fig. 1). The climate of the region is Mediterranean, with an average annual rainfall ranging from 900 mm in the south to 600 mm in the north. Evaporation from the area is in excess of 1000 mm/yr.

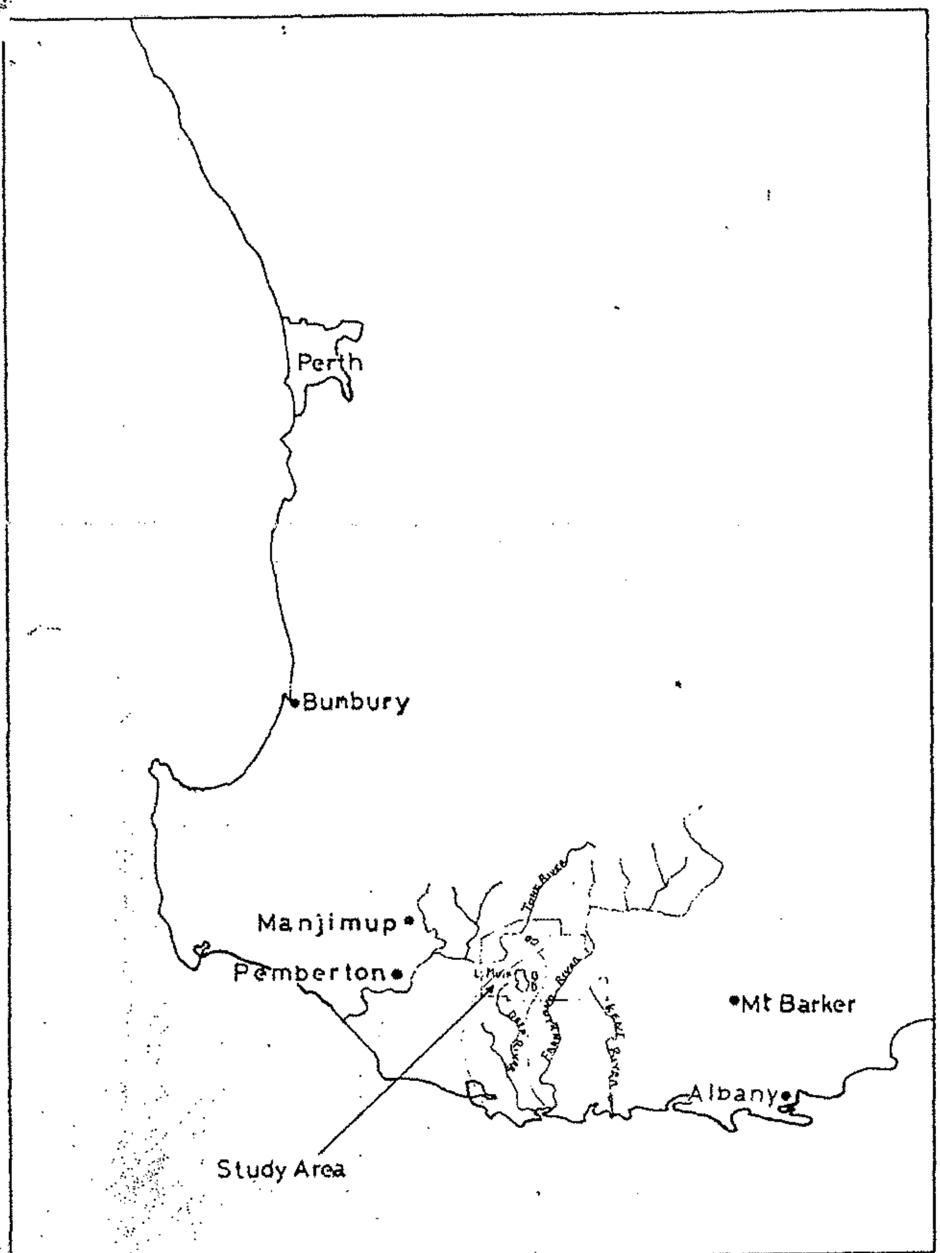
The general land surface slopes gently to the south. Maximum elevation in the north is 300 m, while in the south, elevations rarely exceed 225 m. The study area can be subdivided into two broad physiographical units; the undulating plains of the central zone, and the flanking incised country (Fig. 2). With the exception of the Noobijup Lake, the lake and swamp system is contained within the first physiographical unit. However, minor swamps and seeps occur within the second unit.

Jarrah forest borders much of the country to the south and west of the area. This vegetation type grades into Jarrah low forest, Marri Wandoo woodland and Paperbark woodland toward the east. Much of the remaining area has been cleared for agricultural purposes, mainly grazing of cattle and sheep, and dryland cropping. Pockets of natural vegetation occur within the central zone, particularly on steeper slopes and areas subject to inundation. With the exception of conservation reserves and isolated uncleared blocks; the farmland extends to the eastern boundary of the study area.

GEOLOGY

Precambrian granite, granitic gneiss and migmatite of the Albany-Frazer Province represent the basement material underlying the study area. Outcrops of these rocks are confined to the incised valleys of the drainage system.

Mapping of the Cainozoic deposits was carried out by the



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date
Comp	MWM	27/2/80
Drawn	MWM	27/2/80
Chkd		
Apvd		

Fig.1 Study Area

1:2,500,000

To accompany HYD. REPT. No 2110 M MARTIN

Map Index

GSWA 18520

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Geological Survey as part of the Pemberton 1:250 000 geology sheet compilation (Wilde, in press) (Fig. 3, 1-4).

Deposits of conglomerate, sand and clay (Tg) of possible alluvial origin, occur in isolated pockets throughout the area. The more important of these sediments occur along the Tone River, and in a fairly extensive deposit about 1 km east of Poorginup swamp. Although the subsurface extent of this unit is unknown, these deposits may be quite thick, (Wilde, pers. comm., 1980), and may play an important role in the hydrogeology of the area.

Laterite (Czl) occurs throughout the area as isolated inliers and as a capping for the hills and ridges. The profiles associated with this unit can be expected to conform with laterites found throughout the Darling Range. North of Rocky Gully, the laterite profile may be as much as 60 m thick. However, south of Lake Muir, the laterite forms a thin veneer over fresh granite, with little or no clays or grits (Wilde, pers. comm., 1980). In places, the laterite may be overlain by a veneer of (eolian?) sand (Czs) derived from the ancient drainages channels. These sands may grade into colluvial sand or alluvium.

Sandy alluvium (Cza) and a slightly higher lateritized surface (Czat) occupy much of the broad irregular valleys within the study area. The laterite terrace forms a capping over sand, and both Cza and Czat have been considered as one hydrogeological unit. The valleys may be traversed by low dunes, and may represent an earlier Tertiary drainage system.

Colluvial deposits (Qrc) and sandy colluvium (Qrcs), derived from reworked Tertiary sand, tend to occur as valley infill deposits. Swamp and lacustrine deposits (Qrw) are associated with the present drainage system. Recent alluvial material (Qra) occupies the modern drainage systems.

HYDROGEOLOGY

DESCRIPTION

The hydrogeology of the area has been assessed using salinity data collected from the swamps and lakes of the area, and by appraisal of 1:20 000 topographic maps contoured at 5 m intervals. A bore census was carried out toward the end of 1979 and in early 1980. However, the wells located were concentrated along the Tone and Frankland Rivers and in an area around Rocky Gully. Hence the data collected cannot be considered as representative of the hydrogeology over the whole area.

The lakes and swamps throughout the area represent the shallow unconfined water table. Staff gauges have been installed and levelled on the larger and more permanent water bodies by officers of the PWD (Fig. 4). Data collected from these sites are contained in Table 1. In general, the shallow water table follows the topography of the area. It should be noted that some of the swamps and lakes are located on the surface water divides.

The topography of the area suggests that the country between the Tone and Frankland Rivers represents an enclosed basin. However, because of low relief in some areas, and the nature of the sediments, it is likely that drainage from the area occurs via underground flow. Areas where underground flow from the basin may be occurring are delineated on Figure 4. Cross sections through the two main lake systems, Lake Muir (AA^1) and Lake Unicup (BB^1), have been constructed (Fig. 5). Probable water table levels have been indicated. It should be noted that the subsurface distribution of sediments is poorly known, and the indicated water table may be altered as more information becomes available.

Salinity data collected during the bore census have been used as a guide to groundwater flow directions, with the direction of flow being toward the increasing salinity. Several factors influence the distribution of salinity in wetland country. In this case, the more important factors appear to be the size of individual catchments, and the nature of the vegetation contained within those catchments. The size of catchment will determine the volume of surface water entering a lake, and hence the quantity of salt added to the lake. Subsequent evaporation from the water surface, and concentration of salts, will be determined by the surface extent of the water body. Where vegetated areas exist around a catchment, the groundwater tends to be fresher than that found in cleared catchments. This is a reflection of the trend found within catchments throughout the Darling Range.

DISCUSSION

The salinity data suggest that the Lake Unicup system and the Lake Muir system is unconnected. Evidence for this is the low salinity (4100 mg/L) measured at Buranganup swamp, which lies between the two systems. The maximum salinity in the Lake Unicup system was 26 000 mg/L, while on the Lake Muir system, maximum salinity was 6900 mg/L (Fig. 4, Table 2). The southerly slope of the surface precludes the suggestion that groundwater flow is northwards. However, Buranganup swamp is contained within forest country, and this may account for the lower salinities. Groundwater to the east or below this swamp may be found to be saline.

