SPECIAL REPORT

W22 G. J. STANDER and Co-workers. A survey of river pollution in the Witwatersrand catchment area of the Vaal River

NATIONAL INSTITUTE FOR WATER RESEARCH

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

C S I R Special Report W22, pp. 1-83, UDC 628.19(282.1), Pretoria, South Africa, November, 1963

C O N T E N T S

Page

SYNOPSIS

A preliminary mapping survey of that portion of the Witwatersrand catchment area which drains into the Vaal River was followed by an extensive quantitative survey of regular and accumulated mineral loads carried by streams as a result of industrial mining and sewage activities. The effects on water supplied to the Witwatersrand consumer, were investigated.

The results reveal that although most of the tributaries of the Vaal River in this area arise as streams of exceptional purity, they become heavily contaminated within a few miles of their sources, and carry mineral loads far in excess of those expected from natural sources. These mineral loads reach alarming proportions in the rainy season when mineral salts which have accumulated in mining areas during the dry season contaminate the run-off waters and when irregular discharges of large volumes of slimes-dam penstock water occur.

The pollution of streams has a marked effect on the quality of the water supplied to the Witwatersrand consumer and it is shown that industry, agriculture and the general economy are all directly or indirectly affected.

It is recommended that a programme of pollution abatement by quality control be drawn up in close consultation with all major bodies involved and that the possibility of abatement by storage, diversion and controlled discharge of streams be investigated.

SAMEVATTING

'n Voorlopige karteer-opname van die deel van die opvanggebied van die Witwatersrand wat in die Vaalrivier dreineer, word deur 'n uitgebreide kwantitatiewe opname gevolg. Die hoeveelhede gereelde en opgehoopte minerale ladings as gevolg van nywerheids-, myn- en rioolbedrywighede asook hul gesamentlike uitwerking op die watervoorsiening aan die Witwatersrandse verbruiker, is ondersoek.

Die resultate toon dat alhoewel meeste van die sy-strome van die Vaalrivier in hierdie gebied as strome van buitengewone suiwerheid begin, hulle baie gou swaar besoedel word binne 'n paar myl van hulle oorspronge en veel groter minerale ladings dra as dié wat volg op natuurlike oorsake. Hierdie minerale ladings bereik onstellende afmetings in die reënseisoen wanneer minerale soute, wat gedurende die droë seisoen in myngebiede opgebou het, die vloedwaters besoedel en wanneer slykdamwaters onreëlmatig in groot hoeveelhede in riviere uitgestort word.

Die besoedeling van die strome het 'n merkbare invloed op die gehalte van die water wat aan die Witwatersrandse verbruiker verskaf word terwyl dit getoon word dat die nywerheid, landbou en die algemene ekonomie almal regstreeks of onregstreeks geraak word.

Dit word aan die hand gedoen dat 'n program van besoedelingsbestryding deur beheer oor kwaliteit opgestel word in noue samewerking met alle groot belanghebbendes en dat die moontlikheid van bestryding deur opgaring, verlegging en beheerde uitvloei van strome, ondersoek word.

SURVEY OF RIVER POLLUTION IN THE WITWATERSRAND AREA OF THE VAAL RIVER.

INTRODUCTION

On 27th October, 1950, a special meeting of the Advisory Sub-Committee on Water Treatment of the Council for Scientific and Industrial Research was held to discuss the suggestion that a survey should be made of the Klip and Suikerboschrand Rivers and their tributaries, which drain the industrialized areas of the Witwatersrand and flow into the Vaal River.

The Committee approved the project and a preliminary, general mapping survey of the area was initiated. This was followed by a detailed quantitative investigation to obtain a rough estimate of the extent of pollution from existing and potential sources such as sewage disposal works, mining properties and secondary industries.

This report is an abstract of the most important information contained in the main reports (parts I to VII) on the investigation.

OBJECTIVES/.......

O B J E C T I V E S

After the completion of the preliminary survey, a meeting of the Special Committee for Stream Surveys in the Witwatersrand Area was held on 22nd February, 1952, and a survey programme was approved which incorporated the following objectives:-

(a) to examine all effluents draining into the streams under investigation in order to evaluate mineral pollution quantitatively;

(b) to investigate natural springs and other forms of natural flow, and their influence on the extent of pollution; and

(c) to recommend ways and means of improving the quality of the streams.

In pursuance of recommendations made by the Committee, representations were made to interested parties for financial assistance, but these were unsuccessful. The Chamber of Mines, however, decided to undertake an investigation into effluents from gold mines and selected the West Rand area between Luipaardsvlei and Welverdiend station for a detailed survey of river pollution of streams draining into the Mooi River. In terms of a contract agreement, the Council for Scientific and Industrial Research acted in a consultative capacity in respect of the work which was in progress and carried out the survey for that part of the Witwatersrand area which drains into the Vaal River upstream of Vereeniging. In consequence of the Chamber's action, objective (a) above was achieved as far as mine effluents were concerned. As these results are of a confidential nature, the data are not included in this report. It can nevertheless be stated that this work contributed greatly towards the achievement of objective (c) above.

Since extra funds could not be obtained, the project was undertaken with such existing staff as could be assigned to it, and it was found necessary to alter objectives to the following:-

(d) to /....

(d) to obtain a quantitative picture of the mineral loads carried at various points by the streams during the wet and dry seasons of the year and during specific periods of time; and

(e) to evaluate the effects of these mineral loads on the Vaal River and on the quality of water supplied to the Witwatersrand area.

CHAPTER/......

C H A P T E R   O N E

DESCRIPTION OF THE CATCHMENT AREA

General

The catchment area dealt with in this report lies in the province of the Transvaal, South Africa, between latitudes 26°5' and 26°45' and longitudes 27°45' and 28°30', and is commonly referred to as the Witwatersrand.

Area and physical features

The country represented on Map no. 5 embraces an area extending some 45 miles from east to west and 35 miles from north to south, or about 1,600 square miles.

The gold mining and associated industries are restricted chiefly to a zone about 10 miles wide extending along the northern boundary of the area. This zone follows approximately the line of outcrop of the Main Reef and lies to the south of the main ridge of the Rand. The southern slopes of the ridge, which are drained by the Klip and Suikerboschrand Rivers are gentle and impart little erosive power to the drainage in general. Johannesburg, the centre of the goldmining industry, occupies a position midway between the east and west extensions of the gold-bearing reefs. Krugersdorp, Lewisham and Roodepoort lie to the west of Johannesburg, and Boksburg, Benoni, Springs, Brakpan and Nigel, all gold-mining towns, to the east. The towns of Heidelberg and Balfour lie to the south-east of the area while Grasmere is located near the south-western corner. Vereeniging, which is a coal-producing area, occupies a position to the extreme south of the area.

The /......

The Witwatersrand forms part of the Transvaal 'High Veld'. It has a general elevation of 5,000 feet above sea level, with extreme elevations of 6,000 feet in the vicinities of Johannesburg and Heidelberg.

The Witwatersrand ridge constitutes part of the principal watershed of South Africa. This watershed, known as the Griqualand-Transvaal axis of uplift, traverses the country just to the north of Johannesburg. This crustal deformation feature is responsible for the separation of the drainage basins of the Vaal and Limpopo River systems. The Vaal River drains the southern slopes of the high veld and flows into the Atlantic Ocean after joining the Orange River near Kimberley. The Limpopo River drains the northern slopes and flows into the Indian Ocean. The main water divide in the Witwatersrand area coincides with the highest portion of the Witwatersrand and passes through the centre of Johannesburg.

The elevated hilly country between Krugersdorp in the west and Germiston in the east, is the dominating physical feature of the whole area. To the east of Germiston, towards Brakpan and Nigel, the weather-resistant Witwatersrand formations are overlain by horizontally disposed Karroo rocks. These formations are less resistant to weathering than are the Witwatersrand rocks, and easily break down into sandy surface drift and soils which give rise to broad, gently sloping undulations referred to as 'bulte'.

This eastern section of the area, covered by generally elevated Karroo formations, is traversed from north to south by a shallow depression forming the broad featureless valley of the Blesbokspruit. Denudation of the thin Karroo sediments by the Blesbokspruit has exposed the underlying dolomites and Kimberley shales for some 20 miles along its course.

'To the south of Johannesburg the high ground formed mainly by rocks of the Witwatersrand system, includes in its southern margin a fairly high

range /......

range known as the Kliprivierberg, which represents the edge of the mass of volcanic rocks usually referred to as the Kliprivier amygdaloid[1]. In a southerly direction from the Kliprivierberg, the country opens up into a low and wide expanse occupied by Karroo sediments and dolomites. The comparatively low dolomite areas usually produce featureless grass-covered country. To the south-east and the south-west of the area high grounds are again encountered, composed mainly of Ventersdorp lava and rocks of the Pretoria series respectively. In the vicinity of Heidelberg the incision of deep valleys gives the area a rather mountainous character. The escarpments of Pretoria quartzites found in the south-west give rise to a type of country characteristic of these formations, as is evidenced by the numerous roughly parallel ridges and valleys corresponding with the alterations of quartzite and shale of which the Pretoria series is largely composed.

Drainage

The Vaal River and its tributaries drain the whole area. The principal tributaries are the Klip River and its tributaries, the Klipspruit, Natalspruit, Elsburgspruit and the Rietspruit, and the Suikerboschrand River, with its tributary the Blesbokspruit, which is the main stream draining the East Rand.

The Blesbokspruit is re-excavating a pre-Karroo valley and roughly follows a belt of Kimberley shales in its lower stretches where it meanders in broad alluvial flats.

The Klip River and the Klipspruit together drain the west Witwatersrand area around Lewisham and Roodepoort. The Natalspruit drains the country immediately to the south-east of Johannesburg. From its gathering grounds in the Kliprivierberg, the Klip River flows southwards to join the Vaal River near Vereeniging only about two miles distant from the confluence of the Suikerboschrand and Vaal Rivers.

Although /.....

Although the Klip River and its tributaries invariably originate over formations of the upper Witwatersrand and Ventersdorp systems, they flow mainly over formations belonging to the Karroo system and dolomites of the Transvaal system. The Blesbokspruit arises and flows mainly over Karroo system rocks and dolomites.

Springs are abundant in the area and, apart from contributing considerable amounts of high quality water to the various streams, are extensively used by farmers for irrigation and agricultural purposes.

METHODS OF IMPLEMENTING THE SURVEYS

In the preliminary survey the course of each river was reconnoitred and points of possible pollution and contamination were marked on the appropriate maps. Local and mining authorities and plant managers were approached about the areas under their jurisdiction in an endeavour to trace all sources of pollution. Samples for chemical analysis were collected at various points along the rivers and streams, including all points at which there were suspect seepages and effluents that might have access to the rivers. The points at which samples were taken are represented on the relevant maps by the reference numbers used to identify the respective analysis values in the figures and tables.

For the sake of brevity, the various rivers were subdivided into sections denoted by the alphabetical symbols shown below:

Map	Section	River section
1	A	Upper Klip River - from origin at Lewisham to Jackson's Drift.
	B	Klipspruit - the entire tributary of the Klip River.

Continued /....

Map	Section	River section
2 and 4	AA	Lower Klip River - from Jackson's Drift to Vereeniging.
2	C	Natalspruit - from origin to confluence with Klip River.
	D	Elsburgspruit - from origin to confluence with Natalspruit.
	CC	Rietspruit - from origin in Brakpan to confluence with Natalspruit.
3	E	Upper tributary of the Blesbokspruit in the Benoni area.
	F	Blesbokspruit and Small Blesbokspruit in the Springs area.
	G	Blesbokspruit in the Nigel-Heidelberg area.

Analytical methods

The chemical analysis included the following parameters: pH value; conductivity in micro-mhos; total dissolved solids (TDS); suspended solids; mixed oxides of iron and aluminium; total hardness (TH); chlorides; sulphates; oxygen consumed in four hours from N/80 $KMnO_4$ (i.e. OA); and alkalinity. The results are all expressed in parts per million except where otherwise stated.

Except in the cases of total hardness and sulphate determinations, the methods used have been those described in Standard Methods for the Examination of Water and Sewage.[8]

For /.......

For the total hardness determinations, modification of the Schwarzenbach method was used in which the calcium and magnesium ions are titrated against a standard solution of ethylene diamine-tetra-acetate, using eriochrome black-t as indicator.

Sulphates were determined by using a Cambridge photo-electric turbidimeter, and a modified method of V. Zahn[10] and R.T. Sheen and others.[6]

Physical measurements

In addition to the chemical analyses, the detailed quantitative investigation included the following functions which are discussed further below:

flow measurements at selected sampling points;

recording of daily rainfall figures,

estimation of mineral load from analyses and flow data,

a preliminary investigation of natural vleis and their influence on the extent of pollution, and

daily analysis of tap water from a selected point.

Flow measurements at selected points
(See Maps nos 1, 2, 3 and 4)

The Department of Water Affairs erected 29 gauging stations, of which nine were supplied with permanent weir structures; the Department prepared discharge tables for these weir stations. The remaining stations were calibrated by flow-meter technique. Daily, weekly or bi-weekly gauge readings were made at all stations.

Flow readings of the Klip and Suikerboschrand Rivers at Vereeniging were obtained from the Rand Water Board which maintains two recording weirs at these sites. Owing to the frequent silting up of the bed of the stream with sand at a number of gauging places some recordings were of doubtful value, particularly during the rainy season.

Recording of daily rainfall figures

Thirty nine rainfall stations on the Reef were selected, and records were made of the daily rainfall at these stations from figures supplied by the Weather Bureau in the form of monthly returns.

Estimation of mineral load from analyses and flow data

These values were calculated for the most important points in the area from flow gaugings and total dissolved solids (TDS) determinations.

(a) Dry weather flow:

Any measurement (in cusecs) made during the normal dry months (May-October) is taken as dry weather flow. The average of these measurements is the average dry weather flow.

(b) Wet weather flow:

Any flow measurement (in cusecs) made at any time during the rainy season (November-April) or any other rainy period (e.g. out-of-season rain) is regarded as a wet weather flow.

(c) Run-off flow:

The difference between (b) and (a). This includes surface and sub-surface flows and increased flows from springs during the rainy season.

(d) Observed total dissolved mineral load:

Total dissolved solids x flow in cusecs x 5.38 = TOTAL MINERAL LOAD in lb/24 hours.

(e) Natural /......

(e) Natural dissolved mineral load:

This is the mineral load which would be carried in solution if the observed flows were not contaminated by unnatural mineral salt discharges, i.e. flow x average TDS of RUN-OFF FLOWS (100 ppm) x 5.38 = lbs/24 hours.

(f) Expected dissolved mineral load:

For the area under investigation run-off resulting from rainfall or springs (Table 4)carries a Natural Total Dissolved Solid concentration (TDS) varying between 25 and 146 ppm. and the dissolved mineral salts carried in these waters constitute the NATURAL MINERAL LOAD. Therefore if run-off (surface or sub-surface and increased spring flow) from rainfall reaches a stream carrying a DRY WEATHER FLOW (of whatever origin, e.g. sewage, or mine effluent or spring water) the TDS of the resultant flow decreases in proportion to the dilution afforded by the run-off having a NATURAL TDS of 25 to 146 ppm (average approximately 100 ppm) but the TOTAL DISSOLVED MINERAL LOAD contributed by the whole flow increases, the increase being the mineral load dissolved in the RUN-OFF water (difference between an observed WET WEATHER FLOW and the AVERAGE DRY WEATHER FLOW). From the foregoing therefore, the EXPECTED MINERAL LOAD at any time during a wet season is the sum of the average dry weather OBSERVED TOTAL MINERAL LOAD (AVERAGE DRY WEATHER FLOW x AVERAGE DRY WEATHER TDS) and the NATURAL MINERAL LOAD contributed by the RUN-OFF FLOW. Towards the end of April (i.e. beginning of dry season) the flow in the main streams drops rapidly and remains fairly uniform except towards the end of the dry season when much water is pumped for irrigation and effluent discharges decrease. The dry season flow consists of normal spring flows and regular effluent discharges (mine water pumped from underground slimes dam penstock water, reduction works effluent and seepages from slimes dams and rock dumps); run-off flow becomes negligible. During the dry season, therefore, the mineral load contributed by RUN-OFF disappears and there is consequently no necessity for calculating the EXPECTED MINERAL LOAD for this period; the streams carry a dry-weather OBSERVED TOTAL MINERAL LOAD only.

(g) Accumulated /.....

(g) Accumulated dissolved mineral load:

During the rainy season, run-off water is contaminated with mineral salts derived from slimes dams and sand dumps. Erosion of slimes dams and sand dumps, and the oxidation of pyritic material to sulphuric acid and iron sulphate with the concomitant leaching of salts from mineral material, are the main sources of pollution resulting from mining activity. The discharge of large volumes of slimes dam penstock water during rainy periods is another source of heavy mineral pollution. Areas under irrigation also contribute mineral salts during rainy periods. Two important phenomena are observed when these run-off waters reach streams carrying dry season flows (natural springs and regular effluent discharges):

(i) The Total Dissolved Solids of the resultant flow do not decrease materially and in proportion to the dilution afforded by the run-off.

(ii) The observed total mineral load exceeds the expected mineral load. The difference between the former and the latter represents the accumulated mineral salts which have been leached from the soil, and/or dissolved solids in slimes dam waters which have been discharged irregularly as effluent during storms or wet weather. This load is designated as ACCUMULATED MINERAL LOAD.

(h) Total excess dissolved mineral load:

The difference between the observed total dissolved mineral load and the natural dissolved mineral load represents the total addition of soluble mineral salts from unnatural sources (no allowance being made for increase due to evaporation). This figure is called EXCESS MINERAL LOAD and represents the ACCUMULATED MINERAL LOAD and the MINERAL LOAD FROM REGULAR EFFLUENT DISCHARGES.

A Preliminary Investigation of Natural Vleis

Natural vleis in the water courses of the Witwatersrand have been found to constitute important purification barriers:

The Olifantsvlei, which is one of the most important of these vleis in the Witwatersrand area, was the subject of a separate investigation carried out by the NIWR. The results of the ecological studies on the Olifantsvlei were published in a NIWR report[3], and will not be dealt with in detail in this report.

The salient characteristics are given in the following summary.

It has been noted in the chemical survey that the polluted waters of the Klip River and the Klipspruit were considerably improved after passing through the Olifantsvlei. The ecological studies were undertaken to determine more accurately the effects of the vlei on the polluted waters, to find out what part, the different regions of the vlei were playing in this purification, to work out the biology of the various regions and, if possible, to gain some idea of the processes taking place.

From the survey it became apparent that the vlei possesses an extraordinary power of self-purification (maturation process) and is capable of dealing with a complicated set of polluting factors more efficiently than a river.

Three main types of pollution were present in streams entering the vlei: mineral-acid pollution; organic pollution; and bacterial pollution by organisms of faecal origin. All three types of pollution were removed to some extent.

The acid is neutralized by the underlying dolomite. However, the vlei cannot deal with the larger volume of acid water pouring in during the rainy season and the acid is then neutralized lower down the Klip River.

There was very little free organic matter present in the Klipspruit by the time it reached the upper arm of the vlei, but there was still a fair amount of saline ammonia and nitrates originating from the Klipspruit Sewage Works. The vlei dealt with most of the ammonia nitrogen and the nitrate nitrogen by the time the water reached the outlet.

Bacterial purification was marked. The Klipspruit carries mainly bacteria of faecal or possible faecal origin from the sewage works effluent, but also saprophytic and soil bacteria, the latter particularly during the rainy season. All these types showed marked reduction, though there was evidence of incidental faecal pollution (bird and animal life) in the vlei itself which was masking an otherwise efficient removal. The increase of saprophytic bacteria again in the lower parts of the vlei was probably due to the fact that this deeper area contains large amounts of decaying vegetable matter.

Daily analysis of tap water

In order to evaluate the extent to which mineral pollution affects the water supply to the Witwatersrand, daily samples of tap water were analysed over a period of 18 months.

Presentation of results

The chemical analysis figures of the preliminary survey are given in Tables 1, 2 and 3.

C H A P T E R   T W O /......

C H A P T E R T W O

PRELIMINARY MAPPING SURVEY

The upper Klip River and the Klipspruit

(See Map no. 1, sections A and B)

General

The Klipspruit and the Klip River, into which the Klipspruit flows about ten miles from its source, together with a number of tributaries of both these rivers, all arise in the range of hills running east-west from Lewisham to central Johannesburg. The area is characterized by large numbers of springs, whose waters are of a very high quality. A second important source of water here is run-off from mining properties. Some of this mine water is pumped from underground and the quality of nearly all of it leaves much to be desired, as it is acidic and has a very high salinity. The effects of this contamination by mine waters in this area are lessened to some extent by dilution due to water from springs and also to effluent from sewage disposal works. (Analytical results are given in Table 1).

Detailed description

The source of the Klip River is a spring at Lewisham. This water is immediately contaminated by run-off water from the East-Champ D'Or mine (Pollution point P1), which has a total dissolved solids (TDS) concentration of over 10,000ppm. The combined stream below the mine has a pH of 3.1 and TDS concentration of over 4,000ppm. Approximately five miles downstream (P2) the pH is 3.2, but the TDS concentration has decreased to 500ppm, owing to dilution by springs along the course. The water is crystal clear, but there are no signs of aquatic life. Mine sand has penetrated the bed of the stream for a distance of about two miles; a small dam then prevents further penetration.

The Klip River is now joined by a rather faster-flowing tributary with two main branches, the first coming from Roodepoort West and the second flowing westward through the Durban-Roodepoort Deep Mine property.

The Roodepoort West stream, despite some organic pollution from the Roodepoort location, is of a good chemical quality until it reaches the lower of two dams where a small stream, originating in Roodepoort and passing through a disused mine dump area (P3), enters the dam. An immediate increase in TDS of the dam is noticed. This is due mainly to increased hardness. Approximately three-quarters of a mile below this dam a second highly contaminated run-off enters the stream. This arises due west of Roodepoort in the vicinity of old slimes dams (P4). The total dissolved solids concentration of this water is over 2,000ppm and the area appears to be a very bad source of contamination, particularly during heavy rains, since no provision is made to prevent mine sand or contaminated water from entering the main stream.

The stream from the Durban-Roodepoort Deep Mine (P5) is of very poor quality, having a TDS concentration of over 2,000ppm. The pH of the water here varies considerably, as the mine has a lime-treatment plant (P6) situated about half a mile above the confluence of this stream and the stream from Roodepoort West. A pH of 11.7 was recorded immediately below the treatment plant on one occasion. A heavy precipitate of ferrous hydroxide forms in the stream and is deposited in quiescent pools. The principal constituents of these mine waters are ferrous iron, calcium, and magnesium chlorides and sulphates, particularly sulphates. Sulphates (SO_4) in concentrations of over 1,000ppm are the rule, while concentrations of over 2,000ppm are quite common. Not much mine sand finds its way down this stream as a rule, because sedimentation takes place in three dams situated above the lime-treatment plant. A sewage effluent of unknown

quality /.......

quality enters the stream above the lime-treatment plant, while a second sewage disposal works (P7) discharges partially treated sewage with an oxygen demand (OA, i.e. oxygen absorbed from N/80 $KMnO_4$ in 4 hours) of from 60 to 70ppm. By dilution this value soon falls to less than 20ppm.

Below the confluence of the Klip River and the stream from Roodepoort West, and the Durban-Roodepoort Deep Mine, there are no further sources of pollution or contamination for about twelve miles, and the Klip River flows through pastoral and agricultural countryside. The water of the river (P8) is of poor chemical quality and its use is limited owing to its low pH of 3 to 4 and the high TDS concentration of 1,000 to 2,000ppm. Dilution by spring water does, however, result in decrease of salinity. Market gardening in the area is mainly dependent for water supply on the numerous springs and small tributaries, and not on the river itself.

The next major source of pollution of the Klip River is the Klipspruit (Map no. 1, section 'B').

The Klipspruit has a number of tributaries of about equal importance as far as flow and the incidence of pollution and contamination are concerned. The main stream arises in the storm-water drains of Johannesburg (P9) in the vicinity of the Johannesburg market and the suburb of Vrededorp. Somewhere in this vicinity one of the city's sewers was faulty and as a result sewage, on occasion, entered the storm-water system. A snap sample of the contents of one of these drains had an OA of 1,290ppm; another had an OA of 89ppm. Dilution by incoming drains reduces these values to about 70ppm in the vicinity of the municipal tar plant in Booysens (P11). A fairly large drain discharges mining waste water and seepage water from the Robinson Deep Mine sand dumps (P10) into the main stream just above this tar plant. The TDS concentration of the main stream at the tar plant is high, namely about 1,000ppm.

A canalized stream coming from the direction of the Turffontein golf course (P12) joins the main stream immediately below the tar plant.

This stream is badly polluted, having an OA of approximately 40ppm, and a TDS concentration of over 3,000ppm; the latter consists mainly of calcium and magnesium sulphates, which probably originate from factories next to the stream. (This matter was being investigated by the Johannesburg municipality).

About 300 yards below the junctions of these two streams, a canalized stream discharges seepage water from slimes dams lying to the south of Robertsham (P13). This water has a pH of 6 and a TDS concentration of over 2,000, due mainly to calcium and magnesium sulphates which cause permanent hardness.

The Klipspruit here flows through the Crown Mines area. Here storm-water run-off from slimes dams and sand dumps has direct access to the river, which is heavily silted up in consequence.

Approximately 200 yards above the upper Concordia Dam a considerable flow of contaminated water (with a pH of 6 to 7 and TDS concentration of over 1,500ppm) coming from a reduction works (P14) on the north bank, enters the river.

The main stream now enters the Concordia Dams. At this point the stream has a pH of 4 to 5 and a TDS concentration of over 2,000ppm. Dilution of the water in the dam is effected by a fairly strongly flowing stream of good chemical quality, which enters the dam from the south. This benefit is counteracted to a large extent, however, by contamination due to run-off from slimes dams (P15) along the north bank of the dams, particularly during heavy rains. The two dams have an important function in that they bring about the sedimentation of mine sand. The effluent from the lower dam contains no suspended solids; the dissolved solids concentration is of course not affected materially, the effluent having a concentration of over 2,000ppm.

The river flows past a further series of slimes dams (P16) which are a potential and actual source of contamination during storms, and, about two miles below the Concordia Dams, discharges into the Canada Dam.

Two /......

Two other streams also discharge into the Canada Dam. The first arises at Industria (P17), an industrial suburb to the north of Johannesburg; its water quality is reasonable, but highly variable. Sewage effluent from the Antea disposal works at Industria was admitted to the stream until March, 1951. The water is now contaminated as a result of industrial activity, and the Johannesburg Municipality was studying the matter. Before entering the Canada Dam, this stream from Antea is joined by a stream which starts near Maraisburg, as a spring of exceptional purity, but which is contaminated by run-off from mine dumps and slimes dams (P18) all along its course.

During dry weather, however, the chemical quality of the combined streams entering the Canada Dam is reasonable.

A third stream enters the Canada Dam from the west. This water (P19) is heavily contaminated by iron, calcium and magnesium sulphates, having a TDS concentration of over 2,000ppm; organic pollution was also noticed, the source being a mine compound of the Consolidated Main Reef Mine.

The effluent from the Canada Dam, at the time of the survey, was free from suspended matter but had a pH of 4.8, a TDS concentration of over 1,000ppm and zero oxygen demand (OA).

South of the Canada Dam the Klipspruit is joined by a stream of poor quality from the east. This contains sewage effluent, mine water run-off, and seepage from the Crown Mines (P20). The pH is fairly high 8.8, indicating lime treatment of the mine water; the OA is about 70ppm; and the TDS concentration is over 3,000ppm.

Another important stream, viz the effluent from the Rand Leases Dam, now enters the main stream (the Klipspruit) from the west; the stream has a pH of 8 and TDS concentration of 2,000ppm. The OA is negligible. The principal contaminants are calcium and magnesium sulphates.

The Rand Leases Dam has two main contributing streams. The first arises at the eastern reduction works of the Durban-Roodepoort Deep Mine. It is of poor quality to start with, and before entering the dam it is further contaminated by seepage and rain water run-off from slimes dams (P21) of the

Durban-Roodepoort Deep Mine and the Rand Leases Mine. The TDS concentration is over 2,000ppm and the pH about 7. In addition the stream carries over 5,000ppm suspended solids consisting mainly of mine sand, and the Rand Leases Dam, which serves to prevent this mine sand from getting into streams further down, is heavily silted up in consequence.

The second stream from Florida Lake entering this dam is of a reasonable chemical quality, having a TDS concentration of approximately 400ppm and a pH of 8. Permanent hardness accounts for most of this salinity which is mainly derived from sand-dump seepage (P22) from south of the Florida Dam. This stream has its origin in a number of springs of exceptional quality situated to the east of Roodepoort and between Florida and Discovery. The conductivity of these spring waters is around 15 micro-mhos. Storm water run-off from Roodepoort, Discovery and Florida, mixes with these spring waters and flows into the Florida Lake and thence into the Rand Leases Dam.

The Klipspruit, having been joined by the stream from the Rand Leases Dam, now flows through the Orlando Bantu township, where it is further polluted, particularly during rain storms. Just south of this township the Orlando Power Station Dam (P23) overflows into the Klipspruit. This dam provides cooling water for the power station. It is fed by two small streams of good chemical quality and by approximately 2 million gallons per day of high grade, sand-filtered sewage effluent from the Klipspruit sewage disposal works (P24). The use of this sewage effluent for power-station cooling water is one of our best examples of the re-use of water for industrial purposes. During normal weather there is no overflow from this dam, but the flow of water into the Klipspruit is maintained as a result of the ash disposal system in use at the station. The quenched ash is carried by water to a site below the dam where it is dumped, and the excess water then goes on into the Klipspruit. The water has a pH of 7.9 and a TDS concentration of approximately 800ppm, consisting mainly of calcium and magnesium chlorides and sulphates.

Drainage water, from sewage irrigation on ryegrass fields in the Pimville Bantu township area (P25), enters the Klipspruit a short distance

below /......

below the Orlando Power Station Dam stream. The quality of this water can vary enormously, but has in recent years been fairly good. It is usually a stable effluent with an oxygen demand of less than 30 ppm. Nitrates are often present and a nitric nitrogen concentration of as much as 20ppm has been recorded.

A short distance below the point of entry of this sewage effluent, a stream (P26) of good chemical quality enters the Klipspruit from the north-west. The pH is 8.1 and the TDS concentration less than 100ppm. In spite of this dilution, the water of the Klipspruit sampled at the bridge on the Potchefstroom road is still of poor chemical quality, having a pH of 5.9 and a TDS concentration of approximately 2,000ppm. The chemical contaminants are almost exclusively salts which cause permanent hardness.

Just south of the Potchefstroom road, effluent from contact-type biological filters (P27) that treat kitchen waste-water from the Moroka Bantu township, flows into the Klipspruit. The quality of this water is poor and oxygen demands of 30 to 40ppm are not uncommon; but the flow is small. This is the last major source of pollution of the Klipspruit, and about three miles downstream it joins the Klip River, which is now a fairly strongly flowing river.

The Klip River, sampled about a mile below its confluence with the Klipspruit, that is at the bridge on the road to Vanderbijlpark, had a pH of 7.4 and TDS concentration of over 1,500ppm. The high pH appears strange, in view of the acidity of the Klipspruit and Klip River only a few miles upstream. The river at this stage flows very slowly, however, owing to the flat and marshy nature of the countryside, so that changes in chemical quality brought about by rain would take some time to be transmitted downstream. Then, too, spring waters here are alkaline.

Olifantsvlei farm, a Johannesburg municipal sewage disposal farm (P28), is situated along the north bank of the Klip River at this point. The road from Johannesburg to Vanderbijlpark passes through the farm, which for many years has been irrigated with primary settling-tank sewage effluent.

The farm is large and the irrigation well-controlled, so that no run-off of a serious nature is encountered. The Harrington Spruit crosses the farm; its source is just east of the Klipspruit sewage disposal works and it runs westwards through Klipspruit farm (P29) where a certain amount of organic pollution is picked up. Nitrates make their appearance and the OA figure rises from zero to a variable value between 10ppm and 40ppm. The Harrington Spruit then flows southwards into Olifantsvlei farm and from there into the Klip River. During this last stage the chemical composition was found to remain practically unchanged at a pH of about 7.5 and a TDS concentration of about 1,000ppm. The OA was approximately 15ppm, the saline ammonia nitrogen was about 7ppm and there was a trace of albuminoid ammonia nitrogen.

The Klip River now continues to flow through swampy areas (vleis) and a sample taken about a mile and a half downstream (P30), where the Johannesburg-Vereeniging road crosses the river, had a pH of about 7; a TDS concentration of about 900ppm; no nitrate nitrogen and little albuminoid and saline ammonia. The OA was negligible. The decrease in TDS concentration is directly attributable to dilution as this area contains a fairly large number of springs.

Gradual improvement of the Klip River, due principally to dilution, is maintained for the next eight or nine miles until just before its confluence with the Natalspruit (see Map no. 2). Here the pH was 7.9 and the TDS concentration about 800ppm. The increase in pH to 7.9 is due to the alkalinity of some of the ground water in the area, which is in contact with the dolomite series of the Transvaal system and has, according to Bond[1], (p.69), an average pH of 7.9. As a result of the high pH the iron and aluminium content drops to a negligible value, the remaining contaminants being calcium and magnesium sulphates and chlorides.

Discussion

This survey of the upper Klip River and the Klipspruit has indicated that the two rivers, which start off as springs of exceptional purity, both become so heavily contaminated within a few miles of their sources that they

are /.....

are rendered unfit for most agricultural and industrial uses.

During dry weather the main sources of contamination are seepage water from slimes dams, sand dumps and regular effluent discharges from mine workings [see page 11, item (f)]. During storms, large quantities of water are involved when storm-water run-off from slimes dams and sand dumps carries with it considerable quantities of salts in solution, and sand and silt in suspension. In this area the problem of mining water is a serious one and warrants a special study, with particular attention to the re-use of water.

Penetration of mine sand into the beds of these two rivers and their tributaries is very serious, since the normal aquatic life has been disturbed and self-purification processes impaired. Fortunately most of this sand is removed by dams in the area, but as these dams are rapidly silting up they will not be effective for very long, unless extensive dredging is carried out.

Of the sewage disposal works encountered, the two Johannesburg municipal works, Klipspruit and Olifantsvlei, are the most important. The effluents which enter the rivers from these are of reasonable quality being limited to run-off and seepage from irrigated land. In fact the sewage effluents reduce salinity, because their total dissolved solids concentrations are generally lower than those of the streams. The Olifantsvlei is an effective pollution barrier which should be protected against the ravages of silt, sand and acid waters.

The Klip River leaves the area covered by this section of the report at Jackson's Drift. Analyses made so far show that the quality of the Klip River water leaves much to be desired, but they do indicate the beneficial effects of dilution and it must be considered fortunate that the Witwatersrand is a fairly well watered region. In more arid parts of South Africa, similarly contaminated streams would stand no chance of recovery by dilution.

The Natalspruit, Elsburgspruit, Rietspruit from
Brakpan, and the middle reaches of the Klip River
(See Map no. 2, Sections C, D, CC, and a portion of AA)

General

The Natalspruit, Elsburgspruit, and the Rietspruit all arise in an arc along the eastern Witwatersrand. This arc extends from Johannesburg in the west, through Germiston and Boksburg, to a position south of Brakpan in the east. The original sources of the streams in this area have been lost in a maze of mining and industrial effluents as a result of the intensive mining activity and industrial development in the area. Although dilution of these contaminated streams is effected by numerous springs and tributaries to the south, pure unpolluted streams that might serve as diluents are rare in the head-water zones. The analyses of the waters in this area are presented in Table 2.

Detailed description

The Natalspruit, which is the largest stream in the area under discussion, has its source in the storm-water drains of eastern Johannesburg, a predominantly industrial area. At Wolhuter (P31), where these drains emerge into the open, a sample of the water indicated severe mineral and organic pollution. The water had a TDS concentration of over 1,000ppm, and the OA was 62ppm. All along the banks of the river here, we find slimes dams and sand dumps. Seepage water and storm-water run-off have easy access. After passing through one small dam the Natalspruit enters the Rosherville Power Station Dam (P32), which is of considerable size and provides cooling water for the power station. It is also the focal point for two other streams.

The more important of these two streams comes from the Wemmer Pan (P33) to the south-west of Rosherville. The water of this pan is maintained by springs and storm-water run-off from the surrounding suburbs and sand dumps, but the effluent from the pan is of reasonable chemical quality with a TDS concentration of about 550ppm and an OA of 7ppm. The pH of 4, however, is

fairly /......

fairly low. Shortly after leaving the pan, this stream is joined by run-off of poor quality from the direction of the City Deep Mine reduction works (P34). The TDS concentration of this water is over 1,000. Here, too, penstock waters and seepage from slimes dams and sand dumps have direct access to the stream, which is heavily silted up in consequence. This stream crosses the Durban road and enters the Rosherville Dam. Along this section it is canalized and passes close to a large slimes dam (P35), from which seepage enters the furrow. This seepage has a TDS concentration of over 2,800ppm and contains over 5,500ppm of suspended solids.

The second stream enters the Rosherville Dam from the north. It also drains a mining area (P36), as is evidenced by a TDS concentration of over 3,000ppm, consisting mainly of calcium and magnesium salts.

The effluent from the Rosherville Dam, the Natalspruit, is of a very poor quality with a pH of 5.3 and TDS concentration of over 2,000ppm. Sand and silt in suspension have, of course, been effectively removed by the dam, but the capacity of this is reduced accordingly.

About a quarter of a mile below the dam the Natalspruit is joined by a steadily flowing stream which enters from the south-west. Along its upper reaches in the Klipriviersberg area (P37) the stream is very clean, but it is contaminated by seepage water from the Wemmer Pan stream, since these two pass very close to each other at one point.

A few hundred yards after crossing the road from Johannesburg to the Rand Airport, the Natalspruit is joined from the north by another badly contaminated stream, with a pH of 3.5 and TDS concentration of over 3,500ppm. This stream arises in the vicinity of Geldenhuis Station (P38), and is maintained by seepage from slimes dams and by storm water drainage. Seepage from one slimes dam in the area had a pH of 4 and TDS concentration of over 4,000ppm consisting mainly of salts responsible for permanent hardness. Sand and silt are removed by a small dam before this stream joins the Natalspruit, which now flows through a gap in the range of hills and enters the town of Alberton.

In Alberton the Natalspruit water has a pH of 3.8 and TDS concentration of over 2,000ppm. Here the river is joined by a small stream (P39) from the west, but this water is of good chemical quality. South of Alberton the Natalspruit enters a marshy valley, and at this point (P40), it is joined by a stream of considerable importance, the Elsburgspruit, with water of variable quality. At the time of sampling it had a pH of 7.2 and TDS concentration of over 1,700ppm.

The Elsburgspruit arises in the vicinity of Delmore Station and drains a large mining area (P41) to the north-east of Germiston. Waste water and seepage water from these mine properties collect in a small dam (P42) next to the main Germiston-Boksburg road, where so much sand and silt have been deposited over the years that the dam is now completely filled. Water pumped from this dam is re-used by the mines but the excess water, which has a pH of 4.6 and TDS concentration of over 3,000ppm, crosses the abovementioned road and enters the Elsburg Dam from the north-west.

A second stream enters the Elsburg Dam from the north-east. The area (P43) to the north-west of Boksburg is drained by a furrow which passes through the Comet Deep property and crosses the Germiston-Boksburg road to enter the Angelo Pan (P44). This water is largely made up of effluent and seepage from mining activity and has a pH of about 4.0, a TDS concentration of over 10,000ppm, suspended solids of 11,000ppm and an OA of 450ppm. The effluent from the Angelo Pan, which is still acidic, is treated with lime by the mining authorities, and flows into dam 'B'. A second stream enters dam 'B' from the north, and this is also treated with lime since it is an acidic mining effluent with over 3,000ppm dissolved solids. Judging by the smell and appearance of this water, it contains a fairly large proportion of waste water from a compound for Bantu workers (P45) north of the railway line. Seepage water from dam 'B', at the time of this survey, has a pH of 3.5 in spite of the lime treatment.

Dam 'A' (see Map no. 2) also contains mine water, the stream (P46) from north of Angelo Station having a pH of 4.3, and TDS concentration of over 4,000ppm. This stream is joined by another from the west, which is largely compound waste water, with an OA of 50.3ppm.

The /.....

The combined effluents from dams 'A' and 'B', having a pH of 4.6 and TDS concentrations of over 3,500ppm, flow into the Elsburg Dam, where the remaining sand is removed from suspension. The effluent from the dam is joined at some distance further down-stream by a stream from the west, which originates north of Germiston in the vicinity of the Simmer-and-Jack and the Rose Deep mines (P47). This water, which is almost entirely run-off from mining property, has a pH of 8.5 indicating lime treatment, and TDS concentration of over 3,000ppm, due mainly to calcium and magnesium salts. It enters a storm-water drain and flows into the Victoria Lake (P48), carrying with it approximately 4,000ppm of sand in suspension. This silt load necessitates dredging of the lake, which is silting up rapidly. A second stream of contaminated water enters the lake from the west. This stream drains the area occupied by the southern Simmer-and-Jack slimes dams and sand dumps (P49) and is of extremely poor quality, having a TDS concentration of over 4,000ppm. The pH of 9.4 indicates lime treatment of the mine water. The effect of these contaminated streams on the water of the Victoria Lake is indicated by the state of its overflow water, which has a TDS concentration of 4,000ppm and a pH of about 5.5.

About a mile from the lake the overflow is joined by the Georgetown stream (P50), which originates in Germiston itself and now functions primarily as a storm-water drain. At the time of sampling (dry spell) the water was of fair quality, with a TDS concentration of 600ppm. Nearly two miles further downstream the combined stream joins the Elsburgspruit which is the overflow from the Elsburg Dam.

Immediately to the west of the Elsburg Dam, several morgen of land have for many years been used as a land disposal site (P51) for molasses-slop from a local chemical factory. During dry weather conditions this disposal system does not impose an additional pollution load on the stream below the site, but during storms a considerable quantity of very heavily polluted water finds its way into the Elsburgspruit and constitutes a serious nuisance. This is evident for a considerable time after rain storms because the Elsburgspruit, before joining the Natalspruit, enters a wide, reed-filled swamp and flows very slowly so that septic conditions sometimes prevail.

About a mile to the south of Elsburg town another important stream enters the Elsburgspruit. This is the overflow from the Cinderella Dam (P52) near Boksburg; it has a pH of 4.5, TDS concentration of over 2,000ppm, and OA of 14.8ppm. The main stream, which enters the Cinderella Dam from the north, arises about two miles north-east of Boksburg. It is a clear stream until joined from the east by effluent from a petroleum refinery (P53). This effluent is of extremely variable quality, but a snap sample taken at a time of large flow had a pH of 9.4, a TDS concentration of 1,700ppm and an OA of 504ppm. A short distance below the confluence of this effluent with the stream, the first mining contamination is encountered; the quantity, however, is small during dry weather conditions. The source of this contamination is the East Rand Proprietary Mine (P54), where catchment dams and pumps have been provided in an effort to prevent storm-water run-off from entering the stream and, subsequently, the Boksburg Lake. As far as surface drainage is concerned, these measures are effective in all but the heaviest storms.

During storms the Boksburg Lake (P55) receives, in addition to the mine run-off water and water from the refinery, large quantities of storm-water from Boksburg. This water prevents the TDS concentration of the lake water from rising above 600 to 700ppm. At the time of this survey, the pH was 4.3 and the TDS approximately 500ppm.

About three quarters of a mile below the lake, its effluent enters the Cinderella Dam, which suffers contamination from mining activity along its banks, giving rise to the TDS concentration mentioned earlier, of over 2,000ppm.

The Elsburgspruit, having been joined by the Cinderella Dam effluent, is now a fairly large stream. Some dilution of the river water is effected a little lower down by a clean water stream from the east, but the volume of water involved is not large in dry weather. A sample from the main stream below this point showed that the water is still extremely saline, having a TDS concentration of over 2,000ppm and a pH of 4.6

The next important source of water in this area is the Rondebult sewage purification works (P56), which serves both Germiston and Boksburg.

It /.....

It is a modern, well equipped works; sewage effluent, which is of good quality, is utilized for irrigation and only seepage from irrigated land enters the Elsburgspruit which flows past to the north of the disposal works. The seepage entering the spruit has an average TDS concentration of 1,020ppm, an OA of 11.5ppm, and its pH averages 7. The alkalinity of the run-off has the effect of precipitating iron and aluminium in the Elsburgspruit, and the pH is raised to about 6.3, while the TDS concentration drops by approximately 300ppm.

It has long been the practice to irrigate this area with Elsburgspruit water and effluent from the Cinderella Dam, but, owing to the acidity of the water, liberal applications of agricultural lime have been necessary to prevent damage to crops. The high salinity of the water has affected the soil considerably, with the result that crops are poor. Better results are reported, however, by farmers using the Elsburgspruit water after admixture with Rondebult sewage effluent, although the salinity is still rather high.