Two bores located west of the Lake Unicup system had salinities of 270 mg/L and 340 mg/L respectively. This suggests that saline water from the lakes may be contained within a deeper aquifer in this area. An alternate suggestion is that beds beneath the lake act as an aquiclude, and the lake represents a sump for the Lake Unicup drainage system.

A similar situation to this may occur for the Lake Muir system. The low salinity (2200 mg/L) water measured in Lake Muir during the census is thought to be caused by a recent draining of Red Lake and Cowerup swamp rather than by the persistence of a relatively fresh water body in Lake Muir. In the southwest corner of Lake Muir, a swamp occupies the divide between the lake and the Deep River drainage system. As the salinity of this swamp is low (400 mg/L), this may represent a perched water table and deeper underground flow may be entering the Deep River drainage system.

To the east of Poorginup swamp, a large body of Tertiary alluvium (Tg) exists. Depending upon the nature and distribution of these sediments, drainage to the Frankland River from the Lake Muir system may be occurring via this unit.

Between the Kent and Frankland Rivers, groundwater salinities ranged from 330 mg/L and 9700 mg/L. However, there appears to be no systematic varieties of salinity with bore depth or position in the landscape. It is suggested that this variation is the result of land clearing and salinization of the water table in isolated areas.

HYDROGEOLOGICAL EFFECTS OF CONVEYANCE SYSTEMS

If clearing restrictions were lifted in areas upstream of a diversion structure on the Tone River, the maximum predicted salinity of diversion water would be 20 000-25 000 mg/L (Loh pers. comm. 1980). The duration of flow for this salinity level is expected to be 1-2 weeks. Although the predicted stream salinities are less than the maximum measured salinity in the study area, they are in excess of most groundwater salinities as indicated by lake and swamp samples.

In order to discuss the effect of various types of conveyance structures, two hypothetical situations must be considered. The first is one where a drain is constructed above the water table, and the second considers a drain which penetrates below the water table (Figs 7, 8).

Case 1.1 Unsealed drain above the water table

Because of the nature of the sediments in the area, especially the more flat lying country, an unsealed drain can be assumed to lose a proportion of its water over a traverse. Because of the high salinity of the discharge water, this would be unacceptable.

A second influence this type of structure may have is to cause a rise in the water table around the drain. This would subject larger areas to evaporation and secondary salinization, and may also induce a greater flow of groundwater into the Tone River below the diversion structure. Hence Case 1.1 is undesirable in hydrogeological terms as it may tend to defeat the purpose of the exercise.

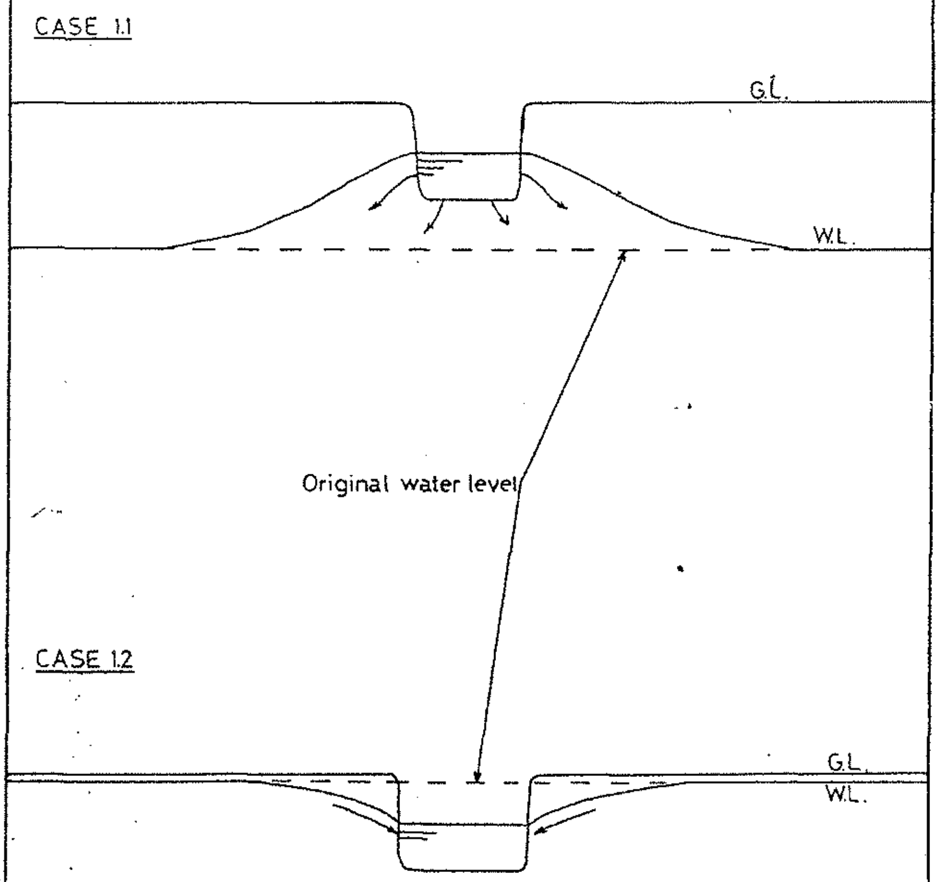
Case 1.2 Unsealed drain penetrating below the water table

Although some saline dispersion from the drain may occur in this situation, if adequate gradients are maintained along the drain, it is unlikely that serious deterioration of the surrounding groundwater will occur.

However, Case 1.2 may result in a general lowering of the water table around the drain. While this may be desirable in terms of land reclamation, it may have a significant impact upon the ecology of the area. This proposal should be investigated more fully before any recommendations are made.

Case 2.1 Sealed drain above the water table

This system is unlikely to have a great impact on the



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Fig.7 Unsealed drain, cases 1.1 & 1.2

	Initial	Date
Comp	MWH	
Drawn	MWH	4/3/80
Chkd		
Apvd		

To accompany Hydro. Rept. No. 2110 M. Martin.

Map Index

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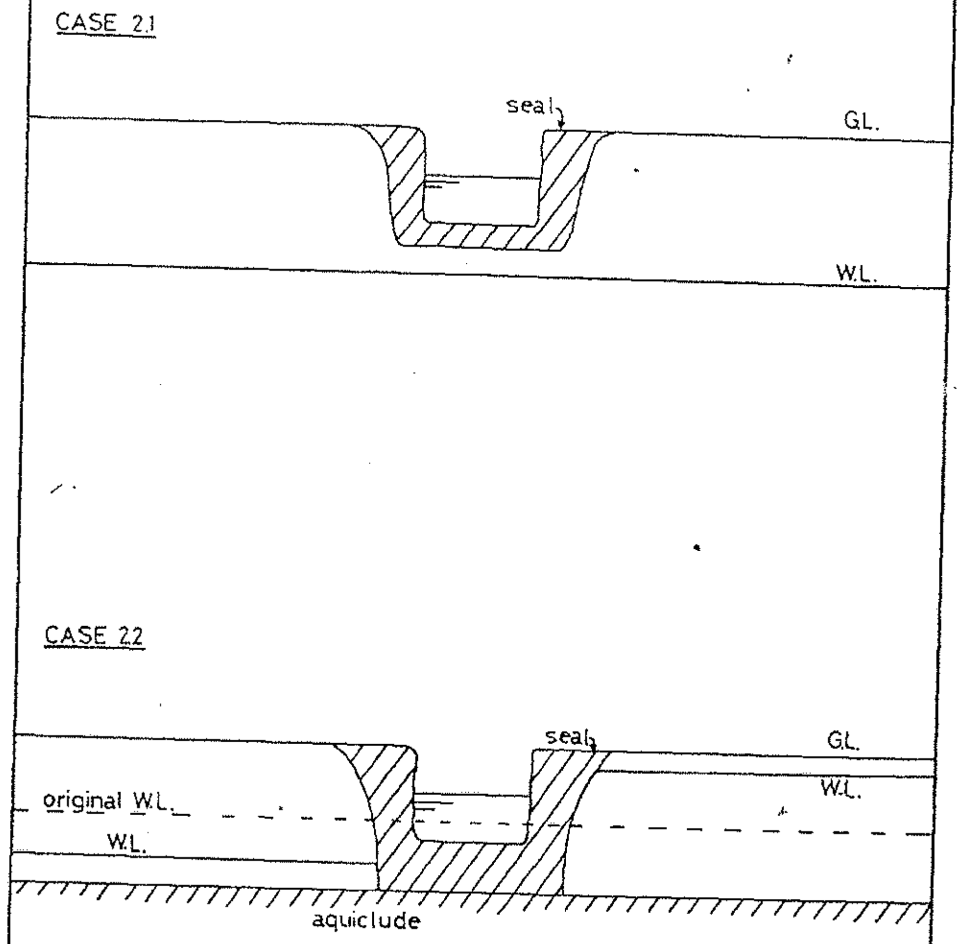

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date
Comp	MWM	
Drawn	MWM	4/7/80
Chkd		
Apvd		

Fig. 8 Sealed drain, cases 2.1 & 2.2

To accompany HYDRO. REPT. No 2110 M. MARTIN.