The Elsburgspruit enters the Natalspruit a few miles to the north-west of Rondebult and the resultant stream has an average pH of 6.1 and TDS concentration of approximately 2,000ppm. From this junction for a distance of about eight miles, the Natalspruit flows through pastoral and agricultural countryside, where some dilution of the river water is effected by springs. A sample of the river water taken just before its confluence with the Riet-spruit (P57) had a TDS concentration of 1,500ppm and pH of 7.9.

The Rietspruit, which enters the Natalspruit from the north-east, arises in the Witpoort gold area (P58) about four miles to the south-west of Brakpan. The stream is a small one so that seepage and run-off from mines in the area soon affect its composition adversely, the TDS concentration immediately south of the Van Dyk mine being over 1,000ppm. About seven miles from its source the Rietspruit is joined by a small stream that originates near the S.A. Lands mine (P59). This stream is contaminated to much the same extent as the Rietspruit by seepage from slimes dams along its course. By the time the Rietspruit joins the Natalspruit, dilution by springs along its course has reduced the TDS concentration to about 350ppm.

About /.....

About two miles below its confluence with the Rietspruit, the Natalspruit flows into the Klip River (P60), which here has a pH of 8 and TDS concentration of about 800ppm, while the Natalspruit has a pH of 8 and TDS concentration of 1,400ppm.

The upper reaches of the Klip River, extending to Jackson's Drift, are discussed under 'General', (p.15). At Jackson's Drift the Klip River has a pH of about 7 and TDS concentration of about 900ppm; it can be seen, therefore, that by the time the Natalspruit is encountered the pH has increased by one unit to a pH of 8, and the TDS concentration decreased to 800ppm. Both these changes are directly attributable to the influence of spring water which, in this area, comes into contact with the dolomite series of the Transvaal geological system and has in consequence a high average pH of 7.8 (See Bond[1] p.69).

The Klip River water, which now contains the Natalspruit's contribution, has at this stage in its flow to the Vaal River a TDS concentration of about 1,100ppm; moreover, because of the high pH of 8, only traces of the iron and aluminium salts derived from mining and industrial sources are detectable. The dissolved solids, now comprise almost entirely calcium, magnesium and sodium salts, resulting in a fairly hard water but one that is not altogether unsuitable for irrigation purposes.

The lower reaches of the Klip River will be fully discussed at a later stage, but for the sake of completeness it is worth mentioning that the river water eventually enters the Vaal River and, at the time this survey was conducted (late summer), had a TDS concentration of approximately 800ppm and a pH of 8, indicating further dilution.

Discussion

This preliminary survey of the areas drained by the Natalspruit, the Elsburgspruit, and the Rietspruit, has indicated that mineral contamination of these rivers is especially prevalent and that pure unpolluted tributaries are not encountered along the upper reaches. The high salinity of these river waters make them unfit for nearly all agricultural and industrial uses;

furthermore /....

furthermore, signs of aquatic life are rare along many stretches.

During dry weather conditions, the main sources of contamination appear to be seepage water from slimes dams and sand dumps and regular effluent discharges from mine workings [see page 11, item (f)]. In addition, large quantities of water are involved during storms, when storm-water run-off from slimes dams and sand dumps carries with it large quantities of salts in solution and sand in suspension. Indeed, mine waters in general present a big problem and one that certainly warrants investigation, particularly with regard to possible re-use of the water by the mines or by industry.

The penetration of mine sand into the beds of the rivers is another important feature in this area, since normal stream life is disturbed and natural self-purification properties are impaired. The marshy, reed-filled vleis, where sand readily collects, are important pollution barriers and must be protected. Fortunately, however, most of the sand and silt is removed from the stream by dams in the area, but these dams are rapidly silting-up and will be effective for only a limited time unless extensive dredging is carried out.

In addition to mining contamination, some unsuitable industrial effluents are being discharged into these rivers, a practice that must be actively discouraged. This is not unreasonable in view of the fact that suitable methods of treatment are available, or can be developed, for most industrial effluents.

The only sewage purification plant in the area is at Rondebult, and this serves both Germiston and Boksburg. This plant, which treats approximately six million gallons daily, contributes seepage water of good quality to the Elsburgspruit and cannot be regarded as a source of pollution. In fact this seepage water is of better chemical quality than the river into which it flows. Organic pollution of rivers in the area under discussion was, however, noted at a few points, notably near Bantu compounds where kitchen waste-water was discharged without any treatment.

On leaving the mining and industrial areas, all the streams gradually improve in quality, owing to dilution by springs and tributaries. The increase in pH which dilution brings about, results in the precipitation of iron and aluminium salts. The remaining contaminants are chiefly calcium, magnesium and sodium salts, which give rise to a rather hard water, not very suitable for agricultural use.

The upper tributary of the Blesbokspruit, the Blesbokspruit and the Small Blesbokspruit in the Springs area, the Blesbokspruit in the Nigel-Heidelberg area, and the Suikerboschrand River.
(Map no. 3, sections E, F, and G).

General

There is a marked resemblance between the mining and industrial activities of the Central Rand and the East Rand; consequently the nature of mining and industrial effluents does not differ greatly for the two areas. Although the Blesbokspruit is burdened by a considerable load of pollution in its upper reaches, the extent of dilution by springs and tributaries to the south markedly restores the self-purification processes of the river. Analytical results are presented in Table 3; p.6.

Detailed description

The Blesbokspruit arises a few miles to the north-east of Springs. It is a small stream of little importance until it is joined near Welgedacht Station (P61) by a large tributary from the west, which has it source in numerous springs in the vicinity of the Jan Smuts Airport (P62) and Kempton Park. To start with, the water of this tributary is of excellend chemical quality, having a pH of 7.1 and a TDS concentration of 128ppm. Three dams north of Benoni are actually popular fishing spots. The lowest of the three dams, the so-called Laundry Dam (P63), receives the first important contamination by way of a storm-water drain from Benoni. This contains seepage from sewage-irrigated land (P64) and from some industrial waste, the mixture having a pH of 7.7, a TDS concentration of 680ppm and an OA of 9.8ppm.

The /.....

The first mining contamination is encountered immediately below the Laundry Dam. This consists of mine waters, seepage water from sand dumps and slimes dams and waste water coming from the direction of the New Kleinfontein mine (P65). As a result, the nature of the stream changes abruptly; the TDS concentration increases to over 2,500ppm, consisting mainly of calcium and magnesium sulphates, but the pH remains constant at about 7.4, indicating lime treatment of the waste water. At the time of sampling (late summer), the flow in the stream here was small and about two and a half miles downstream it had ceased completely. This stretch of the stream is a very bad one during rain storms, since slimes dams and sand dumps on both banks must contribute large quantities of contaminated run-off water, and the bed of the stream is silted up with mine sand.

After flowing eastwards the stream now suddenly turns southwards and at this point (P66) it is joined by two small tributaries. The first is the overflow from the Rynfield Lake (P67) and is a reasonably good water with a TDS concentration of about 600ppm; the second is run-off from the Modder B Mine (P68), with a pH of 5.6, a TDS concentration of over 2,000ppm, and an OA of 37.6ppm. This second stream also contains kitchen waste-water and has a most unpleasant smell. After its confluence with these two small streams the main stream continues to flow between slimes dams, and, by the time it reaches the Geduld Dam (P69), the TDS concentration has risen to about 3,500ppm while the pH has dropped to 3.1.

Three other streams enter the Geduld Dam. The first of these, which enters from the west, consists almost entirely of mining effluent from the Brakpan mines (P70) and is a water of poor quality, with a pH of 3.8, and a TDS concentration of about 4,700ppm. The second stream is a strongly running furrow, which enters from the south-west and which originates in the Brakpan Lake (P71). Brakpan's modern sewage purification plant is the main source of water for the lake; the effluent is of good quality with a pH of 7.2, a TDS concentration of 438ppm, and an OA of 11.8ppm. A power station situated on the north bank of the lake uses the water for cooling purposes. Under normal conditions the lake has no outlet, but when the water reaches a certain level it is pumped into the furrow referred to above.

A sample /.....

A sample of this water had a pH of 9 and TDS concentration of 956ppm. Kitchen waste-water from compounds of the State mines (P72) and waste-water from mining activity also enter the furrow; the TDS concentration increases to over 1,100ppm and the OA value to 44.0ppm. The third stream enters the Geduld Dam next to the dam overflow, just south of Dersley Station. This stream enters from the south and contains mining effluent from the Geduld mine, no. 7 shaft (P73). The water has a pH of 8, indicating lime treatment, and a TDS concentration of 2,000ppm.

The effluent from the Geduld Dam is of very poor chemical quality, as its pH is 3.1 and the TDS concentration about 4,000ppm, while iron and aluminium oxides amount to 360ppm. This water immediately enters a further dam where some dilution probably takes place during storms, since the effluent, although still very acidic, has a TDS concentration of 2,000ppm which is considerably less than that of the Geduld Dam.

Cowls Dam (P74), into which the stream now flows, is the last of a series of dams which provide water for mines and industries in the area. This dam, together with a mine, a factory, and a sewage disposal works, form what is nearly a closed circuit in water utilization, the main sources of raw water being the disposal works and underground water from the mine. Owing to the poor quality of the mine water, the factory has had to install a treatment plant at considerable cost, in order to obtain water suitable for process use. For many years the water from this factory was a serious contaminant of the stream, but in recent years considerable improvements have been effected and the effluent, although still not completely satisfactory, is fit for re-use by the factory. The sewage works (P75) mentioned above serves the Springs municipality and produces an effluent of reasonably quality. None of this, however, enters the stream since it is all used by industry.

The effluent from the Cowls Dam now enters the Blesbokspruit (P61) and the combined stream samples at the bridge on the road from Springs to Delmas had a pH of 7.2 and TDS concentration of over 2,000ppm. The fact that the pH of this water is so much higher than that of the influent to the

Cowls Dam is due to the alkaline nature of the factory effluent, discussed above. Slimes dams in this area contribute contaminated run-off and seepage water during storms.

About five miles below its confluence with the large tributary from Benoni, the Blesbokspruit is joined by the Small Blesbokspruit (P76), a fairly strongly flowing tributary which originates west of Springs (P77) and flows through a mining and industrial area. Here seepage and drainage from slimes dams, sand, rock dumps, and other mining activity soon affect its mineral composition adversely. Drainage from one rock dump (P78) had the uncommonly high TDS concentration of 56,530ppm, and a pH of 2.8.

Approximately one mile before its confluence with the Blesbokspruit, the Small Blesbokspruit receives the seepage and run-off water from sewage-irrigated land (P79). This effluent comes from the Ancor sewage purification plant that serves a large portion of Springs. It is of good chemical quality, having a pH of 7.2, a TDS concentration of 400ppm and an OA value of about 11.0ppm. The Small Blesbokspruit at this stage has a pH of 3.6 and a TDS concentration of 3,400ppm. The sewage effluent, therefore, serves as a diluent.

The Blesbokspruit now flows southwards down a long marshy valley, which extends to within a few miles of the mining town of Nigel. Along this stretch of the river are a few potential sources of contamination, namely the Daggafontein (P80), Vogelstruisbult (P81) and Marievale (P82) mines. It is possible, however, that only during the more severe rain storms can run-off water from slimes dams and sand dumps find its way into the Blesbokspruit; but the position needs to be watched.

The next major source of contamination is a stream which arises north-west of Nigel in the vicinity of the Vlakfontein gold mine (P83). A sample, taken where the Springs-Nigel road crosses the stream, had a pH of 5 and a TDS concentration of 2,000ppm, due mainly to calcium and magnesium sulphates and chlorides which might be of sewage origin. More mine water enters this stream about two miles lower down. This is seepage water from slimes dams of the Sub-Nigel mine (P84) and it has a pH of 3.3 and 2,400ppm dissolved solids.

This /....

This tributary of the Blesbokspruit now flows into two successive dams, bounded by mining property and slimes dams (P85) just north of Nigel, and the overflow, which has a pH of 4.3 and 2,600ppm dissolved solids, passes through the town and into the main river about one mile further down. A sample taken from the combined streams about a mile below this confluence had a pH of 7.4 and TDS concentration of 2,100ppm. The Nigel sewage disposal works (P86), which is situated here, produces an effluent of good quality but none of this enters the Blesbokspruit as it is all used for land irrigation.

Additional contamination from mining sources can enter the river below this point, for example from the Spaarwater (P87) and Poortjie mines (P88), but here again this is only possible during unusually severe storms. During dry weather, dilution by springs and small tributaries is the main factor in this section; and by the time the river reaches Heidelberg, a decrease of approximately 400ppm in TDS concentration has been brought about.

A tannery (P89) in Heidelberg disposes of its effluent in a series of small settlement pools, but these appear to be barely adequate and seepage water was seen to enter the river. No sample was obtainable, but tannery wastes are known to be generally undesirable in streams because of their large oxygen demands.

From Heidelberg until its confluence with the Suikerboschrand River (P90), the Blesbokspruit receives no further pollution and the TDS concentration falls to about 1,300ppm, while the pH rises to 7.8. The gradual rise in the pH of the river water, from about 7 at Springs to 7.8 here, is due to the alkalinity of the ground water in the area.

The Suikerboschrand River, which is a fairly strongly running stream under normal conditions, rises about thirty miles east of Heidelberg. Since this river passes through agricultural and pastoral countryside, no mining or industrial contaminants have access to it and in consequence the water is of good chemical quality, the pH being 7.8 and the TDS concentration 125ppm.

From /......

From its confluence with the Blesbokspruit, the Suikerboschrand River flows through open countryside for a further twenty miles before entering the Vaal River a few miles above Vereeniging (P91, Map no. 4). At the time of the survey the pH of the water here was 7.3 and the TDS concentration over 700ppm, while the conductivity was 1,000 micro-mhos. Rand Water Board records indicate that, for this river water, the average monthly conductivities over the last few years have varied between 390 and 1,400 micro-mhos. This big variation is seasonal, the high conductivities corresponding with the rainy months, when rain water run-off from sand dumps and slimes dams comes down in flood.

Discussion

Of the rivers discussed so far, the Blesbokspruit is the only one with appreciable stretches of fairly unpolluted head waters (e.g. main tributary). The mineral pollution in the mining areas from Benoni to Bethal is, however, so severe that its deleterious effect is observed in the whole stretch of the river below Benoni. The points at which pollution enters the river's course below Bethal are separated at five to seven mile intervals and this helps to maintain an almost steady degree of pollution right up to Heidelberg.

The flow in the Blesbokspruit is small during winter, the river is sometimes completely lost in the reeds north of Nigel, so that the accumulated mineral pollution is very marked. Also, along the stretch of river below Bethal, the slimes dams and mine heaps, which are the contributors to pollution, are far removed from the river. Accumulations from them are retained and are swept into the river during heavy rains.

The dams in the upper river must have a beneficial effect on flow conditions. During mild rains the dams do not contribute to the flow in the initial stages so that mineral pollution lower down the river is separated from the mineral pollution in the upper reaches. This must prevent some of the 'slugging' effect of mineral pollution discharged in one operation.

For /.....

For several miles, the Blesbokspruit passes through vlei-areas. In any scheme to combat the pollution of the Blesbokspruit, investigation should be made into the possibility of utilizing the vlei's purification capacity.

The lower Klip River and Vereeniging area
(Map no. 4, Section AA)

General

The Klip River at Jackson's Drift contains drainage water of a large part of the West Rand from Johannesburg to Lewisham (see Map no. 1). This water consists of run-off and seepage water from mines, industrial and sewage effluents, and natural water from springs and unpolluted tributaries. It had, at the time this survey was conducted, a pH of 7 and a TDS concentration of 900ppm, which is a distinct improvement on the value of 1,500ppm found a few miles upstream. Gradual improvement, due principally to dilution, is maintained for the next 8 to 9 miles, until just before the confluence with the Natalspruit (see Map no. 2) when the pH was 7.9 and the TDS concentration about 800ppm.

Detailed description

The Natalspruit water, with its pH of about 8 and TDS concentration of over 1,400ppm (see 'Detailed description', p.24) is the major source of the pollution occurring in the Klip River which now has a dissolved solids concentration of over 1,000ppm. In the course of the next twelve miles this value drops to about 800ppm, again by dilution.

The next important source of contamination is the Klip Power Station (P92), which discharges water with a pH of 8.7, a TDS concentration of 271ppm, and an OA of 74.2ppm. Judging by its appearance this water is derived mainly from ash quenching and conveyor systems.

At Vereeniging the Klip River had a pH of 7.9 and a TDS concentration of 823ppm, but records of the Rand Water Board indicate large fluctuations in quality, and average monthly conductivities of over 1,000 micro-mhos are common during the rainy season.

A final source of contaminated water must be mentioned. Although the volume of water is small and the chemical quality reasonable, the main trouble here is floating mineral oil. The source is South African Farm Implement Manufacturers, Limited (P93), who discharge waste-water containing oil into the Klip River at the bridge on the road from Vereeniging to Vaal Dam. About one mile lower down (P94) the Klip River flows into the Vaal River.

In the Vereeniging area a few other sources of contamination are of note. The first and most important discharge consists of the combined effluents from Stewarts and Lloyds (P95) and the Union Steel Corporation (P96) factories. Individual analyses of these two waters indicated pH's of 6 and 3.8 and TDS concentrations of 194ppm and 779ppm respectively. Both these waters are objectionable: that from Stewarts and Lloyds mainly because of floating oil, and that from Union Steel Corporation because of both its acidity and its TDS concentration which is due almost entirely to iron sulphate in solution. The combined effluents discharge into the Houtkopspruit, a small stream which rises north-west (P97) of Vereeniging and flows into the Vaal River near the Riviera Hotel. On occasions floating oil from this stream has made swimming in the Vaal River below the confluence most unpleasant.

The Vereeniging Power Station (P98) is also a source of contaminated water, since water from ash quenching operations has direct access to the Vaal River. A sample of this water had a pH of 13.2 and TDS concentration of 3,478ppm consisting mainly of calcium sulphate.

The last important effluent in this area comes from a Union Steel Corporation factory (P99), situated on the north bank of the Vaal River immediately below Vereeniging. This plant discharges a steady stream of water with a TDS concentration of about 200ppm, which is not significant; floating oil, however, is the main contaminant and should be removed.

Discussion

The Klip River shows improvement in quality in its run from Jackson's Drift to the confluence with the Natalspruit (see 'Detailed description' p.24) and has a pH of 8 and TDS of 800ppm. After the confluence with the Natalspruit the TDS rises to 1,000ppm and twelve miles downstream decreases to 800ppm. If the drop in TDS was brought about by dilution only, then the contribution to the flow by springs along this length of river must at least equal three quarters of the Natalspruit flow. In the absence of gauging weirs on the streams from natural springs, this could not be verified. The river flows through vleis and reeds in this area and a reasonably accurate determination of the flow contributions of the springs would permit one to establish whether dissolved solids were being removed along the length of the river by these vleis.

Except for the discharge occurring as a result of ash quenching at the Vereeniging power station which is almost completely saturated with dissolved solids, the pollution along this stretch of river is of a different nature from that resulting from mining operations. The main pollution is by oily effluents which, apart from unsightliness, do not cause much damage to the quality of the water. The discharges in this area are all 'controllable' in that they are dissipated as they are produced. In contrast to the Accumulated Mineral Loads carried in run-off during the rainy seasons, these effluents offer a wider scope for safe-guarding the river because control can be exercised over manufacturing processes as well as over the disposal of effluents.

DISCUSSION /.....

DISCUSSION OF THE RESULTS OF THE PRELIMINARY SURVEY

It is unfortunate that, while the rivers dealt with in this preliminary survey of streams in the Witwatersrand area start off as crystal clear springs, all are usually badly contaminated within a few miles of their sources. All the rivers and streams studied in this survey pass through extensive mining and industrial areas and the water is soon rendered unfit for most industrial and agricultural uses.

Seepage from slimes dams and sand dumps, waste water from reduction works, water pumped from underground workings of mines, compound waste water, and industrial effluents constitute the main contaminants under dry weather conditions. Sewage effluents are also encountered, but these are generally of far better chemical quality than the streams into which they flow. During the rainy season additional large quantities of contaminated water are involved when storm-water run-off from slimes dams and sand dumps carries with it considerable quantities of salts in solution, together with sand and silt in suspension.

Penetration of sand and silt into the water courses is very far advanced and large stretches are completely silted up, as are many of the dams which have long arrested the advance of the sand. This is a very serious aspect of the problem, because the sand soon chokes normal aquatic life in the natural vleis, and the self-purification effected in these important pollution barriers is impaired.

Dilution of the contaminated river water by springs and tributaries is again of great value, but its effects are not as noticeable on the Blesbokspruit as they are on the Klip River, because mining activity is encountered much further to the south in this area and fresh contamination keeps the dissolved solids concentration high. Only when the water reaches the Suikerboschrand River does its quality approach a more reasonable standard.

Industrial activity in the Vereeniging area has resulted in a number of undesirable effluents. This is to be deprecated, particularly as these effluents are of such a nature that they could fairly readily be rendered innocuous.

This /.....

This preliminary mapping survey of the rivers draining southwards from the Witwatersrand and discharging into the Vaal River above Vereeniging has clearly indicated both the nature of the contamination encountered and its principal sources. These sources are mainly slimes dams and sand dumps of active and derelict mines, and also reduction works, while isolated industrial concerns are responsible for discharging highly mineralized waters.

In view of the fact that the value of water for re-use is largely determined by its initial total mineral-salt concentration, this contamination from mining and industrial sources must be actively discouraged so as not to jeopardize future industrial expansion along the southern Witwatersrand. Water leaving sewage disposal works and industrial waste-treatment plants must be of such a nature that it can readily be re-used.

C H A P T E R   T H R E E/.....

C H A P T E R   T H R E E

QUANTITATIVE SURVEY OF THE KLIP RIVER AND THE NATALSPRUIT AND THEIR TRIBUTARIES

(Map sections A, B, AA, C, D and CC)
(Tables 5 to 17 and diagrams 1 to 13)

The Klip River at Vereeniging

(Map no. 4, sampling point AA4c)

The mineral load data are represented graphically in Figures 2 and 2A, p. 57 and some specific data are summarized in Table 26, p. 50.

Observations:

(a) During the dry months (May to October), average dry-flow conditions prevail in the Klip River at this point, except that towards the end of the dry season there is a rapid decrease in the flow with a corresponding decrease in the observed total mineral load.

(b) The dry-weather flow (May to October) consists of effluent discharges from mines, sewage disposal plants (directly and via underground percolation), and natural flows from springs. Run-off resulting from rainfall can be considered as nil, except for out-of-season rains. Therefore, for this period observed total mineral loads only are recorded. Some assessment of the quantity of the dissolved mineral load which is carried in the regular effluent discharges reaching this point during the dry season, is obtained by the difference between the observed total mineral load and the natural total dissolved mineral load. The latter figure represents the dissolved mineral load which would be contributed by a natural flow equal to the observed flow. This assumption represents approximately the true position since all effluent waters (sewage and industrial) originate from either domestic water supplies (TDS 100 to 200ppm during dry months) or natural underground water (for TDS see Table 4, p. 7). Data on the total dissolved mineral load carried in regular effluent discharges reaching point AA4c, are plotted in Figure 2A, p. 58.

(c) The /....

(c) The average dissolved mineral load - see Figure 2(a), p. 58 - carried in the regular effluent discharges, calculated as detailed in (b) above and reaching the Klip River at Vereeniging during the dry season, was 50 and 65 tons per 24 hours for 1952 and 1953 respectively. The maximum and minimum loads for the corresponding period were 105 and 10 tons per 24 hours, respectively.

(d) During July 1952 rain fell on the Witwatersrand; the observed total mineral load rose sharply and exceeded the expected total mineral load considerably. On 28th July the excess was 300 tons per 24 hours. This latter figure represents the accumulated mineral load, e.g. solids dissolved from slimes dams, sand dumps, mining areas, and solids in solution in water released during storms from slimes dams, which reached the Vaal River by way of the Klip River at the time the measurements were taken.

(e) For the whole of the rainy season the observed mineral load exceeded the expected mineral load very materially. This observation indicates quite clearly that, during the summer months, the flow in the Klip River at Vereeniging carried a heavy accumulated mineral load. The maximum recorded was 4,035 tons per 24 hours during floods, and the minimum was 70 tons (Table 26, p. 50) towards the end of the rainy season (April 1953) when little rainfall was recorded and flows were not high. The average accumulated dissolved mineral load was 860 tons per 24 hours.

(f) During the rainy season mineral load contributions by regular effluent discharges can be estimated from the difference between the expected total mineral load and the natural mineral load. (See (b) above and refer to definitions). It is a most remarkable feature that the mineral contributions by regular effluent discharges during the rainy season did not fluctuate as widely as those for the dry season. The extreme limits recorded were 50 and 82 tons per 24 hours, with an average of 60 tons per 24 hours; whereas during the dry season - see (c) above - the limits were 105 and 10 tons per 24 hours.

(g) The data plotted in Figure 2A, p.58, indicate clearly that, during the latter half of the dry season, the dissolved mineral load resulting from regular effluent discharges decreased rapidly, in consequence of which the composition of the water in the Klip River at point AA4c approached that of a natural water. That is, the TDS concentration in the water decreased.

Klip River - Natalspruit confluence
(Map no. 2, sampling points AA1a, AA1b and AA1c)

The mineral load data for the Klip River - Natalspruit confluence are detailed in Figures 3, 3A, 4, 4B, 5 and 5A, pp.59 to 62.

The general picture at each of the three sampling points is identical with that of the Klip River - point AA4c, Figures 2 and 2A, p.57 - at Vereeniging. The general observations made above for the Klip River at Vereeniging (p.43) are also applicable for the Natalspruit - Klip River confluence. Table 27, p. 50, summarizes outstanding specific data only.

Observations

(a) The general observations made above for the Klip River at Vereeniging - Point AA4c - are also applicable to the Natalspruit - Klip River confluence.

(b) The mineral load data given in Table 27, p. 50 for the Klip River below its confluence with the Natalspruit do not represent in detail the sum total of the relative mineral loads of these two rivers before their confluence, as will become evident from the following observations.

(c) Flow recordings for the three observation points AA1a, AA1b and AA1c were not always made on the same day. Peak flow gaugings, for example at AA1c, never coincided with recordings at AA1a and AA1b. Sufficient data were available for point AA1c to indicate that actual peak flows were not recorded for AA1a and AA1b. For example, when the maximum observed mineral load for point AA1c was recorded for the period 10 - 13 November, 1952, no corresponding measurements were made for AA1a and AA1b.

(d) Maximum or minimum load recordings for the Natalspruit and Klip River above their confluence did not always coincide. For example, the maximum load from regular effluent discharges was recorded for the Natalspruit - Figure 5A, p.62, - on 3rd July, 1952, whereas the maximum for the Klip River - Figure 4A, p.61, - was reported on 6th May, 1953.

(e) Dissolved mineral load contributions from the Natalspruit appear to be less than those from areas drained by the Klip River above the point of confluence of the two streams. It should be explained, however, that the quantitative data for point AA1b are far too incomplete for a definite statement of fact. For example, in the case of AA1b the average dissolved mineral load contributed by regular effluent discharges during the dry season of 1953 - Figure 5A, p.62, - was reported as 17 tons, as compared with 36 tons for 1952; whereas the corresponding dry season figures for both 1952 and 1953 for point AA1a - Figure 4A, p.61, - remained fairly constant.

Comparison of Klip River at points AA1c and AA4c
(See Maps nos. 2 and 4 respectively)

In comparing the relative mineral load data for the Klip River at points AA1c below its confluence with Natalspruit, and AA4c at Vereeniging, careful note should be taken of certain factors, particularly of data for the rainy seasons, before drawing any conclusions.

Observations:

(a) During the rainy season flow recordings at Vereeniging, AA4c, could not be made when the flow exceeded 230 cusecs, i.e. the maximum that could be recorded at this particular weir. Consequently the more regular gaugings made during the rainy season at the Lime Works, AA1c, were used in calculating the mineral load data for point AA4c.

(b) During the rainy seasons TDS concentrations fluctuated very frequently at both point AA1c and point AA4c. For many flow recordings at point AA1c no TDS concentrations were determined; and in order to evaluate the average mineral load data for regular effluent discharges and accumulated mineral load reported in Table 27, p.50, TDS data were calculated by interpolation. In consequence of this, the mineral load data for point AA1c are not as reliable as those for point AA4c, for which a very wide range of TDS data were available.

(c) During the dry season, flows and TDS concentrations at both points remained fairly constant except late in the season when flow and TDS decreased, and approximately natural conditions prevailed in the Klip River. A fair comparison could, therefore, be made between the relative dry season mineral load data for the two points. The outstanding feature was that a considerable decrease in dissolved mineral load occurred between AA1c and AA4c, in spite of the fact that average flows for both points did not differ very materially (Figure 6, p.63), certainly not sufficiently to explain the decrease in dissolved mineral load contributions. No decisive explanation for the decrease can be given as the scope of the survey did not provide for the collection of sufficient data. The most obvious explanation, however, is that a considerable volume of water is used for irrigation from the Klip River between these two points, but natural inflows from springs (average TDS 100ppm) compensate for flow decrease due to water abstraction and evaporation. Under such conditions the relative mineral load contributions and TDS concentrations as measured at AA4c would decrease. That is, conditions in the streams at this point tend to become natural. Observations at point AA4c seem to support such an explanation.

Klip River above the Natalspruit confluence
(Map no. 1)

In Tables 5 to 7, (pp. 9 to 13) some data are given in order to present a general picture of the excess dissolved mineral loads which were recorded at various points in the catchment area of the Klip River above the Natalspruit confluence. The tables also contain data for sulphates and total hardness; these salts predominate in waters contaminated with dissolved mineral salts.

For this area, data concerning chemical analyses of the water at all sampling points above Jackson's Drift are very incomplete. Consequently the mineral load data could be calculated for only a few points.

Observations:

(a) At Jackson's Drift (A12), the mineral loads increased very materially during the rainy season but remained fairly constant during the dry season, except towards the end of October.

(b) For the reasons given above it is advisable not to venture any comment on the waters above Jackson's Drift (sampling points A7, B7b, A1, B3a, B9a and B9c), though two statements may be made: first, that the waters draining from the various mining areas carried heavy excess dissolved mineral loads, in consequence of which the TDS of the main streams were far in excess of those of the inflows from natural springs and other natural flows (A4'b, A4'c, B1b, B4a, B6a, B4'b, B4'd, B11c, B14b); and second that the TDS of sewage effluent seepages (B5b, B5'b, A8, A9, A10) into the Klipspruit were less than those of inflows from the mining areas (B3c, B9c) drained by the Klipspruit, and seemed to have had a diluting effect on these inflows (compare B3c and B9c with B7b).

Natalspruit before confluence with the Klip River
(Map no. 2)

Tables 8 to 17 (pp. 15 to 33) detail some data on the outstanding dissolved mineral constituents in the water, and on the magnitude of the excess dissolved mineral load contributed at some of the sampling points in the Natalspruit catchment area.

Observations:

(a) For the Rietspruit system, before confluence with the Natalspruit (Table 8, p.15, point C11b), the excess mineral load is quite significant,

particularly /.....

particularly during the rainy season when accumulated salts are leached out.

(b) The Natalspruit, before its confluence with the Elsburgspruit, drains an extensive and complicated mining area. Apparently, from the data presented in Tables 9 to 12, pp. 17 - 23, it is essentially mine effluents that contribute to the high TDS of the water. Analytical data on waters passing points C1a, C1c, C4a, C4c, C6a, C9a and C10d indicated mainly storm water, spring water, surface water, sewage effluent, some factory effluent, but very little, if any, mine water. The sample taken at point C10a, on the Natalspruit, reflects the total pollutional load for this area, as shown in Table 9, p. 17. It should be noted that on 5th November, 1952, an observed mineral load and an accumulated mineral load of 1,570 and 1,480 tons respectively were measured. These loads were in excess of those recorded in the data for sampling point AA1b (Table 27, p. 50, and Figure 5, p. 62), thus indicating quite clearly that, during floods, much larger mineral loads escaped recording at sampling points AA1c, and AA4a. The same observation applies to the data recorded on 12th October, 1953. Generally, the picture was the same as at other sampling points on the Klip River.

(c) Comparison of the relative data for the Elsburgspruit (Tables 13 to 17, pp. 25 to 33) and Natalspruit before their confluence indicates that the mineral load contribution from the Elsburgspruit was considerably less during the period of survey. The data also indicate that, with a few exceptions, the Elsburgspruit carried mineral salts which must have originated from mining areas.

(d) The mineral loads reported for point AA1b (Table 27 and Figure 5) do not necessarily represent the sum total of mineral load contributions from points C11b, C10a and D3c (Tables 8, 9 and 14, pp. 15, 17 and 27).

DISCUSSION /.....

DISCUSSION OF THE RESULTS OF THE QUANTITATIVE SURVEY OF THE KLIP RIVER SYSTEM

Comparison of the Vaal Dam discharge and Klip River at its confluence with the Vaal River

The TDS of the Vaal Dam discharge (Figure 1) at Engelbrechts Drift before its confluence with the Klip and Suikerboschrand Rivers vary between 75 and 110ppm, with an average of 95ppm during wet and dry seasons. This water carried the natural mineral load of run-off flows encountered in the area under investigation. Consequently the observed total mineral load for the Vaal Dam flow plotted in Figure 1A also represents the natural mineral load. In the Klip River catchment area the TDS concentration in uncontaminated springs and run-off is of the same order (Table 4) as that of the Vaal Dam discharge.

For purposes of comparison, the corresponding data for the Klip River at Vereeniging are given on the same graph in Figure 1A. Discussion of a few specific examples should be sufficient to illustrate that the mineral load carried by the Klip River far exceeds that of the Vaal Dam discharge, particularly during periods of rainfall in the catchment area of the Klip River. Thus:

(a) During the dry months the total mineral load contributed by the Klip River is less than that from the Vaal Dam, whereas its TDS (Figure 1, p.56) is higher. It should be noted, however, that the heavier load carried by the Vaal Dam discharge in comparison with the Klip River is not in proportion to the difference in relative flows. For example, on 13th October, 1952, the total mineral loads for the Vaal Dam and Klip River were 775,000 and 50,000lb per 24 hours respectively. That is, the Vaal Dam load was about 16 times that of the Klip River, whereas its flow was more than 100 times that of the latter. Such a discrepancy could be explained only by heavy mineral contamination of the Klip River water.

(b) During July, 1952, rain fell on the Witwatersrand and the flow in the Klip River increased temporarily. The total mineral load of the

Klip River immediately increased to more than twice that of the Vaal Dam discharge, whereas the flow from the Vaal Dam was more than four times that of the Klip River.

(c) During the rainy season the total mineral load of the Klip River generally exceeds that of the Vaal Dam discharge. On 15th December, 1952, the Klip River (in flood) discharged dissolved mineral salts at a rate of nearly 4,500 tons per 24 hours, as compared with 150 tons from the Vaal Dam (viz 30 times as much), whereas the flow in the Klip River was approximately only $3\frac{1}{2}$ times that of the Vaal Dam. Such a general condition during the rainy season must result in an increase in the TDS concentration in the Vaal River water below its confluence with the Klip River.

(d) Occasionally during the rainy season, the Vaal River is in heavy flood. During such a period, the total mineral load of the Vaal Dam overflow exceeds that of the Klip River. For example, on 9th March, 1953, the Vaal Dam overflow (8,200 cusecs) carried a total mineral load of 1,680 tons in comparison with 260 tons from the Klip River (no flood flow recorded during 24 hour period). Comparison of the relative flows shows that the Vaal Dam overflow was approximately 70 times that of the Klip River, whereas its total mineral load contribution was only approximately seven times as much.

Comparison of the relative mineral loads carried by the Vaal Dam discharge and the Klip River indicates quite clearly that the Klip River carries dissolved mineral loads far in excess of those expected from natural sources. For example, during the dry season of 1952, the average discharge from the Vaal Dam (996 cusecs) was 29 times that of the Klip River (34 cusecs). But the total mineral load carried by the Vaal Dam (average 274 tons per 24 hours) was only 4.5 times that of the river (63 tons per 24 hours). See Figure 1A, p.56.

This apparent contradiction was also observed during the rainy season, particularly during flood periods. On 16th February, 1953, for example, both the Vaal and Klip Rivers were in flood and although the flow of the Vaal River (7,080 cusecs) was approximately 6 times that of the Klip River (1,295 cusecs), the total mineral load carried by the Vaal River (1,810 tons per 24 hours) was only one half that of the Klip River (3,650 tons per 24 hours).

The abovementioned phenomenon can be attributed only to mineral pollution.

Mineral pollution

A survey of natural sources indicated quite clearly that the dissolved mineral salts from these sources could not account for the loads observed, nor for the rise in TDS concentrations in the Vaal River during the rainy season. In order to demonstrate the extent of this mineral pollution, a quantitative survey was made of the dissolved mineral load carried by the Klip River at Vereeniging, both before and after its confluence with the Natalspruit. The quantitative survey was extended, in somewhat lesser detail, to the upper reaches of the Klip River and the Natalspruit in order to obtain an approximate picture of the relative magnitudes and constituents of contributions from the various areas.

The data recorded at all the main sampling points-AA4c, AA1c, AA1b and AA1a - indicated two main types of dissolved mineral pollution.

(i) Regular mineral pollution from other than natural sources:

There was regular discharge of mineralized waters from other than natural sources. It appeared that, in the dry season, both the maximum and minimum daily discharges occurred with considerable intermediate variations. At Vereeniging (AA4c) the maximum and minimum mineral load contributions from regular effluent discharge were 105 and 10 tons per 24 hours respectively. During the rainy season minimum and maximum mineral load contributions from regular effluent discharge did not differ very materially.

(ii) Accumulated mineral pollution:

During the rainy season and particularly during heavy rains, the Klip River carried a dissolved mineral load greater than could be accounted for by the regular effluent discharges and natural flows, namely springs and run-off water. This mineral load was due to the dissolving of mineral salts which had accumulated in the soil under irrigation, in sand dumps and slimes dams in mining areas and due to irregular discharges of large volumes of penstock waters. This type of mineral pollution has been termed accumulated mineral load. The magnitude of this accumulated mineral load depended largely upon the rain that had fallen, and during floods as much as 4,035 tons per 24 hours were measured at the Vaal River confluence (AA4c). During the rainy season it was found to be many times greater than the dissolved mineral load contribution from regular effluent discharge (See Tables 26 and 27, p.50). The average and maximum values at AA4c for accumulated mineral load were, respectively, nearly 15 and 49 times as great as the corresponding values for dissolved mineral load from regular effluent discharges.

The accumulated mineral load reaching the Vaal River during the rainy season appeared to be largely responsible for the rise in TDS of the Vaal River water after confluence with the Klip River. The magnitude of this mineral load was of such an order that the combined diluting effects of the run-off water in the Klip River catchment area and of the Vaal River were completely masked, even during heavy floods - see Figures 1 and 1A, p. 56. Had no mineral pollution been present the TDS would have been less than 90ppm.

QUANTITATIVE SURVEY OF THE SUIKERBOSCHRAND RIVER AND ITS TRIBUTARIES, THE BLESBOKSPRUIT, THE SMALL BLESBOKSPRUIT AND THE UPPER TRIBUTARY OF THE BLESBOKSPRUIT

(Map Sections E, F and G)
(Tables 18 to 25 and Diagrams 14 to 21).

Suikerboschrand River at Vereeniging

(See Map no. 4, sampling point G18a)

The mineral load and TDS data are represented graphically in Figures 7, 8 and 8A, p. 63 to 65, and some specific data are summarized in Table 28, p. 51.

Observations

(a) During the period, May to July, 1952, no appreciable flow was recorded and accordingly the mineral load contributed by this river was negligible. Rain was recorded for the week that ended 14th July, and as a result the load increased the next week from 10 to 25 tons per 24 hours. After more rain in the following week, there was a further increase to 40 tons per 24 hours.

(b) Following the rainy spell, there was a dry period lasting from August to the beginning of October, 1952. The flow stopped completely during this period. Although it started raining in October no flow was recorded before the middle of November.

(c) On 17th November, 1952, the observed mineral load exceeded the natural mineral load by nearly 250 tons per 24 hours. This figure represents the excess mineral load, which reached a value of 2,385 tons per 24 hours on 15th December, 1952.

(d) The average dissolved mineral load - Figure 8A, p.65 - carried by regular effluent discharges reaching the Suikerboschrand at Vereeniging during the dry season was 4.5 and 8.0 tons per 24 hours for 1952 and 1953 respectively, and the maximum and minimum loads were 18.4 and nil tons respectively. During the rainy season the average was 10.0 tons with a maximum and minimum of 13.5 and 5.5 tons.

(e) The observed mineral load exceeded the expected mineral load throughout the rainy season, indicating an accumulated mineral load carried by the Suikerboschrand during the normal rainy season. The maximum and minimum accumulated mineral loads for the wet season November, 1952 to April, 1953, were 2,385 and nil tons per 24 hours respectively, and the average for this period was 220 tons per 24 hours.

(f) As in the case of the Klip River - Natalspruit system, mineral load contributions by regular effluent discharges were reflected in two main characteristics:

(i) Towards the end of the dry season contributions decreased to almost nil.

(ii) During the rainy season or a wet period (July, 1952) it increased and remained fairly constant.

The Suikerboschrand River before confluence with Blesbokspruit
(Sampling point G17b)

Although regular sampling was carried out at this point, no flow was recorded. Approximate flows were obtained for a few selected dates from the differences of recorded flows at Vereeniging on the Suikerboschrand and at Heidelberg on the Blesbokspruit. Calculated mineral load and TDS data are represented graphically in Figure 9, p.66.

Observations

(a) It will be seen that the observed mineral load never materially exceeded either the expected or the natural mineral load throughout the dry seasons. The only conclusion drawn from this fact is that, up to this point there was no mineral pollution in the river.

(b) During /.....

(b) During the rainy season the observed mineral load exceeded the expected mineral load to only a limited extent. This indicated very limited solution of accumulated salts. The accumulated mineral load which was recorded probably originated from land which had received fertilizer treatment. The maximum accumulated mineral load recorded was 5.75 tons per 24 hours on 6th January, 1953, when it rained in the area.

(c) The mineral load data for this point clearly illustrate the definitions given for expected and accumulated mineral load given in (f) and (g), p. 11.

The Blesbokspruit (in the Heidelberg area)
before the Suikerboschrand.
(Sampling points G15b, G15a, G15c, G10a and G11b)

The analytical data for G15a and G15c are presented in Table 18, p. 35. G15a is an effluent from a tannery in Heidelberg. It is offensive in nature (note, OA 4 hours) and has a very high concentration of dissolved solids. The mineral load and TDS data for point G15b are detailed in Figures 10 and 10A, p.67. Table 29, p.51, summarizes outstanding specific data.

Observations

(a) Only a limited number of recordings per month were made at point G15b and consequently the maximum and average data for the rainy season, as represented in Table 29, p.51, are of limited value only. In Table 28, p.51, however, more accurate assessment of the maximum mineral load contributions arising from the Blesbokspruit catchment area is recorded for point G18a, where regular recordings were made. And it may be noted that only limited additions of accumulated mineral salts were made between G15a and G18a. (See Observations, p.55).

(b) Minimum data for the rainy season, recorded in Table 29, p.51, can be taken as a true reflection of run-off conditions when flow and TDS variations were limited. Consequently, in comparing minimum data recorded during dry spells in the rainy season for points G18a and G15b (Tables 28, 29, p.51) it will be noticed that material reduction in mineral load occurred between these points. There appear to be two reasons for this reduction, viz. use of the water for irrigation purposes during dry spells, and infiltration into sub-strata.

(c) During the dry season the maximum and average mineral load contributions recorded at point G15b (Table 29) were consistently higher than those recorded at point G18a (Table 28, p.51). This reduction in mineral load is also ascribed to the factors detailed in (b) above. For the period September to November, 1952, flow ceased at both points G15b and G18a.

(d) Mineral load contributions by regular effluent discharges during the rainy season or wet period in July 1952 - Figure 10A, p.67 - remained fairly constant and fairly high, whereas towards the end of the dry season the decrease was very rapid.

(e) The exceptionally high TDS concentrations recorded here afford ample confirmation of the high TDS data observed at point G18a, which is on the Suikerboschrand River after confluence with the Blesbokspruit.

(f) Flows at points G11b and G10a were mainly due to natural springs and, although mine seepage was observed, it was not revealed in the analysis.

Blesbokspruit - Vlakfontein stream at Nigel
(Sampling points G8c, G8d, G5a, G4c, G9c, G2c, G1c and F1c)

Analytical data for these sampling points are presented in Tables 19 and 20, pp. 37 to 39.

Observations

The Vlakfontein stream drains a mining area, a fact which is clearly reflected in the mineral load data for point G8c.

All /......

All the remaining points receive mine effluents which are reflected in the total hardness and sulphate data. Similar to points G18a and G15b, the TDS concentrations recorded at G9c were exceptionally high throughout the dry and rainy seasons.

The Small Blesbokspruit Springs area
(Sampling points F2b, F4c, and F3b)

Analytical and mineral load data for these points appear in Table 21, p.41.

Table 30, p.52, presents mineral load data for the dry season at F2b. Analytical data for the rainy season were recorded too infrequently for even an approximate estimate of mineral load data to be made.

Observations

The general conditions prevailing in this stream are identical with those in the Suikerboschrand at Vereeniging and the Blesbokspruit at Heidelberg.

Sampling points F4c and F3b yielded typical examples of mining effluents. The total dissolved solids concentration at F3b was 83,870ppm in August, 1953, and throughout the period of survey it never dropped below 26,000ppm.

The Blesbokspruit - Upper tributary confluence with Blesbokspruit
(Sampling points E11c, E11b and E10c)

Tables 22 to 25, pp. 43 to 49, should be consulted in connection with analytical data relating to this section. It will be observed that the Blesbokspruit above the confluence with the upper tributary (E11b) was not flowing during dry periods. The data recorded did not indicate serious pollution, if any. In the case of E11c, however, there are very definite signs of pollution caused by the inflow of the upper tribuary (sampling points E10c, E10b, E10a, E9c, E9a, E8a, E8b, E8d, E7a, E7b, E5d, E5b, E5a, E3a, E3b).

Figures 11 and 12 illustrate graphically the mineral load data for points E10c and E9c, viz the effluents from Cowl's and Geduld Dams respectively. These were the only two points in this section where regular flow recordings could be made.

Summaries of the outstanding data are contained in Tables 31 and 32, pp. 52, 53.

Observations

(a) At Cowl's Dam the gauging weir was too small to record high flows during the rainy season, and the mineral load contribution from this dam to the Blesbokspruit could, therefore, not be calculated during flood periods.

(b) The regular mineral load leaving the Cowl's Dam is considerably higher than that contributed by the Geduld Dam. Consequently a very heavy mineral load is added between the Geduld Dam and the Cowl's Dam.

(c) All these sampling points receive mine effluents, except E10b, E3b and E3a. E10b is an effluent from S.A. Pulp and Paper Industry; E3b is an unpolluted stream entering the Laundry Dam at Benoni, and E3a is a storm water drain carrying treated sewage effluent which enters the Laundry Dam.

(d) The general characteristics are the same as those of the Suikerboschrand at Vereeniging (G18a).

DISCUSSION OF THE RESULTS OF THE QUANTITATIVE SURVEY OF THE SUIKERBOSCHRAND RIVER SYSTEM

Comparison of the Vaal Dam discharge and Suikerboschrand River at its confluence with the Vaal River

The comparative mineral load data are presented graphically in Figures 7 and 7A, pp. 63, 64.

Observations /......

Observations

(a) The TDS of the Suikerboschrand River, like that of the Klip River, is affected by seasonal rains. There is an immediate increase at the beginning of the rainy season, with continual fluctuations throughout the season. The maximum TDS during the period of the survey was 2,540ppm, recorded in November, 1952, whereas the minimum was 73ppm, recorded in February, 1953. This latter figure, however, was recorded when only the Suikerboschrand River was in flood and the flow in the Blesbokspruit was low.

(b) Increase in flow during the wet season resulted in general increase in the TDS concentration, and here again the increase in the dissolved mineral load was entirely out of proportion to the flow in the river. In the Vaal River, however, the TDS concentration remained remarkably constant throughout the sampling period and the increase in dissolved mineral load was in proportion to the flow in the river - see Figure 7A, p. 64.

(c) As in the case of the Klip River, the heavier mineral load carried by the Vaal Dam discharge, and the lesser load of the Suikerboschrand River, were not in proportion to the respective flows. This is illustrated by the following examples:

(i) On 15th December, 1952, the Suikerboschrand River was in flood and its flow was equal to that of the Vaal River. Yet its observed mineral load was more than 16 times that of the Vaal River.

(ii) On 12th January, 1953, the flow of the Vaal River was approximately three times that of the Suikerboschrand River, yet its observed mineral load was only one fifth that of the Suikerboschrand.

(iii) During the dry season, the observed mineral load of the Vaal River always exceeded that of the Suikerboschrand, but not in proportion to its different flow. On 5th May, 1952, the total mineral load of the Vaal River was twenty times that of the Suikerboschrand River, yet its flow was 300 times as great.

As in the case of the Klip River, the excessive mineral load of the Suikerboschrand River can only be explained by heavy mineral pollution.

Mineral pollution

Unlike the Klip River system, the Blesbokspruit and Suikerboschrand River do not carry much natural spring water. Consequently, the effects of mineral pollution are much more obvious, as evidenced by the exceptionally high TDS concentrations during both dry and rainy seasons. Mining and industrial effluents are discharged directly and indirectly into the Blesbokspruit almost as far down as its confluence with the Suikerboschrand, and the dilution afforded by natural springs, particularly during the dry season, is negligible. The natural flow from the Suikerboschrand exerts a significant diluting effect only during the rainy season. The data indicate that a substantial reduction in mineral load of the Blesbokspruit occurs between Heidelberg and the Suikerboschrand confluence. The use of the Blesbokspruit for irrigation purposes is one of the main reasons for this reduction in mineral load. It may, however, be stated here that the prolonged use of this water for irrigation will result in irreparable damage to the soil.

The complexity of the Blesbokspruit system and the limited technical assistance available did not permit a sufficiently detailed recording of mineral load data. The mineral load data presented in Figures 7A, 8 and 10, pp. 64, 65, 67, therefore, although presenting the same general picture as for the Klip River, do not reflect the true mineral load contributions during the rainy season. Thus, for example:

(a) On 16th and 23rd February, 1953, both the Vaal and Suikerboschrand Rivers were in flood but the Blesbokspruit carried only a small flow. Consequently the observed mineral load for point G18a - Figure 8A, p. 65 - on these dates consisted mainly of natural dissolved solids (see page 54 for Suikerboschrand River data). The TDS concentration of the combined flows from the Blesbokspruit and the Suikerboschrand was almost identical with that of the Vaal River water.

(b) On /......

(b) On both 5th and 6th January, 1953, the Blesbokspruit at Heidelberg carried a mineral load of 400 tons per 24 hours (Figure 10, p.67). Yet less than 100 tons were recorded before the confluence with the Vaal River - Figure 7A, p.64. This reduction was roughly in proportion to the decrease in flow.

(c) On 25th February, 1953, the Blesbokspruit (Figure 10, p.67) carried an observed mineral load of 600 tons per 24 hours. No corresponding analytical recordings were made at the Vereeniging sampling point - Figure 7A, p. 64; flow recordings, however, indicated that this mineral load actually reached the Vaal River.

As in the case of the Klip River system, data for the Blesbokspruit area indicated two main types of dissolved mineral pollution, viz regular effluent discharge and accumulated mineral load. The characteristics of these two types of pollution are similar to those in the Klip River system. In comparing data for the Blesbokspruit and Suikerboschrand sampling points, viz. G18a and G15b, with those for the Klip River after its confluence with Natalspruit (see page 45 and Table 27, p.50), it appears at first that the Natalspruit system carries a much heavier mineral load.

This conclusion, however, is shown to be somewhat controversial, if the dry season data for the Small Blesbokspruit (Table 30, p. 52) and for the Cowl's Dam overflow (Table 31, p. 52) are carefully examined. These two systems, apart from minor mineral effluent contributions from the Vlakfontein stream and other sources in the Heidelberg area, drain the bulk of their mineral load from industrial and mining areas. By totalling the dry season data for these two systems (Tables 30 and 31, p. 52), it can be shown that during the dry season the Klip River - Natalspruit system carries 50 per cent more mineral load than the Blesbokspruit - Suikerboschrand system.

For the rainy season no conclusion could be drawn as to the relative mineral load contributions by the Klip River and Blesbokspruit systems, since fluctuations were wide and frequent and too limited a number of

samples /.....

samples was taken for a statistical evaluation to be made. The maximum accumulated mineral load of 2,385 tons reported in Table 28, p. 50, was recorded on 15th December, 1952. Subsequent to this date higher flows were gauged in this system, but no samples for analysis were taken. Consequently it is impossible to conclude that the reported figures were the true maximum.

C H A P T E R F O U R/.......

CHAPTER FOUR

THE TOTAL EFFECT OF EXCESS MINERAL LOAD CONTRIBUTIONS BY THE KLIP RIVER AND THE SUIKERBOSCHRAND RIVER SYSTEMS ON THE VAAL RIVER WATER AS SUPPLIED TO THE CONSUMER ON THE WITWATERSRAND

The results of the quantitative survey indicated two main types of unnatural mineral load contributions:

Regular mineralized effluent discharges; and
Accumulated mineral salts.

The total mineral load resulting from contributions of these two types constitutes the total excess mineral load discharged into the Vaal River by the two river systems surveyed. The second type of mineral pollution is the most significant quantitatively and manifests itself only during the rainy season or other wet periods. This accumulated mineral load is many times greater than the load carried by regular effluent discharges. The cumulative effect of the total excess mineral load derived from the two sources mentioned on the quality of the Vaal River water and the water supplied to the Witwatersrand, becomes of paramount importance. The water is no longer of the quality required for many usages, and as a result water conditioning systems have to be designed for industry to deal with the big differences in quality.

The effect of total excess mineral and hardness loads on the Vaal River water

The total excess mineral and hardness loads discharged by the Klip and Suikerboschrand River systems into the Vaal River are presented graphically in Figures 13 and 14, pp. 70, 71.

The data illustrates quite clearly the effect of increased run-off water on the mineral and hardness loads carried by these two river systems:

(a) During the dry season the excess mineral load contribution is at a minimum since there is no run-off water to leach out accumulated mineral salts. During this period excess mineral load contributions are mainly from regular effluent discharges and, judged by the low TDS of the Vaal River, the polluting effect is at a minimum.

(b) During the rainy season both TDS and total hardness (TH) in the Vaal River increased very rapidly and the normal diluting effect of flood waters was not noticeable at all. This unnatural increase in TDS and TH of the Vaal River water always occurs simultaneously with the heavy contributions of excess mineral and hardness loads from the Klip and Suikerboschrand Rivers.

(c) It can be observed from Figure 14, p. 71, that the excess hardness load contributed by the Klip and Suikerboschrand Rivers is in direct proportion to their excess mineral load contributions. As a result of the very heavy excess mineral and hardness loads that these rivers contribute to the Vaal, this phenomenon manifests itself even in the resultant Vaal River water. Figure 15, p. 71, illustrates quite clearly that the increase in TDS is directly proportional to the total hardness. This proportionality is futher clearly illustrated by the mirror image relationship of Figures 18 and 19 (p. 74) for excess mineral load and total hardness. Furthermore, this observation is compatible with current knowledge (only recently established) of chemical and microbiological reactions which occur when pyritic material in underground workings of mines, in slimes dams and sand dumps, comes in contact with air and the forces of nature.

The effect of total excess mineral and hardness loads on the water supply to the Witwatersrand

In order to evaluate the relationship between the TDS and TH of the Vaal River water after confluence with the Suikerboschrand and Klip Rivers, and of the purified water supplied to the Witwatersrand, tap water samples were analysed daily during the period of the quantitative survey (pp. 43 - 6?). Figures 16 and 17, pp. 72, 73, illustrate the relationship clearly, and show that any changes in the TDS and TH of the Vaal River water are proportionately reflected in the purified water supplied to the Witwatersrand.

From the foregoing considerations it is, therefore, quite clear that the excess mineral and hardness load contributions by the Suikerboschrand and Klip Rivers are entirely responsible for the steep increase in the mineral content of the Witwatersrand's water supply during the rainy season. These observations are illustrated in Figures 18 and 19, p. 74.

Figures 18 and 19, p. 74, also give a quantitative assessment of the excess mineral salts in the water supply to the Rand, which originate entirely from the unnatural excess mineral load contributions by the Suikerboschrand and Klip River systems.

The excess mineral load contributions occur mainly during the rainy seasons when, according to the data recorded on pp. 43-63, thousands of tons of mineral salts are leached from industrial areas.

During the dry season, when excess mineral load contributions originate mainly from regular effluent discharges, the water supplied to the Rand is at its best and the effect of these excess mineral salt contributions is hardly noticeable.

The effect of excess mineral salts on water uses in the Witwatersrand

For purposes of evaluating the effect of mineral salt pollution on the Witwatersrand water supply, the uses of water on the Rand can be classified into two main categories:

Domestic use

The effect of the quality of the water on its use for domestic purposes can be assessed on the basis of the excess hardness carried by the water (Figures 18 and 19, p.74) as well as by increased dosage of chemicals required for water purification.

(a) Table 33, p. 53, was compiled from records of the Rand Water Board and illustrates very approximately the relationship between TDS and aluminium sulphate dosage. Lime dosage and recarbonation data have not been analysed since very little significant variation has occurred.

In compiling Table 33, p. 53, the exceptionally high aluminium sulphate dosages recorded during the period 17th to 28th December, 1952, were ignored; they are recorded in Table 34, p. 54. During December, 1952, high mineral load contributions were recorded as a result of heavy rains. The quality of the Vaal River water changed considerably and there is no doubt that the high aluminium sulphate dosages were necessitated by this change. The TDS concentrations reported in this Table were determined on spot samples. It is known that very wide fluctuations may occur between consecutive determinations.

(b) The increase in soap consumption caused by an increase in total hardness of water is detailed in Figure 20, p.75, which was prepared from data published in 'Water treatment for Industrial and other Uses' by Eskel Nordell[5], p. 52.

(c) According to the records of the survey, the average total hardness of the Vaal River water before contamination with excess mineral salts is between 30 and 50ppm, and during the dry season when these effects are at a minimum the average total hardness of the Witwatersrand water supply is approximately 70ppm (Figures 18 and 19, p. 74). If this latter amount is accepted as a normal limit (i.e. including the small effects of regular effluent discharges) the increase in the daily soap consumption by an increase in the TH of the Rand's water supply, could be determined from Figure 20, p. 75.

(d) On the Witwatersrand the average water consumption is 70 gallons per head per day (White and non-White population). It is generally accepted that of this one gallon of water per head per day reacts with soap.

Therefore, 1/70 of the daily supply of Vaal River water to the Rand reacts with soap, namely approximately 1.5 million gallons. Figure 21, p. 75, was prepared from these data and serves to show the costs resulting from the increase in daily soap consumption caused by the unnatural increase in the TH of the water supply to the Rand. It is quite likely that this increase in hardness will encourage the domestic consumer to use synthetic detergents. Experience has shown that where softened water is supplied to a community, soap is used in preference to synthetic detergents.

(e) The rise in the TH during the rainy season results in an increase in the scale-forming properties of the water. It is logical to expect undue scaling of household hot water systems during such periods. Unfortunately, no statistics have been compiled on which to base estimates of the daily costs which the population of the Rand has to face for repairs and damages to hot water systems resulting from increased scaling.

Industrial use

The varied industrial activity on the Rand requires, in addition to the data collected up to the present, somewhat more specific information for an evaluation of the costs to industry caused by the sudden and material changes in water quality during the rainy season. It is, however, possible to make a few observations on the effects of these changes in water quality on equipment and pre-treatment costs generally.

(a) Cost and other implications due to an increase in total hardness

The formation of scale in boilers and cooling water systems gives rise to heavy treatment and supervision costs, damage to equipment and loss of power. The hardness of the water supply to the Rand increases very materially during the rainy season as will be seen from Figures 13 to 19, pp. 70 to 74; the most alarming feature of this change is its unpredictable suddenness and magnitude. Consequently industry has to face, in addition to high treatment costs, heavy investments in elaborate and flexible plant, the maintenance of which also involves heavy expenditure.

(b) Technical /....

(b) Technical implications due to an increase in TDS concentration

Quite apart from hardness, the TDS concentration in the water supply of the Rand, with all its unpredictable characteristics, constitutes a constant source of worry and expenditure. This is because steam and power-generating plants, and cooling and evaporator installations require water with a constant TDS. Where an increase in TDS necessitates blow-down or bleed-off operations, a low dissolved mineral content is of primary importance. Blow-down and bleed-off operations necessitate the provision of make-up water with its concomitant treatment costs and problems, and also result in unavoidable loss of valuable heat.

(c) Secondary treatment by certain industries is necessitated to acquire water conforming to their own specific requirements

Many other types of industries such as textile factories, canneries, mineral water factories, ice factories and process industries require water of specific quality and each industry has to treat the water to make this conform to its own specific requirements. The TDS and TH in the water supply are determining factors in the treatment costs. A few specific examples are quoted to show the extent to which the concentration of dissolved mineral matter in water affects costs of water treatment and make-up water.

(i) Cooling water blow-down:

A cooling-water plant with a designed circulation capacity of 156,000 gallons per minute and with a continuous automatic blow-down, at a TDS of 1,200ppm, may require the quantities of make-up water for different TDS concentrations in the raw water intake that are presented in Table 35, p.54.

In the absence of pollution by excess mineral load contributions the TDS of the water supply to the Rand should not exceed 150ppm. Therefore, any increase in costs, for operating cooling-water systems necessitated by an increase in the TDS of intake water beyond 150ppm, must be regarded as the result of mineral pollution of the Suikerbosch-rand and Klip Rivers.

(ii) Boiler blow-down (Hypothetical illustration):

A boiler producing steam at a rate of 10^6 lb per hour at 400 to 500lb per square inch, with 70% make-up water and a continuous blow-down at a TDS of 2,000ppm, would require the rates of blow-down for different TDS concentrations in the make-up water as listed in Table 36, p.55.

As in the case of cooling-water blow-down, any increase in costs necessitated by an increase in the TDS and TH of the make-up water beyond 150 and 70ppm respectively, must be attributed to mineral pollution.

(iii) Ion exchange processes:

Table 37, p.55 illustrates the type of relationship between TDS concentration of a water supply, and costs of chemicals and depreciation of ion-exchange materials, in a complete demineralization plant.

In the case of ordinary base-exchange processes using sodium chloride for regeneration, Table 38 gives an example of the type of relationship between the TH of the water and the costs of chemicals and depreciation of base-exchange material.

Observations and discussion of the effects of pollution

The results of the present survey indicate quite conclusively the effects of the mineral pollution of the Vaal River on the quality of the water supplied to the Rand.

The outstanding features of this present evaluation of the effects of mineral pollution of the Suikerboschrand and Klip River systems on the Vaal River water and the Witwatersrand water supply, can be summarized as follows:

(a) During the rainy season, the mineral composition of the water supplied to consumers and industries is subject to alarming and unpredictable fluctuations. This variable nature of the Rand water supply is imposing a serious burden on industry.

(b) Quite apart from the sudden and wide variation which occurs, the magnitude of the total hardness and the total dissolved solids of the Rand's water supply must contribute materially towards increasing running costs within industry.

(c) There is no doubt that domestic consumers, as a whole, have to face certain costs as a result of mineral pollution. Increased consumption of detergents and cleansing materials, increased depreciation of clothing due to washing in hard water, and repairs to domestic equipment due to scale formation cannot be regarded as insignificant when one takes the whole population into consideration. The details for soap consumption given in Figures 20 and 21, p. 75, illustrate this quite clearly.

(d) The effects of mineral pollution are confined mainly to the rainy season when the accumulated mineral salts are leached from industrial areas. A most outstanding finding of this survey is that the effects of accumulated mineral load contributions to the Vaal River are of alarming magnitude, many times those of regular effluent discharges.

(e) The effect on the Vaal River water of mineral salt contributions from regular effluent discharges is exceedingly small and insignificant when compared with that resulting from accumulated mineral load contributions.

(f) The results of the whole survey, and the present evaluation of the relative effects of different mineral contributions to the Rand's water supply, indicate quite conclusively that regular effluent discharges present a mere facet of the problem of mineral pollution arising from industrial activity within the catchment areas of the Suikerboschrand and Klip Rivers. In fact it is an insignificant part of the whole problem of the accumulation in mining areas of mineral salts (acid and ferrous sulphate included). Any future investigations into mineral pollution of the Vaal River by the Klip and Suikerboschrand streams must be directed towards towards finding a solution to the problem, or practical means of minimizing the access of these salts to the streams.

(g) The need for investigation, and the extent to which the problem of mineral pollution should be investigated, are determined by four main factors:

(i) the total costs which the domestic consumer and industry have to pay annually for mineral pollution;

(ii) the limitation which mineral pollution imposes on the exploitation of the Vaal River, particularly as regards re-use of water;

(iii) evaluation of codes of practice for the management of the release of high accumulated mineral loads during rainy periods; and

(iv) the implementation of codes of management of effluents on mining property, of codes of construction of slimes dams and of codes of closure of mines, with due regard to the factors which are responsible for the oxidation of pyritic material.

In this connexion it should be noted that the present magnitude of pollution from mines is not so much attributable to a general slovenliness in regard to effluent management, as to the lack of exact quantitative information with respect to the role of slimes dams, sand dumps and of the oxidation of pyritic material. This data is now available and the core of the problem has been identified, consequently mining industry could be assured of the success of corrective measures.

CONCLUSIONS/....

CONCLUSIONS

General

The results of the survey show that both the Klip River and the Suikerboschrand River systems are polluted. The principle pollutants are mineral and acid accretions from various sources together with sand which accumulates on the river beds. The mineral pollution loads carried by these streams, have a marked effect on the quality of the Vaal River, particularly during the rainy season.

Sources of Pollution

The worst pollutants are derived from the erosion of slimes dams and dumps and the oxidation of pyritic material to sulphuric acid and iron sulphate with the concomitant leaching of salts from mineral material. This chemical pollution is aggravated by the accumulation of mineral salts which do not reach the streams in the dry season but are washed into the river during the rainy season, so that quite contrary to expectations, the effects of pollution on the river are much more pronounced in the rainy than in the dry season. Another major source of mineralization of streams during the rainy season is the irregular discharge of large volumes of penstock water from slimes dams. Briefly the worst pollution effects are due to run-off waters carrying accumulated mineral salts into streams during the rainy season.

The effects of regular effluent discharges (see page 11) as reflected by data of the dry seasons, are of secondary importance as far as the quality of the Vaal River is concerned. During the dry season, the dilution capacity of natural flows, purified sewage effluent and of certain industrial effluents are quite adequate to maintain the mineral quality of the water in the Klip River, the Blesbokspruit and the Suikerboschrand River (after confluence with the Blesbokspruit) at the acceptable levels for a second grade water.[2,7,9]

Industrial /......

Industrial effluents from a variety of sources other than mining property, enter these streams and pollute them. Agricultural pollution also occurs to an appreciable extent.

River Recuperation

The recuperative powers of a river are highly dependent on the fauna and flora in the river water and the benthic organisms in the mud deposits. Under favourable conditions, this biological life can effect purification of organic pollution to a marked extent. Destruction of these organisms reduces the self-cleansing capacity of a river.

Long stretches of river bed have been observed in which biological life was completely absent because it had been smothered by mine sand or exterminated by highly concentrated mineral and acid 'slugs' passing down the river.

The problem

The main pollution problem arises when erosion from slimes dams, sand dumps and mineral and acid accretions mentioned previously, enter the streams. Not only do they destroy the organisms which bring about natural biological purification of the organic pollutants but they also impair water quality. To overcome this second problem the pollutional load must be removed or prevented from entering the river, or it must be controlled so that it enters the river at such times when the deleterious effects are minimal. To implement such control would require large capital expenditure and engineering skill. The problem would be less complex if the main pollution occurred at times of low flow since storage and controlled discharge would balance 'shock' discharges of pollutants into the streams.

The analyses of water supplied to consumers clearly reflects the necessity for special purification treatment, consequently the high costs which will be incurred in protecting the quality of the water supplied to domestic and industrial users, warrant early planning of remedial measures. Coupled with the fact that the Vaal River's ultimate capacity will be reached within the next 30 years, the problem becomes quite urgent since mineral pollution has a deleterious effect on the value of water for re-use, a factor which could have a limiting effect on the exploitation of the full capacity of the water resources of the Vaal River for industrial, domestic and agricultural purposes.

RECOMMENDATIONS/......

RECOMMENDATIONS

It was not within the scope of this survey to examine the possible solution to the problems outlined above. This would require research and fact finding of a different nature, probably in the fields of civil engineering, mine management and legal administration.

The problem has been formulated, however, and it is suggested that the following avenues should be explored further:

(a) Continued survey work

The survey needs to be reinforced by further sampling to reveal specific tendencies with respect to flows carrying heavy mineral loads. Some sampling was done at certain key points after the completion of this survey and valuable results were obtained which are to be used in planning a pollution abatement programme. The need for continuing such sampling is stressed here.

(b) Control of pollution at the source

It would be appropriate if a thorough investigation were made into the conditions in mines and industries where the mineral pollution, especially the accumulated mineral salts and sand from mine dumps which are washed into watercourses by rain, originates. Such an investigation could best be carried out by the polluters themselves and any remedial measures necessary applied by them. A code of practice involving special techniques for the abatement of pollution, administered by a central controlling body, could serve as a major step towards improving the quality of the streams.

(c) Major supplementary measures for the abatement of pollution

While much can be done towards keeping undesirable effluents out of the river by the measures suggested above, it must be realized that the rivers will remain polluted. The pollution will originate from accumulated

mineral /......

mineral loads and sand from abandoned mine dumps and mining sites when they are washed over by storm-water and from water pumped from old mines.

Some method must be found for dealing with the pollutants from these sources, still present in the river.

When the graphs linking mineral load with time, are studied, a feature which is immediately noticeable, is that very sharp peaks occur immediately after rainfalls. This would suggest that although heavy mineral loads are carried down the river immediately after rainfall, this only happens for periods of short duration.

The value of storage dams for holding back these shock admissions of pollution should be investigated. It seems that dams of large capacity are unnecessary since only peak-flows of run-off should be considered. The following benefits which would accrue from such storage dams could well justify their construction economically:-

(i) 'Balancing' dams in the tributaries draining into the Vaal would hold a good second-grade quality water suitable for many industrial uses. There would be a better utilization of water because of the improved quality of water in the river systems and in the Vaal River. Industry and agriculture would both benefit by this diversion of second-grade waters.

(ii) The disposal of effluent into streams and drains above the dams could be allowed greater latitude than is otherwise possible. The whole aspect of pollution control would be placed on an organized basis.

(iii) These dams would be available as recreation centres for varied types of water sport. There are in fact a number of thriving recreational areas in these river catchments and these could be exploited to the benefit of the community.

(iv) The whole East and West Rand is known to have subterranean dolomitic compartments of almost limitless capacity, suitable for storing water. This national asset, which would be of great value in times of war, must sooner or later be used as an immense evaporation-free storage reservoir. The acid-laden and mineralized waters originating in mining areas on the Witwatersrand must be prevented from penetrating these dolomitic compartments, otherwise they will be rendered useless for the aforementioned purpose. The balancing dams would serve admirably to ensure that only good quality water reached the dolomitic compartments.

(v) In cases of emergency (during war, for example) a whole series of small dams from which emergency supplies could be drawn, would be available.

(vi) The costs of the secondary purification of water to suit specific requirements of industry would be considerably reduced.

(d) Research

The problem of the oxidation of pyritic material with the concomitant production of waters carrying, in accordance with environmental circumstances, high concentrations of iron sulphate, sulphuric acid, sulphates of calcium and magnesium, will always be present. The ultimate elimination of pollution could only flow from results of research on these problems. Research into four main directions seems necessary:-

(i) desalination aimed at removal of sulphates from concentrated effluents;

(ii) elimination of air penetration into slimes dams by e.g. establishment of vegetation, clay walling, and reducing moisture content;

(iii) inhibition of sulphur oxidizing organisms, e.g. in copper mines, where pyritic material also occurs, this oxidation process is at a minimum or absent; and

(iv) recovery of pyritic material.

CO-WORKERS/.....

C O - W O R K E R S

G.R. Botha, N.I.W.R. Now Synthetic Rubber Co., Sasolburg.

R. Snyders, N.I.W.R. Late Bio-Chemist, Municipality of Worcester.

E.G. White, City Chemist, Johannesburg.

P.R. Krige, City Bio-Chemist, Germiston. Now N.I.W.R.

R.J. de Boer, Bio-Chemist, Brakpan.

J. Heynike, Bio-Chemist, Springs. Now I.S.C.O.R.

J.J. Barnard, N.I.W.R. Now City Bio-Chemist, Germiston.

J.D.M. Anderson, Town Bio-Chemist, Nigel. Now Durban.

S.R. Caplan, N.I.W.R. Now Weitzman Research Institute, Israel.

A C K N O W L E D G E M E N T S

(1) The Department of Water Affairs for the erection of weirs and gauging stations and the preparation of discharge tables.

(2) The Rand Water Board, for making available records of flow and analyses for inspection.

(3) The Chamber of Mines for arranging flow measurements at some of the gauging stations.

(4) The municipalities of all the Reef towns for their assistance in sample analysis and recordings of flow.

(5) Miss B.C.M. Jackson, Miss D. Sampson and Messrs. G.S.F. Botha and P.O. Finsen, for their kind assistance in analysing samples.

(6) Messrs. M.R. Henzen, P.T. Viljoen and C.S. Bredekamp of the N.I.W.R., for editing this report.

R E F E R E N C E S/......

R E F E R E N C E S

1. BOND, G.W. A geochemical survey of the underground water supplies of the Union of South Africa, with particular reference to their utilization in power production and industry. Geological Survey, memoir no. 41, Pretoria, Government Printer, 1947, 234 p., maps.

2. HENZEN, M.R. and STANDER, G.J. C.S.I.R. Special Report W16, 1962, 42 p., tables, diagr., maps, bibliog. .

3. NATIONAL INSTITUTE FOR WATER RESEARCH. Ecological studies on Olifantsvlei, near Johannesburg. Hydrobiologia, vol. XV, nos. 1 - 2, 1960, pp. 89 - 134, bibliog.

4. NATURAL RESOURCES DEVELOPMENT COUNCIL. Report on the water supplies of the Vaal River in relation to its future development. 1953 - Report.

5. NORDELL, Eskel. Water treatment for industrial and other uses. New York, Reinhold publishing corp., 1951, 526 p.

6. SHEEN, R.T. and others. Turbidimetric determination of sulphate in water: Betz-Hellige method. Industrial and engineering chemistry (analytical edition) vol. 7, 1935, pp. 262 - 265.

7. SOUTH AFRICAN BUREAU OF STANDARDS. Specification for water for domestic supplies. S.A.B.S. 241, 1951.

8. STANDARD METHODS FOR THE EXAMINATION OF WATER AND SEWAGE. 9th Edition. New York, American Public Health Association, 1947, 286 p.

9. WORLD HEALTH ORGANIZATION. International standards for drinking water, 1948, 29 p.

10. ZAHN, V. Determination of small proportions of sulphur. Industrial and engineering chemistry (analytical edition) vol. 9, 1937, pp. 543 - 550.

<u>PRETORIA</u>.
CSB/ZS/LL.
January, 1964.

I N D E X

T/......

****

LIST OF CONTENTS

TABLE 1. CHEMICAL ANALYSES FIGURES OF THE WATERS OF THE UPPER KLIP RIVER AND KLIPSPRUIT – SECTIONS A AND B.

No.	Sample	Flow	pH	Dionic cond. (micro-mhos)	Total dis-solved solids (ppm)	Sus-pended solids (ppm)	Mixed oxides (ppm)	Total Hard-ness (ppm $CaCO_3$)	Chlo-rides as Cl' (ppm)	Sul-phates as SO_4'' (ppm)	4 Hr. O/A (ppm)	Alka-linity (ppm) $CaCO_3$	Remarks
Sampled: 5.2.1951													
A 1a	Run-off from stone crusher	Trickle	7.0	1316	1046	52.0	5.0	1028	46.0	545	8.0	–	
A 1	200 yds below old dam wall	Weak	3.1	3636	4820	13.0	1315	696	–	3420	83.0	–	
A 5a	Klip river before confluence with Roodepoort stream	Steady	3.2	1042	527	Trace	52.0	162	14.0	354	3.0	–	
A 5b	Roodepoort stream before confluence with Klip river	Strong	4.8	1613	1470	142	61.0	696	42.0	1005	*22.0	–	*Organic pollution
A 5c	Below confluence of A5a and A5b	Strong	4.5	1563	1369	121	60.0	665	39.0	980	18.0	–	
A 4a	Stream from Roodepoort dams	Steady	4.2	357	261	114	24.0	124	14.0	150	12.0	–	
A 4b	Stream from Roodepoort Deep	Steady	4.6	2500	2460	104	128.0	1362	58.0	1700	24.0	–	
A 4c	Below confluence of A4a and A4b	Strong	4.3	2146	2037	140	114.0	1080	42.0	1590	20.0	–	
A 4e	Sewage * effluent into combined Roodepoort stream	Steady	7.2	909	453	504	8.0	170	68.0	101	66.0	–	*Septic sewage
A5'b	Stream N.of Doornkop entering Klip river	Steady	8.5	204	139	21	3.0	93	Trace	Trace	Nil	–	
A 6c	Klip river at Potchefstroom-Johannesburg road	Strong	3.7	1316	1008	Trace	23.0	510	24.0	675	2.0	–	
Sampled: 13.2.1951													
A 4f	Below lime treatment plant D.R. Deep stream	Steady	11.7	3846	2849	1066	nil	1712	65.0	1620	20.0	–	)Sampled)after)heavy rain)on pre-)vious)day.
A 4g	Immediately above lime-treatment plant	Steady	4.0	2410	2650	7.0	241	1475	85.0	2080	12.4	–	
Sampled: 21.2.1951													
A4'a	Stream into upper Roodepoort dam from east	Steady	6.1	31	77	Trace	10.0	6.0	4.0	nil	0.4	10	
A4'b	Stream into upper Roodepoort dam from north	Steady	6.4	74	77	Trace	7.0	10.6	8.0	nil	0.4	25	
A4'c	Overflow from upper Roodepoort dam	Steady	6.9	161	135	12	12.0	53.2	12.0	nil	0.8	50	
A4'h	Stream running into lower Roodepoort dam from east	Steady	7.4	480	–	–	–	–	44.0	–	92.0	81	Municipal records
A4'd	Stream into lower dam from north	Steady	6.5	37	65	Trace	13.0	5.0	4.0	nil	2.4	15	
Sampled: 21.2.1951													
A4'e	Overflow from lower Roodepoort dam	Strong	6.5	123	107	Trace	6.0	21.2	10.0	Trace	2.4	22.6	
A4'f	Drainage from mine dump area into A4'e	Trickle	3.2	2439	2259	302	616	298	158	1360	27.0	–	
Sampled: 27.2.1951													
B12c	Effluent from Blue Star dam at Antea	Steady	8.2	500	473	33	8.0	107	68	52	20.0	76	
B10a	Stream flowing eastward from Maraisburg	Steady	4.5	455	430	Trace	19.0	174	14	88	nil	–	
B 9a	Influent to Canada dam from north	Strong	7.5	735	635	44	7.0	252	78	115	7.6	76	
B 9c	Effluent from Canada dam	Strong	4.8	1852	1248	Trace	25.0	1038	74	107	nil	–	
B 9b	Influent to Canada dam from east	Steady	5.4	1667	2004	1	68.0	878	68	1190	5.6	–	
B 9d	Influent to Canada dam from west	Steady	8.5	2195	2235	–	26.0	1131	44	1094	57.6	147	Municipal records
B 6b	Stream from Crown mines at Orlando boundary	Steady	8.8	2703	3558	22	16.0	1622	134	1080	70.4	64	
B 3c	Effluent from Rand Leases dam	Strong	8.0	1754	2166	1	10.0	1023	74	1400	0.4	26	

B3a/ ....

TABLE 1

Upper Klip River and Klipspruit Survey - Sections A and B

No.	Sample	Flow	pH	Dionic cond. (micro-mhos)	Total dis-solved solids (ppm)	Sus-pended solids (ppm)	Mixed oxides (ppm)	Total hard-ness (ppm $CaCO_3$)	Chlo-rides as Cl' (ppm)	Sul-phates as SO''$_4$ (ppm)	4 Hr. O/A (ppm)	Alka-linity (ppm $CaCO_3$)	Remarks
Sampled: 27.2.1951													
B 3a	Stream from Durban Roodepoort Deep entering Rand Leases dam	Steady	7.0	2062	2503	5272	41.0	760	80	1520	52.0	8	
B 3b	Stream from Florida Lake entering Rand Leases dam	Trickle	8.0	465	429	2	5.0	160	26	49	0.4	186	
B 5a	Klipspruit above stream from Orlando dam	Strong	5.6	1786	2052	9	131.0	1023	70	595	4.8	-	
B 5b	Stream from Orlando dam	Steady	7.9	1020	829	12	4.0	292	162	570	2.4	116	
B5'b	Sewage irrigated land drainage - Pimville area	Steady	7.3	970	500	-	-	-	200	-	35.0	-	Municipal records
B 6a	Meadowlands stream entering Klip-spruit	Steady	8.1	125	96	Trace	8.0	94	Trace	Trace	2.4	76	
B 7a	Effluent from Moroka contact beds	Steady	7.7	606	509	92	1.0	200	54	390	22.4	190	
B 7b	Klipspruit crossing Potchefstroom road	Strong	5.9	1667	1946	Trace	102.0	1023	86	515	1.2	6	
Sampled: 7.3.1951													
B18a	Storm-water drain from Fordsburg area	Steady	8.8	4348	-	-	-	-	-	-	1290.0	-	) Small) samples) taken
B18b	Storm-water drain from Market area	Steady	7.3	500	-	-	-	-	-	-	89.6	-	))
B19b	Drainage from Robinson Deep mine	Steady	3.4	5400	7480	-	1286	2125	122	3870	86.6	-	
B17a	Storm-water drain from city at tar plant, Booysens	Steady	7.6	1515	1014	224	11.0	390	-	140	72.4	310	
B17b	Storm-water drain from Turffontein at tar plant	Steady	4.2	2941	3451	200	421.0	1260	-	2460	46.4	-	
B16b	Canalized stream from south, approximately 300 yds. below tar plant	Steady	6.0	2222	2168	74	46.0	1150	-	1510	3.2	12	
B15a	Discharge from Crown mines - above Concordia dam	Steady	6.5	1563	1580	81	11.0	800	-	950	48.4	90	
B14b	Stream into upper Concordia dam from south	Steady	6.6	488	389	Trace	13.0	110	70	110	8.0	54	
Sampled: 7.3.1951													
B14a	Main stream entering upper Concordia dam	Strong	4.7	2326	2613	824	280.0	1100	-	1690	28.8	-	
B13a	Stream into lower Concordia dam from north	Trickle	7.1	833	748	Trace	12.0	447	24	360	1.2	70	
B13c	Effluent from lower Concordia dam	Strong	4.0	2222	2413	8	71.0	1192	80	1600	nil	-	
A11	Harrington spruit leaving Olifantsvlei	Trickle	7.7	970	568	-	7.0	-	180	-	11.2	260	Municipal records
A 7	Klip River at bridge - Johannesburg-Vanderbijl Park road	Strong	7.4	1660	1580	-	4.8	764	100	844	1.7	33	Municipal records
A12	Klip river at Jackson's drift	Strong	6.8	943	901	9	3.0	490	65	360	5.1	57.5	

TABLE 2 — CHEMICAL ANALYSES FIGURES OF THE WATERS OF THE NATALSPRUIT, ELSBURGSPRUIT, RIETSPRUIT FROM BRAKPAN AND THE MIDDLE REACHES OF THE KLIP RIVER - SECTIONS C,D, CC AND A PORTION OF AA.

No.	Sample	pH	Dionic cond. (micro-mhos)	Total dissolved solids (ppm)	Suspended solids (ppm)	Mixed oxides (ppm)	Total hardness (ppm $CaCO_3$)	Chlorides as Cl' (ppm)	Sulphates as SO_4'' (ppm)	4 Hr. O/A (ppm)	Alkalinity (ppm $CaCO_3$)	Remarks
C1a	Stream entering Wemmer Pan from south	6.8	276	210	Trace	7.0	100	26	44	1.2	44	
C1c	Overflow from Wemmer Pan	4.0	645	581	Trace	11.0	240	48	440	7.0	-	
G2b	Run-off and seepage from direction of City-Deep Reduction Works	4.1	1389	1262	343	46.0	650	88	880	7.2	-	
C2c	Combined C1c and C2b at road bridge	3.6	1667	1677	33	397.0	480	56	1030	1.2	-	
C3b	Seepage from slimes dam into Wemmer stream	8.3	2703	2874	5563	11.0	1690	126	1830	72.0	52	
C4a	Storm water drain (Natalspruit) at Wolhuter	4.6	1190	1151	105	32.0	560	120	870	62.0	-	
C5b	Stream entering Rosherville dam from north	5.5	2857	3112	146	14.0	2030	120	2080	32.0	12	
C5c	Overflow from Rosherville dam	5.3	2083	2167	Trace	18.0	1400	72	1360	1.8	10	
C7	Stream from Klipriviersberg at road from Rosettenville to South Hills	7.0	65	60	Trace	14.0	30	10	Trace	1.2	18	
C6a	Stream from Klipriviersberg at Durban road	3.7	1075	950	Trace	48.0	450	56	660	2.2	-	
C6c	Combined C5a and C6a (Natalspruit)					Not sampled						
C8b	Geldenhuis stream at Rand Airport road	3.5	3333	3620	Trace	436.0	1680	184	1840	30.8	-	
C12b	Run-off from mine south of Geldenhuis	4.0	3448	4084	254	500.0	3360	230	208	32.0	-	
C 9a	Stream from Oakdene, before entering Natalspruit	7.5	143	90	Trace	32.0	90	8	4.3	2.4	56	
C10a	Natalspruit before confluence with Elsburgspruit	3.8	2128	2015	Trace	82.0	1150	96	1440	1.8	-	
C10b	Elsburgspruit before confluence with Natalspruit	7.2	1923	1776	Trace	28.0	980	138	1110	21.6	108	
C10c	Natalspruit after confluence with Elsburgspruit				Not	sampled						
D 1b	Storm water drain entering Victoria lake from north-east	8.5	2632	3286	4075	20.0	1760	104	1820	26.4	8	
D 1a	Stream entering Victoria lake from north-west	9.4	3333	4388	955	22.0	2560	114	2355	Nil	35	
D 1c	Overflow from Victoria lake	5.5	-	4141	-	-	-	89	-	0.8	-	Germiston Municipal records
D2b	Georgetown spruit in Germiston	6.9	714	601	Nil	10.0	329	304	110	2.1	100	
D 5b	Overflow from dam in Delmore valley	4.6	2500	3259	88	130.0	1930	24	1630	5.6	-	

D7a/....