Map Index

GSWA 18527

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hydrogeology of the area provided efficient sealers are used. Failure of seals would result in a situation as described in Case 1.1. Observation wells would be required along the length of such a construction to enable monitoring for leakage from the channel.

Case 2.2 Sealed drain below the water table

The main consideration with this type of structure would be the disturbance of groundwater throughflow. If the drain was constructed such that adequate throughflow was maintained, the structure would have little effect on the hydrogeology of the area. If, however, the drain penetrated to an aquiclude (Fig. 8), and circumscribed a groundwater isopotential, impounding of upgradient groundwater and reduced recharge below the structure may occur. To prevent a rise in upslope water levels, it may be necessary to install inlets along the drain. The effect of reduced recharge would mainly be an ecological one, as discussed in Case 1.2. The long term effect of such a situation cannot be assessed until more information is available.

Case 3 Pipeline

This situation would pose no serious threat to the hydrogeology of the region between the Tone and Frankland Rivers.

It should be noted that the cases discussed above deal only with the situation of an unconfined aquifer. For Cases 1.2 and 2.2, if a confined aquifer was penetrated, it would seem that the feasibility of such a structure would be limited by the potentiometric head of the confined aquifer.

SUMMARY

In general, the groundwater salinities measured for the area between the Tone and Frankland Rivers are less than the predicted post clearing maximum salinity of diversion water from the Tone River. Ecological and hydrogeological considerations suggest that transportation of saline water to this area is undesirable.

The area between the Kent and Frankland Rivers is dominated by surface or near surface basement material, which may be the main control for that hydrogeological regime. The possible effects of saline water introduced to this area is likely to be a localized one.

To ensure the safeguarding of the hydrogeological environment of the study area, the most desirable conveyance system for saline water would be a pipeline. However, a sealed drain system may be adequate, provided the situations discussed under Cases 2.1 and 2.2 are accounted for in the construction of such a structure.

ENGINEERING GEOLOGY
TONE-FRANKLAND AREA, ENGINEERING SOILS

For the purposes of this study, the geological units described above have been used as the basis for a more general grouping of soil types. Five geotechnical units are recognized (Fig. 9).

Sandy soils

The most extensive group is that of the sandy soils. This unit includes the sandy alluvium, both lateritized and unlateritized (Czat, Cza), the sand deposits overlying laterite (Czs), sandy colluvium (Qrcs), and Tertiary and Recent alluvium (Tg, Qra). All of these deposits were found in the field to be dominated by white to light grey generally clean medium grained sub-angular to sub-rounded sand. There is evidence to suggest that the fines content of some of the sands (particularly the Cza unit) may increase with depth, but it is thought likely that permeabilities will remain moderate to high. The cohesive properties of the lower sand layers will proably allow a more stable excavation than will be possible in the near-surface material.

Laterite

This material generally occurs at higher elevation than the sandy soils. In the area of interest it is usually seen to be a gravelly pisolite, although indurated and cemented laterite is also present. It is likely that the in situ permeability of this material will be high, and its excavation characteristics will be variable.

Swamp or standing water

Swamps and standing water are usually found at lower elevations than the sandy soil. They are associated with recent alluvial deposits which vary from uncohesive sands to plastic clays and organic peats. These various materials have all suffered little or no consolidation, and consequently the uncohesive soils can be expected to be loose and the cohesive soils will be soft and compressible.

Clayey soils

These would perhaps be better described as loamy soils and consist of the colluvium which is usually a valley infill deposit. The permeability of these soils is probably significantly less than that of most other soils in the area. It is unlikely that the colluvium will have consistent material properties throughout the area of interest, and variability can be expected both laterally and vertically over relatively short distances.

Near surface rock

This unit defines areas where outcrop is present, and, more commonly, where in situ weathered material is seen at the surface. Outcrop is in fact almost totally restricted to the major water courses and fresh rock, for much of the area covered by this unit, would probably only be found beneath a variable cover of weathering products of the bedrock. Such products can be expected to have geotechnical properties most closely resembling those of the clayey soils or colluvium.

TONE RIVER, DAM SITES

A reconnaissance of possible dam sites on the Tone River (Fig. 10), Locations 1-7, was made on 19th and 20th November, 1979. The area of Locations 1-4 (Fig. 11) can be reached via Talling Road and a vehicular track that approaches the area from the east. The area of Locations 5-7 (Fig. 11) can be reached via Roo and Leafminer Roads and then a vehicular track that approaches the area from the north.

Location 1 (PWD Site 1)

This location was approached from the vehicular track to its north across an area covered by grey sandy and silty soil with scattered fragments of granitic rock and laterite.

At Location 1, granitic rocks crop out in the bed and on the steep banks of the Tone River. The rocks are medium to coarse grained with some pegmatitic phases and foliation in part. The foliation, which is contorted in some places, has a general north-south strike. Prominent joints spaced 0.4-3 m apart and of 3-5 m extent, strike 015° and dip 70°E. Straight sections of the Tone River both up and down stream of Location 1 are parallel to the strike of this prominent joint set. Another joint set, not as well developed as the prominent set, strikes at 95° and dips 80°S. Sheet joints subparallel to the ground surface were noted.

For 150 m upstream there are abundant outcrops on both banks. Beyond this for about 40 m there is less rock. At