TABLE 2

No.	Sample	pH	Dionic cond. (micro-mhos)	Total dis-solved solids (ppm)	Sus-pended solids (ppm)	Mixed oxides (ppm)	Total hard-ness (ppm $CaCO_3$)	Chlo-rides as Cl' (ppm)	Sul-phates as SO_4'' (ppm)	4 Hr. O/A (ppm)	Alka-linity (ppm $CaCO_3$)	Remarks
D 7a	Stream entering Angelo pan from north-west of Boksburg	4.3	6061	13110	11860	3664	2650	56	6520	452.0	–	
D 7c	Stream from Angelo pan entering dam 'B'	4.6	3175	4347	81	271.0	1978	88	2900	19.3	–	
D 6d	Stream from north entering dam 'B'	5.0	3030	3786	250	260.0	1382	192	2100	50.3	7.5	
D 6f	Stream from north of Angelo station before dam 'A'	4.3	3333	4480	100	79.0	2234	96	3000	7.3	Nil	
D 6e	Stream from west entering D6f	4.7	909	1281	538	128.0	277	136	475	134.8	Nil	
D 6a	Overflow from dam 'A'				Not	sampled						
D6b	Seepage from dam 'B'	3.5	3030	3690	Nil	125.0	1798	112	1840	6.4	Nil	
D 6c	Combined D6a and D6b	4.6	2857	3752	47	362.0	2350	72	2180	29.6	–	
D 3c	Elsburgspruit after confluence with Victoria lake effluent	4.7	2273	2729	16	108.0	2030	80	2000	12.4	–	
D 4b	Overflow from Cinderella dam	4.5	1961	2085	Trace	69.0	1038	80	1450	14.8	–	
D10b	Effluent from Satmar.	9.4	1667	1711	244	6.0	209	226	288	504.0	255	
D 9a	Run-off from ERPM entering Satmar effluent				No run-off	at time of	sampling					
D 8	Overflow from Boksburg lake	4.3	526	476	Trace	30.0	308	28	304	3.2	–	
D12b	Rondebult Purification Works seepage water	7.0	–	1020	–	–	–	131	–	11.5	–	Germiston municipal records
C11b	Rietspruit before entering Natalspruit	7.9	590	369	Trace	Nil	278	26	119	2.8	210	
CC1	Rietspruit below van Dyk's mine southern shaft	7.4	1613	1438	Trace	Nil	627	86	804	1.3	78	
CC2	Stream from S.A. Lands mine before CC1	7.3	1429	1210	Nil	Nil	574	142	596	3.6	34	
AA1b	Natalspruit before Klip river	8.2	1408	1476	Trace	3.0	830	83	590	–	62.5	
AA1a	Klip river before Natalspruit	7.9	1050	796	Trace	Nil	463	90	364	1.4	132.0	
AA1c	Klip river after confluence with Natalspruit	8.2	1117	1106	6	5.0	620	82	420	–	122.5	

TABLE 3

Chemical analysis figures of the waters of the upper tributary of the Blesbokspruit, the Blesbokspruit and the Small Blesbokspruit in the Springs area, the Blesbokspruit in the Nigel-Heidelberg area, the Suikerboschrand river and the Lower Klip river. (Sections E,F,G and AA)

No.	Sample	Flow	pH	Dionic cond. (micro-mhos)	Total dis-solved solids (ppm)	Sus-pended solids (ppm)	Mixed oxides (ppm)	Total hard-ness (ppm $CaCO_3$)	Chlo-rides as Cl' (ppm)	Sul-phates as SO_4'' (ppm)	4 Hr. O/A (ppm)	Alka-linity (ppm $CaCO_3$)	Remarks
Sampled: April to July, 1951													
E11b	Blesbokspruit before confluence with Benoni stream	Weak	8.1	963	698	118	27	380	124	66	13.2	-	
E 3b	Benoni stream entering Laundry dam	Steady	7.2	227	232	8	120	55	40	Trace	5.2	-	
E 3a	Storm water drain entering Laundry dam	Steady	7.7	1100	680	8	10	198	140	123	9.8	308	
E 3c	Effluent from Laundry dam below Kleinfontein mine	Steady	7.4	2273	2762	296	11	1510	68	1800	4.0	-	
E 5a	Benoni stream before confluence with Rynfield lake effluent					Not	flowing						
E 5b	Rynfield lake effluent	Weak	7.2	769	680	Trace	7	320	72	205	8.8	-	
E 5d	Furrow from Modder-bee mine entering Benoni stream	Steady	5.6	1853	2063	50	13	970	64	1260	37.6	-	
E 7b	Benoni stream entering Geduld dam	Steady	3.1	3175	3509	Trace	258	1540	64	2300	2.0	-	
E 7a	Stream from Brakpan mine entering Geduld dam	Steady	3.8	3846	4791	301	205	2640	100	3000	48.0	-	
Sampled: April to July, 1951													
E 8b	Water pumped from Brakpan/Yake to Geduld dam						Not	flowing					
E 8a	Furrow draining from State mines into Geduld dam	Steady	6.9	1282	1182	300	11	450	134	490	44.0	-	
E 9a	Furrow from Geduld mine, No. 7 shaft entering Geduld dam	Steady	8.0	1887	2061	63	12	1280	150	1130	2.0	-	
E 9c	Geduld dam overflow	Strong	3.1	3448	3942	4	360	1540	68	2260	3.0	-	
E10a	Benoni stream entering Cowls dam	Steady	3.2	2273	2114	Trace	64	860	80	1300	Nil	-	
E 8d	Brakpan Sewage Works effluent	Steady	7.2	850	438	51	30	181	72	88	11.8	240	
E11c	Blesbokspruit at bridge on Springs-Delmas road	Strong	7.2	2083	2471	82	22	970	600	980	19.0	-	
F 3b	Drainage from rock dump at Springs mines	Weak	2.8	17240	56530	Trace	18585	4360	200	33000	11.2	-	
F 2b	Small Blesbokspruit before confluence with Ancor effluent	Steady	3.6	3448	3439	-	58	820	93	1950	10.5	-	
Sampled: April to July, 1951													
F 2a	Ancor sewage effluent	Steady	7.0	625	422	26	Trace	170	88	113	18.8	76	
F 1c	Blesbokspruit after confluence with Small Blesbokspruit	Strong	7.1	2000	1613	14	18	710	340	675	11.6	50	
G 1c	Blesbokspruit at causeway near Marievale mine	Strong	6.8	2439	1997	-	13	810	368	795	5.4	68	
G 2c	Blesbokspruit at bridge on Nigel-Balfour North road	Strong	7.6	2778	2366	Trace	16	978	540	945	3.6	60	
G 4c	Vlakfontein stream at bridge on Springs-Nigel road	Weak	5.0	2632	2270	-	25	862	500	905	3.6	2	
G 5a	Slimes dam seepage: Sub-Nigel mine, Betty shaft	Weak	3.3	2667	2463	-	114	755	256	1375	22.4	-	
G 6d	Vlakfontein stream entering dams north of Nigel	Steady	7.1	2174	1748	-	10	872	206	915	80.8	54	
G 8c	Effluent from Nigel dams	Steady	4.3	2722	2694	Trace	75	895	400	1230	0.9	-	
Sampled: April to July, 1951													
G 9c	Blesbokspruit below Nigel Sewage Works	Strong	7.4	2564	2132	-	12	872	490	850	2.2	40	
G10a	West Spaarwater stream at Nigel-Heidelberg road	Steady	7.5	233	171	10	14	85	38	17	6.3	80	
G15b	Blesbokspruit above tannery in Heidelberg	Strong	7.6	2128	1748	-	11	723	400	645	2.2	40	
G17a	Blesbokspruit before confluence with Suikerboschrand river	Strong	7.8	1750	1324	Trace	23	597	292	545	3.3	40	
G17b	Suikerboschrand river before confluence with Blesbokspruit	Strong	7.8	170	125	Trace	8	62	4	Trace	4.7	78	
G18a	Suikerboschrand river before confluence with Vaal river	Strong	7.3	1000	747	Trace	27	339	100	365	3.3	52	

AA2c /....

TABLE 3

Analytical results

No.	Sample	Flow	pH	Dionic cond. (micro-mhos)	Total dis-solved solids (ppm)	Sus-pended solids (ppm)	Mixed oxides (ppm)	Total hard-ness (ppm $CaCO_3$)	Chlo-rides as Cl' (ppm)	Sul-phates as SO_4'' (ppm)	4 Hr. O/A (ppm)	Alka-linity (ppm $CaCO_3$)	Remarks
Sampled: April to July, 1951													
AA 3a	Effluent from Klip Power Station	Steady	8.7	375	271	6168	3	154	22	119	74.2	100	
AA 4c	Klip river at bridge on Vereeniging-Vaal dam road	Strong	7.9	885	823	1	5	490	58	260	-	135	
AA 4a	Effluent from S.A. Farm Implement Manufacturing Co.	Trickle	7.8	550	328	Trace	Nil	103	92	66	6.5	90	Floating oil
AA10b	Effluent from Stewarts and Lloyds factory	Steady	6.0	325	194	33	53	115	22	72	4.2	26	Floating oil
AA10a	Effluent from Union Steel Corporation's northern factory	Steady	3.8	900	779	177	283	110	70	485	28.5	-	
AA11	Houtkopspruit above factory effluents				Not flowing								
AA13	Water from Vereeniging Power Station ash disposal plant	Weak	13.2	8000	3478	183	14	2487	22	1435	42.5	1950	
AA14	Effluent from Union Steel Corporation's southern factory	Steady	8.2	270	262	69	109	125	14	51	7.1	76	Floating oil

WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

TABLE 4

Total dissolved solids concentration in ppm of unpolluted springs and surface water in the Witwatersrand area

Source	Period of sampling	Range		
		Min.	Max.	Aver.
Vaal River, below Vaaldam, discharge (surface water)	Jan. 1950 - Dec. 1953	70	110	95
A1' Klip River source at Lewisham (spring)	July 1953 - Jan. 1954	17	35	30
A4'a Stream entering upper Roodepoort dam from east (spring)	April 1953 - Jan. 1954	29	89	43
B1a Stream entering Hamburg dam from the west (spring)	Sept. 1951 - Jan. 1954	17	76	44
B1b Eye at Discovery (spring)	Nov. 1950 - Jan. 1954	17	35	25
B6a Stream from Meadowlands (spring)	Feb. 1951 - Sept. 1953	81	176	115
B4'a Bailey's stream entering Orlando Power Station dam (spring)	May 1949 - May 1953	63	139	84
A4'b Stream into upper Roodepoort dam from the north (surface water)	Feb. 1951	One sample taken only		77
A4'd Stream into lower Roodepoort dam from the north (surface water)	Feb. 1951			65
Zuurbekom well	1950 - 1953	Very constant		146
A4'c Upper Roodepoort dam overflow (surface water)	Nov. 1950	95	137	109
A4'e Lower Roodepoort dam overflow (surface water)	Nov. 1950	53	142	102
C7 Kliprivierberg stream (spring)	Feb. 1951 - April 1953	46	145	90
C9a Oakdene stream (spring)	Feb. 1951 - Oct. 1953	66	185	123
G17b Suikerboschrand River above Blesbokspruit	April 1951 - Dec. 1953	60	144	113

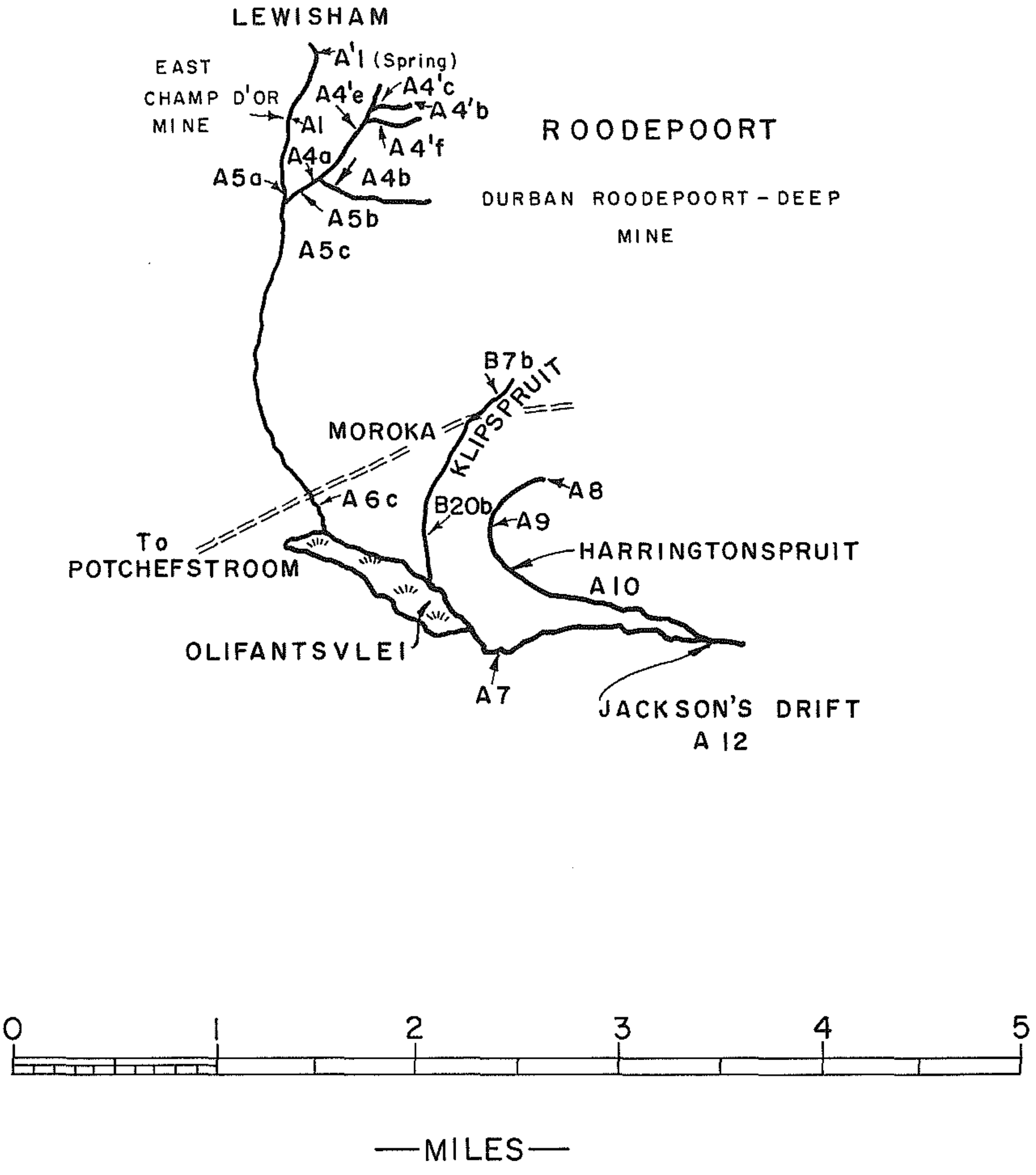

LEWISHAM
A'1 (Spring)
EAST CHAMP D'OR MINE
A4'e
A4'c
A4'b
A1
A4'f
A4a
A5a
A4b
A5b
A5c
ROODEPOORT
DURBAN ROODEPOORT - DEEP MINE
B7b
KLIPSPRUIT
MOROKA
A6c
B20b
A8
A9
To POTCHEFSTROOM
HARRINGTONSPRUIT
A10
OLIFANTSVLEI
A7
JACKSON'S DRIFT
A 12
0
1
2
3
4
5
—MILES—

DIAGRAM 1

WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

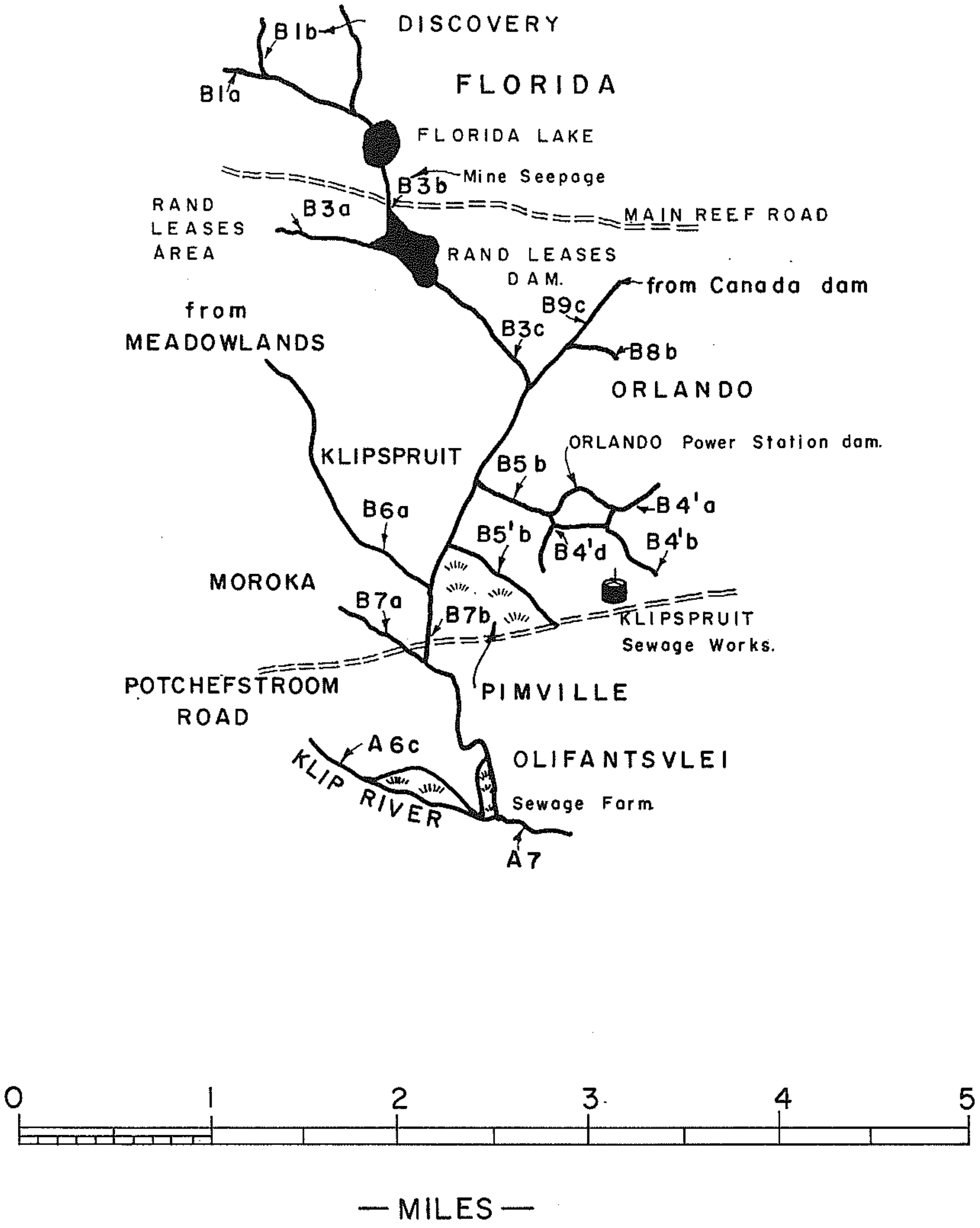
TABLE 5

(Read in conjunction with diagram 1)

Chemical and mineral load data for Klip River at and above Jackson's/drift (Sections A and B)

Sampling and gauging point numbers	Year and Month	Total dissolved solids in ppm	Total hardness as $CaCO_3$ in ppm	Sulphates as SO_4 in ppm	Observed mineral load lb/ 24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/ 24 hours
	1952						
A 12	April	820	440	292	73000	64100	Nil
	May	865	495	337	86600	76600	Nil
	June	835	400	321	80100	70500	Nil
	July	950	580	420	97000	86800	Nil
	Aug.	960	550	449	96000	86000	Nil
	Sept.	740	460	259	55000	47600	Nil
	Oct.	660	415	210	47600	40400	Nil
	Nov.	1420	785	786	2315000	2151000	2091000
	Dec.	870	505	449	788000	697500	638000
	1953						
	Jan.	940	495	477	491000	438700	372550
	Feb.	740	413	222	67700	58500	Nil
	March	840	463	420	756000	666000	599700
	April	930	493	461	486000	433800	367550
	May	820	453	362	161000	141400	Nil
	June	860	483	333	84200	74400	Nil
	July	900	463	350	84300	74900	Nil
	Aug.	810	488	377	72000	63100	Nil
	Sept.	690	480	185	58300	49800	Nil
	Oct.	660	383	148	47600	40400	Nil
	1952						
A 10	April	1361	522	160)			
	Sept.	1269	534	89)			
	1953			)			
	May	871	342	128)			
	1952			)			
A 9	April	1220	570	175)			
	Sept.	962	424	91)	No flow recorded		
	1953			)			
	May	887	349	137)			
	1952			)			
A 8	April	1210	550	101)			
	Sept.	785	268	83)			
	1953			)			
	May	657	181	116)			
	1952						
A 7	April	1605	820	452	276500	259250	
	1953						
	May	1298	602	252	167500	154500	
	June	1320	690	780	32000	29500	
	June	1390	740	680	21350	19400	
	July	1462	745	590	19700	18400	
	Oct.	2203	995	83	-	-	
	1954						
	Jan.	1383	725	785	238500	217700	
	Feb.	992	422	530			
	1953						
	June	1457	805	1100)			
B 20b	July	1400	755	605)	No flow recorded		
	1952						
A 6c	June	1778	868	573)			
	1953			)			
	June	1010	540	418)			
	June	929	520	690)			
	July	1008	565	470)			
	Oct.	2181	714	343)			
	1952			)			
A 5c	Jan.	1937	824	-)			
	1953			)			
	June	1198	610	1080)			
	1953			)			
A 5b	June	1288	1090	62)			
	1952			)			
A 4b	June	2664	1450	688)			
	Sept.	2500	1400	754)			
	1953			)			
	June	2140	1180	831)			
	1952			)			
A 4a	June	-	32	54)			
	1953			)			
	June	342	89	-)			
	1952			)			
A4'f	May	562	36	262)			
	Sept.	1718	146	752)			
	1953			)			
	June	401	106	101)			
	Oct.	472	47	77)			
	1952			)			
A4'o	May	91	44	27)			
	Sept.	142	46	32)	No flow recorded		
	1953			)			
	June	53	16	13)			
	1953			)			
A4'b *	June	108	54	36)			
	1952			)			
A4'c	May	98	38	6)			
	Sept.	98	64	24)			
	1953			)			
	June	99	59	3)			
	1952			)			
A5a	Feb.	615	300	-)			
	Feb.	707	238	617)			
	May	1649	1008	657)			
	1953			)			
	June	941	360	700)			
	Oct.	16270	1256	2379)			
	1952						
A1*	Feb.	7286	1480	-			
	May	16450	723	2720	155000	154000	
	1953						
	May	2314	262	945	-	-	
	June	2349	-	1570	8350	8000	
	Oct.	18860	1083	2695	67000	66600	

* Direct inflow from mines.



DISCOVERY
B1b
B1a
FLORIDA
FLORIDA LAKE
B3b
Mine Seepage
MAIN REEF ROAD
RAND LEASES AREA
B3a
RAND LEASES DAM.
from Canada dam
B9c
from MEADOWLANDS
B3c
B8b
ORLANDO
ORLANDO Power Station dam.
KLIPSPRUIT
B5 b
B4'a
B6a
B5'b
B4'd
B4'b
MOROKA
B7a
B7b
KLIPSPRUIT Sewage Works.
POTCHEFSTROOM ROAD
PIMVILLE
A6c
OLIFANTSVLEI
KLIP RIVER
Sewage Farm
A7
0
1
2
3
4
5
— MILES —

DIAGRAM 2

TABLE 6

(Read in conjunction with diagram 2)

Chemical and mineral load data for Klipspruit (Section B)

Sampling and gauging point numbers	Year and Month	Total dissolved solids	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours
	1952					
B 7b	May	1778	868	572	76500	72000
	Sept.	1470	650	461	43000	39000
	1953					
	May	1324	790	620	185500	171000
	June	1010	540	418	185000	167000
	July	1514	845	570	228500	213400
	Oct.	1615	770	500	150000	142000
	1954					
	Jan	1597	860	-	352500	131500
	1952					
B 7 a	May	393	130	15		
	Sept.	402	118	28		
	June	429	220	47		
	1952					
B 6 a	Sept.	96	82	-		
	1953					
	June	115	90	12		
	Sept.	84	68	2		
	1952					
B 5'b	April	1110	380	169		
	Sept.	978	376	78		
	1953					
	May	1093	427	155		
	1952					
B 5 b	April	929	260	168		
	Sept.	1194	374	75		
	1953					
	May	860	258	162		
	1952					
B 4'd	April	703	206	186	No flow recorded	
	May	935	340	175		
	1952					
B 4'b	April	109	64	4		
	Sept.	174	112	1		
	1953					
	May	296	103	10		
	1952					
B 4'a	April	89	46	9		
	Sept.	63	32	2		
	1953					
	May	72	32	18		
	1952					
B 3 c *	Jan	-	1260	-		
	May	2572	1340	575		
	Sept.	2395	1270	1015		
	1953					
	June	2120	1100	715		
	1952					
B 3 a*	Feb.	2087	1304	-		
	May	2436	1320	415		
	Sept.	2195	1200	944		
	1953					
	April	2508	1520	492	77500	74500
	June	2380	1300	790	99100	95000
	July	2079	1130	900	67800	64500
	Aug.	1653	960	1020	51000	48000
	1952					
B 3 b *	Feb.	722	496	-		
	Feb.	879	508	358		
	May	598	348	78		
	Sept.	1090	568	404		
	1953				No flow recorded	
	April	480	175	36		
	June	1100	470	347		
	July	1155	602	550		
	1953					
	Aug.	328	200	145		
	Oct.	2320	1170	1030		
	Dec.	2168	1240	1370		
	1954					
	Jan	1113	650	720		
	1952					
B 1 b	May	24	3	5		
	Sept.	35	7	7		
	1953					
	June	24	8	4		
	July	17	12	-		
	Aug.	28	8	6		
	Dec.	23	6	7		
	1954					
	Jan	35	7	-		
	1952					
B 1 a	May	64	24	5		
	Sept.	73	34	13		
	1953					
	June	76	30	11		

* Direct inflow from mines

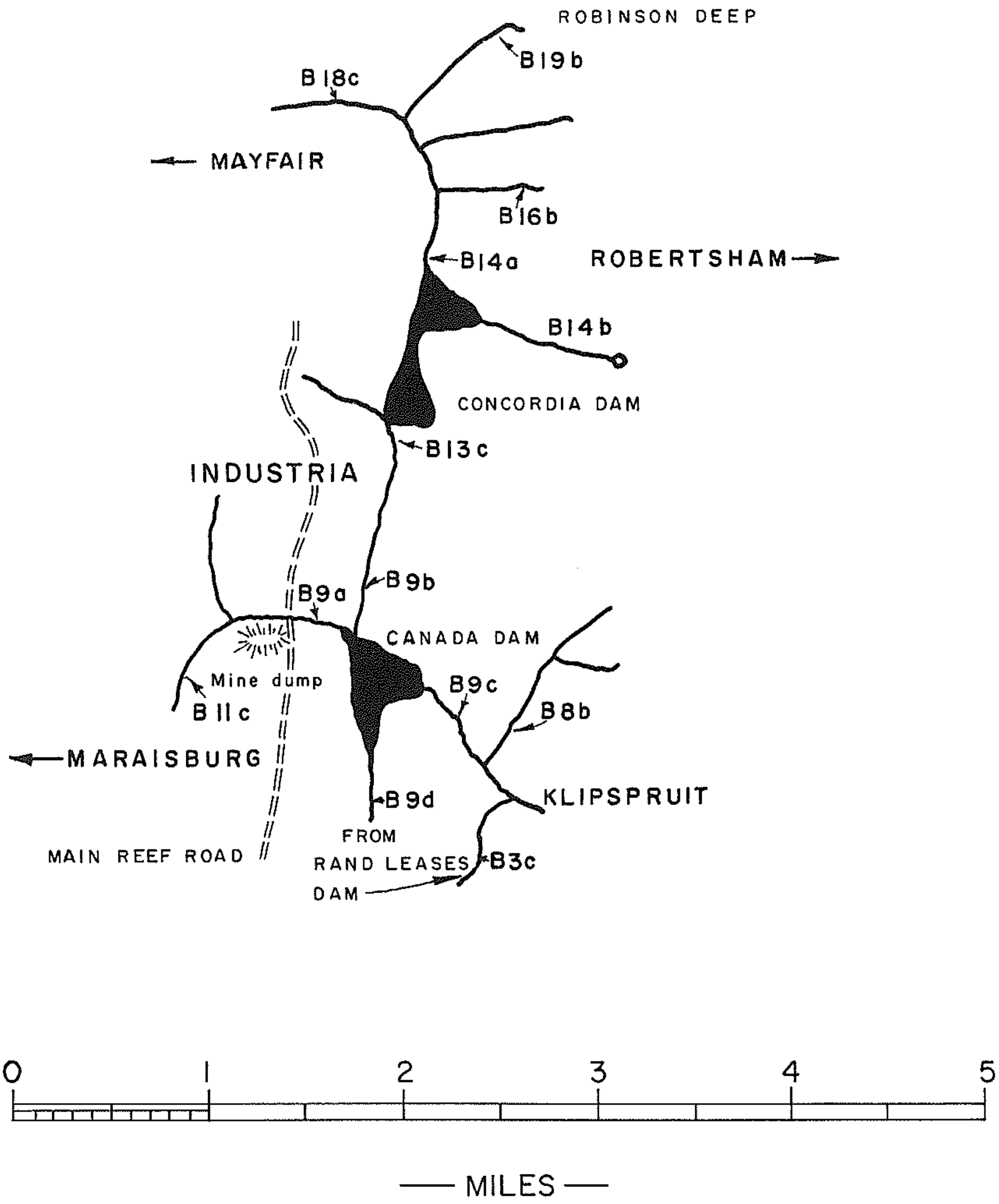

ROBINSON DEEP
B19b
B18c
MAYFAIR
B16b
B14a
ROBERTSHAM
B14b
CONCORDIA DAM
B13c
INDUSTRIA
B9b
B9a
CANADA DAM
Mine dump
B11c
B9c
B8b
MARAISBURG
B9d
KLIPSPRUIT
FROM
RAND LEASES
DAM
B3c
MAIN REEF ROAD
0
1
2
3
4
5
MILES

DIAGRAM 3

TABLE 7

(Read in conjunction with diagram 3)

Chemical and mineral load data for Klipspruit (Cont.) Section B

Sampling and gauging point numbers	Year and Month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours
	1952					
B 8 b *	May	2930	1690	1140	-	-
	Oct.	3050	1274	1075	No flow	recorded
	1953					
	June	2353	1237	911		
	Oct	2628	982	700		
	1952					
B 9 c	Jan.	-	1070	-		
	Oct.	3091	1463	1072	16620	16000
	1953					
	June	2119	1314	985	91200	87000
	Oct.	3878	1700	587	197000	192000
	1952					
B 9d	Jan	-	980	-		
	Feb.	2305	1210	1083		
	May	2385	1280	878		
	Oct.	2276	1154	895		
	1953					
	June	2752	1382	957		
	Oct.	2690	900	396		
	1952					
B 9 a *	Jan	-	360	-		
	May	1642	857	561	No reliable	flow records
	Oct.	2425	1065	787		
	1953					
	June	1140	599	380	45450	41450
	Oct.	3130	1074	489		
	1952					
B 11 c	May	229	98	88		
	Oct.	273	40	78		
	1953					
	June	159	83	51		
	1952					
B 9 b	Jan.	-	770	-	No flow	recorded
	Feb.	2007	870	1040		
	May	3163	1520	1250		
	Oct.	4488	1433	1650		
	1953					
	June	3480	1604	1385		
	Oct.	3714	1102	566		
	1952					
B 13 c	May	3166	1570	1230	26800	26000
	Oct.	3340	1234	1422	-	-
	1953					
	June	3631	1652	1445	50200	59000
	1952					
B 14 b	May	395	120	69		
	Oct.	369	119	54		
	1953					
	June	366	125	57		
	1952					
B 14 a	May	3394	1430	1350		
	Oct.	4126	1483	1490		
	1953					
	June	3587	1622	1400		
	1952					
B 16 b	May	2154	978	790		
	Oct.	1665	701	624		
	1953				No flow	recorded
	June	1553	682	575		
	1952					
B 19 b *	May	5338	2490	2240		
	Oct.	5077	936	1870		
	1953					
	June	5315	2136	2240		
	Oct.	12050	2239	1670		

* Direct inflow from mines

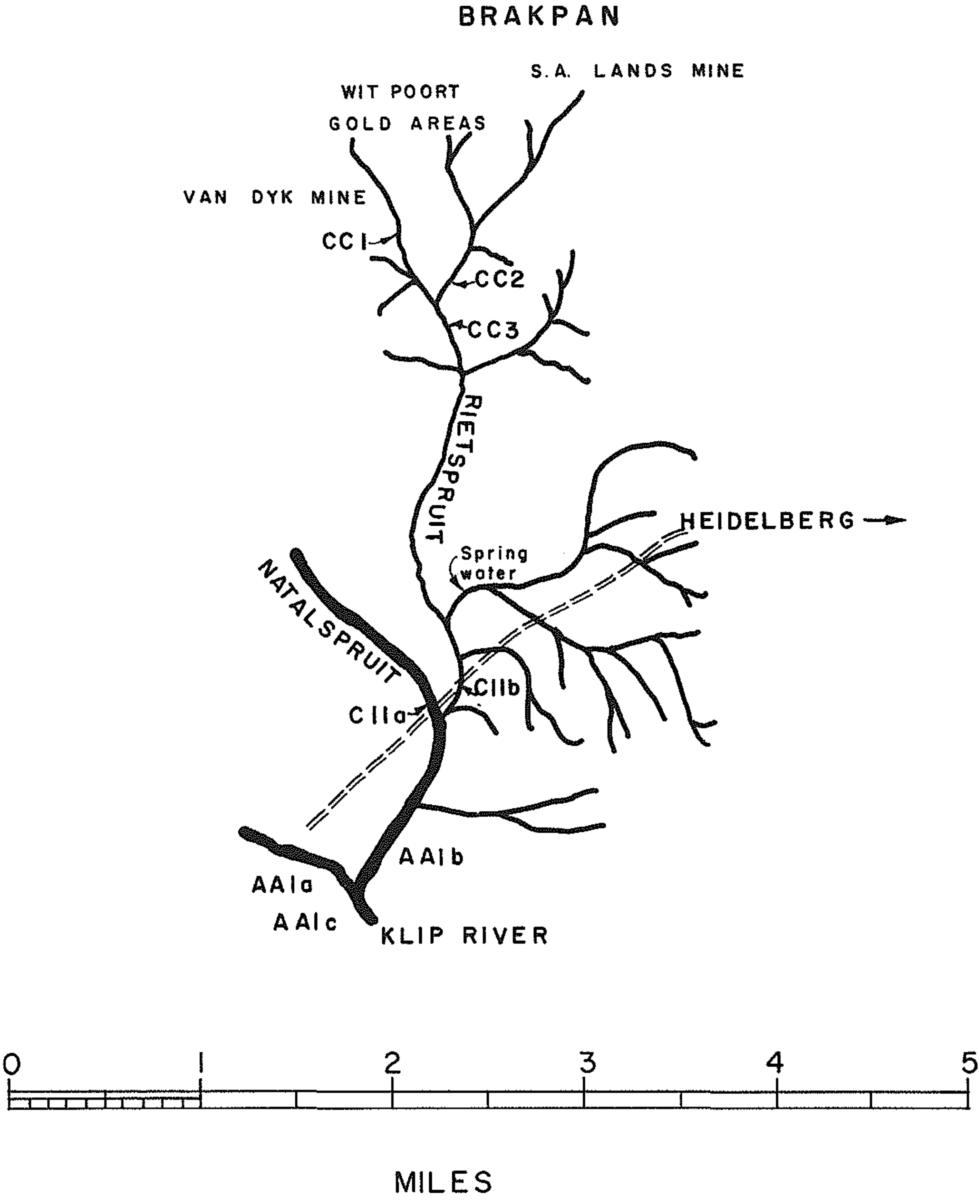

BRAKPAN
S.A. LANDS MINE
WIT POORT
GOLD AREAS
VAN DYK MINE
CC1
CC2
CC3
RIETSPRUIT
HEIDELBERG
Spring water
NATALSPRUIT
C11b
C11a
AA1b
AA1a
AA1c
KLIP RIVER
0
1
2
3
4
5
MILES

DIAGRAM 4

TABLE 8

(Read in conjunction with diagram 4)

Analytical and mineral load data for Rietspruit before confluence with the Natalspruit (Sections C and CC)

Sampling and gauging point numbers	Year and Month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4''	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
C 11 b	June	321	258	49	1600	1120	Nil
	July	289	283	25	1200	780	Nil
	1953						
	Jan.	492	323	141	13000	10490	7200
	Feb.	348			130000	93400	189100
	April	406	293	87	5700	4500	Nil
	June	450	290	123	5700	4340	Nil
	Aug.	360	350	72	7800	5400	Nil
	Oct.	333	300	-	27100	19000	15600
	1952						
CC3	March	630	480	435			
	April	1400	770	740			
	June	600	360	123			
	July	1500	912	798			
	Sept.	1000	750	493			
	Oct.	300	-	205			
	Dec.	1130	554	563			
	1953						
	Jan.	610	608	610			
	Jan.	840	430	840			
	Jan.	790	400	399			
	March	700	220	450			
	May	600	360	304			
	June	900	570	300			
	July	830	230	493			
	Oct.	744	490	-			
	Nov.	5700	-	316			
	1952				No flow recorded		
CC2	March	1950	1080	633			
	April	2700	1060	1192			
	June	2400	1172	1233			
	July	2500	1260	1205			
	Sept.	3500	1890	1890			
	Oct.		No flow				
	Dec.	1400	1200	814			
	1953						
	Jan	540	700	292			
	Jan	1190	580	637			
	Jan	1440	695	769			
	March	1300	500	459			
	May	1600	780	332			
	June	1520	804	710			
	July	1400	540	680			
	Oct.	4426	2250	-			
	Nov.	5000	-	2754			
	1952						
CC 1	March	1400	808	805	-	-	-
	April	1700	760	757	3940	3708	-
	June	1300	632	652	2310	2132	-
	July	1600	636	617	11190	10517	-
	Sept.	4000	600	2400	635	619	-
	Oct.	10000	-	5506	1076	1065	-
	Dec.	1220	490	617	8210	7537	-
	1953						
	Jan	1050	330	246	Over 11320	-	-
	Jan	500	190	115	" 5390	-	-
	Jan	1580	190	102	"17000	-	-
	March	400	60	209	2695	2122	-
	May	700	-	243			
	June	1000	560	353	Gauge out of order		
	July	640	450	370			
	Oct.	2740	1040	-	14150	13633	-
	Nov.	1600	-	976	1800	6375	

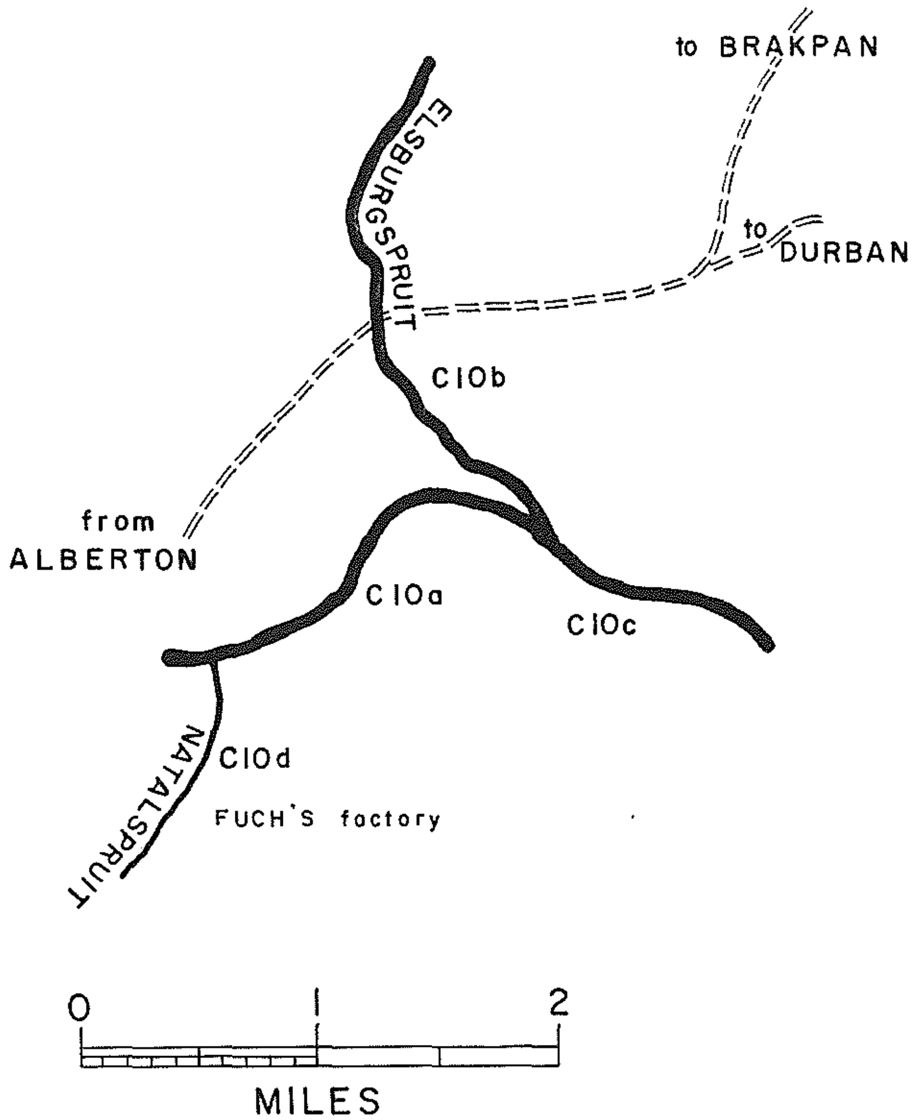

to BRAKPAN
ELSBURGSPRUIT
to
DURBAN
C10b
from
ALBERTON
C10a
C10c
NATALSPRUIT
C10d
FUCH'S factory
0
1
2
MILES

DIAGRAM 5

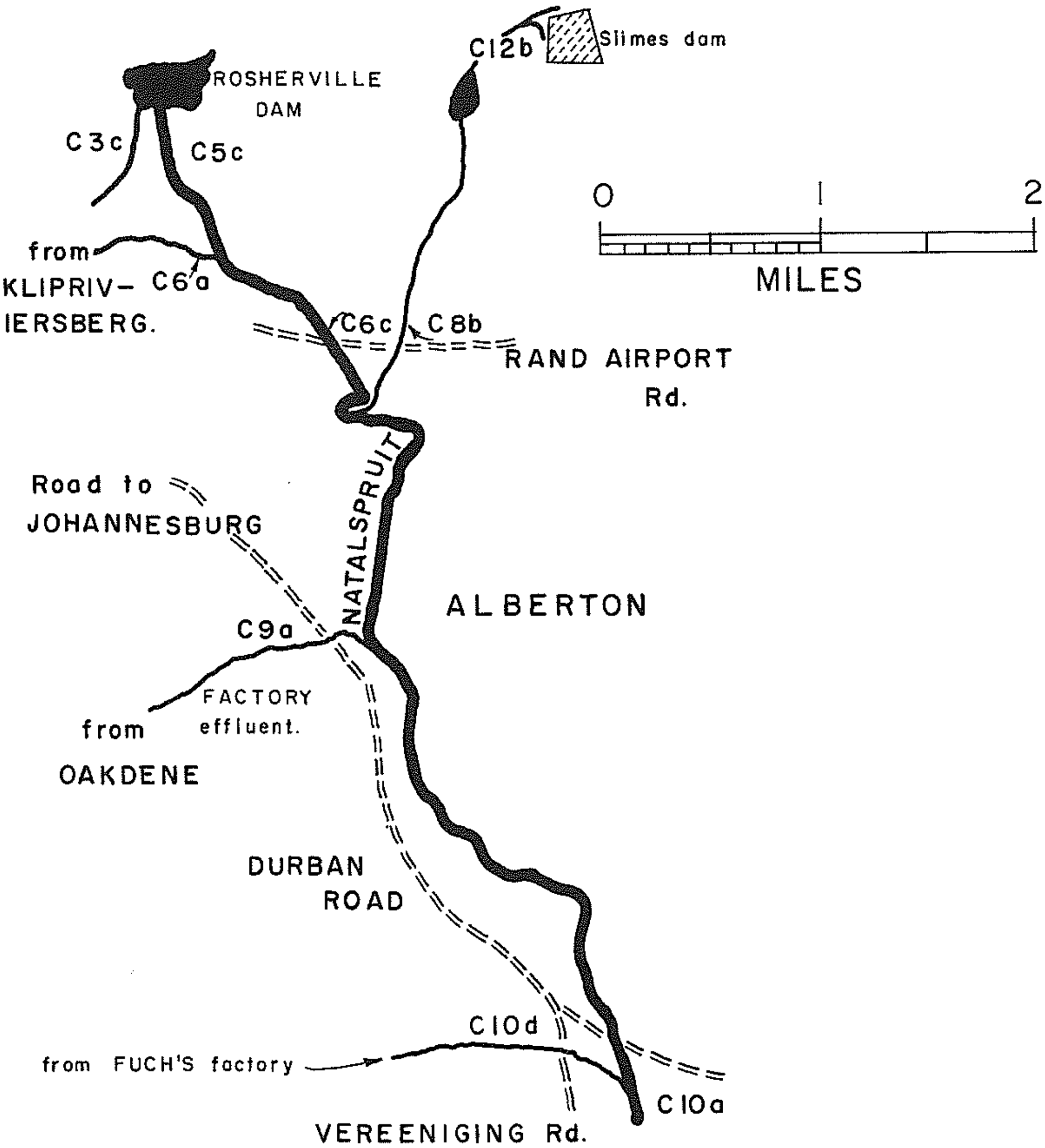
WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

TABLE 9

(Read in conjunction with diagram 5)

Analytical and mineral load data for the Natalspruit before confluence with Elsburgspruit (C 10 a) Section C

Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4''	Flow in cusecs	Observed mineral load in lb/24 hours	Total excess mineral load in lb/ 24 hours	Accumulated mineral load in lb/ 24 hours
1952							
April	2398	1370	1525	11	142000	136060	36000
May	2702	1380	1618	No record			
June	3118	1530	1725	" "			
July	3500	1740	1911	10	188000	183120	Nil
Aug	3717	1870	2096	10	200000	194120	Nil
Sept	4215	2040	2298	Nil	-	-	-
Oct				No flow			
Nov	3897	1760	2261	150	3140000	3059100	2960000
Dec	2313	1210	1345	111	1380000	1320100	1221000
1953							
Jan	1760	890	877	17	161000	152370	Nil
Feb	1439	880	887	57	442000	411300	123000
March	2098	1140	1177	78	1250000	1207900	920000
April	1709	1010	1012	39	358500	337410	49500
May	2518	1470	1439	41	566000	533900	246000
June	2810	1600	1570	25	378000	364500	Nil
July	3100	1710	1757	19	327000	316480	Nil
Aug	3490	1710	1868	17.5	329000	320090	Nil
Sept	3030	1700	2139	6	97800	94560	Nil
Oct	6020	1900	3666	100	3240000	3186200	2898000
Nov	4010	2250	2509	80	1730000	1686800	1399000



C12b
Slimes dam
ROSHERVILLE
DAM
C3c
C5c
0
1
2
MILES
from
KLIPRIV-
IERSBERG.
C6a
C6c
C8b
RAND AIRPORT
Rd.
Road to
JOHANNESBURG
NATALSPRUIT
ALBERTON
C9a
FACTORY
effluent.
from
OAKDENE
DURBAN
ROAD
C10d
from FUCH'S factory
C10a
VEREENIGING Rd.

DIAGRAM 6

TABLE 10

(Read in conjunction with diagram 6)

Analytical data for the Natalspruit below Rosherville dam before confluence with Elsburgspruit, Section C

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4''
	1952			
C 10 d	June	362	83	74
	July	406	100	163
	Oct	678	161	77
	1953			
	Jan	992	220	190
	Feb	768	315	324
	June	616	160	188
	Aug	474	75	83
	1952			
C 9 a	March	66	-	12
	May	100	40	16
	June	105	48	22
	Sept	101	-	14
	1953			
	Jan	158	72	23
	Feb	140	62	29
	April	143	66	24
	May	108	71	25
	Oct	185	120	-
	1952			
C 8 b	March	3638	1675	2940
	April	3637	1330	2330
	May	4497	2000	2940
	June	4548	1925	2920
	Aug	4889	1735	2960
	Sept	4147	1990	2200
	1953			
	Jan	2414	1124	1680
	Feb	2476	1150	1410
	April	3002	1140	1700
	May	4016	1070	2080
	Aug	3451	1680	2040
	Oct	3070	1340	-
	Nov	3563	-	1910
	1952			
C 12 b *	Jan	22089	3460	-
	April	17601	1625	10040
	May	16078	2220	10000
	June	13588	1750	8200
	Aug	13031	1810	7440
	Sept	13568	2130	7840
	1953			
	Jan	12120	2630	8720
	Feb	3066	2075	1940
	April	6930	2425	4810
	May	8674	1375	5550
	Aug	5271	1920	3240
	Oct	4426	1510	-
	Oct	9617	940	-
	Nov	8553	2150	4650
	1952			
C 6 c	Feb	2641	1500	1900
	March	1922	1325	1290
	April	2133	1300	1245
	May	2070	1400	1500
	June	3050	1800	1830
	Aug	2888	1800	1760
	Sept	3103	1872	1740
	1953			
	Jan	1760	1254	1300
	Feb	1440	940	790
	April	1783	1040	1210
	May	2494	1030	1510
	Aug	3034	1900	1875
	Oct	1895	1050	-
	Nov	3764	2085	2250

* Direct inflow from mines

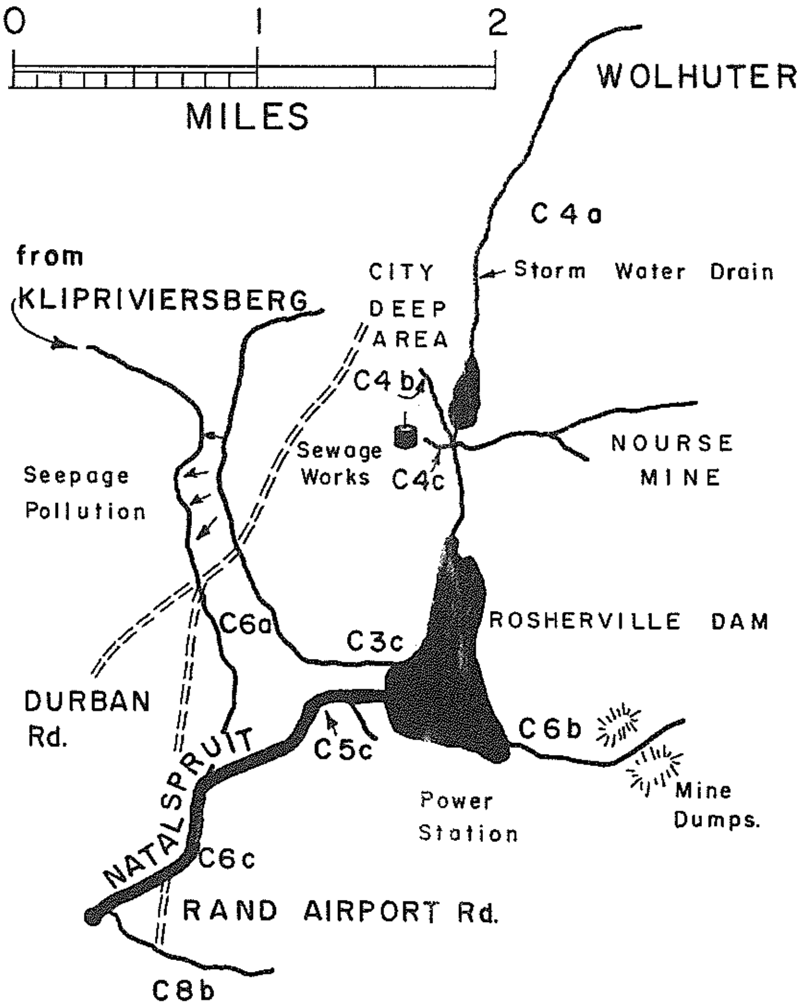

0
1
2
MILES
WOLHUTER
C 4 a
Storm Water Drain
from
KLIPRIVIERSBERG
CITY
DEEP
AREA
C4 b
Sewage
Works
C4c
NOURSE
MINE
Seepage
Pollution
ROSHERVILLE DAM
C6a
C3c
DURBAN
Rd.
NATALSPRUIT
C5c
C6b
Power
Station
Mine
Dumps.
C6c
RAND AIRPORT Rd.
C8b

DIAGRAM 7

WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

TABLE 11

(Read in conjunction with diagram 7)

Analytical and mineral load data for the Wolhuter and Northern streams entering Rosherville Dam and the Kliprivierberg Stream entering Natalspruit. Section C

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as " SO_4	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours
	1952					
C 6 a	May	939	490	580		
	June	932	430	580		
	Aug.	1079	503	604		
	Sept.	1154	580	620		
	1953					
	Jan	696	395	400	No flow recorded	
	Feb.	842	400	485		
	April	1091	450	690		
	May	838	450	535		
	Aug.	844	440	490		
	Oct.	1329	600	-		
	Nov.	344	183	156		
	1952					
C 5 c	March	2279	1485	1420	17200	16447
	May	2758	2090	2240	8910	8587
	June	3090	1910	1960	69800	67540
	Aug	3174	1912	1590	51250	49635
	Sept	3339	2085	1920	25550	24797
	1953					
	Jan	1700	1030	1290	199300	187600
	Feb	1584	1020	1010	90500	84800
	April	1760	1110	1280	142000	133930
	May	2596	980	1455	147000	141350
	Aug	3382	2170	2150	25450	124697
	Oct	2704	1470	-	20350	19597
	Oct	755	260	-	5690	4937
	Nov	3904	2128	2300	88200	85940
	1952					
*C 5 b	March	2384	1450	1470		
	April	2364	1410	1470		
	May	2062	1500	1460		
	June	2861	1750	1670		
	Aug	1365	725	770		
	1953					
	Jan	798	395	545		
	Feb	734	370	463		
	April	965	500	454		
	May	1452	710	895		
	Aug	No flow				
	Oct.	1967	855	-	No flow recorded	
	Nov.	2516	1150	1445		
	1952					
x C4c	April	945	530	475		
	May	910	540	-		
	June	1066	520	565		
	Aug	1151	562	500		
	Sept	1532	835	885		
	1953					
	Jan	1038	450	473		
	Feb	656	300	360		
	April	803	350	590		
	May	1200	820	800		
	1952					
* C 4 b	April	5182	2810	3300		
	June	5268	2800	3440		
	Aug	5491	2600	3740		
	Sept	5148	2450	3540		
	1953					
	Jan	5918	2830	4300		
	Feb	5458	2925	2840		
	April	6055	1575	4700		
	June	6426	2140	4350		
	Oct	4196	2020	-		
	1952					
C4 a	March	1056	440	560		
	April	157	80	59		
	May	1179	470	670		
	June	1364	500	585		
	Aug	1143	468	405		
	Sept	500	250	215		
	1953					
	Jan	1804	498	1005		
	Feb	692	265	410		
	April	-	302	-		
	May	1200	560	690		
	Aug	973	480	390		
	Oct	704	250	-		
	Oct	295	98	-		
	Nov	1759	395	951		

* Direct inflow from mines

x Sewage effluent

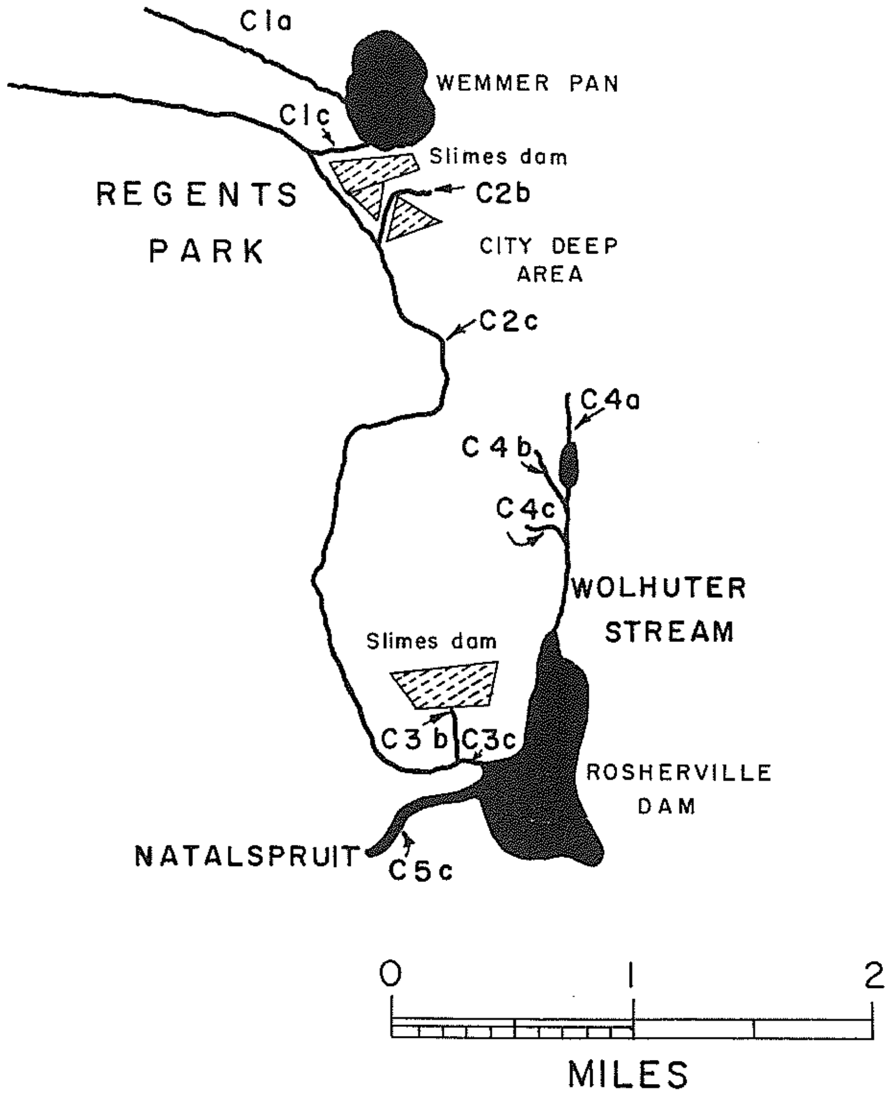

C1a
WEMMER PAN
C1c
Slimes dam
C2b
REGENTS
PARK
CITY DEEP
AREA
C2c
C4a
C4b
C4c
WOLHUTER
STREAM
Slimes dam
C3b
C3c
ROSHERVILLE
DAM
NATALSPRUIT
C5c
0
1
2
MILES

DIAGRAM 8

WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

TABLE 12

(Read in conjunction with diagram 8)

Analytical and mineral load data for Southern stream entering Rosherville dam, Section C

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as " SO_4	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours
	1952					
C 3 c	April	5581	1020	3320	140000	137500
	May	5802	1550	3540	250000	24569
	June	3786	1520	2360	16300	15889
	Aug	4514	1850	2220	147200	143940
	Sept	3852	1730	2350	69400	67590
	1953					
	Jan	1568	606	1050	51100	47840
	April	1838	685	1460	59900	56640
	June	1918	680	1200	21200	20090
	Oct	2984	1220	-	-	-
	Nov	2249	1280	-	24500	23390
	1952					
*C 3 b	March	3898	915	2460		
	April	3274	1360	2070		
	May	3230	1690	1980		
	June	2557	1290	1400		
	Aug	2104	1020	1000		
	Sept	2188	1040	1370		
	1953					
	Jan	2216	1240	1350		
	Feb	2210	1070	1160		
	April	2181	1200	1295		
	June	2090	1020	1240		
	Aug	2153	1040	1280		
	Oct	2344	1080	-		
	Nov	2268	1190	-		
	1952					
* C2 c	Jan.	3107	958	-		
	March	5474	1100	3460	No flow recorded	
	April	1413	175	830		
	May	12110	2400	8880		
	June	10234	1220	5840		
	Aug	6504	1980	3200		
	Sept	7706	1755	4880		
	1953					
	Jan	1540	472	1220		
	Feb	1444	230	760		
	April	2136	920	1480		
	June	5206	500	2950		
	Aug	10569	80	7000		
	Oct	7186	80	-		
	Oct	7534	1570	-		
	1952					
* C 2 b	Jan	1498	572	-		
	March	2401	1477	1450		
	May	1715	640	1190		
	June	2046	640	1200		
	Aug	2541	1470	1215		
	Sept	2013	1057	1265		
	1953					
	Feb	1174	635	695		
	April	1659	1270	925		
	May	2013	730	1220		
	Aug	2184	1330	1450		
	Oct	4588	1250	-		
	1952					
C 1 c	March	681	402	435		
	June	930	427	522		
	1953					
	Jan	673	360	334		
	Feb	604	278	328		
	April	618	272	362		
	May	790	287	496		
	Aug	No flow				
	Oct	No flow			No flow recorded	
	1952					
C 1 a	March	277	153	28		
	May	220	97	18		
	June	274	95	15		
	Aug	297	194	16		
	Sept	174	90	14		
	1953					
	Jan	364	198	95		
	Feb	260	118	36		
	April	298	124	110		
	May	180	108	38		
	Oct	257	135	-		

* Direct inflow from mines

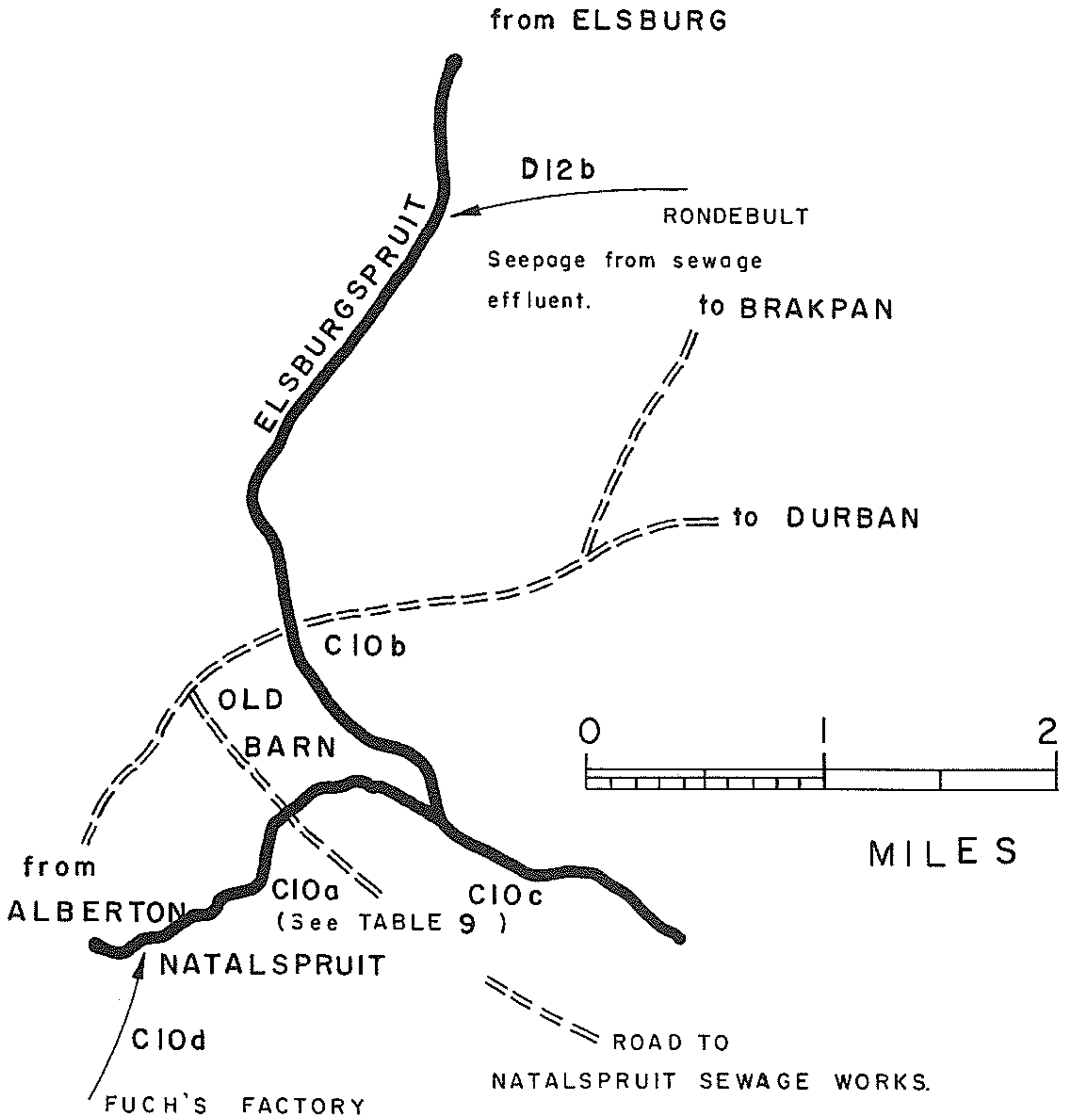

from ELSBURG
D12b
RONDEBULT
Seepage from sewage
effluent.
ELSBURGSPRUIT
to BRAKPAN
to DURBAN
C10b
OLD
BARN
0
1
2
MILES
from
ALBERTON
C10a
(See TABLE 9)
C10c
NATALSPRUIT
C10d
FUCH'S FACTORY
ROAD TO
NATALSPRUIT SEWAGE WORKS.

DIAGRAM 9

WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

TABLE 13

(Read in conjunction with diagram 9)

Analytical and mineral load data for the Elsburgspruit before and after the Natalspruit confluence (Sections C and D)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours
	1952					
C 10 c	April	2263	1390	1338)		
	May	2258	1200	1302)		
	June	2470	1270	1295)		
	July	2470	1240	1229)		
	Aug	2377	1360	1314)		
	Sept	1870	1070	995)		
	Oct	1746	1020	973)		
	Nov	1513	910	800)		
	Dec	1919	1010	862)		
	1953			)	No flow recorded	
	Jan	1590	870	1008)		
	Feb	1202	800	693)		
	March	1786	940	859)		
	April	1476	970	797)		
	May	1678	1200	848)		
	June	1890	1930	972)		
	July	1810	1100	1048)		
	Aug	1830	930	773)		
	Sept	1609	950	857)		
	Oct	Not	sampled	)		
	Nov	1843	1210	1109)		
	1952			)		
C 10 b	April	2756	1610	1552)		
	May	3002	1540	1742)		
	June	2612	1270	1353)		
	July	2420	1210	1163)		
	Aug	2487	1230	1244)		
	Sept	2424	1320	1207)	Gauge readings	
	Oct	2909	1530	1502)	incorrect	
	Nov	3380	1760	1858)		
	Dec	1707	800	634)		
	1953			)		
	Jan	1970	970	926)		
	Feb	1649	930	739)		
	March	1752	940	861)		
	April	1376	890	667	421000	390400
	May	1672	1210	838	526000	494600
	June	1820	1430	901	231500	218800
	July	1620	1010	895	95800	89870
	Aug	1890	1200	722	169700	160700
	Sept	1710	1010	625	57100	53760
	Oct	2010	1100	1103	-	-
	Nov	1740	1200	1064	32700	30815
	1952					
* D 12 b	April	1016	560	453)		
	May	867	470	292)		
	June	905	420	290)		
	July	875	410	268)		
	Aug	1124	530	313)		
	Oct	1190	530	396)		
	Nov	909	440	283)		
	Dec	834	500	258)		
	1953			)		
	Jan	915	550	247)		
	Feb	842	520	201)	No flow recorded	
	March	876	540	227)		
	April	795	420	238)		
	May	926	750	346)		
	June	970	-	282)		
	July	870	540	395)		
	Aug	1700	456	415)		
	Sept	1030	460	310)		
	Oct	990	390	332)		
	Nov	1010	550	367)		

* Seepage from Rondebult sewage works

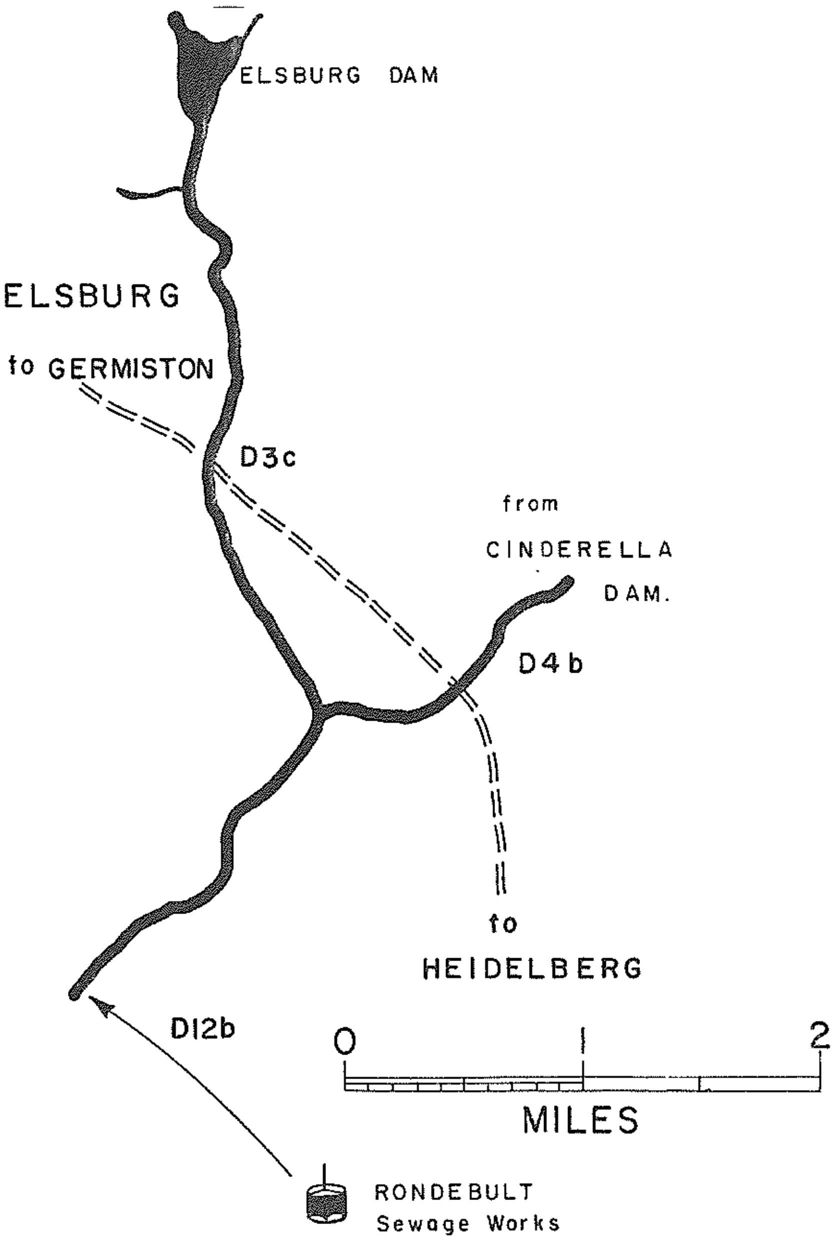

ELSBURG DAM
ELSBURG
to GERMISTON
D3c
from
CINDERELLA
DAM.
D4 b
to
HEIDELBERG
D12b
0
1
2
MILES
RONDEBULT
Sewage Works

DIAGRAM 10

TABLE 14

(Read in conjunction with diagram 10)

Analytical and mineral load data for the Elsburgspruit at Elsburg Bridge (D 3 c) Section D

Sampling and gauging point numbers	Year and Month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as " SO_4	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load lb/24 hours
	1952						
D 3 c	April	3268	1500	1832	176000	170620	148410
	May	3816	2090	2101	61600	59985	Nil
	June	3782	1950	2103	-	-	-
	July	3437	1910	1966	18500	17962	Nil
	Aug.	3288	1890	2014	14150	13719	Nil
	Aug.	3188	1800	1915	Nil	Nil	Nil
	Oct.	2770	1610	1736	-	Nil	Nil
	Nov.	2303	1160	1294	-	-	-
	Dec.	2788	1490	1564	96300	92850	70655
	1953						
	Jan	2882	1290	1530	148750	143580	42010
	Feb.	4395	1360	1047	23650	23112	Nil
	March	2195	1180	1152	63700	60700	Nil
	April	2484	1220	1310	136650	135650	Nil
	May	2296	1450	1286	49400	47250	Nil
	June	2698	1510	1491	87700	86870	Nil
	July	2320	1330	1224	102500	98080	Nil
	Aug.	3000	1410	1465	-	-	-
	Sept.	3080	1290	1265	136000	131580	Nil
	Oct.	1870	1010	1147	516000	488400	386900
	Nov.	2910	1700	1713	214000	207200	105640

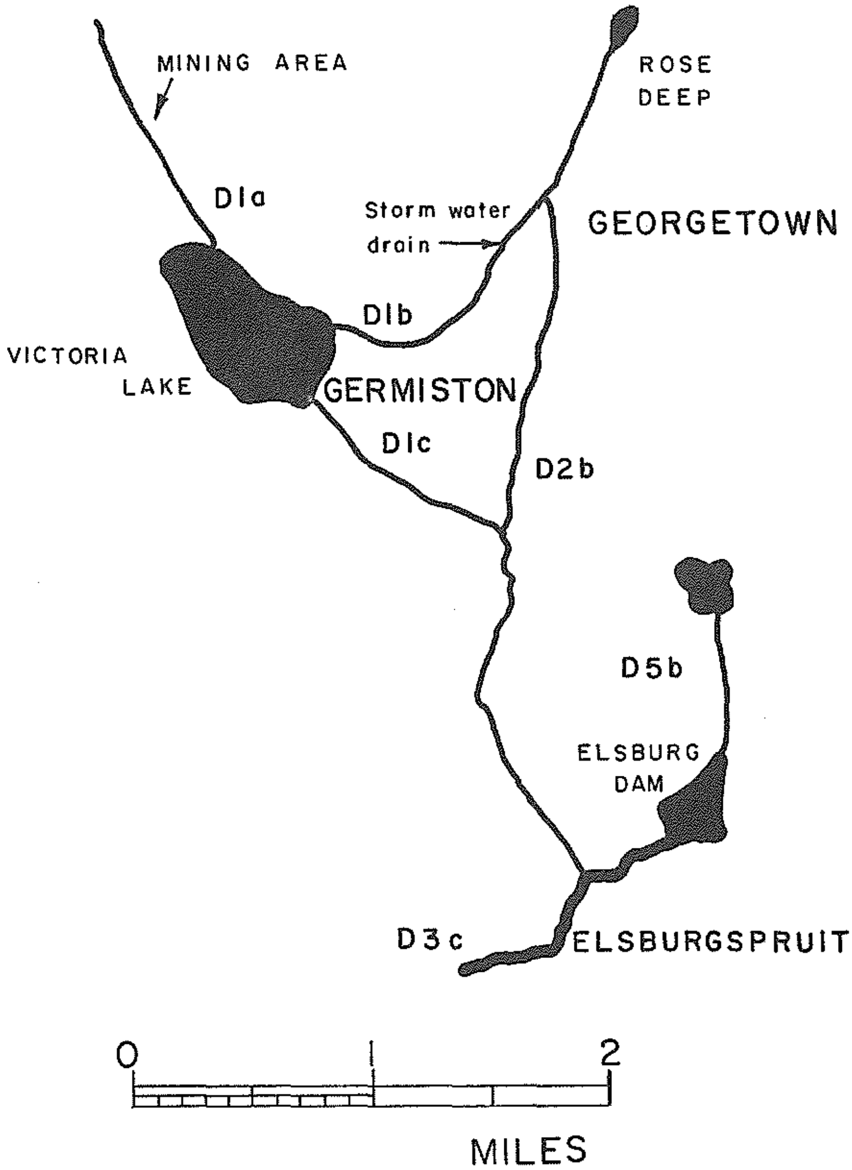

MINING AREA
ROSE
DEEP
D1a
Storm water
drain
GEORGETOWN
D1b
VICTORIA
LAKE
GERMISTON
D1c
D2b
D5b
ELSBURG
DAM
D3c
ELSBURGSPRUIT
0
1
2
MILES

DIAGRAM 11

TABLE 15

(Read in conjunction with diagram 11)

Analytical data for stream from George Town and Victoria Lake, entering the Elsburgspruit after Elsburg dam (Section D)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4 "
	1952			
D 2 b	April	3558	2040	1948
	May	3685	2170	2023
	June	3621	1940	2027
	July	4331	2320	2375
	Aug	3771	2230	2324
	Aug	3438	1900	1903
	Oct	2888	1740	1798
	Nov	2912	750	615
	Dec	2469	460	439
	1953			
	Jan	1610	640	4546
	Feb	2115	620	303
	March	1141	530	223
	April	1156	640	364
	May	959	740	278
	June	3012	810	300
	July	2870	810	423
	Aug	2090	570	217
	Sept	1940	530	207
	Oct	1910	650	425
	Nov	830	650	193
D 1 c		No flow		
	1952			
D 1 b	April	3524	1620	2055
	May	3154	980	952
	June	5768	3120	2952
	July	6181	2790	3970
	Aug	4524	2100	2686
	Aug	4272	2300	2552
	Oct	3274	1750	3345
	Nov	2698	1550	1613
	Dec	4631	2400	2644
	1953			
	Jan	6037	2220	2273
	Feb	4386	2070	2222
	March	3829	2030	2769
	April	3240	1720	1810
	May	3939	2280	2416
	June	4049	2450	2468
	July	4400	2410	1741
	Aug	4540	2280	2489
	Sept	4340	2030	2457
	Oct	3000	1600	1656
	Nov	3930	2340	2381
	1952			
D 1 a	April	5823	2200	3472
	May	5978	2450	3659
	June	4409	2210	2434
	July	1945	890	904
	Aug	4627	2700	2650
	Aug	5752	3500	2415
	Oct	5353	3180	23322
	Nov	6504	2720	3803
	Dec	5851	2600	3552
	1953			
	Jan	6012	2430	3545
	Feb	7808	2710	4085
	March	7130	2870	2802
	April	5604	2540	3048
	May	6056	2800	3701
	June	5370	2420	3343
	July	5930	2700	3156
	Aug	6780	2500	3757
	Sept	6300	2420	3797
	Oct	4520	2030	3263
	Nov	4420	1700	2625

* Direct inflow from mines

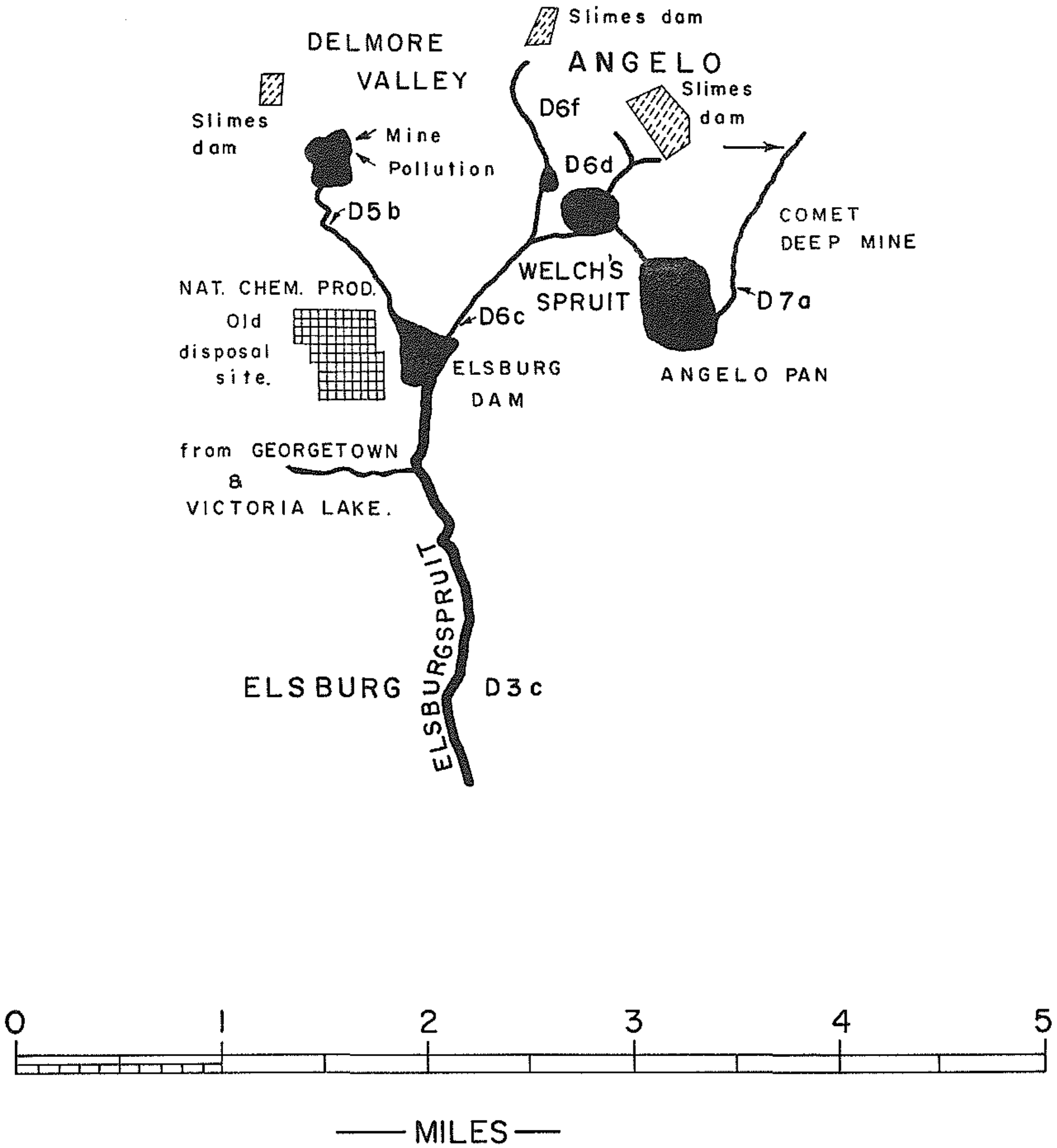

Slimes dam
DELMORE
VALLEY
ANGELO
Slimes
dam
Slimes
dam
D6f
Mine
Pollution
D6d
D5b
COMET
DEEP MINE
WELCH'S
SPRUIT
NAT. CHEM. PROD.
Old
disposal
site.
D6c
D7a
ELSBURG
DAM
ANGELO PAN
from GEORGETOWN
&
VICTORIA LAKE.
ELSBURG
ELSBURGSPRUIT
D3c
0
1
2
3
4
5
MILES

DIAGRAM 12

TABLE 16

(Read in conjunction with diagram 12)

Analytical and mineral load data for the streams entering Elsburg dam (Section D)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4''	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours
	1952					
D 5 b	April	2418	1360	1358)		
	May	4518	2620	2478)		
	June	4406	2270	2460)		
	July	3574	2010	–)		
	Aug	3091	1910	1843)		
	Sept	2718	1550	1584)		
	Oct	3465	1950	2157)		
	Nov	2633	1390	1630)		
	Dec	2500	1450	1449)	No flow recorded	
	1953			)		
	Feb	3007	1540	1571)		
	March	3632	1990	2224)		
	April	3700	1720	2039)		
	May	2712	1330	1411)		
	June	3390	2120	1937)		
	July	3696	1880	1695)		
	Aug	2510	1320	1390)		
	Oct	1360	680	759)		
	Nov	2040	1400	1617)		
	1952					
D 6 c	April	5251	2440	2878	113000	110850
	May	4245	2080	2189	57100	55755
	June	4756	2070	2621	67800	66375
	July	4195	1960	–	67700	66085
	Aug	3425	1650	2022	36850	35775
	Sept	3582	1800	2232	43400	42190
	Oct	3524	1680	2081	56900	55285
	Nov	3766	1760	2377	50600	49255
	Dec	5342	2250	2717	176700	143390
	1953					
	Feb	4182	1780	2495	169000	164960
	March	4962	1720	2964	–	–
	April	4944	1970	2711	276000	268330
	May	4461	1910	2408	24000	23462
	June	5319	2310	3055	–	–
	July	3520	1800	1883	–	–
	Aug	3470	1880	1764	–	–
	Oct	6130	2290	3126	520000	511500
	Nov	4730	2400	2882	50900	49825
	1952				pH	
D 6 f	April	Dry				
	May	6196	2820	3384	4.5)	
	June	6490	2700	2582	4.0)	
	July	5027	2340	–	4.4)	
	Aug	6370	2890	3600	3.7)	
	Oct	Dry			)	
	Nov	4481	870	3032	3.2)	
	Dec	3960	2250	2223	5.0)	
	1953				)	No flow recorded
	Feb	4446	1780	2673	3.4)	
	March	Dry			)	
	April	3322	1170	1869	3.4)	
	May	4557	2220	2869	–)	
	June	No flow			)	
	July	" "			)	
	Aug	" "			)	
	Sept	" "			)	
	Oct	3800	1860	2187	4.2)	
	1952					
* D 6 d	April	3942	1740	2308	5.3)	
	May	4162	1300	2106	4.5)	
	June	4213	1320	2440	4.5)	
	July	3584	1410	–	5.0)	
	Aug	3667	1710	1927	5.7)	
	Sept	3168	1500	1572	8.2)	
	Oct	3254	1530	1908	6.6)	No flow recorded
	Nov	4781	770	2964	4.1)	
	Dec.	5117	1790	1290	4.0)	
	1953				)	
	Feb	4168	1550	2452	4.6)	
	March	3940	1760	2259	5.1)	
	April	4080	1620	2029	4.7)	
	May	3303	1590	1729	5.5)	
	June	2593	1820	2045	5.2)	
	July	2931	1410	1510	5.9)	
	Aug	3560	1780	1939	8.1)	
	Oct	4600	1850	2293	4.2)	
	Nov	4070	2000	2419	5.7)	
D 7 a	See Table 17					

* Direct inflow from mines

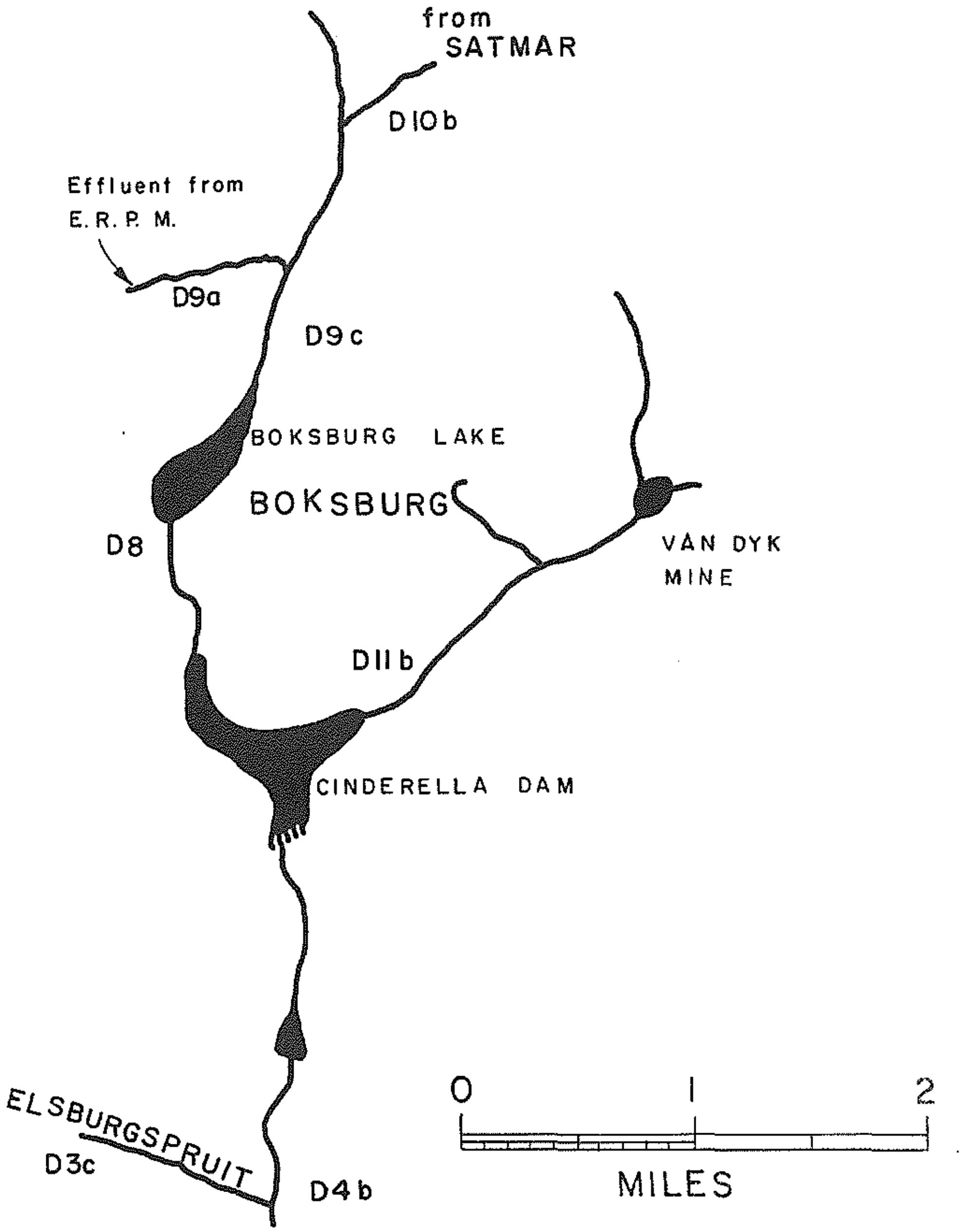

from
SATMAR
D10b
Effluent from
E. R. P. M.
D9a
D9c
BOKSBURG LAKE
BOKSBURG
D8
VAN DYK
MINE
D11b
CINDERELLA DAM
ELSBURGSPRUIT
D3c
D4b
0
1
2
MILES

DIAGRAM 13

WITWATERSRAND STREAM SURVEY - KLIP RIVER SYSTEM

TABLE 17

(Read in conjunction with diagram 13)