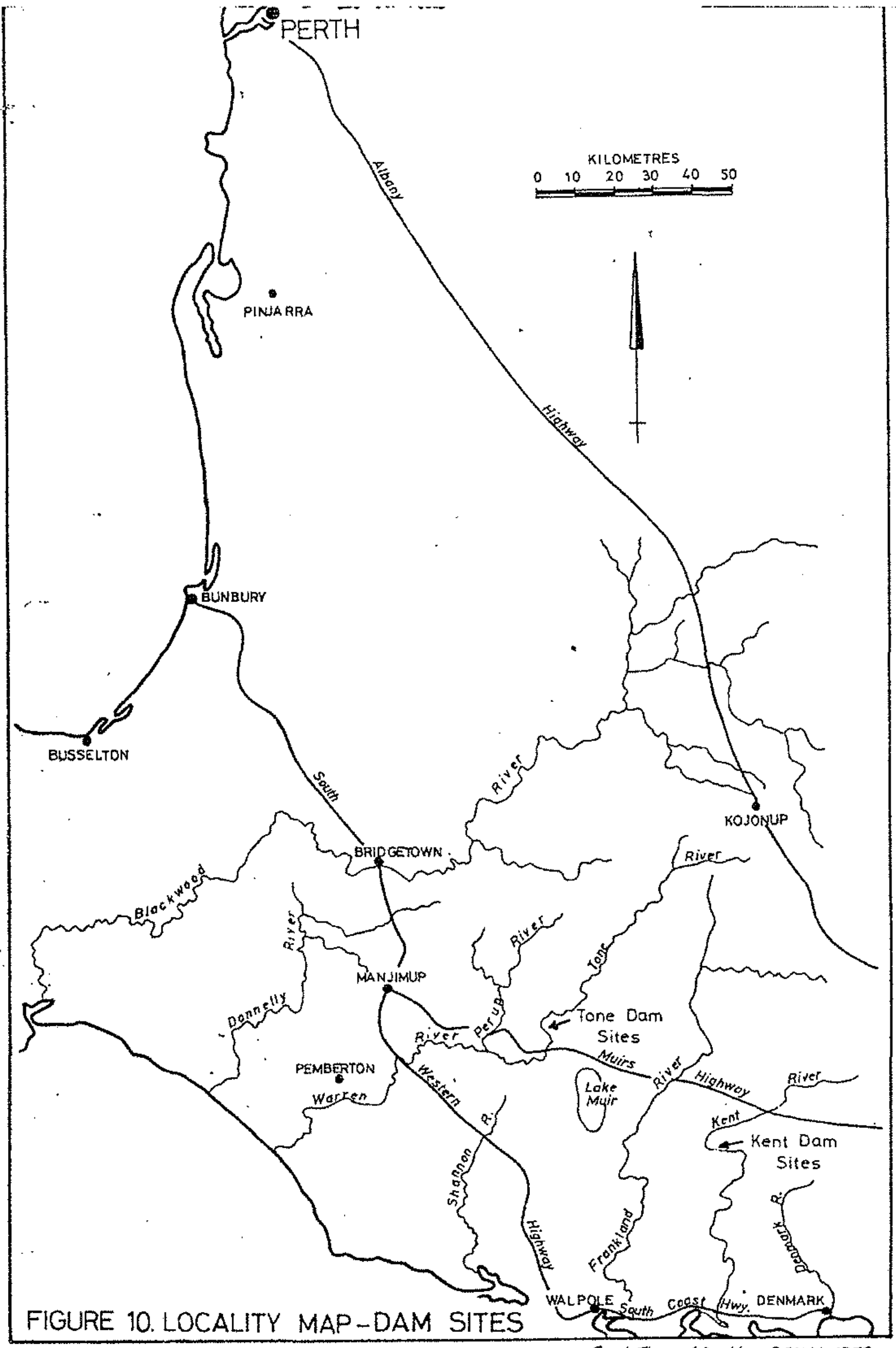

FIGURE 10. LOCALITY MAP-DAM SITES

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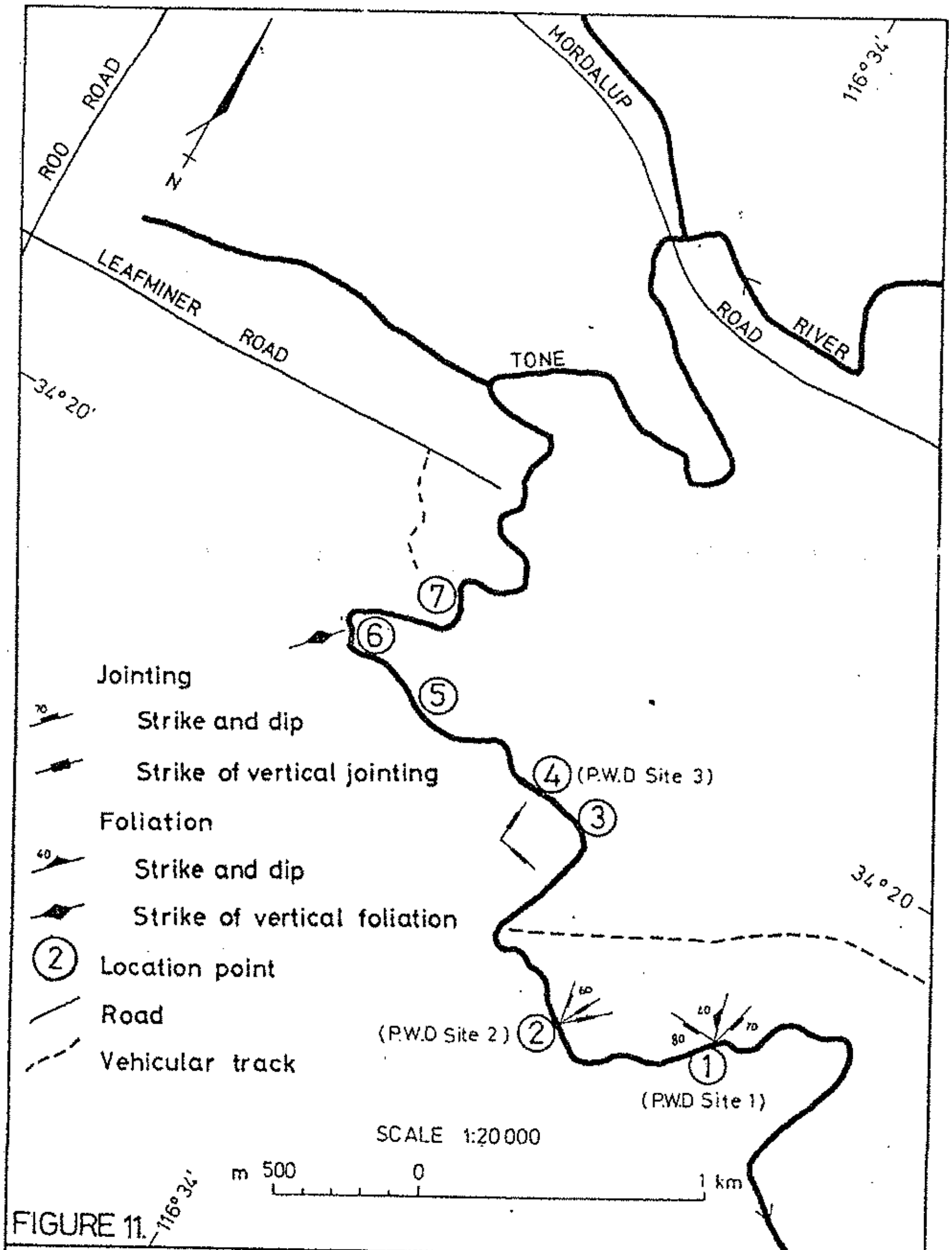

FIGURE 11.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date		
Comp	RPM	12/79	SALINE RIVER DIVERSION	Map Index
Drawn	JYZ	12/79	TONE RIVER DAM SITES	
Chkd			GEOLOGICAL RECONNAISSANCE	SI/50-10
Apvd			To accompany Report to P.W.D. March 1980	GSWA 18530

81712/12/78 2,250-R72

a point about 190 m upstream from Location 1, the left bank is steep and rocky again but the right bank is flatter and little rock is visible from the left bank. Rock continues upstream on the left bank for at least another 60 m.

Location 2 (PWD Site 2)

At this location there are scattered outcrops of granitic rocks on both banks but good continuous outcrops in the river bed. The rock type is similar to Location 1. Prominent steep joints spaced 0.3-3 m apart and of 10 m extent, strike 045°. There are other steep joints that strike 030°.

Sheet joints subparallel to the ground surface were noted.

Location 3

Here the river is barred by granitic rocks and prominent outcrops occur on the right bank. However, the left bank is flatter and no rock was noted. The area is relatively unattractive as a dam site at this stage because of the geology and topography of the left bank.

Location 4 (PWD Site 3)

At this location, scattered outcrops of granitic rocks occur on the right bank from within 30 m of the river to at least 100 m from the river. At this point, 100 m from the river, steep joints strike at 005° and 100°, are spaced at 4 m apart and extend for at least 3 m. At the point 30 m from the river amphibolite crops out and is more closely jointed than the granitic rocks. Between this point and river, and in the river bed, no outcrops were noted. Granitic rocks crop out on the steeper left bank and sheet joints were noted.

Returning from Location 4 in a southeasterly direction to the vehicular track, at a point northwest of Location 1, scattered outcrops of granitic rock were noted till clear of the river. In the vicinity of the track, scattered laterite fragments occur on the higher ground and clayey soil on the lower ground. As already mentioned, north of Location 1, the soil is sandy.

Location 5

In the vicinity of this location medium to coarse grained granitic rocks, foliated in part, crop out on both banks, but none was noted in the river bed.

Location 6

This location was approached from the vehicular track to its north, firstly across an area of fine red silty soil with laterite fragments and then down an easterly trending gully where the ground surface was covered by black organic soil. Downstream from where the gully meets the Tone River, granitic rocks crop out in the river bed and on the left bank. Further downstream, 50 m from the gully junction, outcrops of granitic rock occur on the right bank opposite a pool. Location 6 is at the downstream end of the pool a further 70 m downstream. Here, amphibolite with a steep foliation that strikes 40° crops out on the right bank.

Location 7

At this location massive outcrops of granitic rocks up to 7 m above river level occur on the left bank. Downstream from here, for at least 100 m, the left bank is covered by dark organic soil and no rock crops out. Scattered outcrops of granitic rocks occur on the right bank up to 7 m above the river. Topographically the location is unattractive as a dam site but because of the abundance of rock at river level may be suitable as a weir site.

The area between Location 7 and the vehicular track to the northwest is covered by grey and dark grey clayey and silty soil with some laterite fragments.

KENT-FRANKLAND AREA, ENGINEERING SOILS

A brief study was made of the area between the Kent and Frankland rivers in order to assess the predominant soil types. It was found that the physiography of the area is different from that of the Tone-Frankland region, and is dominated by dissected uplands of in situ weathered rock. Outcrop is much more common than was found to be the case at Tone-Frankland, and the soils of the easterly area are dominated by the weathering products of the rocks. The lower permeability of these soils when compared to the predominantly sandy material found at Tone-Frankland is reflected by the more abundant surface drainage features found in the area.

Subordinate sandy soils are also present, as are colluvium and laterite. The laterite tends to cap higher ground, and the colluvium, which is a similar material to the weathering product of the rock, is usually found as a valley infill material.

KENT RIVER, DAM SITES

A reconnaissance of possible dam sites on the Kent River (Fig. 10), Locations 8-13, was made on 20th and 21st November, 1979. The area of Locations 8-10 (Fig. 12) can be reached from Muirs Highway east of Rocky Gully via Turpin Road and then vehicular tracks and fence lines that approach from the north. The area of Locations 11-13 (Fig. 12) can be reached from Muirs Highway west of Rocky Gully via Normalup and Suez Roads and a vehicular track that approaches from the west.

A reconnaissance of the Kent River was made between Locations 8 and 9, at 10 and between 11 and 13.