Analytical data for streams from Boksburg North entering Cinderella dam and E.R.P.M. stream entering Angelo Pan (Section D)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4"	Observed mineral load in lb/ 24 hours
	1952				
D 11 b	April	867	560	297	
	May	2235	1010	1074	
	June	1139	290	261	
	July	1014	430	-	
	Aug	3023	1360	1681	
	Sept	1700	910	999	
	Oct	1559	420	297	
	Nov	363	220	184	
	Dec	1485	530	852	No flow recorded
	1953				
	Feb	630	410	233	
	March	583	440	198	
	April	826	730	291	
	May	1182	540	650	
	June	1559	950	1040	
	July	1439	880	655	
	Aug	2900	1070	1657	
	Oct	780	580	290	
	Nov	540	300	455	
	1952				
D 8	April	511	380	286	
	May	No	flow		
	June	"	"		
	July	853	450	-	
	Aug	897	470	485	
	Sept	897	500	600	
	Oct	932	420	570	
	Nov	796	420	440	
	Dec	723	360	381	No flow recorded
	1953				
	Feb	596	400	306	
	March	561	430	299	
	April	554	570	282	
	May	631	350	336	
	June	720	990	406	
	July	741	680	451	
	Aug	No	flow		
	Oct	"	"		
	Nov	880	500	606	
	1952				
D 9 c	April	867	560	297	
	May	2235	1010	1074	
	June	1139	290	261	
	July	1014	430	-	
	Aug.	3023	1360	1681	
	Sept	1700	910	999	
	Oct	1559	420	297	
	Nov	533	220	184	
	Dec	1485	530	852	
	1953				
	Feb	630	410	233	
	March	583	440	198	
	April	826	730	291	
	May	1182	540	650	
	June	1559	950	1040	
	July	1439	880	655	
	Aug	2900	1020	1657	
	Oct	780	580	29	
	Nov	540	300	455	
	1952				
* D 9 a	April	No	flow		
	May	"	"		
	June	2270	510	1273	
	July	No	flow		
	Aug	"	"		
	Sept	"	"		
	Oct	"	"		
	Nov	660	220	421	
	Dec	6677	980	2823	
	1953				
	Feb	2531	740	1510	No flow recorded
	March	No	flow		
	April	5866	1170	3094	
	May	4357	2380	1918	
	June	7832	2110	4619	
	July	1043	1130	471	
	Aug	No	flow		
	Oct	1260	600	724	
	Nov	880	310	626	
	1952				
D 10 b	April	1514	480	347	
	May	995	430	150	
	June	890	210	156	
	July	1021	40	-	
	Aug	11650	1660	554	Cl : 5100
	Sept	625	90	93	
	Oct	806	300	210	
	Nov	546	220	144	
	Dec	712	300	228	
	1953				
	Feb	462	420	196	
	March	560	450	227	
	April	696	620	222	
	May	683	290	107	
	June	410	780	832	
	July	599	700	158	
	Aug	770	510	130	
	Oct	600	520	221	
	Nov	710	330	435	
	1952				R_2O_3
* D 7 a	April	6940	2020	4007	350
	May	7312	2250	5551	683
	June	6894	1880	5003	2120
	July	6836	1900	-	2441
	Aug	6581	2130	3777	1169
	Sept	4376	1920	2605	-
	Oct	4450	1850	2603	-
	Nov	9688	1180	5959	2993
	Dec	15937	1600	2870	4410
	1953				
	Feb	4519	1110	2610	1144
	March	5493	1350	3203	939
	April	6847	1820	3450	1420
	May	9235	2400	1318	2335
	June	6656	1910	3803	1654
	July	10250	1710	1848	3060
	Aug	5460	1440	3415	1669
	Oct	11290	1400	5983	2848
	Nov	3170	1120	1904	-

* Direct inflow from mines

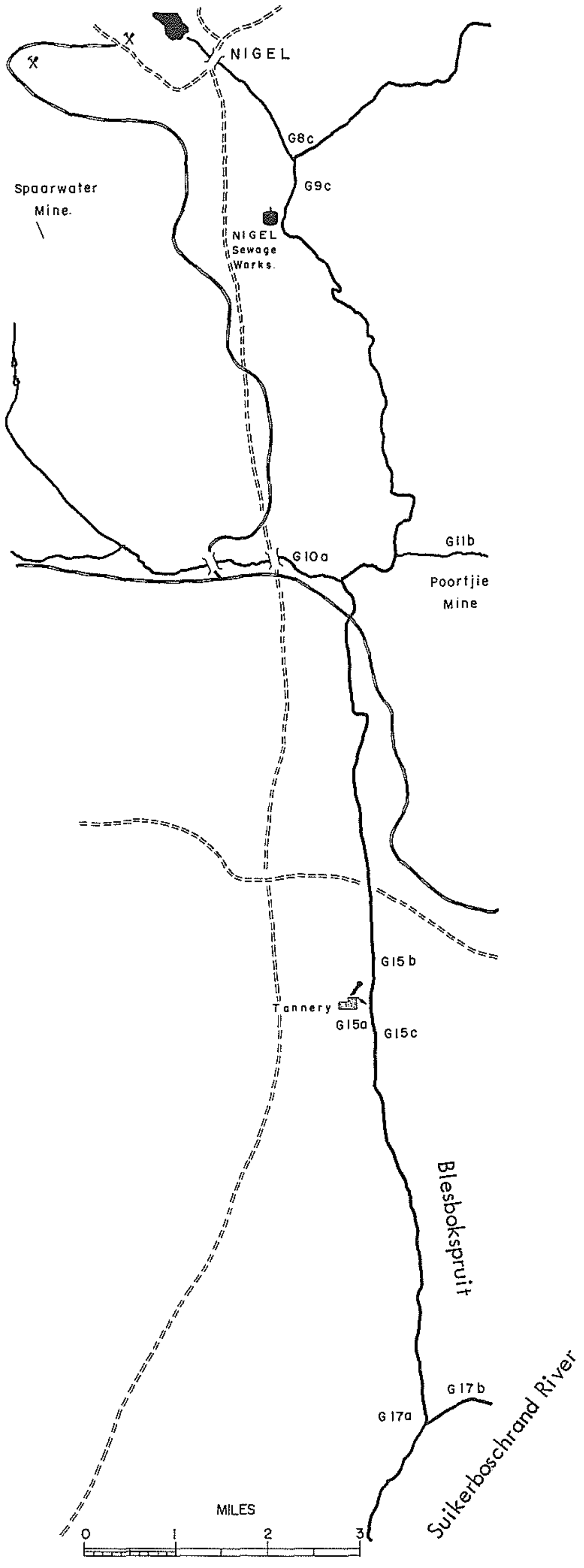

NIGEL
G8c
G9c
Spaarwater
Mine.
NIGEL
Sewage
Works.
G10a
G11b
Poortjie
Mine
G15b
Tannery
G15a
G15c
Blesbokspruit
G17b
G17a
Suikerboschrand River
MILES
0
1
2
3

DIAGRAM 14

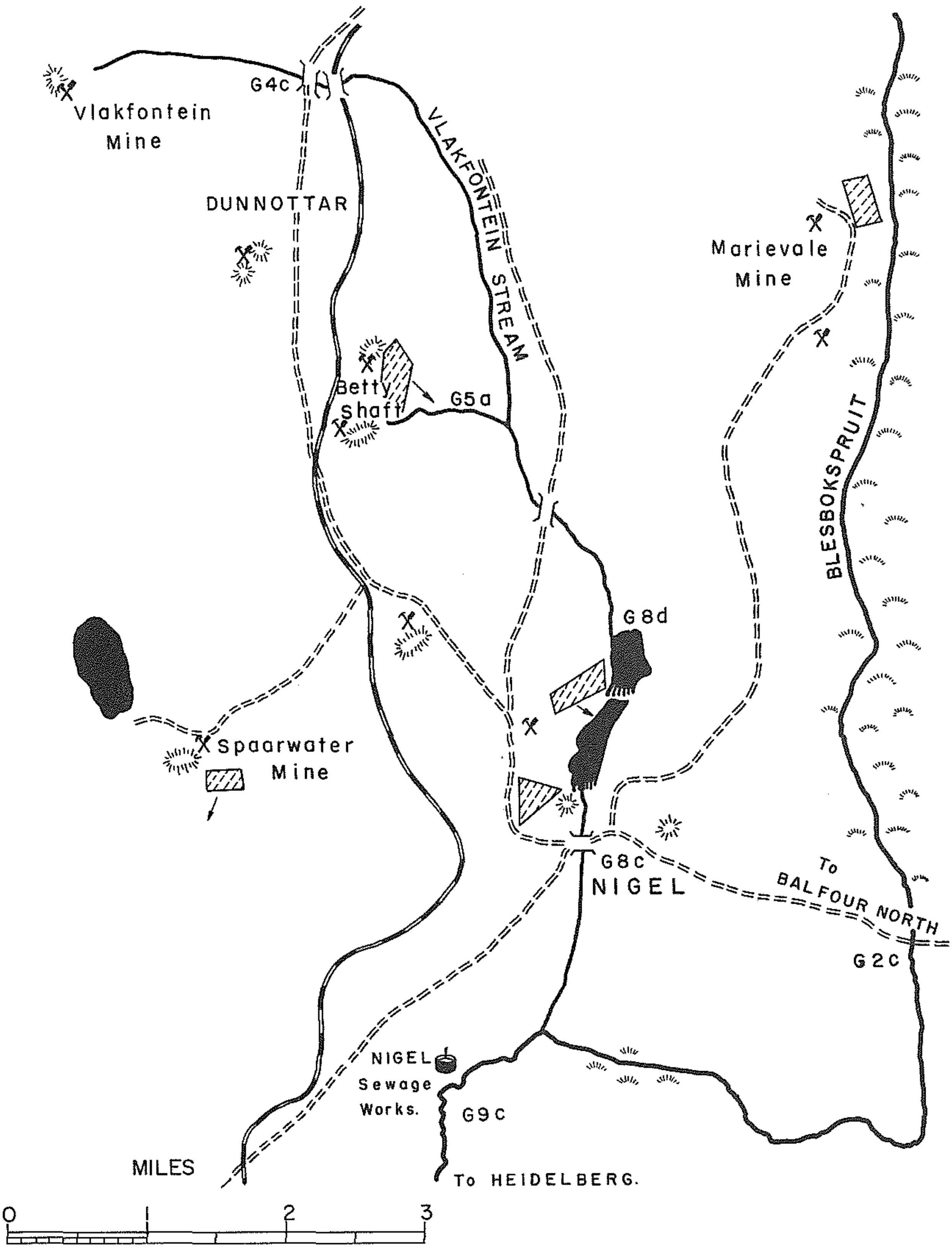
TABLE 18

(Read in conjunction with diagram 14)

Analytical and mineral load data for Blesbokspruit in Heidelberg - Nigel area (Section G)

Sampling and gauging point number	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as $SO_4^{=}$	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
G 17b	See	Figure 9					
	1952						
G 15c	June	2275	1050	880)			
	July	2216	1020	870)			
	Oct	1997	-	-)			
	1953			)	Flow not recorded		
	Jan	1608	915	780)			
	Feb	1724	890	695)			
	April	1220	620	695)			
	June	968	515	410)			
	Aug	1123	530	480)			
	Oct	890	390	-	O.A. 4 hours		
	1952				in ppm		
G 15a	May	4188	1670	1320	231		
	June	6955	1280	1700	852		
	July	4878	940	970	204		
	Oct	5678	1010	650	400		
	1953						
	Jan	5254	1340	1090	408		
	Feb	2526	665	495	224		
	April	4880	660	615	88		
	June	4270	860	715	66		
	Aug	3444	665	800	150		
G 15b	See	Figure 10					
	1952						
G 11b *	May	178	190	42)			
	June	197	98	73)			
	July	155	98	41)			
	Oct	308	-	-)			
	1953			)			
	Jan	220	126	42)			
	Feb	176	117	46)			
	April	186	111	35)			
	June	198	139	59)			
	Aug	161	115	51)			
	Oct	241	125	-)			
	1952			)	Flow not recorded		
G 10a *	May	129	28	3)			
	Aug	154	64	17)			
	Nov	149	46	13)			
	1953			)			
	Jan	138	44	15)			
	Feb	130	49	15)			
	March	124	71	14)			
	April	156	68	19)			
	May	199	87	26)			
	June	184	80	20)			
	July	196	-	-)			
	Sept	100	51	-)			
	Nov	86	-	-)			

* Mining pollution not evidenced yet in these natural streams



G4c
Vlakfontein
Mine
DUNNOTTAR
VLAKFONTEIN STREAM
Marievale
Mine
Betty
Shaft
G5a
BLESBOKSPRUIT
G8d
Spaarwater
Mine
G8c
NIGEL
To
BALFOUR NORTH
G2c
NIGEL
Sewage
Works.
G9c
MILES
To HEIDELBERG.
0
1
2
3

DIAGRAM 15

TABLE 19

(Read in conjunction with diagram 15)

Analytical and mineral load data for Vlakfontein stream at Nigel (Section G)

Sampling and gauging point number	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4 =	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
G 8c *	May	1757	682	320	-	-	-
	Aug	2832	800	1224	-	-	-
	Sept	Dry	Dry	Dry	Dry	Dry	Dry
	Oct	Dry	Dry	Dry	Dry	Dry	Dry
	Nov	3323	1084	1496	Dry	Dry	Dry
	1953						
	Jan	3146	996	1384	-	-	-
	Feb	3408	1114	1516	13920	13511	10788
	March	3613	953	1542	86500	84132	81945
	April	2924	846	1280	90500	87406	84680
	May	2615	850	1328	2815	2707	Nil
	June	2808	826	1350	635	612	Nil
	July	3064	-	-	3790	3666	Nil
	Sept	2876	1088	-	124	120	Nil
	Oct	2590	-	-	> 1395000	> 1341200	> 1338380
	Nov	2106	-	-	533	508	Nil
	1952						
G 8d *	May	1928	686	362)			
	Aug	2121	636	710)			
	Nov	1588	624	684)			
	1953			)			
	Jan	1674	708	725)			
	March	1885	741	824)			
	April	1894	754	810)			
	May	1923	808	866)			
	June	1902	796	850)			
	Sept	1912	774	-)			
	Nov	2336	-	-)			
	1952			)			
G 5a *	May	3496	1406	658)			
	Aug	3678	1992	1946)			
	Nov	3856	1589	1951)			
	1953			)			
	Jan	3652	1506	1846)			
	Feb	3848	1542	1927)			
	March	3979	1556	1772)			
	April	3760	1485	1777)			
	May	3521	1392	1751)	Flow not recorded		
	June	3681	1497	1714)			
	July	3792	-	-)			
	Sept	3893	1532	-)			
	Nov	5402	-	-)			
	1952			)			
G 4c *	May	2607	639	408)			
	Aug	2151	610	690)			
	Sept	No flow	No flow	No flow)			
	Oct	No flow	No flow	No flow)			
	Nov	2415	848	927)			
	1953			)			
	Jan	2384	794	884)			
	Feb	2216	820	895)			
	March	2058	741	796)			
	April	2308	785	864)			
	May	2312	816	927)			
	June	2408	800	846)			
	July	2326	-	-)			
	Sept	No flow	No flow	No flow)			
	Oct	No flow	No flow	No flow)			
	Nov	2968	-	-			

* Mining pollution

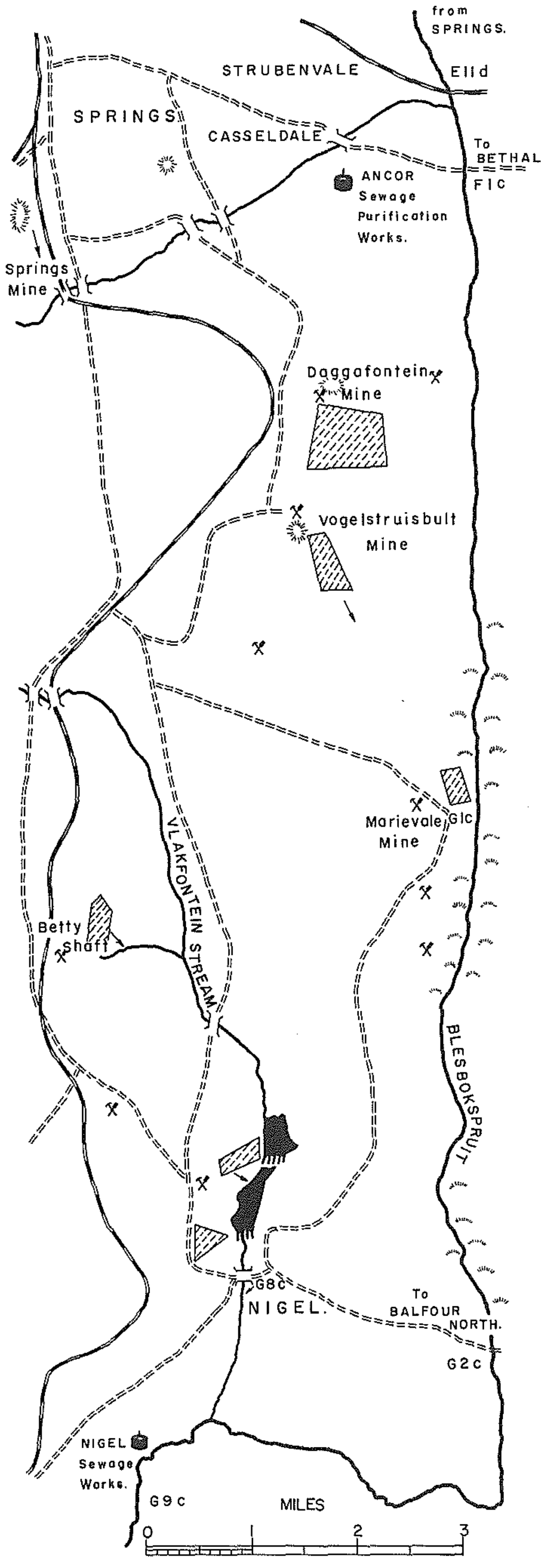

from SPRINGS.
STRUBENVALE
Elld
SPRINGS
CASSELDALE
To BETHAL
FIC
ANCOR Sewage Purification Works.
Springs Mine
Daggafontein Mine
Vogelstruisbult Mine
Marievale Mine
GIc
VLAKFONTEIN STREAM
Betty Shaft
BLESBOKSPRUIT
G8c
NIGEL.
To BALFOUR NORTH.
G2c
NIGEL Sewage Works.
G9c
MILES
0
1
2
3

DIAGRAM 16

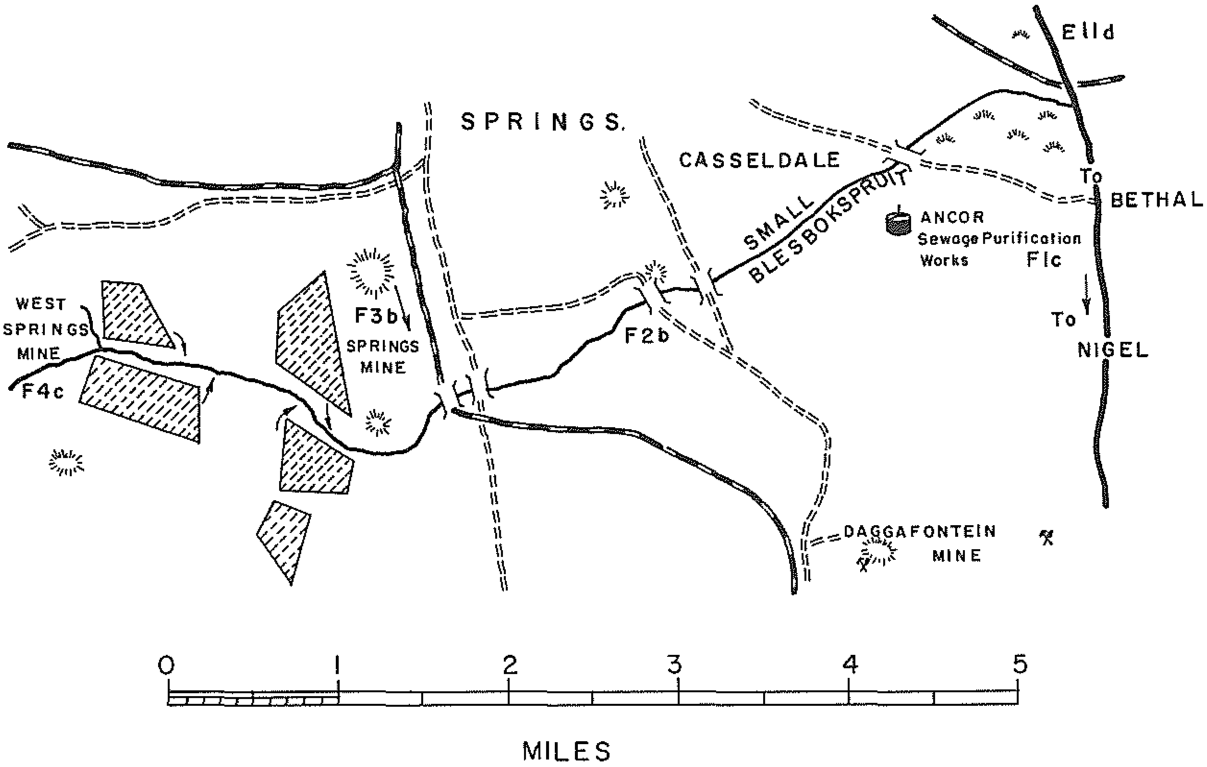
TABLE 20

(Read in conjunction with diagram 16)

Analytical and mineral load data for Blesbokspruit in Springs - Nigel area (Sections F and g)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as $SO_4^=$	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
G 9c	May	3920	1357	580			
	Aug	4342	1788	1645			
	Nov	3928	1461	1221			
	1953						
	Jan	2842	1026	980			
	Feb	2096	842	695			
	March	1693	722	665			
	April	1654	641	504			
	May	1502	664	611			
	June	1722	754	621			
	July	2040	-	-			
	Sept	2471	1044	-			
	Oct	1171	-	-			
	Nov	1695	-	-			
	1952						
G 2c *	May	4240	1465	658			
	Aug	4410	1796	1541			
	Nov	3139	1066	927			
	1953						
	Jan	2530	921	801			
	Feb	1818	846	784			
	March	1178	792	614			
	April	2450	904	800			
	May	1836	812	702			
	June	2064	860	789			
	July	2438	-	-			
	Sept	2068	753	-			
	Oct	1744	-	-			
	Nov	7458	-	-	Flow	not	recorded
	1952						
G 1c *	May	3551	1333	567			
	Aug	3171	1280	1094			
	Nov	2592	927	906			
	1953						
	Jan	1980	742	682			
	Feb	1640	614	519			
	March	1313	572	463			
	April	1830	642	576			
	May	2458	1080	951			
	June	2528	814	754			
	July	2640	-	-			
	Sept	4128	1593	-			
	Nov	4826	-	-			
	1952						
F 1 c	April	3284	1260	1040			
	May	3020	1385	1352			
	June	3096	1375	1235			
	Aug	2988	1210	1034			
	Sept	2942	1258	980			
	Nov	1877	606	384			
	Nov	1832	318	-			
	Dec	2454	618	1245			
	1953						
	Jan	2870	1042	1280			
	Feb	2356	1085	1078			
	March	2277	1019	1020			
	April	1139	422	565			
	June	2485	987	1142			
	Aug	2670	1100	815			
	Oct	3617	1530	-			
	Nov	3727	1600	-			

* Mining pollution



Elld
SPRINGS.
CASSELDALE
SMALL
BLESBOKSPRUIT
To
BETHAL
ANCOR
Sewage Purification
Works
Flc
To
NIGEL
F3b
SPRINGS
MINE
F2b
WEST
SPRINGS
MINE
F4c
DAGGAFONTEIN
MINE
0
1
2
3
4
5
MILES

DIAGRAM 17

TABLE 21

(Read in conjunction with diagram 17)

Analytical and mineral load data for the Small Blesbokspruit in Springs area (Section F)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as $SO_4^{=}$	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
F 2b	April	2274	780	1115	35055	16800	
	May	1910	728	837	5837	Nil	
	June	3145	1245	1027	20457	Nil	
	Aug	2403	868	824	20320	Nil	
	Sept	4237	1915	718	35568	Nil	
	Nov	1238	345	268	55640	37390	
	Dec	2658	681	1396	19246	Nil	
	1953						
	Jan	10887	676	5210	72507	59026	
	Feb	1562	609	790	30650	17275	
	March	2100	692	1084	5395	Nil	
	April	1723	370	916	39250	28875	
	June	4826	1175	2238	31747	Nil	
	Aug	2480	735	2225	14077	Nil	
	Oct	2519	840	-	16247	Nil	
	Nov	2870	1340	1330	65583	52150	
F 3b *	1952				R_2O_3 in ppm		
	April	43900	3465	24580	12930		
	May	41897	2010	22450	12550		
	June	50410	2490	25400	13130		
	Aug	44250	3920	25530	13130		
	Sept	51234	3920	25460	13420		
	Nov	33700	2620	20080	10150		
	Dec	25486	2790	16560	8010		
	1953						
	Jan	34084	2790	21950	10750		
	Feb	33828	3070	19850	10220		
	March	34588	3405	19260	10840		
	April	27134	2660	15180	6870		
	June	66133	3940	40760	15260		
	Aug	83870	4250	37200	19980		
	Oct	54849	-	-	18380		
	1952						
F 4c *	April	2176	1002	1219			
	May	1995	882	1132			
	June	2317	975	1260			
	Aug	2510	955	1282			
	Sept	2367	994	1187			
	Nov	1567	480	387			
	Dec	2410	714	1357			
	1953						
	Jan	2088	583	258			
	Feb	1710	705	982			
	March	2060	824	1107			
	April	1560	556	2030			
	June	1858	838	1428			
	Aug	2395	915	1230			
	Oct	4048	1660	-			

* Mining pollution

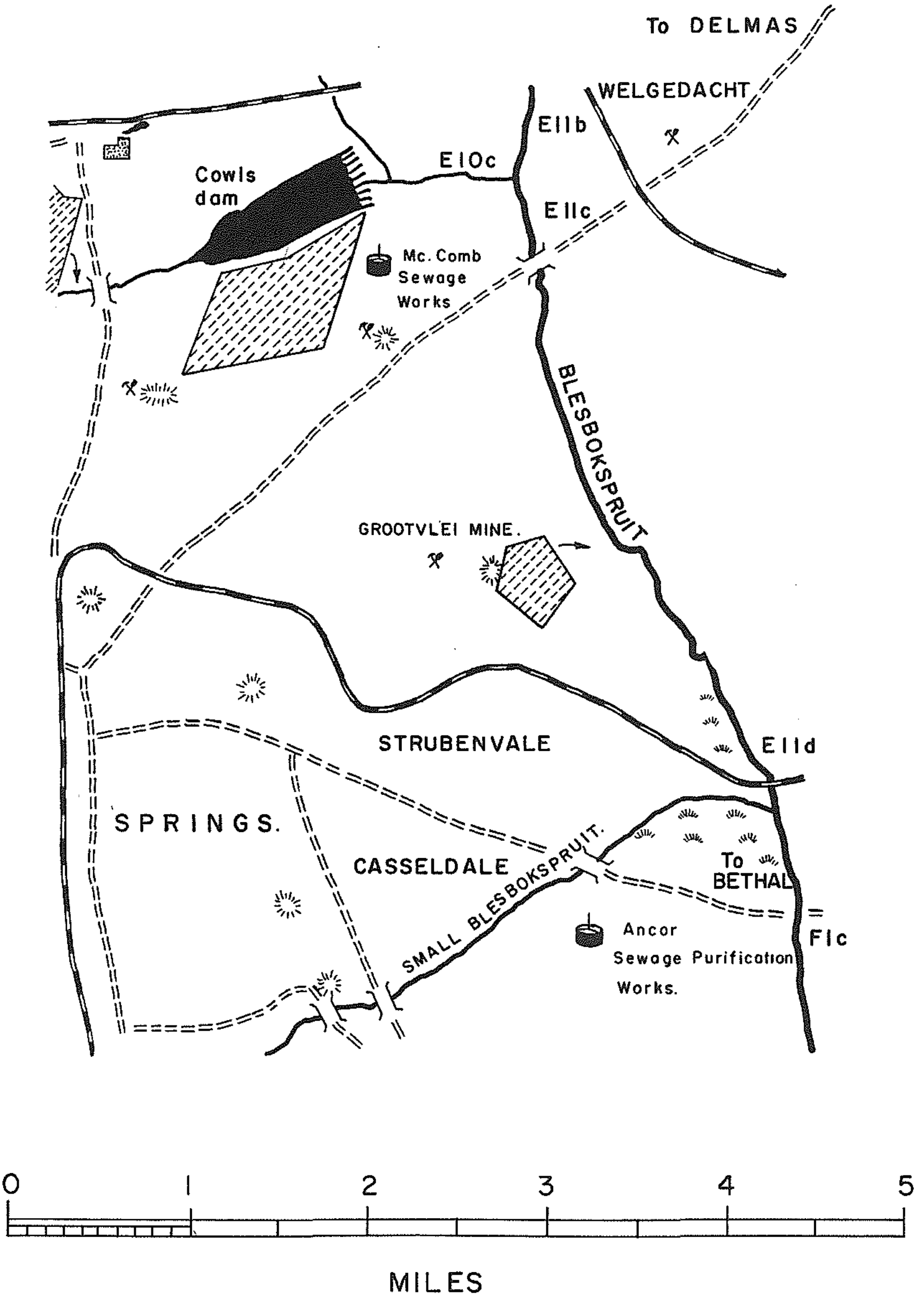

To DELMAS
WELGEDACHT
EIIb
EIOc
Cowls dam
EIIc
Mc. Comb Sewage Works
BLESBOKSPRUIT
GROOTVLEI MINE.
STRUBENVALE
EIId
SPRINGS.
CASSELDALE
SMALL BLESBOKSPRUIT.
To BETHAL
Ancor Sewage Purification Works.
FIc
0
1
2
3
4
5
MILES

DIAGRAM 18

TABLE 22
(Read in conjunction with diagram 18)

Analytical and mineral load data for the Blesbokspruit above confluence with Small Blesbokspruit (Section E)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as $SO_4^{=}$	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
E 11d *	April	2421	1360	1320			
	May	2968	1310	1267			
	June	3118	1367	1255			
	Aug	2856	1240	997			
	Sept	2862	1241	955			
	Nov	2794	606	335			
	Dec	2254	970	968			
	1953						
	Jan	2595	1180	1308			
	Feb	2158	840	855			
	March	2287	1069	1020			
	April	1686	741	730			
	June	2382	1045	1348			
	Aug	2727	1085	845			
	Oct	3758	870	-			
	Nov	2351	900	770			
	1952						
E 11c	April	3091	1420	1341			
	May	3412	1370	1310			
	June	3028	1330	1200			
	Aug	2919	1275	999			
	Sept	2842	1232	910			
	Nov	2442	706	384			
	Dec	2055	907	925			
	1953						
	Jan	2655	1040	1230	Flow	not recorded	
	Feb	2576	1105	1077			
	March	2385	1059	1020			
	April	2286	1019	1010			
	June	2630	1070	1356			
	Aug	2682	1100	845			
	Oct	2824	1050	-			
	1952						
E 11b	April	No flow					
	May						
	June						
	Aug						
	Sept						
	Nov						
	Dec	518	40	Nil			
	1953						
	Jan	No flow					
	Feb						
	March						
	April	244	45	14			
	June	No flow					
	Aug						
	Oct						

* Mining pollution

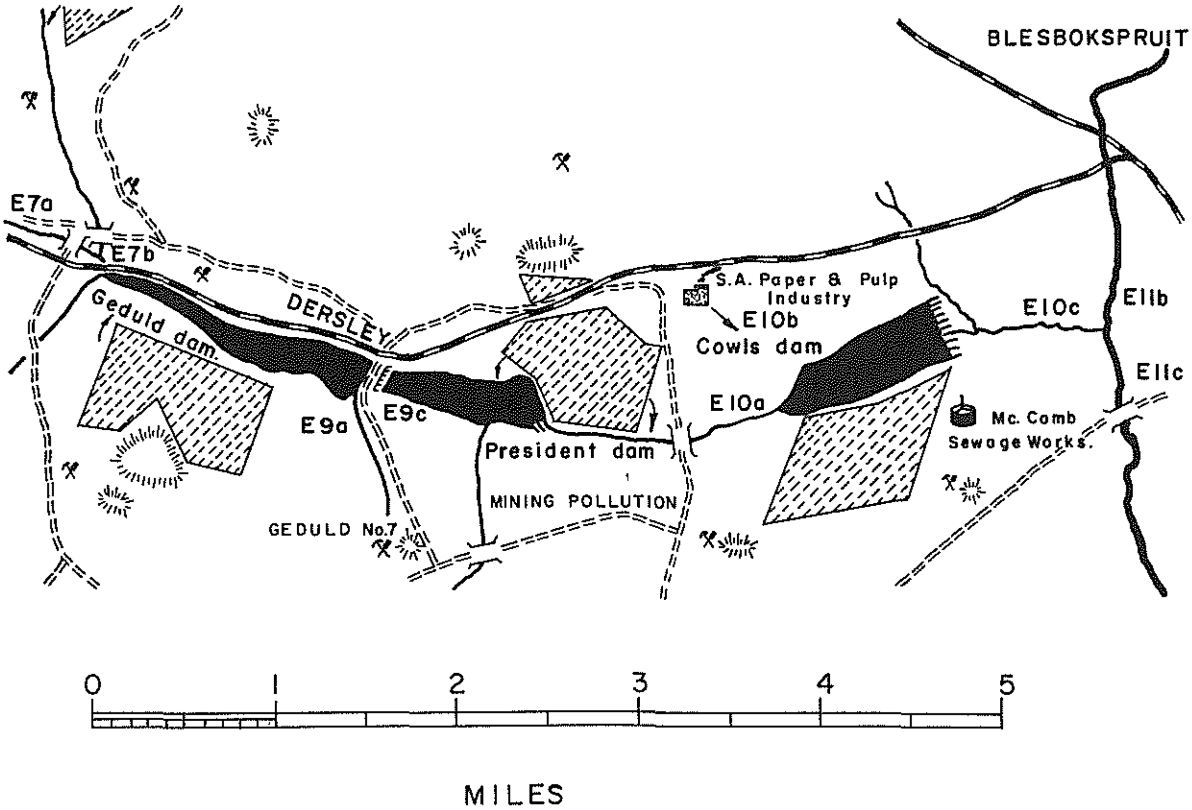

BLESBOKSPRUIT
E7a
E7b
DERSLEY
Geduld dam.
E9a
E9c
President dam
MINING POLLUTION
GEDULD No.7
S.A. Paper & Pulp Industry
E10b
Cowls dam
E10a
E10c
E11b
E11c
Mc. Comb Sewage Works.
0
1
2
3
4
5
MILES

DIAGRAM 19

TABLE 23

(Read in conjunction with diagram 19)

Analytical and mineral load data for the Geduld and Cowl's dams (Section E)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as $SO_4^=$	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
E 10c	See	Figure 12					
	1952						
E 10b	April	1984	Nil	521			
	May	3410	114	580			
	June	2140	722	415			
	Aug	2447	880	432			
	Sept	2534	1005	273			
	Nov	2942	1265	781			
	Dec	2550	904	502			
	1953						
	Jan	2562	910	484			
	Feb	2666	870	425			
	March	2854	970	465			
	April	5715	2460	494			
	June	4390	2305	732			
	Aug	3437	935	551			
	Oct	3212	1260	-			
	1952						
E 10a *	April	3323	1401	1770			
	May	2430	1150	1362			
	June	2916	1340	1642			
	Aug	3140	1255	1878			
	Sept	2992	1360	1784			
	Nov	2456	1160	560			
	Dec	3152	1200	1972	Flow not recorded		
	1953						
	Jan	2306	868	1485			
	Feb	2476	1120	1450			
	March	2303	831	1490			
	April	2888	1070	1592			
	June	2638	1200	1901			
	Aug	2911	1180	1767			
	Oct	1584	1510	-			
E 9c	See	Figure 11					
	1952						
E 9a *	April	2800	1580	1402			
	May	2753	1590	1568			
	June	2637	1690	1510			
	Aug	2697	1580	1483			
	Sept	2577	1582	1484			
	Nov	2473	1370	1297			
	Dec	2844	1690	1704			
	1953						
	Jan	2800	1482	1670			
	Feb	3140	1580	1578			
	March	3130	1980	1930			
	April	3569	2170	2080			
	June	2693	1300	1823			
	Aug	3180	1920	1884			
	Oct	2910	1700	-			

* Mining pollution

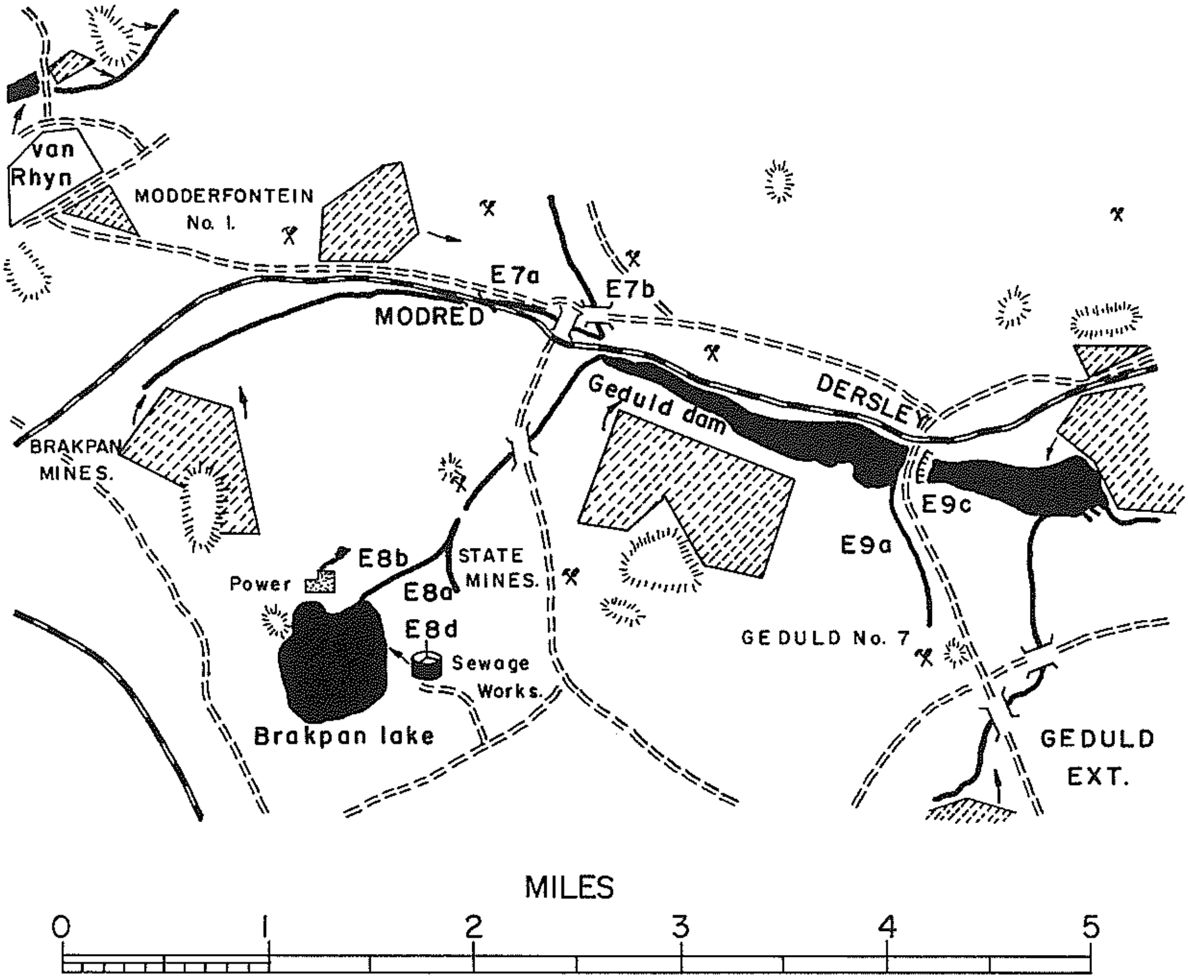

van
Rhyn
MODDERFONTEIN
No. 1.
E7a
E7b
MODRED
DERSLEY
Geduld dam
BRAKPAN
MINES.
E9c
E9a
E8b
STATE
MINES.
Power
E8a
E8d
Sewage
Works.
GEDULD No. 7
Brakpan lake
GEDULD
EXT.
MILES
0
1
2
3
4
5

DIAGRAM 20

TABLE 24

(Read in conjunction with diagram 20)

Analytical and mineral load data for the southern and western streams entering Geduld dam (Section E)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4 =	Observed mineral load in lb/24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
E 8 a	March	300	-	69			
	March	600	204	164			
	April	1200	346	329	23900	21910	
	June	2200	228	152	11820	11282	
	July	1400	850	411	7550	7012	
	Sept.	1000	350	209	6250	5526	
	Oct	400	-	139	1805	1353	
	Dec	610	154	181	13780	11511	
	1953						
	Jan	790	295	329	3390	3013	
	Jan	1580	690	625	4760	4459	
	Feb	600	300	164	4842	4761	
	March	350	-	123	2185	1561	
	May	1600	1040	699	7230	6778	
	July	1720	748	715	3330	3136	
	July	1680	770	885	3250	3056	
	Oct	1179	585	-	2282	2088	
	Nov	600	-	205	1162	968	
	1952						
E 8b	March	No flow					
	April	1300	310	341)			
	June)			)			
	July)	No flow		)			
	Sept)			)			
	Oct)			)			
	Dec	700	141	111)			
	1953			)			
	Jan)			)			
	Feb)			)			
	March)	No flow		)			
	May)			)			
	July)			)			
	Oct	764	215	-)			
	Nov	No flow		)	Flow not recorded		
	1952			)			
E 8d	March	380	102	66)			
	April	400	130	82)			
	June	474	140	47)			
	July	490	312	181)			
	Sept	500	132	41)			
	Oct	400	-	29)			
	Dec	610	234	172)			
	1953			)			
	Jan	524	216	98)			
	Jan	530	155	123)			
	Jan	530	130	82)			
	Oct	361	130	-)			
	1952						
E 7a	Feb	4055	1160	2740			
	March	7100	1520	1640	268000	> 264230	
	April	4900	1470	3100	79200	77585	
	June	5500	1400	3144)			
	July	5000	1392	2552)			
	Sept	7300	-	2959)			
	Oct	5800	-	3083)			
	Dec	2210	500	773)			
	1953			)			
	Jan	5730	1200	1728)	Gauge unreliable due to silting		
	Jan	7530	1300	3763)			
	Jan	-	1600	3801)			
	Feb	6300	3900	2301)			
	March	5550	2800	3041)			
	May	7000	3500	2466)			
	July	7010	1500	1981)			
	July	8460	1400	1880)			
	Oct	2922	1010	-)			
	Nov	10900	-	223)	52800	52316	

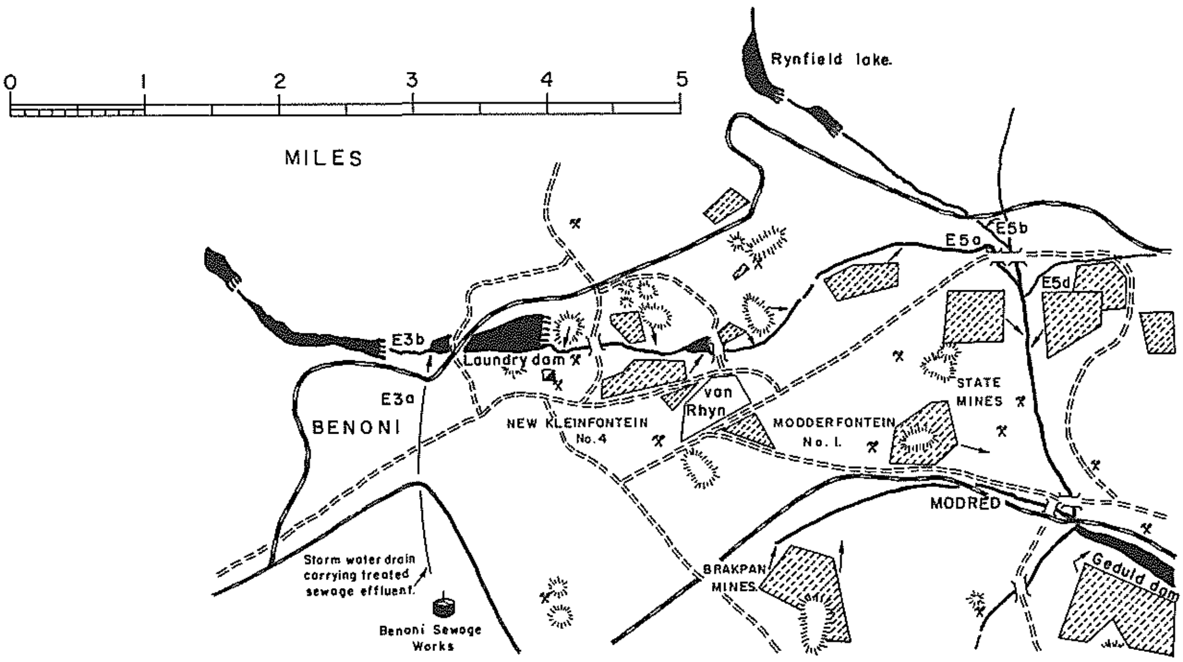

0
1
2
3
4
5
MILES
Rynfield lake.
E3b
E3a
BENONI
Laundry dam
NEW KLEINFONTEIN
No.4
van
Rhyn
MODDERFONTEIN
No. 1.
STATE
MINES
E5a
E5b
E5d
MODRED
Geduld dam
BRAKPAN
MINES
Storm water drain
carrying treated
sewage effluent.
Benoni Sewage
Works

DIAGRAM 21

TABLE 25

(Read in conjunction with diagram 21)

Analytical and mineral load data for the northern stream entering the Geduld dam (Section E)

Sampling and gauging point numbers	Year and month	Total dissolved solids in ppm	Total hardness in ppm as $CaCO_3$	Sulphates in ppm as SO_4 =	Observed mineral load in lb/ 24 hours	Total excess mineral load in lb/24 hours	Accumulated mineral load in lb/24 hours
	1952						
E 7b	Feb	2547	1070	1820			
	March	3340	950	1561			
	April	8660	1090	2400			
	June	9300	1450	2774			
	July	4500	1588	2756			
	Sept	-	1890	2013			
	Oct	3400	-	1150			
	Dec	1710	450	756			
	1953						
	Jan	1850	1300	1189	Gauge silted		
	Jan	6150	-	2139			
	Jan	6080	2200	2929			
	Feb	2900	1900	1685			
	March	5140	3900	2959			
	May	4400	2100	-			
	July	6700	2000	1471			
	July	2880	1200	871			
	Oct	4381	1760	-	304100	297150	
	Nov	1400	-	673	153200	149700	
	1952						
E 5 d	April	2140	1260	1250			
	May	1594	820	745	3780	3543	
	Sept	1700	930	1075	3480	3276	
	1953						
	Jan	1594	1010	1090	Gauge out of order		
	March	2030	1040	860			
	May	1631	1175	970	3340	3136	
	1952						
E 5b	May	366	136	109			
	Sept	2328	1282	1223			
	Remainder of 1952	Dry					
	1953	Dry					
E 5a	1952	Dry					
	1953						
	Jan	1024	610	640			
	Remainder of 1953	Dry					
	1952						
E 3 a	April	919	360	71	Flow not recorded		
	May	691	-	-			
	Sept	346	144	39			
	1953						
	Jan	288	120	43			
	March	648	-	43			
	May	619	222	51			
	1952						
E 3 b	April	208	90	28			
	May	265	60	65			
	1953						
	Jan	140	68	62			
	March	246	110	61			
	May	128	75	16			

TABLE 26

Dissolved Mineral Load Data

Klip River at Vereeniging (Point AA4C)

(Tons per 24 hours)

Dissolved mineral load	Dry season*			Rainy season		
	Max.	Min.	Av.	Max.	Min.	Av.
Observed	120	12	65 (1952) 70 (1953)	4470	150	1020
Accumulated	Nil	Nil	Nil	4025	70	860
Regular effluent discharge	105	10	50 (1952) 65 (1953)	82	50	60
Total excess	105	10	50 (1952) 65 (1953)	4080	135	1080

* Figures recorded during wet period in July 1952 not considered.

TABLE 27

Dissolved mineral load data

(Tons per 24 hours)

Dissolved Mineral load	Klip River below confluence (AA 1(c))						Klip River above confluence (AA 1(a))						Natal Spruit before confluence (AA-1-(b)-)					
	Dry season*			Rainy season			Dry season*			Rainy season			Dry season*			Rainy season		
	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
Observed	150	14	90(1952) 80(1953)	4400	150	1240	100	5	55(1952) 60(1953)	1270	105	-	70	5	2(1952) 19(1953)	950	155	-
Accumulated	Nil	Nil	-	3930	63	1030	Nil	Nil	-	1070	40	-	Nil	Nil	-	970	125	-
Regular effluent discharge	137	17	80(1952) 70(1953)	105	70	80	84.5	14	48(1952) 52(1953)	50.5	46	49	67	2.5	36(1952) 17(1953)	31	10	15
Total excess	137	17	80(1952) 70(1953)	4010	135	1110	84.5	14	48(1952) 52(1953)	1120	90	-	67	2.5	36(1952) 17(1953)	1000	140	-

* Figures recorded during wet period in July 1952 not considered.

TABLE 28

Dissolved mineral load data for Suikerboschrand River at Vereeniging (G 18a)

(Tons per 24 hours)

Dissolved mineral load	Dry season *			Rainy season		
	Max.	Min.	Aver.	Max.	Min.	Aver.
Observed	20.0	Nil	6.5 (1952) 10 (1953)	2515	6.5	260
Accumulated	Nil	Nil	Nil	2385	Nil	220
Regular effluent discharge	15.5	Nil	4.5 (1952) 8.0 (1953)	13.5	5.5	10
Total excess	15.5	Nil	4.5 (1952) 8.0 (1953)	2390	5.5	225

* Recordings during wet period July 1952 not considered

TABLE 29

Dissolved mineral load data for Blesbokspruit at Heidelberg (G 15b)

(Tons per 24 hours)

Dissolved mineral load	Dry season *			Wet season		
	Max.	Min.	Aver.	Max.	Min.	Aver.
Observed	29.5	Nil	8.0 (1952) 10.5 (1953)	603	9.5	154
Accumulated	Nil	Nil	Nil	560	Nil	132
Regular effluent discharge	28.5	Nil	7.5 (1952) 9.5	17.5	9.0	12.5
Total excess	28.5	Nil	7.5 (1952) 9.5 (1953)	572	9.0	144

* Recordings during wet period July 1952 not considered.

TABLE 30

Dissolved mineral load data for Small Blesbokspruit (F 2b)
(Tons per 24 hours)

Dissolved mineral load	Dry season *		
	Max.	Min.	Aver.
Observed	18	3	10.5 (1952) 10.5 (1953)
Accumulated	Nil	Nil	Nil
Regular effluent discharge	18	3	10 (1952) 10.5 (1953)
Total excess	18	3	10.5 (1952) 10.5 (1953)

* Recordings during wet period July 1952 not considered.

TABLE 31

Dissolved mineral load data for Cowl's dam overflow
(Tons per 24 hours)

Dissolved mineral load	Dry season *			Rainy season		
	Max.	Min.	Aver.	Max.	Min.	Av.
Observed	85	53	61.5 (1952) 84.6 (1953)	~450	46.5	204
Accumulated	Nil	Nil	Nil	>363	Nil	127
Regular effluent discharge	82	51.5	59.5 (1952) 81.5 (1953)	> 77	44.5	69
Total excess	82	51.5	59.5 (1952) 81.5 (1953)	>434	44.5	196

* Recordings during wet period July 1952 not considered.

TABLE 32

Dissolved mineral load data for Geduld dam overflow (E 9c)

(Tons per 24 hours)

Dissolved mineral load	Dry season *			Rainy season		
	Max.	Min.	Aver.	Max.	Min.	Aver.
Observed	44	6	9 (1952) 34.5 (1953)	1680	23.5	469
Accumulated	Nil	Nil	Nil	1633	Nil	429
Regular effluent discharge	42.5	45	7.5 (1952) 33.5 (1953)	37	13	27
Total excess	42.5	45	7.5 (1952) 33.5 (1953)	1647	22.5	456

* Recordings during wet period July 1952 not considered.

TABLE 33

Relation between TDS and Aluminium sulphate dosage

TDS of Vaal River water (in ppm)	Aluminium sulphate dosage in tons per 100 million gallons
100 - 300	1.5 - 2.0
300 - 400	2.0 - 3.0
400 - 500	2.5 - 3.5
500 - 700	3.0 - 6.5

TABLE 34

<u>Aluminium sulphate dosage data, period 17th to 28th December 1952</u>

Date December 1952	TDS of Vaal River water (in ppm)	Aluminium sulphate dose (in ppm)
17	572	17
18	550	32
19	559	47
20	578	33
21	406	29
22	395	25
23	483	21
24	386	20
25	373	19
26	368	16
27	357	15
28	513	20

TABLE 35

<u>Data illustrating the type of relationship between TDS and cooling water make-up</u>

TDS of intake water (in ppm)	Daily volume of make-up (in gal)	Total daily costs * (in R)	
		make - up water	Phosphate loss
150	767000	19.2	12.8
250	1400000	37.4	23.4
350	2200000	55.0	36.6
500	3833000	95.8	63.8
600	5366000	134.2	89.4
750	8943000	223.6	149.0

* Cost of raw water = 2.5c per 1000 gallons.
PO_4 content of blow-down = 10 ppm
Cost of Calgen = R200 per ton (60% PO_4 content)

TABLE 36

Illustration of the type of relationship between TDS and boiler blow-down

TDS of make-up water	Daily volume of blow-down (gal)	Total daily costs*(in R)	
		Phosphate loss	Blow-down
150	133000	4.4	15.8
250	234000	7.8	29.4
350	346000	11.6	43.2

* Costs of water to make good blow-down involve

(i) Cost of raw water (assume 2.5c/1000 gal)

(ii) Costs of softening - chemicals alone taken at 10c (hardness increases ignored) i.e. water and chemical costs = 12.5c per 1000 gal - capital and operating costs not included.

PO_4 content of blow-down = 20 ppm

TABLE 37

Illustration of relationship between TDS and costs of demineralization materials

TDS concentration of water supply (in ppm)	Cost of chemicals and depreciation of ion-exchange material (in cent per 1000 gallons)
130	13.55
180	15.88
250	18.80
290	25.18
710	59.95

TABLE 38

Illustration of relationship between TDS and costs of base-exchange materials

TH of water supply (in ppm as $CaCO_3$)	Cost of chemicals and depreciation of base-exchange material (in cent per 1000 gallons)
50	2.5
100	5.0
200	10.0
300	15.0

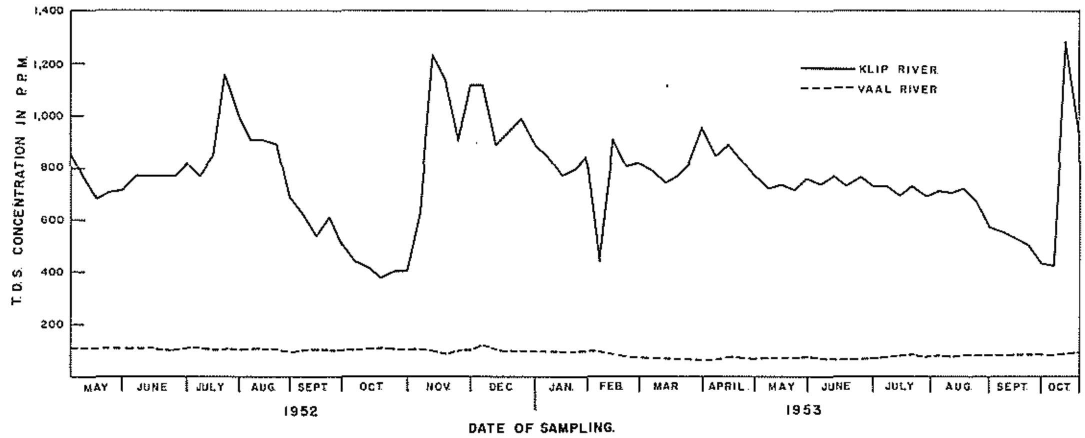


FIG. 1. COMPARISON BETWEEN THE TOTAL DISSOLVED SOLIDS CONCENTRATION OF THE KLIP RIVER AT VEREENIGING (AA4C) AND THE VAAL RIVER AT ENGELBRECHT'S DRIFT WEIR FOR THE PERIOD MAY 1952 - OCTOBER 1953 (IN PARTS PER MILLION).

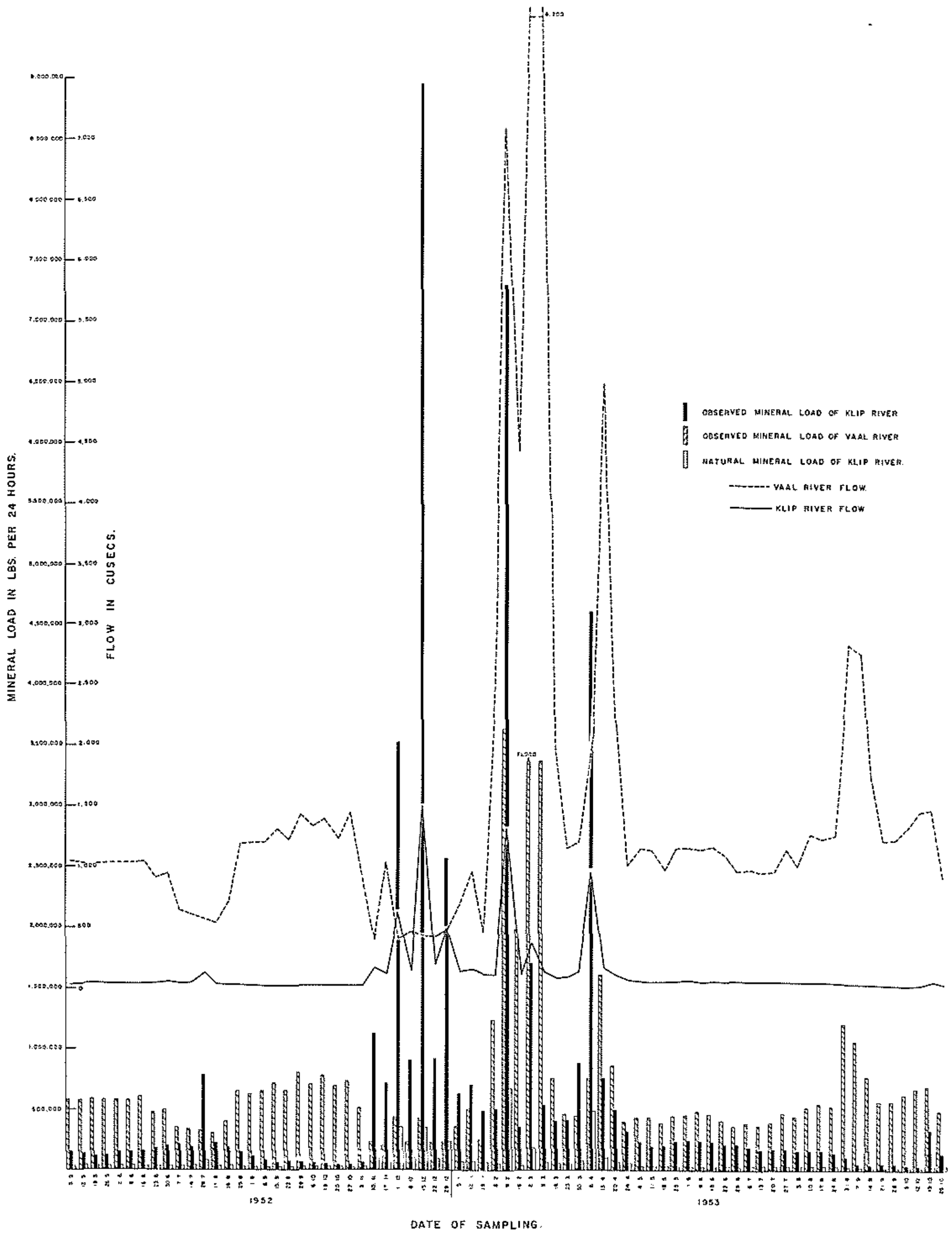


FIG. 1A. MINERAL LOAD DATA (POUNDS PER 24 HOURS). COMPARISON BETWEEN MINERAL LOAD OF KLIP RIVER AT VEREENIGING AND VAAL RIVER AT ENGELBRECHT'S DRIFT WEIR.

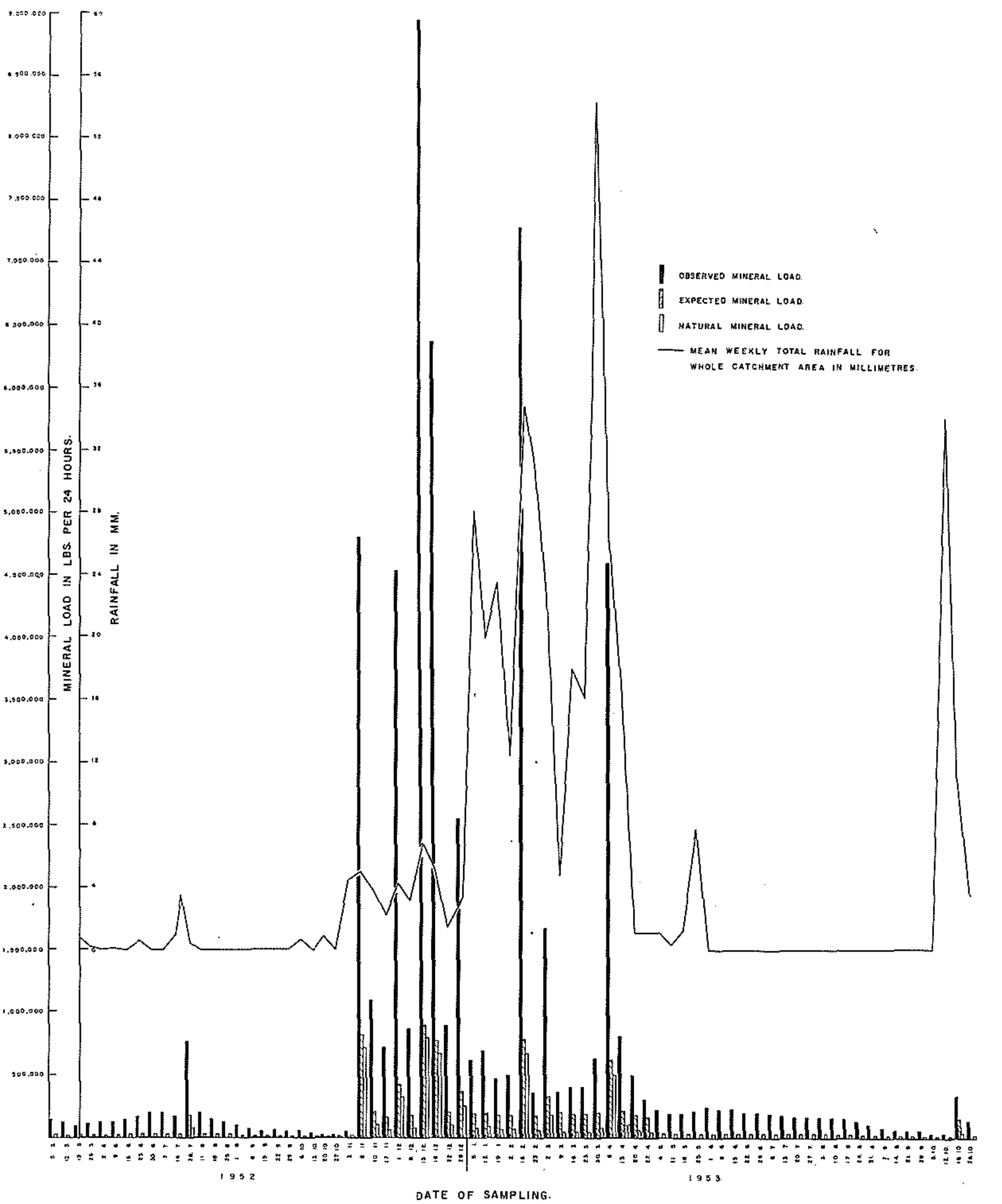


FIG. 2. MINERAL LOAD DATA (LBS. PER 24 HOURS) KLIP RIVER AT VEREENIGING ABOVE CONFLUENCE WITH VAAL RIVER SAMPLING POINT AA4C.

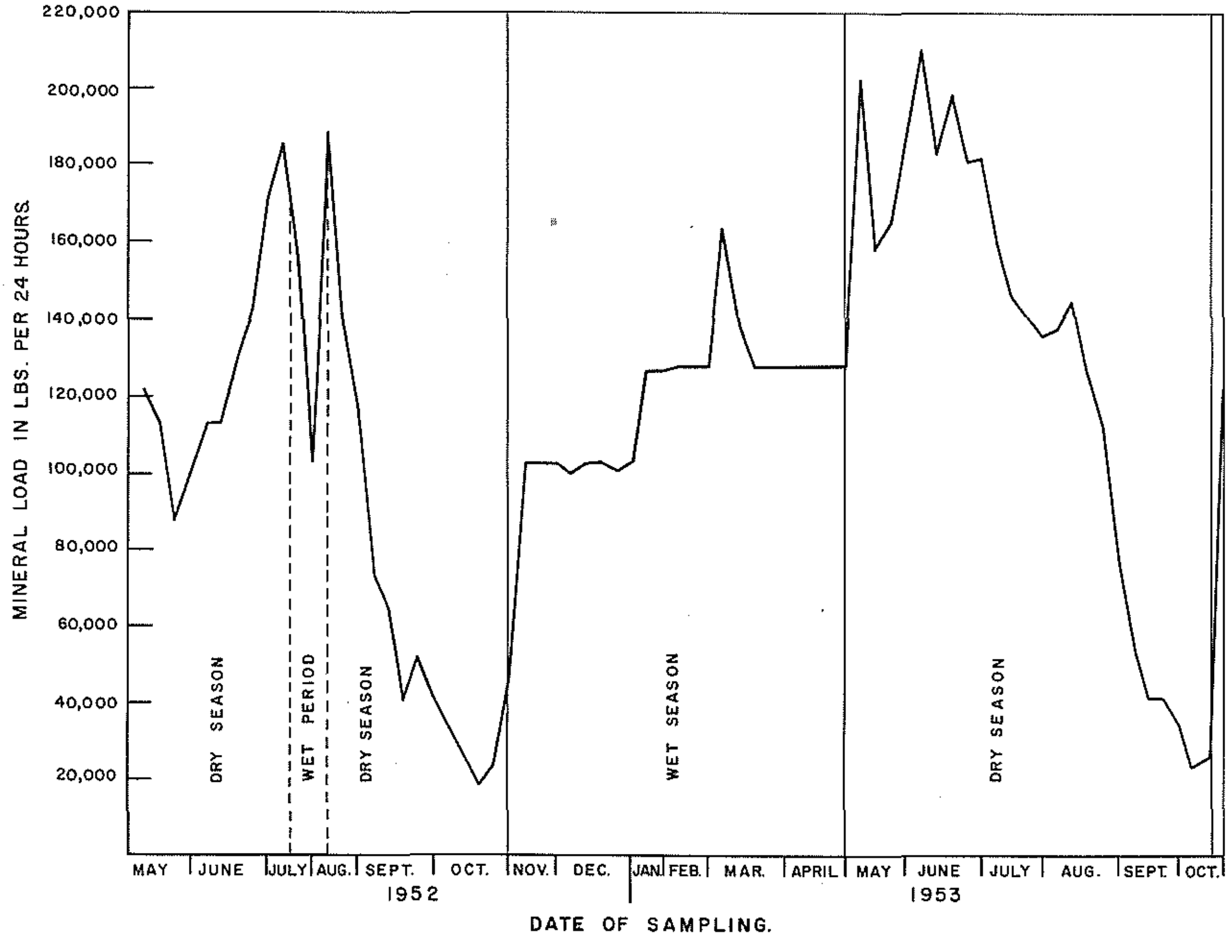


FIG. 2A. DISSOLVED MINERAL LOAD CONTRIBUTED BY REGULAR EFFLUENT DISCHARGES REACHING THE KLIP RIVER AT VEREENIGING (AA4C) (LBS. PER 24 HOURS).

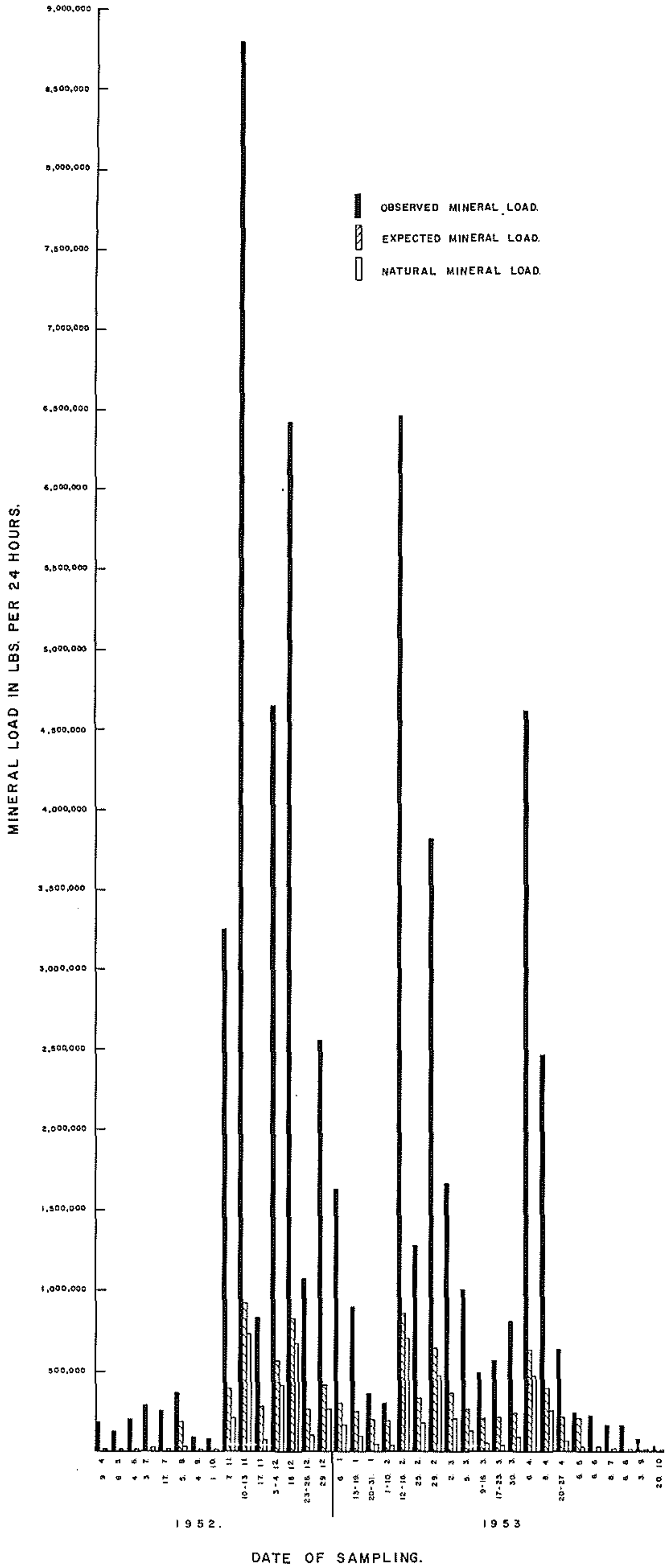


FIG. 3. MINERAL LOAD DATA (LBS. PER 24 HOURS) KLIP RIVER BELOW CONFLUENCE WITH NATALSPRUIT AA1C.

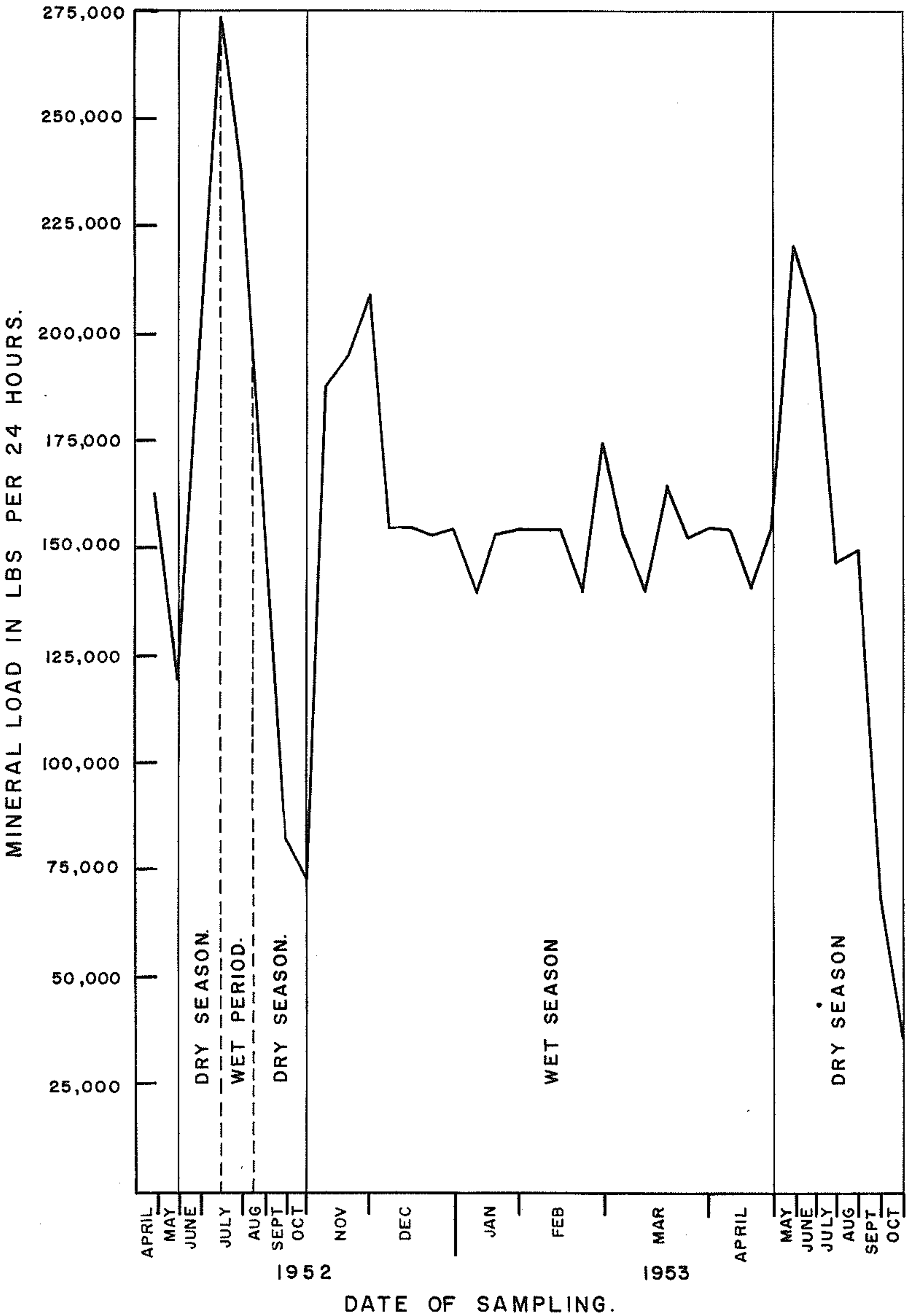
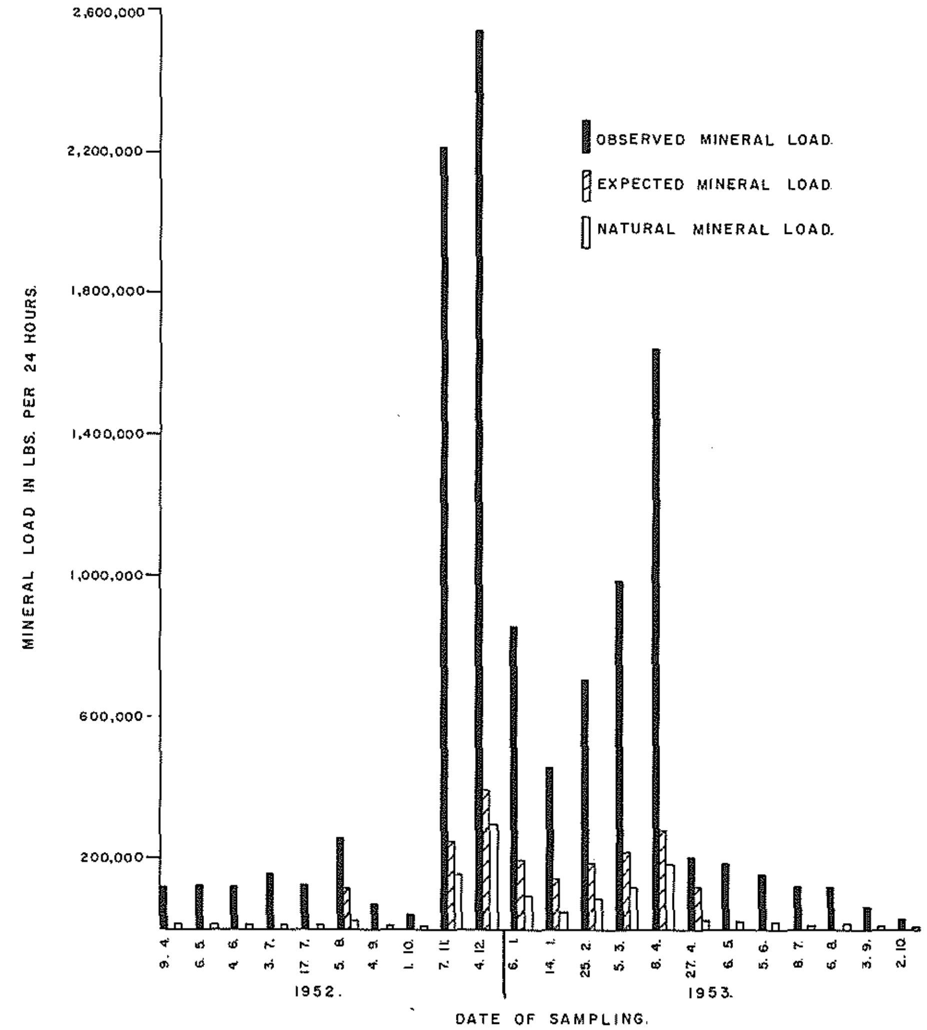


FIG. 3A. DISSOLVED MINERAL LOAD CONTRIBUTED BY REGULAR EFFLUENT DISCHARGES REACHING THE KLIP RIVER BELOW NATALSPRUIT CONFLUENCE (AA1C) (LBS. PER 24 HOURS).

FIG 4. MINERAL LOAD DATA (LBS. PER 24 HOURS) KLIP RIVER ABOVE CONFLUENCE WITH NATALSPRUIT AAIC.



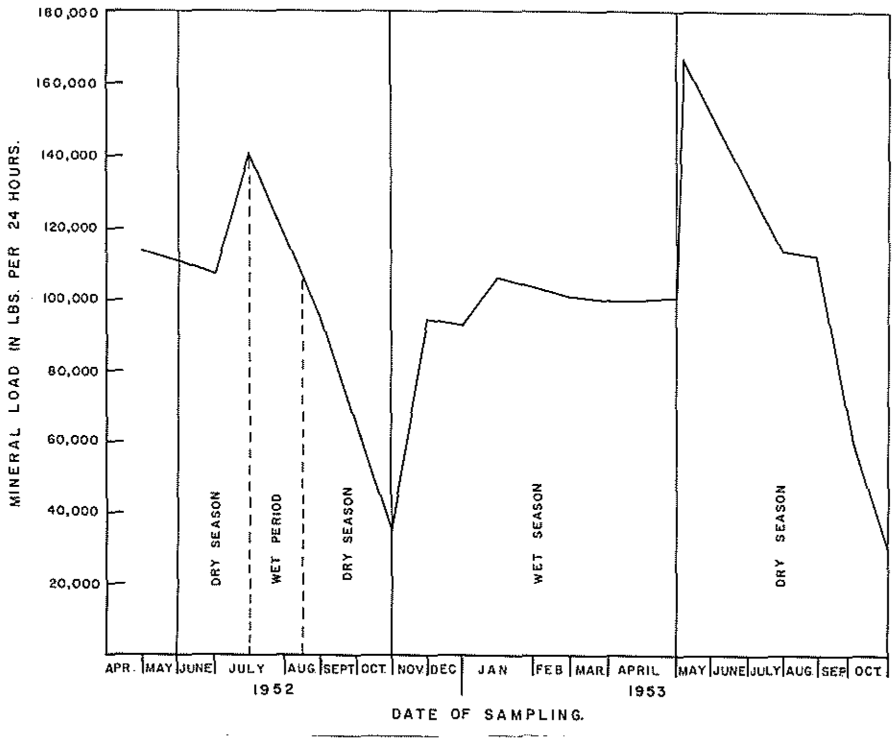
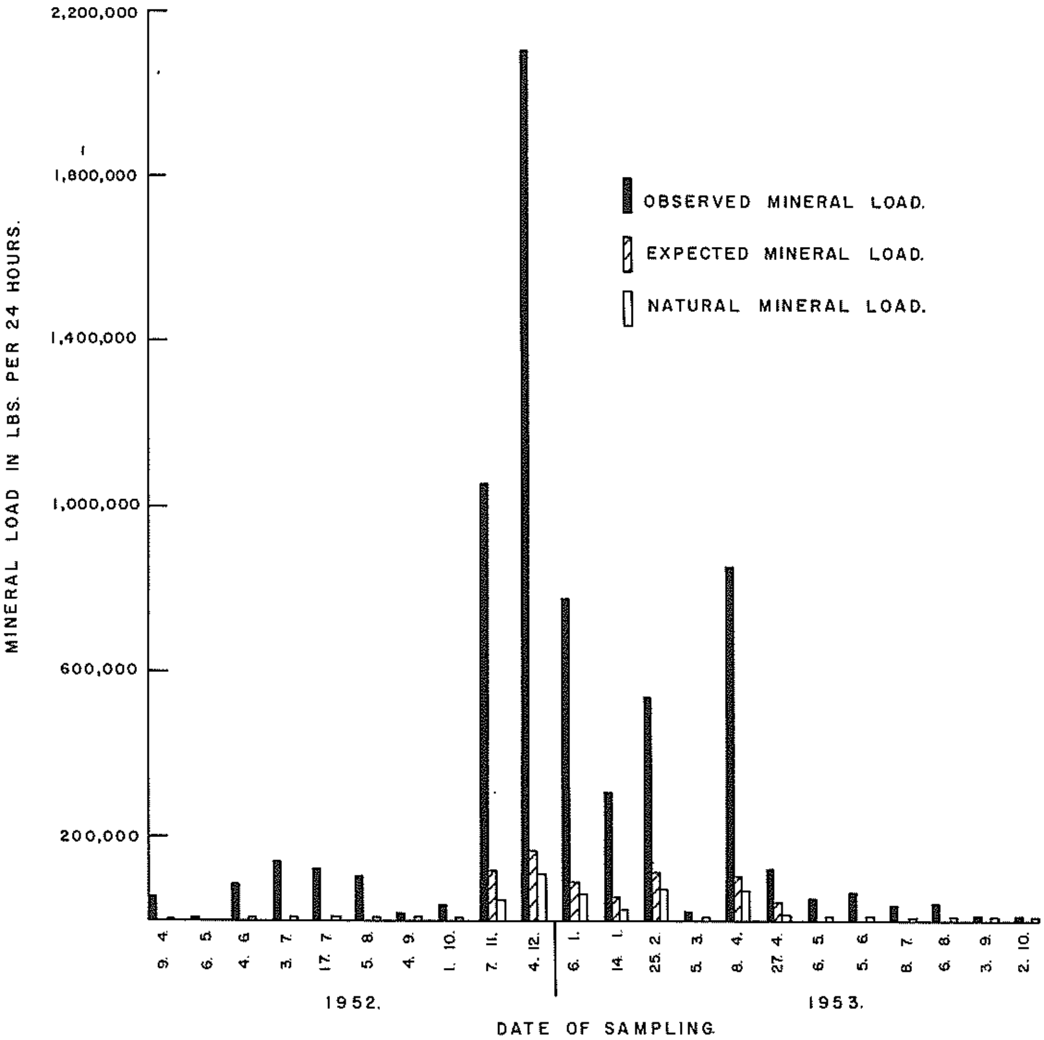


FIG. 4A. DISSOLVED MINERAL LOAD CONTRIBUTED BY REGULAR EFFLUENT DISCHARGES REACHING THE KLIP RIVER BEFORE CONFLUENCE AT NATALSPRUIT (AA1a) (LBS. PER 24 HOURS)

FIG. 5. MINERAL LOAD DATA (LBS. PER 24 HOURS) NATALSPRUIT BEFORE CONFLUENCE WITH KLIP RIVER (AA Ib).



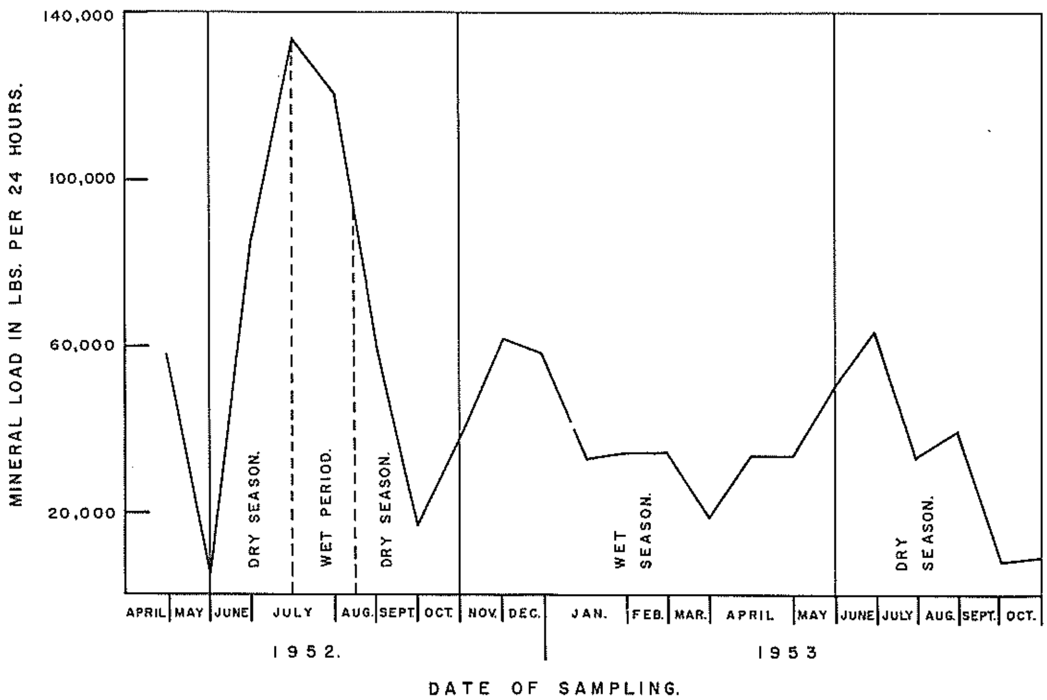


FIG 5A. DISSOLVED MINERAL LOAD CONTRIBUTED BY REGULAR EFFLUENT DISCHARGES REACHING NATALSPRUIT BEFORE CONFLUENCE WITH KLIP RIVER (LBS. PER 24 HOURS) AA Ib.

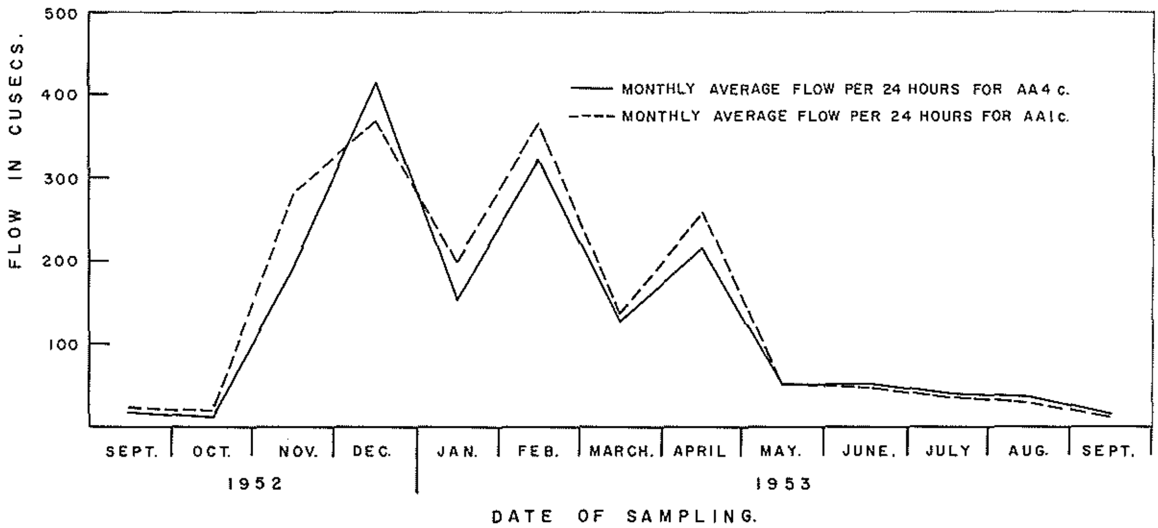


FIG. 6. COMPARISON OF FLOW DATA FOR THE KLIP RIVER AT POINTS AA4C & AA1C.