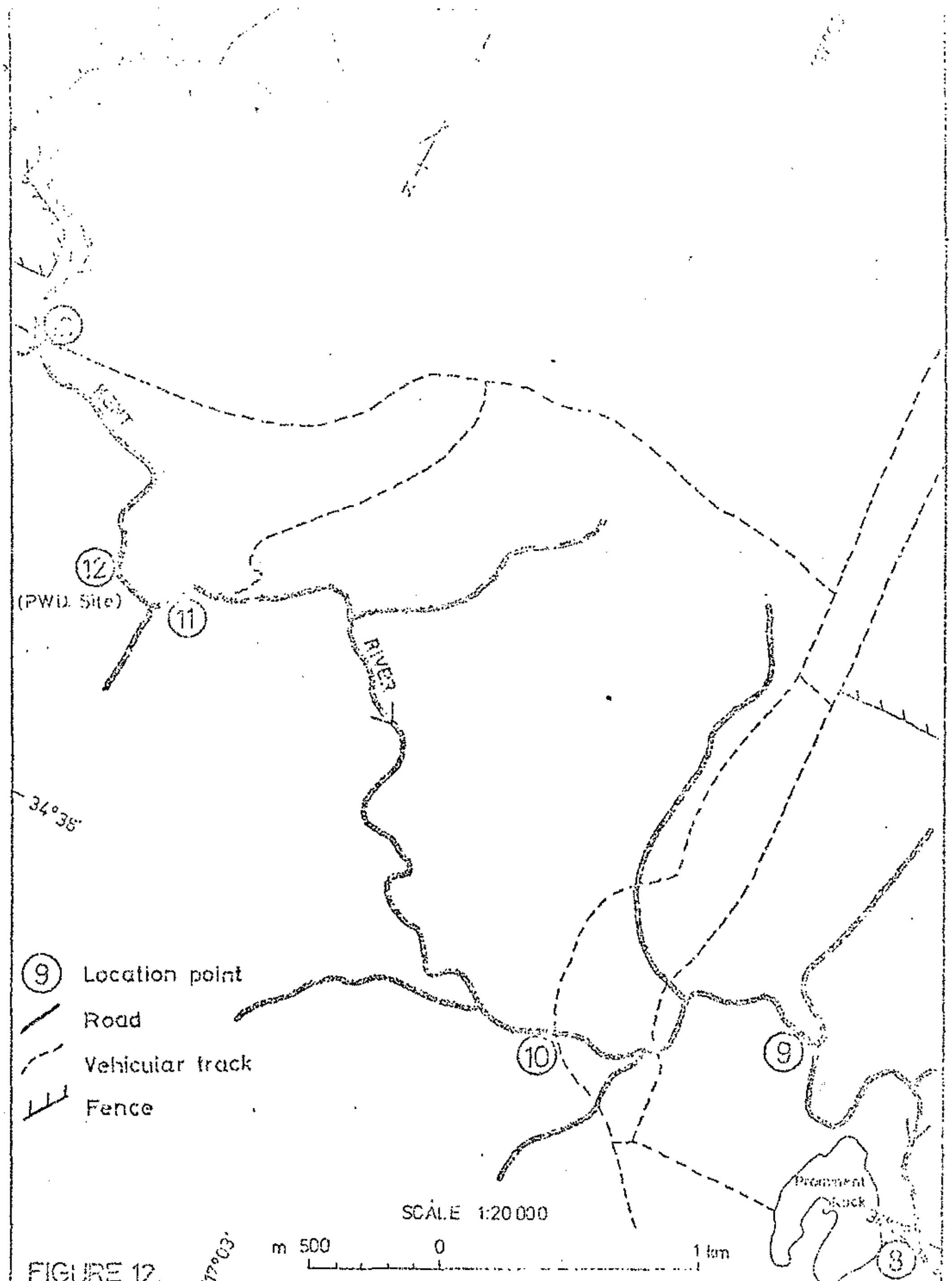

FIGURE 12.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SALINE RIVER DIVERSION
KENT RIVER DAM SITES
GEOLOGICAL RECONNAISSANCE

Location 8

Here and for about 400 m upstream, prominent steep outcrops of granitic rock occur on the right bank. On the left bank there are scattered outcrops, and on the valley floor, which is more than 100 m wide, no outcrops of rock were noted. The wide valley and the apparent lack of outcrops at river level make this area unattractive as a dam site.

Location 9

Between here and the prominent steep outcrops on the right bank downstream in the vicinity of Location 8, there are scattered steep outcrops of granitic rock, but topographically and to a less extent geologically the area appears unattractive for dam sites.

Location 10

At this point black organic soil occurs in the low banks of the Kent River. Fine white sand occurs in road cuttings 2-3 m above river level in the general vicinity and there is laterite beyond, on higher ground on the left bank. This location is unsuitable as a dam site and from a study of the air-photographs no suitable sites appear to exist between Locations 9 and 11.

Locations 11 and 12 (PWD Site)

At Location 11 just upstream of the PWD river gauging station, and for several hundreds of metres upstream to Location 12, scattered outcrops of granitic rock occur on the banks and in the bed of the Kent River. The rock is jointed and foliated, the foliation strikes east-west and has a variable dip. Several sites that appear suitable for dams occur in this vicinity.

Location 13

At this point a mixed sandy soil occurs on both banks and in the bed of the Kent River. A few rock boulders occur in the river bed 40 m upstream. Medium grained granitic rock in which no foliation was noted crops out on the left bank 30 m from the river. The site is unattractive for a dam. A study of the air-photographs and a reconnaissance along the Kent River suggest no suitable dam sites occur between here and Location 12.

SUMMARY

The Tone-Frankland area is dominated by sandy soils, with subordinate laterite and finer grained units, some of which are related to the in situ weathering of rock. This clayey soil becomes dominant in the Kent-Frankland area, although relatively minor occurrences of sandy soils and laterite are also found.

Fresh rock is relatively abundant in the east, but is confined to the beds of major water courses in the west.

From the preliminary information available at this stage, PWD dam sites 1, 2 and 3 respectively at Locations 1, 2 and 4 (Fig. 11) on the Tone River and a PWD dam site between locations 11 and 12 (Fig. 12) on the Kent River appear attractive. Sites at other locations visited on the Tone and Kent Rivers during this reconnaissance appear to be unattractive dam sites either because of the apparent absence of rock or because of poor topographic conditions.

RECOMMENDATIONS FOR FURTHER WORK

It is recommended that the nature and distribution of the sediments within the area be investigated more fully.

It may be possible to achieve this by control drilling to basement, followed up by seismic traverses over critical areas.

It is also desirable that a complete appraisal of the hydrology and hydrogeology of this area is undertaken. This will assist in formulating long term management policies for this wet land area. The first step toward a complete appraisal has been made with the installation of staff gauges on key water bodies throughout the area. Monitoring and sampling at these gauges should continue at monthly intervals for a period of five years. This will facilitate compilation of reliable base line data for the area. This should be followed up by selective monitoring and sampling at three monthly intervals to detect any long term changes which may be occurring in the system.

To allow an appraisal of the groundwater system, it would be necessary to establish an observation well network over the area. As part of this programme, it would be necessary to investigate the nature of the lake beds in the area. This will allow an appraisal to be made of the role which the lakes play in the overall groundwater system.

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TABLE 1 LAKE AND SWAMP LEVELS (AHD PROVISIONAL)

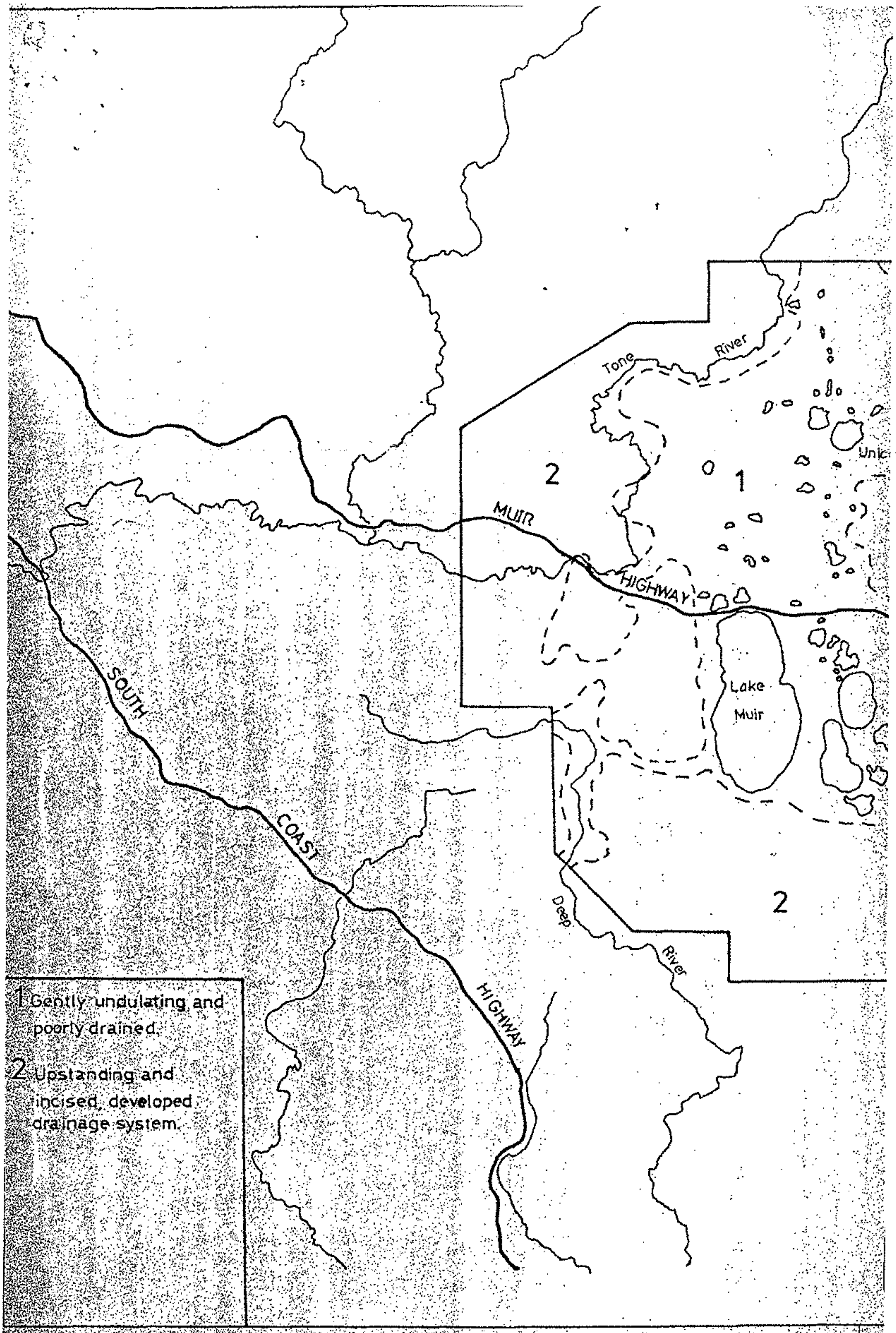
Bench Ref.	Name	R.L. (m)	R.W.L. (m)	Date
B685	Morinup Lake	208.16	Dry	10.1.80.
B697	Buranganup Swamp	186.47	186.50	22.1.80.
B698	Kodjinup Swamp	178.28	180.11	27.2.80.
B696	Little Unicup Lake	199.56	Dry	10.1.80.
B695	Unicup Lake	199.31	200.03	22.1.80.
B695	" "	"	199.86	26.2.80.
B701	Bokarup Swamp	215.98	216.79	21.1.80.
B701	" "	"	216.67	26.2.80
B699	Pindicup Lake	190.30	Dry	10.1.80.
B704	Kulunilup Lake	209.76	210.72	26.2.80.
B702	Yarnup Swamp	228.13	228.92	21.1.80.
B702	" "	"	228.80	26.2.80.
B703	Cobertup Swamp	195.88	196.11	22.1.80.
B703	" "	"	195.99	26.2.80.
B700	Noobijup Lake	219.71	219.79	21.1.80.
B707	Wimbalup Swamp	167.63	167.78	27.2.80.
B682	Byenup Lagoon	172.90	174.88	17.1.80
B683	Tordit-Gurrup Lagoon	173.01	175.66	22.1.80.
B683	" "	"	175.50	26.2.80.
B684	Poorginup Swamp	175.67	175.74	26.2.80.
B6331	Lake Muir	171.39	Dry	10.1.80.
B633	Boyndaminup Swamp	173.37	173.38	27.2.80.

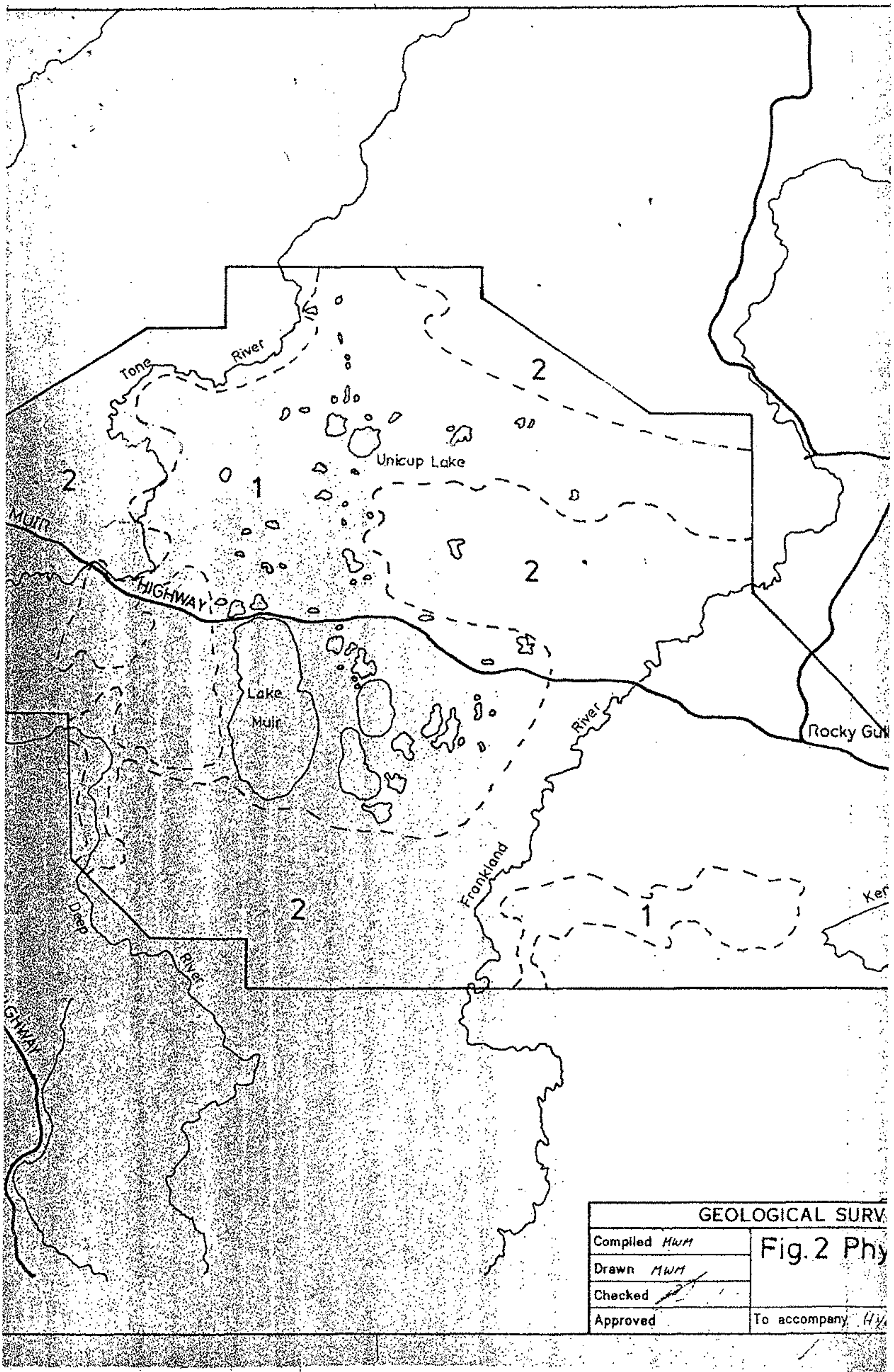
TABLE 2 FIELD SALINITIES

Ref No.	Date	Name	Depth (m)	Water level (m)	Salinity T.D.S. (mg/L)
141	15.1.80		13	4.0	1 950
142	"		4	2.7	175
143	"		24.3	5.0	330
144	"		20.4	0.7	9 700
145	"		22.8	6.3	550
146	16.1.80		10	0.9	9 200
148	"		5.8	3.3	6 500
149	"		3.3	0.1	6 400
150	"		3.0	0	7 000
151	"		8.2	3.7	400
MA1	3.1.80	L. Kulunilup		Lake	1 600
MA24	26.2.80	"		0.96	1 590
MA2	3.1.80	Kulunilup Drain		Drain	3 450
MA3	9.1.80	Sawyer	7.9	3.6	270
MA4	"	Connor	8.8	6.0	340
MA6	10.1.80	M. Muir	1.9	1.76	410
MA8	22.1.80	Buranganup Swamp		0.03	4 100
MA9	21.1.80	Bokerup Swamp		0.81	2 700
MA25	26.2.80	" "		0.69	3 350
MA10	21.1.80	J. Phillips		Swamp	510
MA11	"	Yarnup Swamp		0.79	1 100
MA26	26.2.80	" "		0.67	1 420
MA12	21.1.80	Noobijup Lake		0.08	2 510
MA13	"	Fink		Dam	760
MA14	22.1.80	G Muir		Lake	26 000
MA15	"	Unicup Lake		0.72	5 400
MA27	26.2.80	" "		0.55	7 800
MA16	22.1.80	Dam		1.5	4 400
MA17	"	Dam		"	430
MA18	"	Boyndaminup Swamp			400
MA31	27.2.80	" "	0.01	0.01	11 000
MA19	22.1.80	Poorginup Swamp			640
MA28	26.2.80	" "		0.07	1 580
MA20	22.1.80	Toordit-Gurrup Lagoon		2.65	980
MA29	26.2.80	" " "		2.49	1 080
MA21	22.1.80	Cobertup Swamp		0.23	540
MA30	26.2.80	" "		0.11	735
MA22	25.2.80	L.A..Parke (Dam)	2.5	2	570
MA32	27.2.80	Wimbalup Swamp		0.15	670
MA33	27.2.80	Kodjinup Swamp		1.83	1 490
MA34	27.2.80	Byenup Swamp			5 400

TABLE 3 SALT STORAGE - TOORDIT-GURRUP AND BYENUP LAGOONS

Date	Volume $m^3 \times 10^6$	Na Cl mg/L	Na Cl $kg \times 10^6$
	TOORDIT-GURRUP LAGOON		
16.1.79	7.410	750	5.558
14.3.79	6.225	900	5.603
19.5.79	5.780	1 000	5.780
16.6.79	6.360	850	5 406
19.7.79	7.120	890	6.337
13.9.79	7.545	750	5.659
7.11.79	7.500	800	6.000
14.12.79	7.240	900	6.516
17.1.80	6.110	900	5.449
	BYENUP LAGOON		
16.1.79	3.78	3 300	12.474
14.3.79	2.70	4 000	10.800
19.5.79	2.28	4 300	9.804
16.6.79	2.88	4 050	11.664
19.7.79	3.02	3 700	11.174
13.9.79	3.60	3 300	11.880
7.4.79	4.46	3 300	14.718
14.12.79	4.34	3 400	14.756
17.1.80	2.88	4 200	12.096


Tone
River
Unic
2
1
MUIR
HIGHWAY
Lake
Muir
2
SOUTH
COAST
HIGHWAY
Deep
River
1 Gently undulating and poorly drained.
2 Upstanding and incised, developed drainage system.


Tone River
2
1
Unicup Lake
2
MUIR
HIGHWAY
Lake Muir
River
Rocky Gul
Frankland
2
1
Ker
Deep River
GHWAY
GEOLOGICAL SURV
Compiled MWM
Drawn MWM
Checked
Approved
Fig. 2 Phy
To accompany

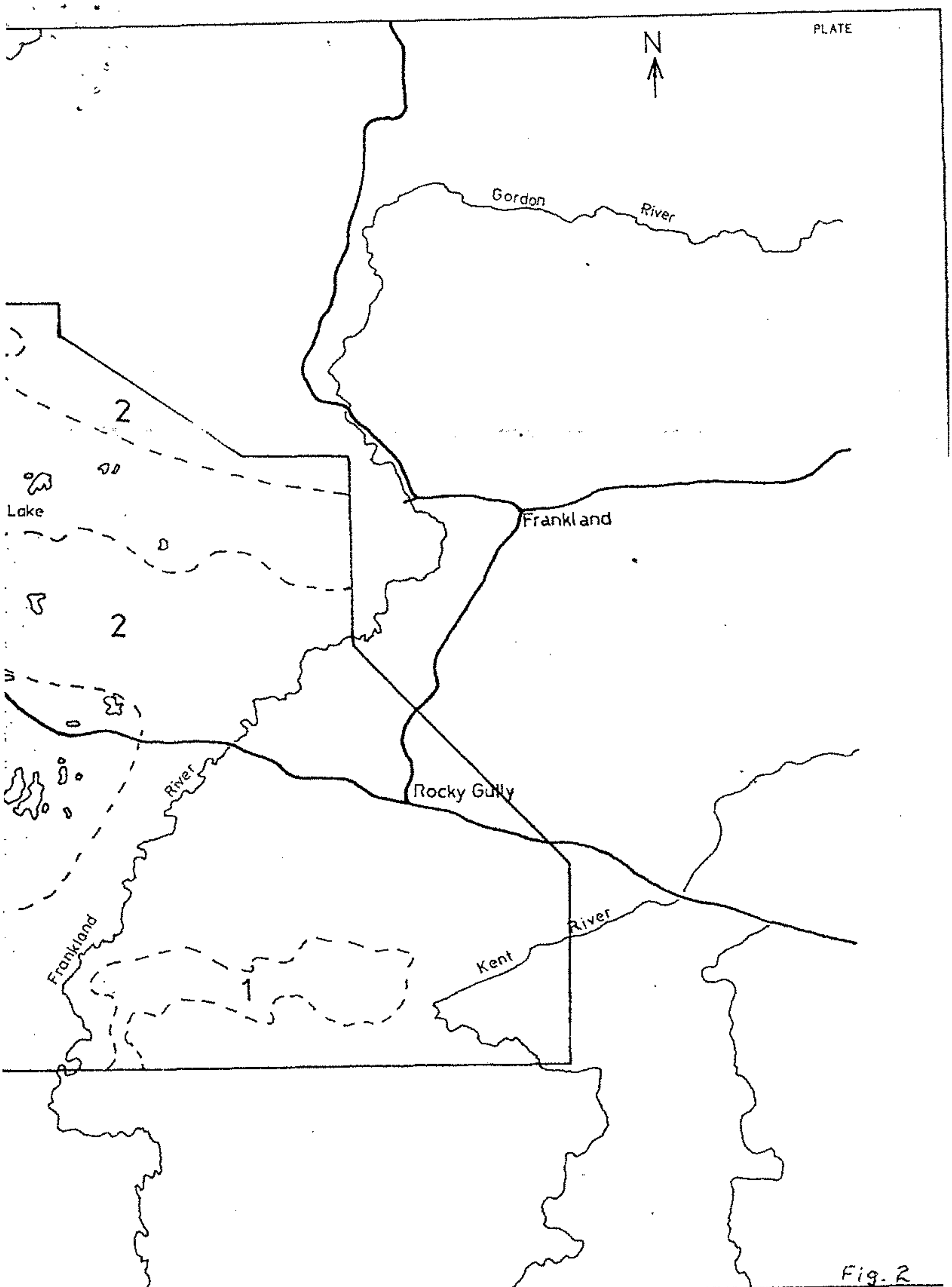
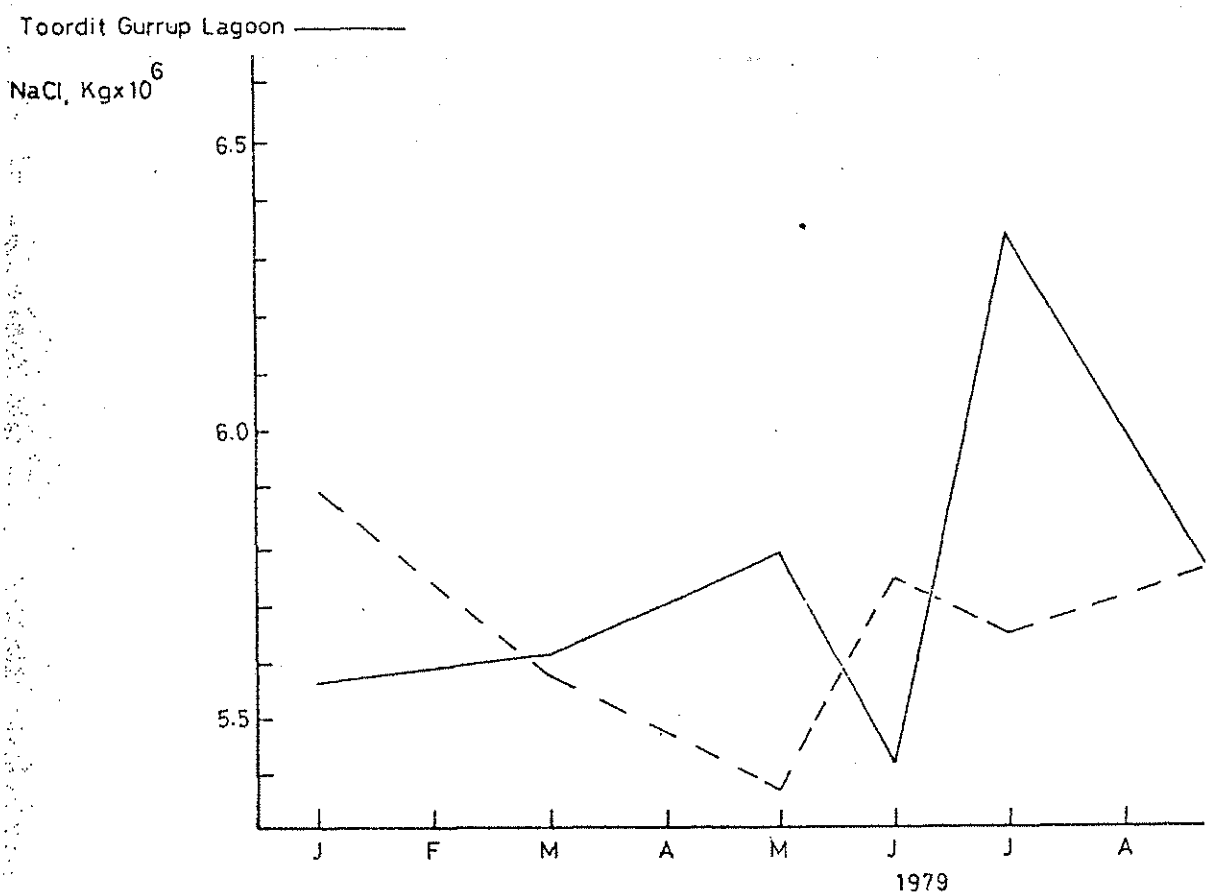


Fig. 2

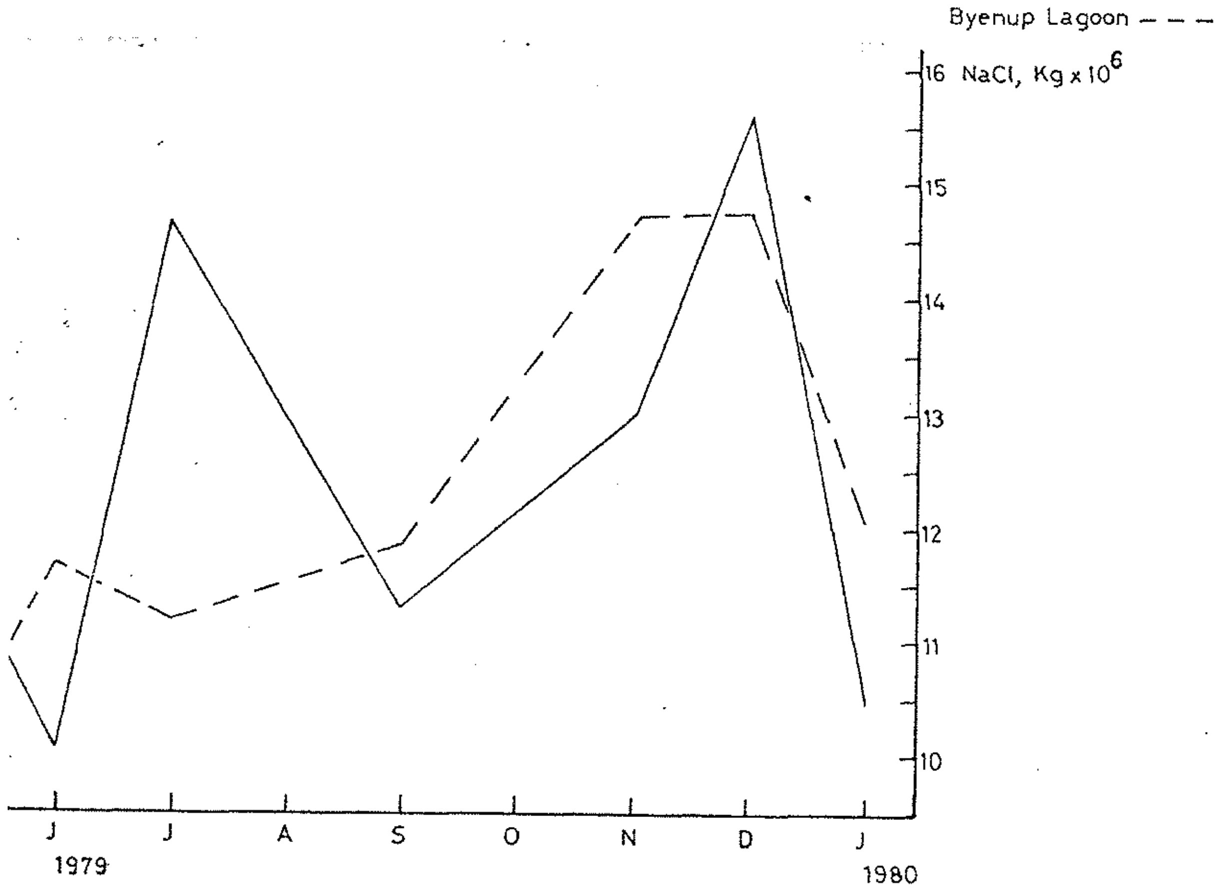
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Fig. 2 Physiography

Compiled MWM	Fig. 2 Physiography	SCALE
Drawn MWM		1:250 000
Checked		
Approved	To accompany HYD. REPT. No. 2110 M. MARTIN	



40081/5/69-200-0



GEOLOGICAL SURVEY OF WESTER	
Compiled	Fig.6 Salt storage (Byenup& Toordit-Gur
Drawn	
Checked	
Approved	To accompany

PLATE

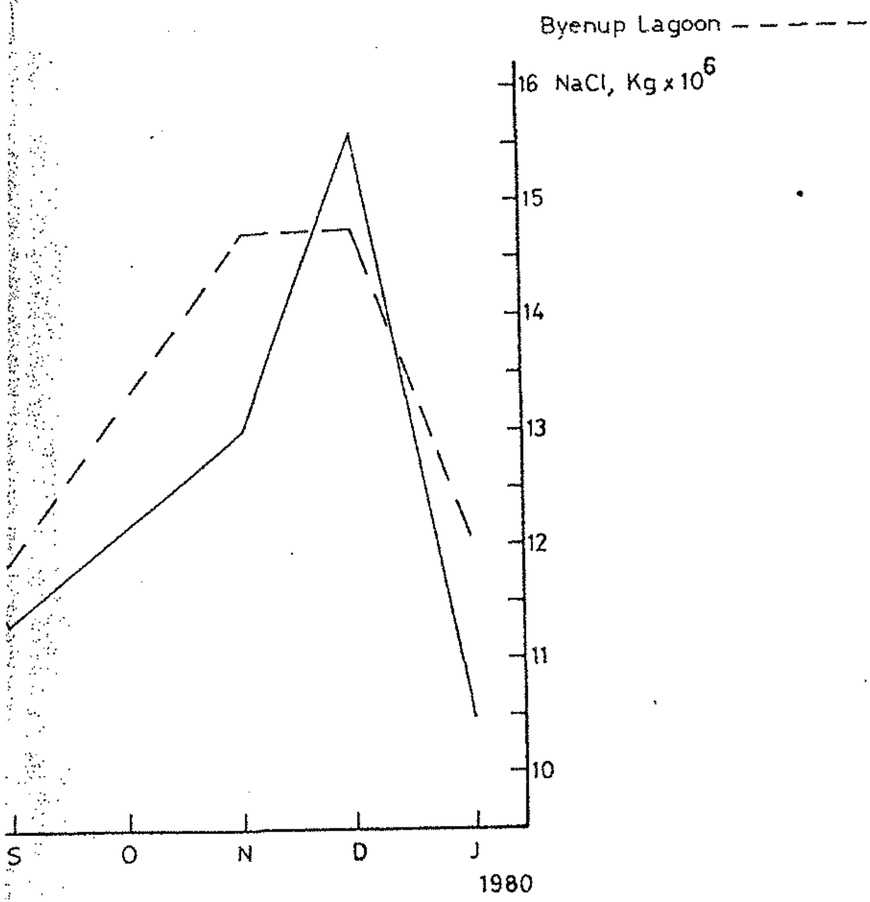


Fig. 6.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Compiled FWM	Fig.6 Salt storage curves, Byenup & Toordit-Gurrup Lagoons.	SCALE
Drawn FWM		
Checked		
Approved	To accompany Hydro. Rept No 2110 M. MARTIN	GSWA 18525

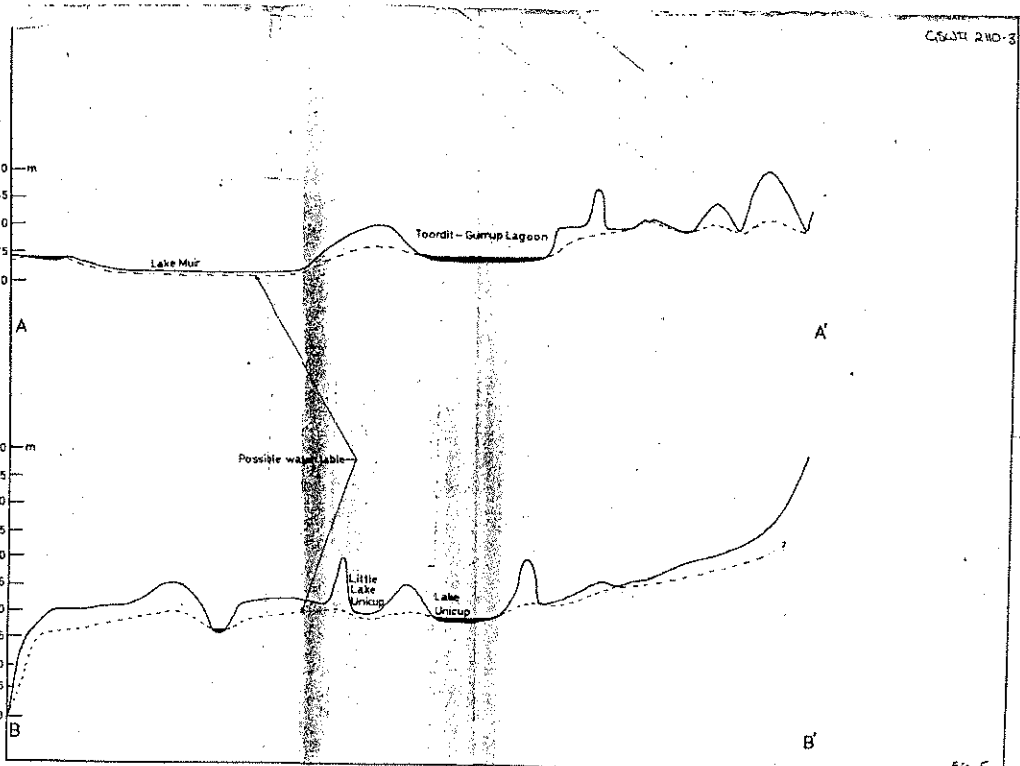


Fig. 5

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Compiled	Fig.5 X – Sections AA', BB'	SCALE
Drawn		
Checked		
Approved	To accompany	

GSWA 18524

Cockburn_Sound_waypoints

UTM WGS 84

	Water Quality 2001/2002 sites			
CS4		50H	376.829	6441.686
CS5		50H	379.308	6441.958
CS6A		50H	382.749	6442.651
CS7		50H	383.323	6439.972
CS8		50H	379.337	6436.947
CS9		50H	383.098	6435.629
CS9A		50H	382.367	6432.396
CS10		50H	381.328	6430.636
CS11		50H	378.890	6429.753
CSNC	north control	50H	372.954	6443.318
CSSC	south control	50H	376.063	6430.632
CSG1	Garden Island HMAS stirling	50H	377.319	6433.380
CSG2	Garden Island HMAS stirling	50H	377.172	6434.955
CSG3	Garden Island HMAS stirling	50H	376.039	6436.793
CSSF	southern flats	50H	378.716	6431.322
WSSB	warnboro sound safety bay	50H	378.444	6424.599
WS4	warnboro sound	50H	379.741	6421.498
NH3	northern harbour jervoise bay	50H		