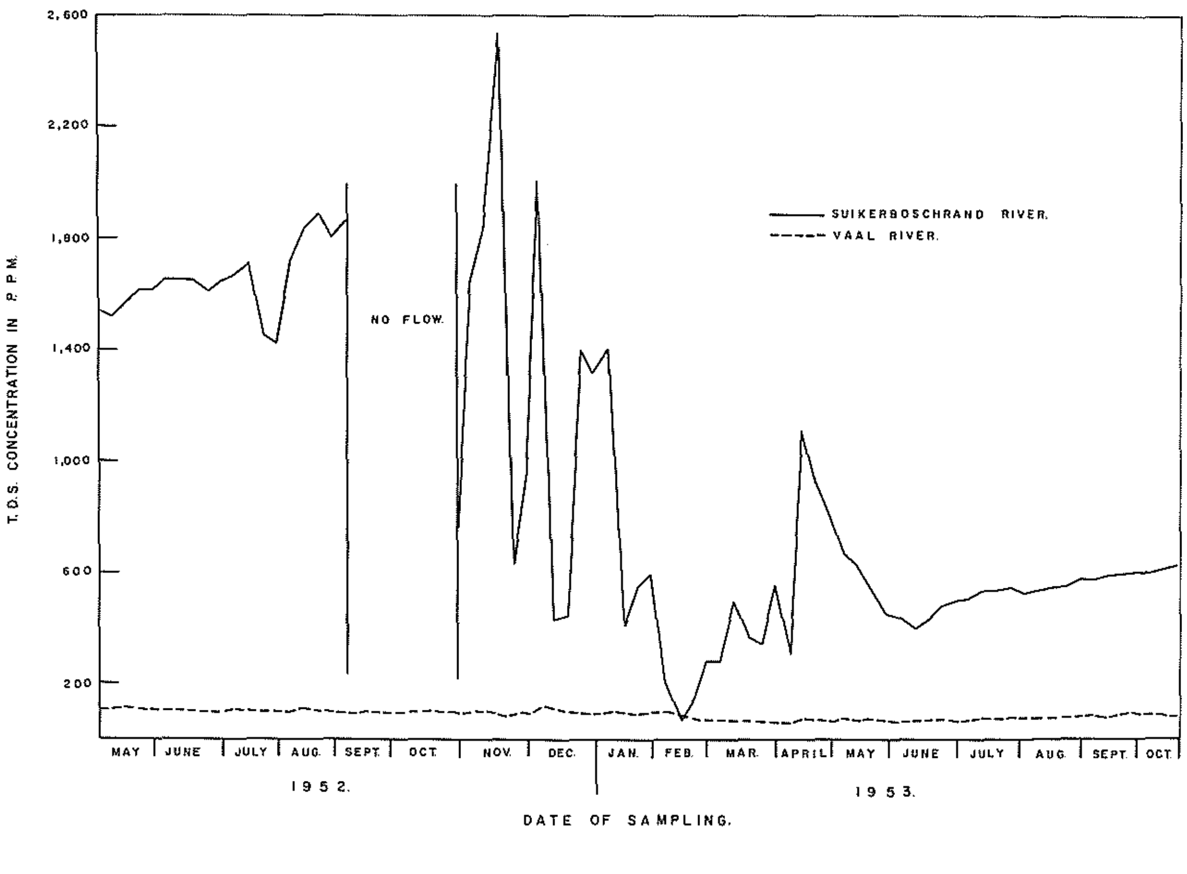


FIG. 7. COMPARISON BETWEEN TOTAL DISSOLVED SOLIDS CONCENTRATION OF SUIKERBOSCHRAND RIVER (G18A) AND VAAL RIVER AT ENGELBRECHT'S DRIFT WEIR FOR THE PERIOD MAY 1952 - OCTOBER 1953.

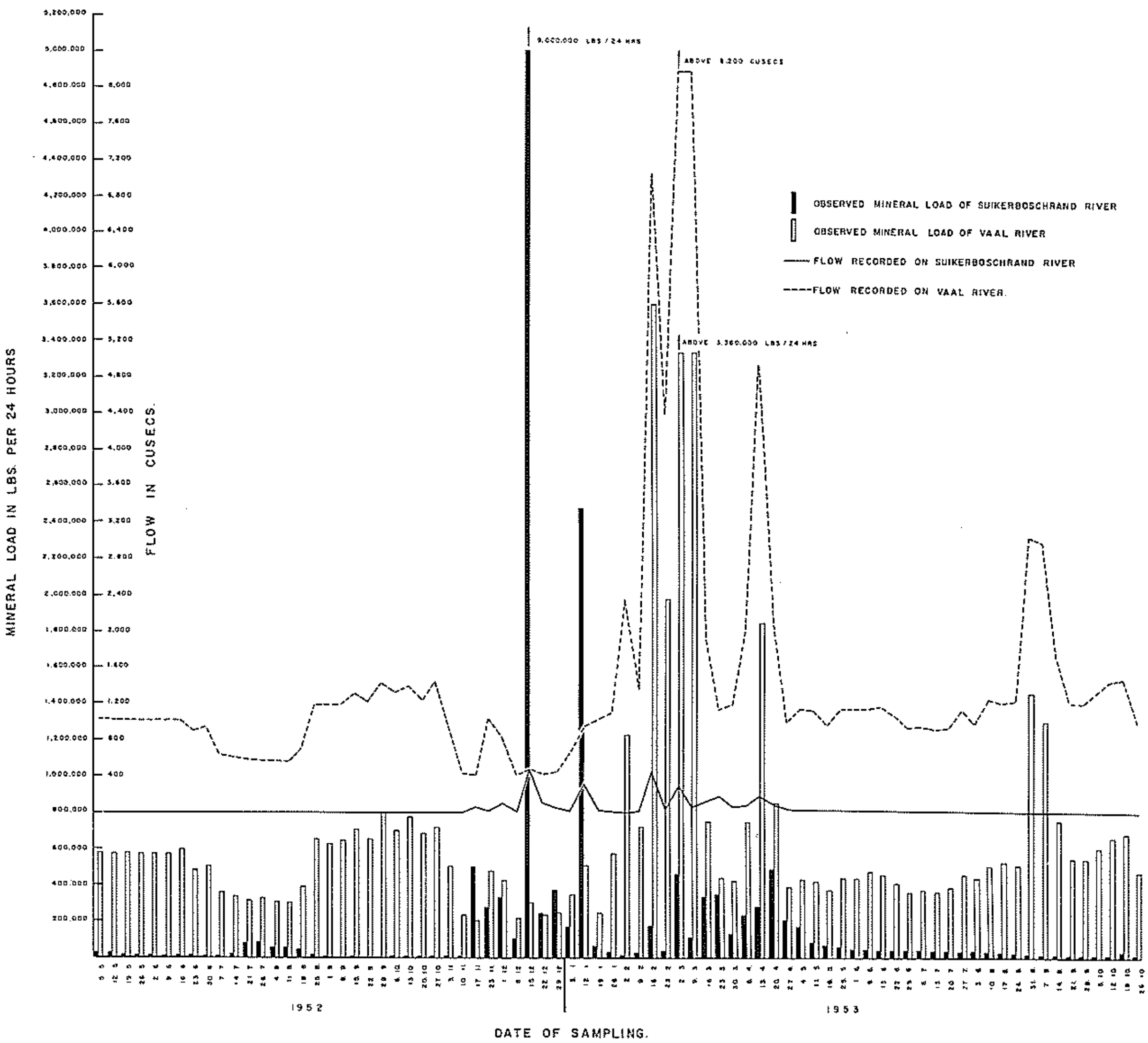


FIG. 7A. COMPARISON BETWEEN OBSERVED MINERAL LOAD AND FLOW OF SUIKERBOSCHRAND RIVER AT VEREENIGING AND VAAL RIVER AT ENGELBRECHT'S DRIFT WEIR.

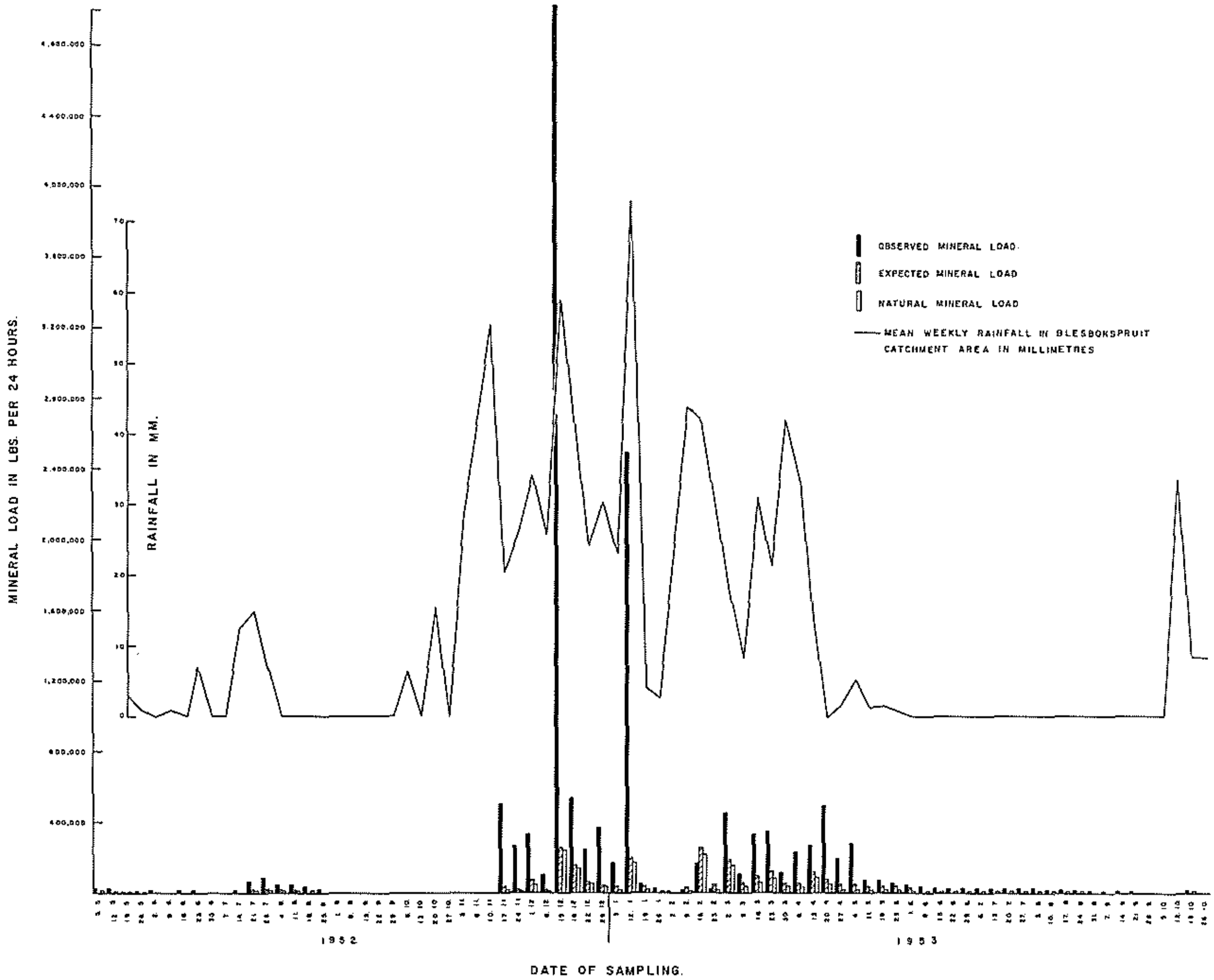


FIG. 8. MINERAL LOAD DATA FOR SUIKERBOSCHRAND RIVER BEFORE CONFLUENCE WITH VAAL RIVER AT VEREENIGING SAMPLING POINT NO. G. 18A.

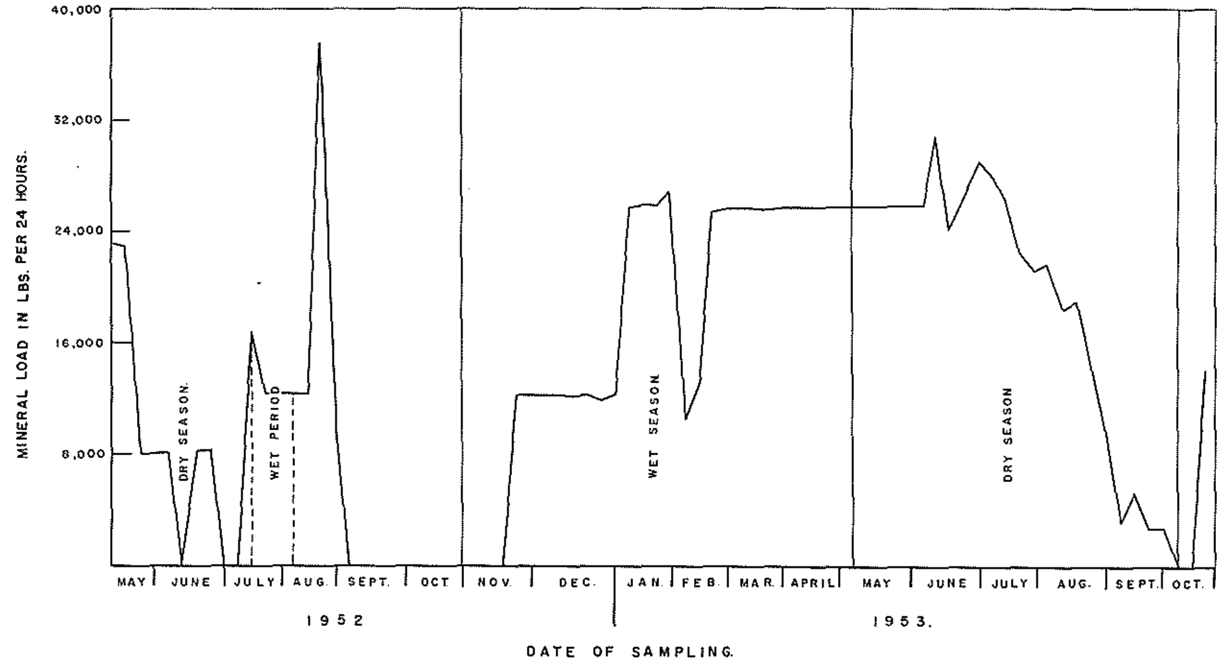
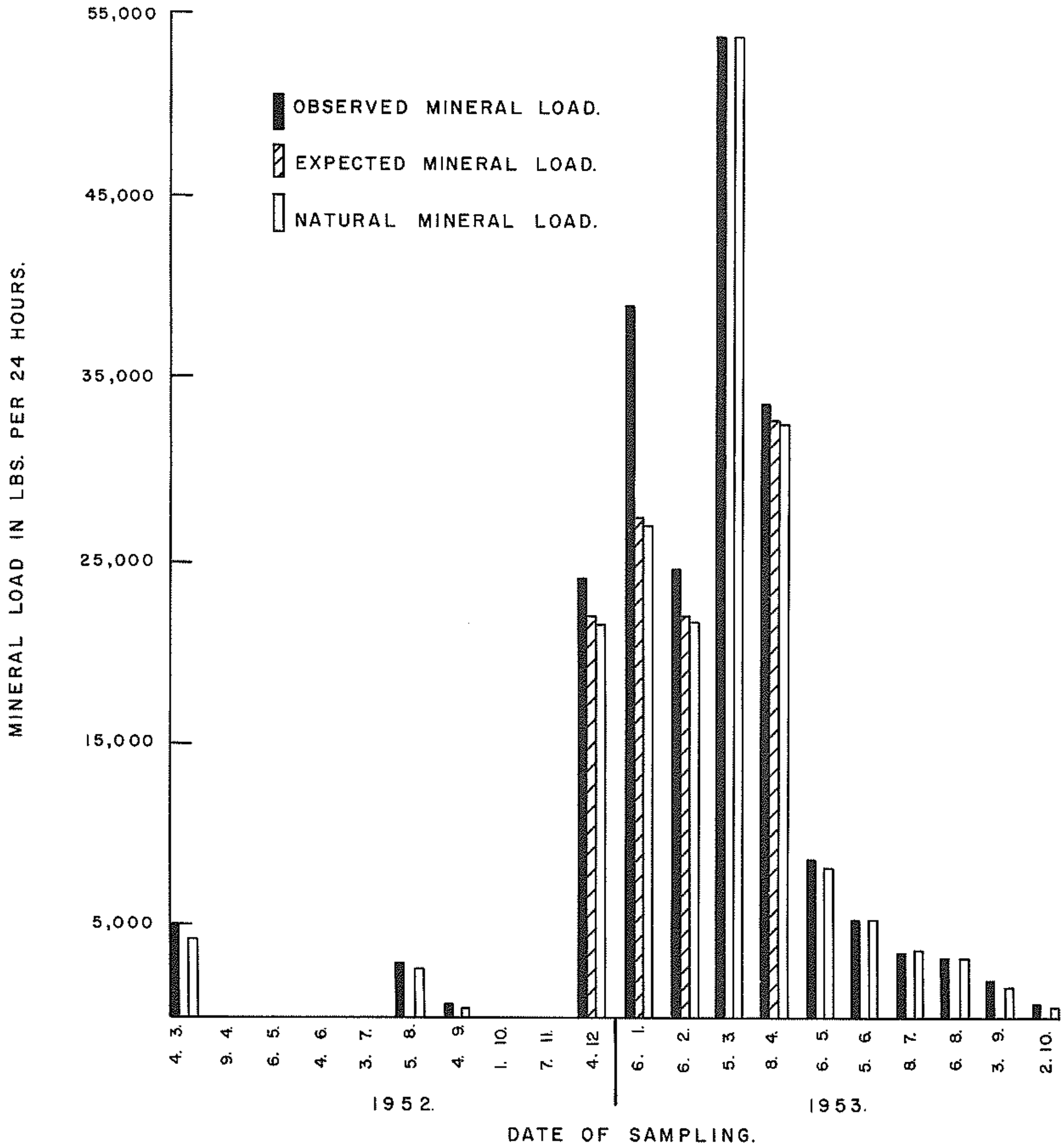


FIG. 8A. MINERAL LOAD CONTRIBUTED BY REGULAR EFFLUENT DISCHARGE REACHING SUIKERBOSCHRAND RIVER AT VEREENIGING (G18A.)

FIG. 9. MINERAL LOAD DATA FOR SUIKERBOSCHRAND RIVER BEFORE BLESBOKSPRUIT. SAMPLING POINT No. G 17b.



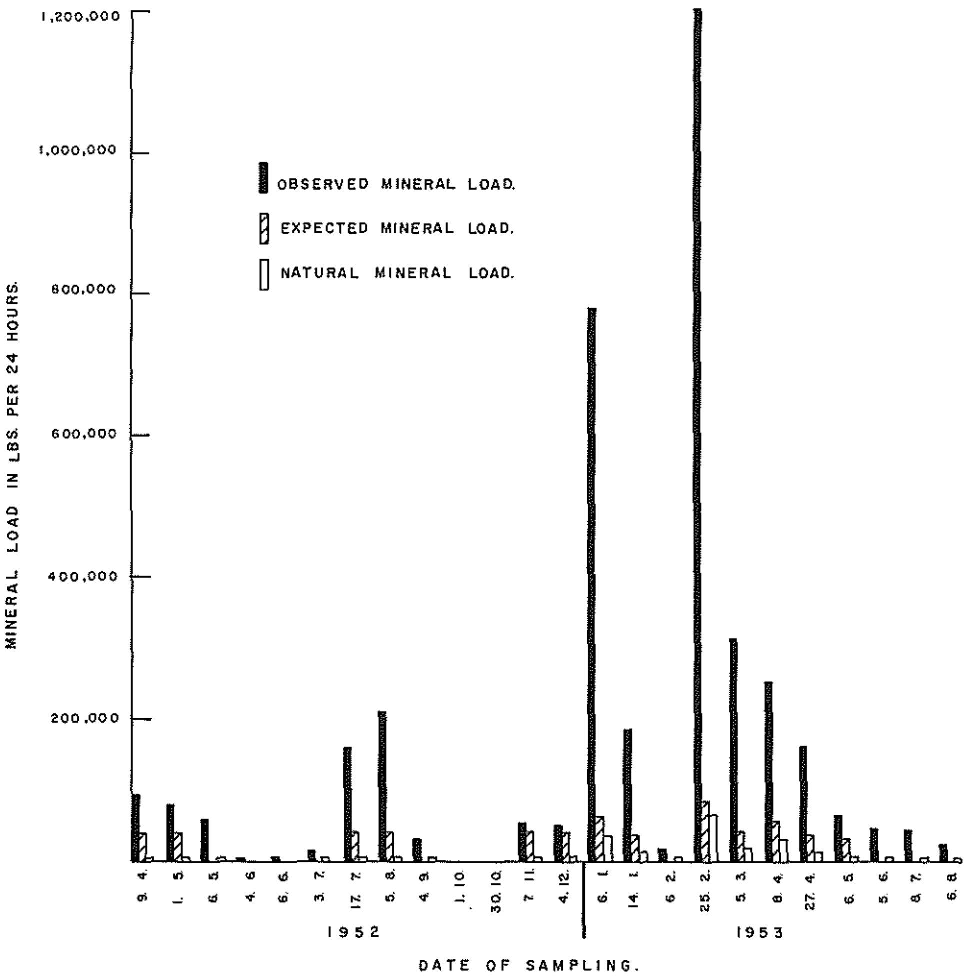


FIG 10. MINERAL LOAD DATA FOR BLESBOKSPRUIT AT HEIDELBERG. SAMPLING POINT No. G 15b.

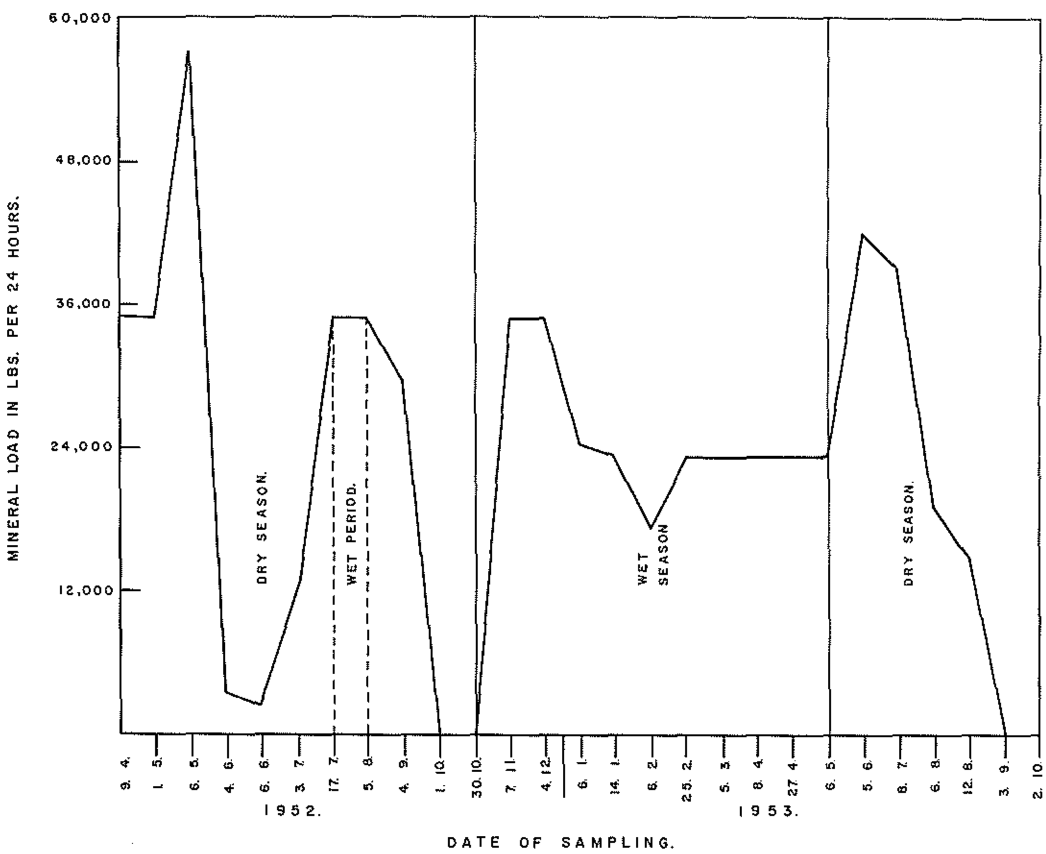


FIG. 10A. MINERAL LOAD CONTRIBUTED BY REGULAR EFFLUENT DISCHARGE CARRIED BY BLESBOKSPRUIT AT HEIDELBERG (G 15b).

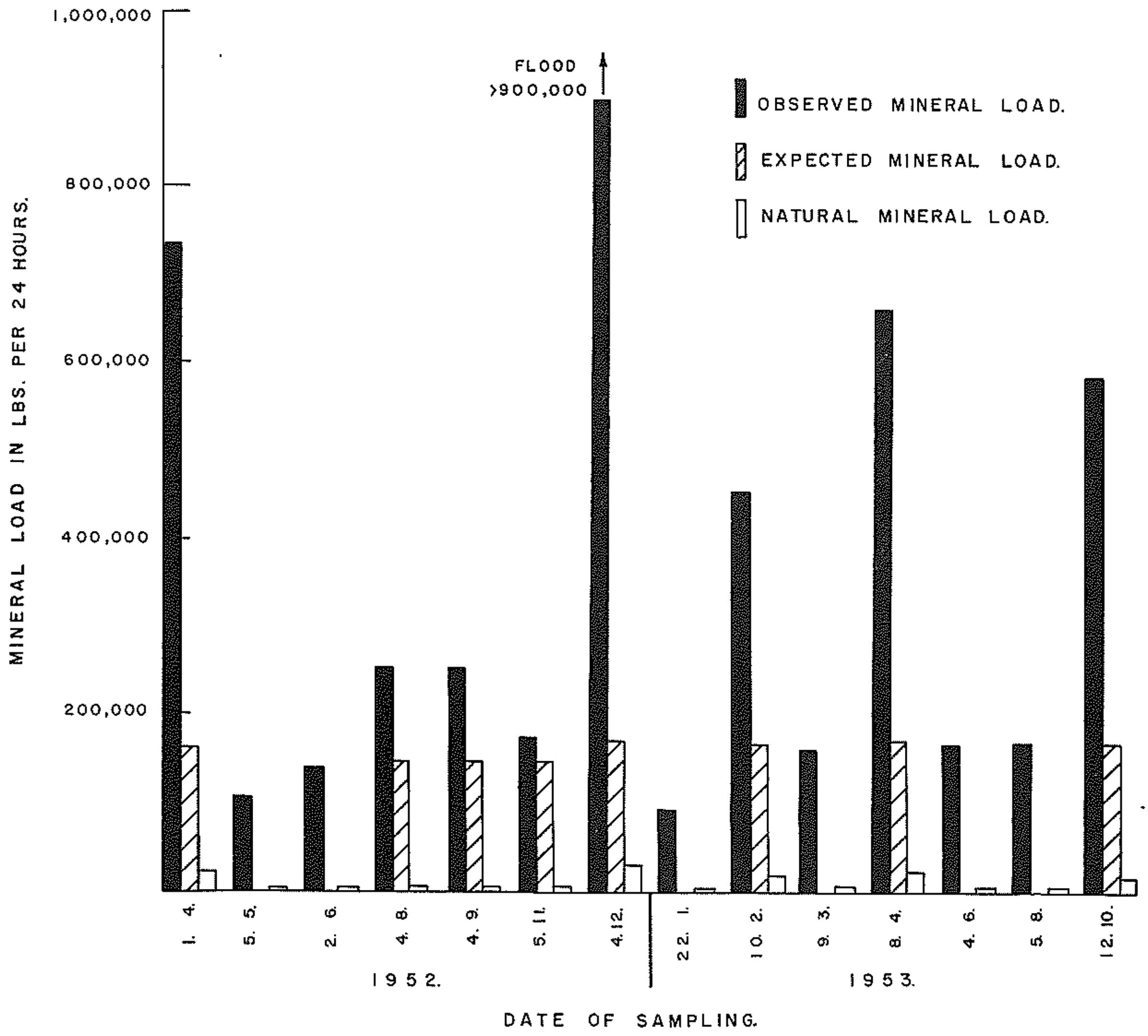


FIG. 11. MINERAL LOAD DATA FOR COWL'S DAM OVERFLOW - SAMPLING POINT E10C.

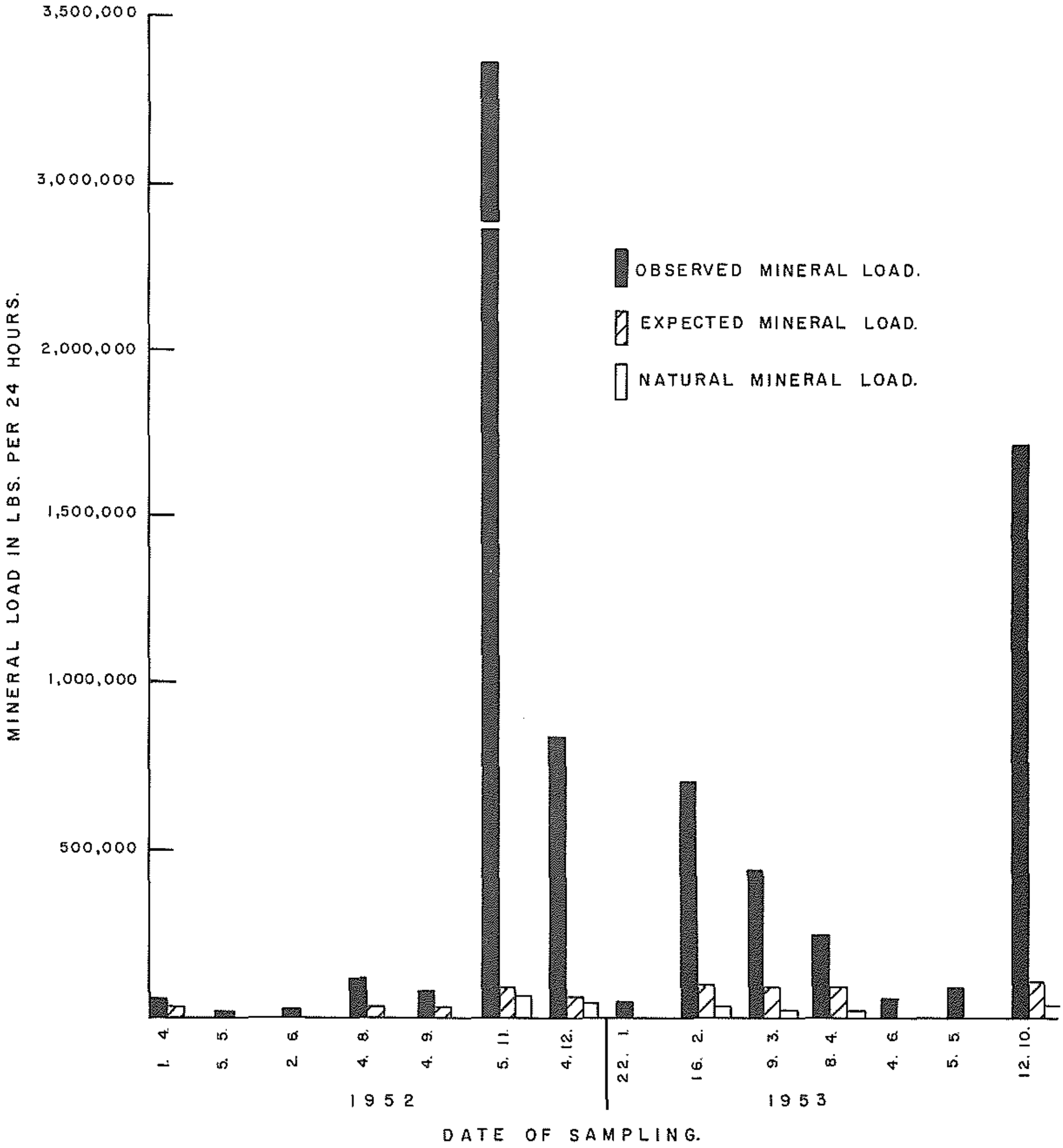


FIG. 12. MINERAL LOAD DATA FOR GEDULD DAM OVERFLOW – SAMPLING POINT E9C.

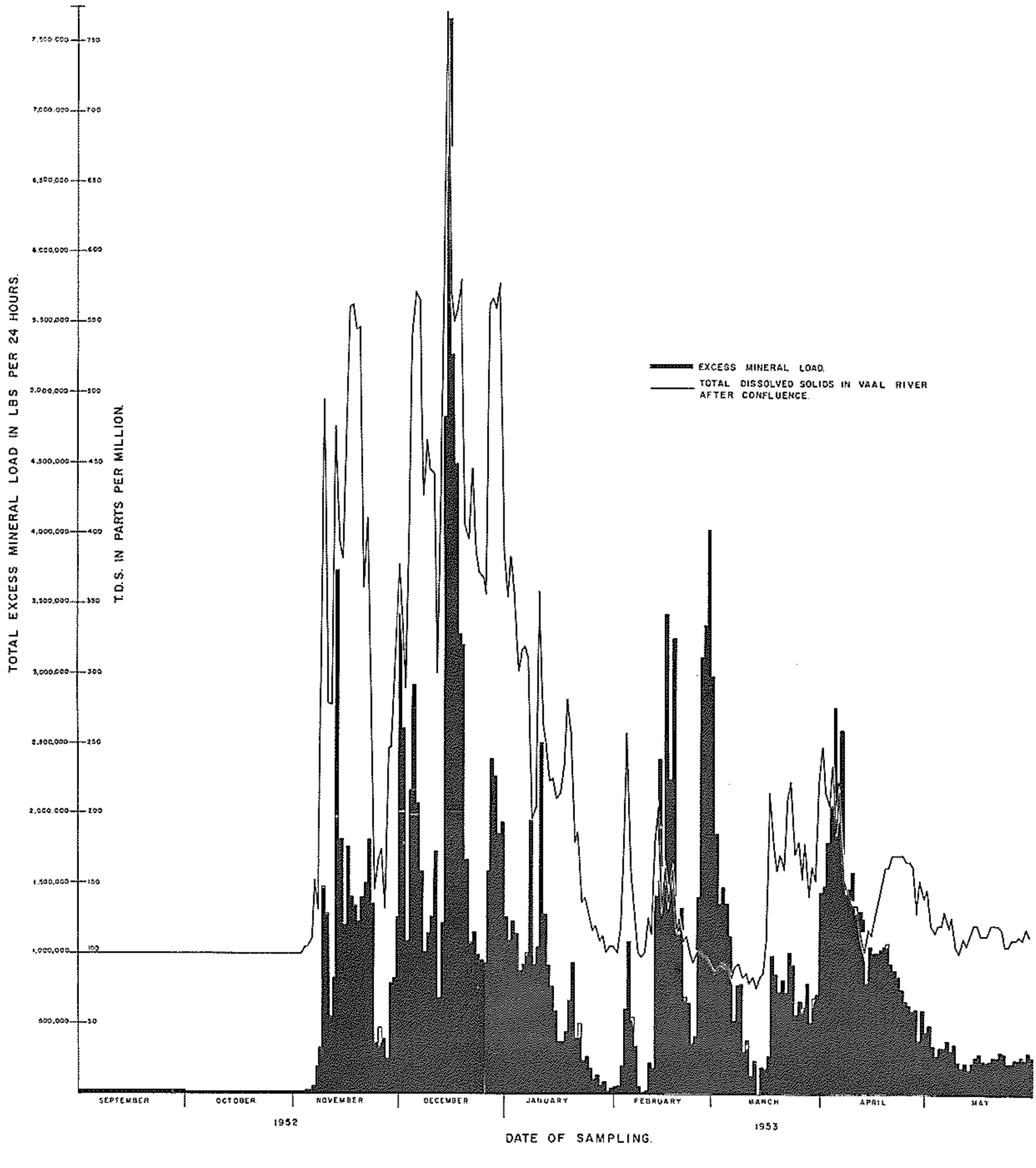


FIG. 13. TOTAL EXCESS MINERAL LOAD DISCHARGED INTO VAAL RIVER BY THE KLIP AND SUIKERBOSCHRAND RIVER SYSTEMS.

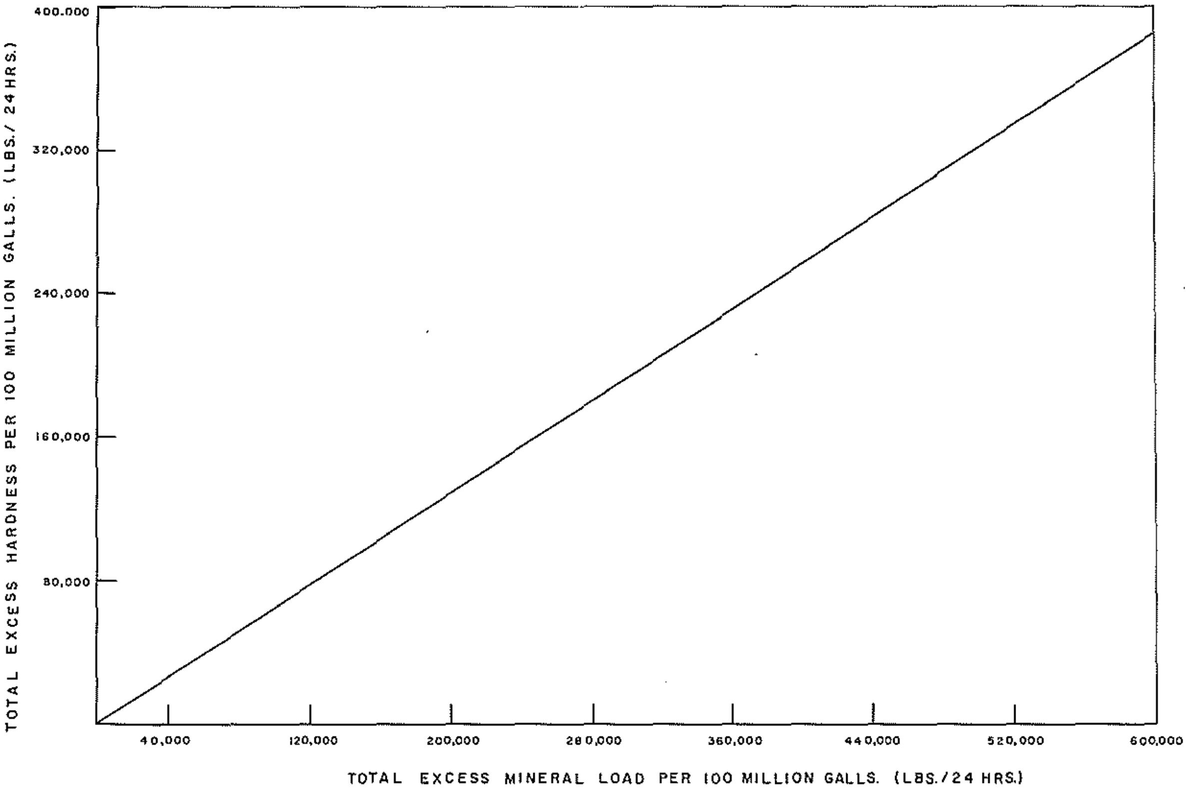


FIG. 14. RELATION BETWEEN TOTAL EXCESS MINERAL LOAD & TOTAL EXCESS HARDNESS CONTRIB. BY KLIP & SUIKERBOSCHRAND RIVERS TO THE VAAL RIVER.

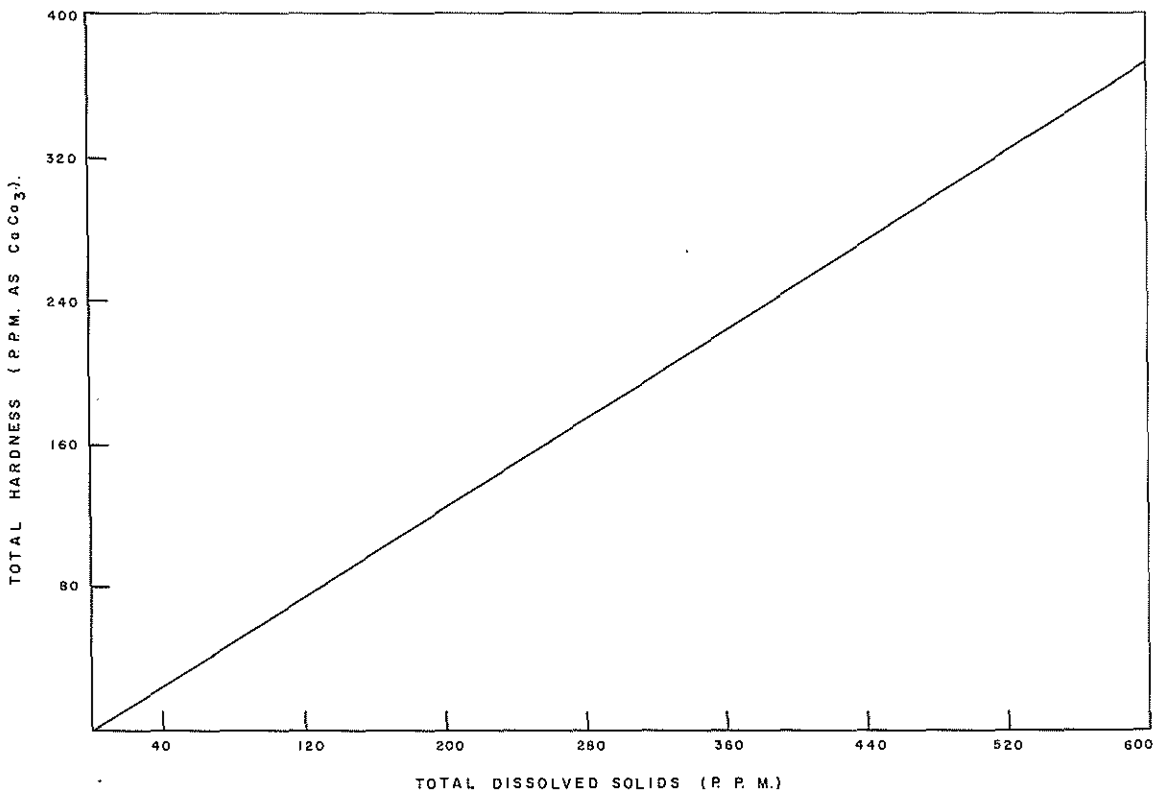
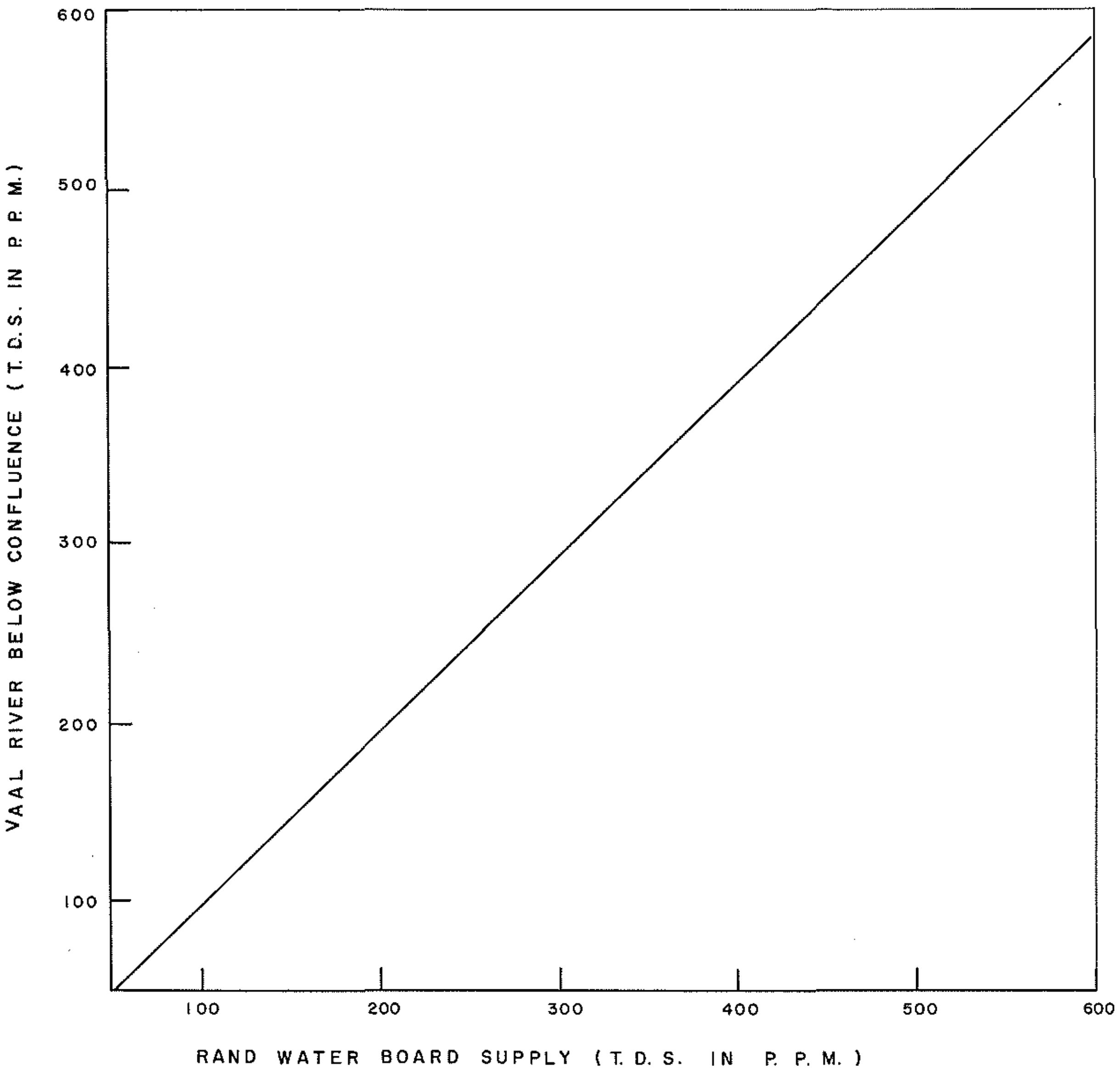


FIG. 15 RELATION BETWEEN TOTAL DISSOLVED SOLIDS & TOTAL HARDNESS OF VAAL RIVER WATER.

FIG. 16. RELATION BETWEEN TOTAL DISSOLVED SOLIDS OF VAAL RIVER BELOW CONFLUENCE WITH KLIP & SUIKERBOSCHRAND RIVERS & TREATED WATER SUPPLIED BY RAND WATER BOARD TO THE WITWATERSRAND.



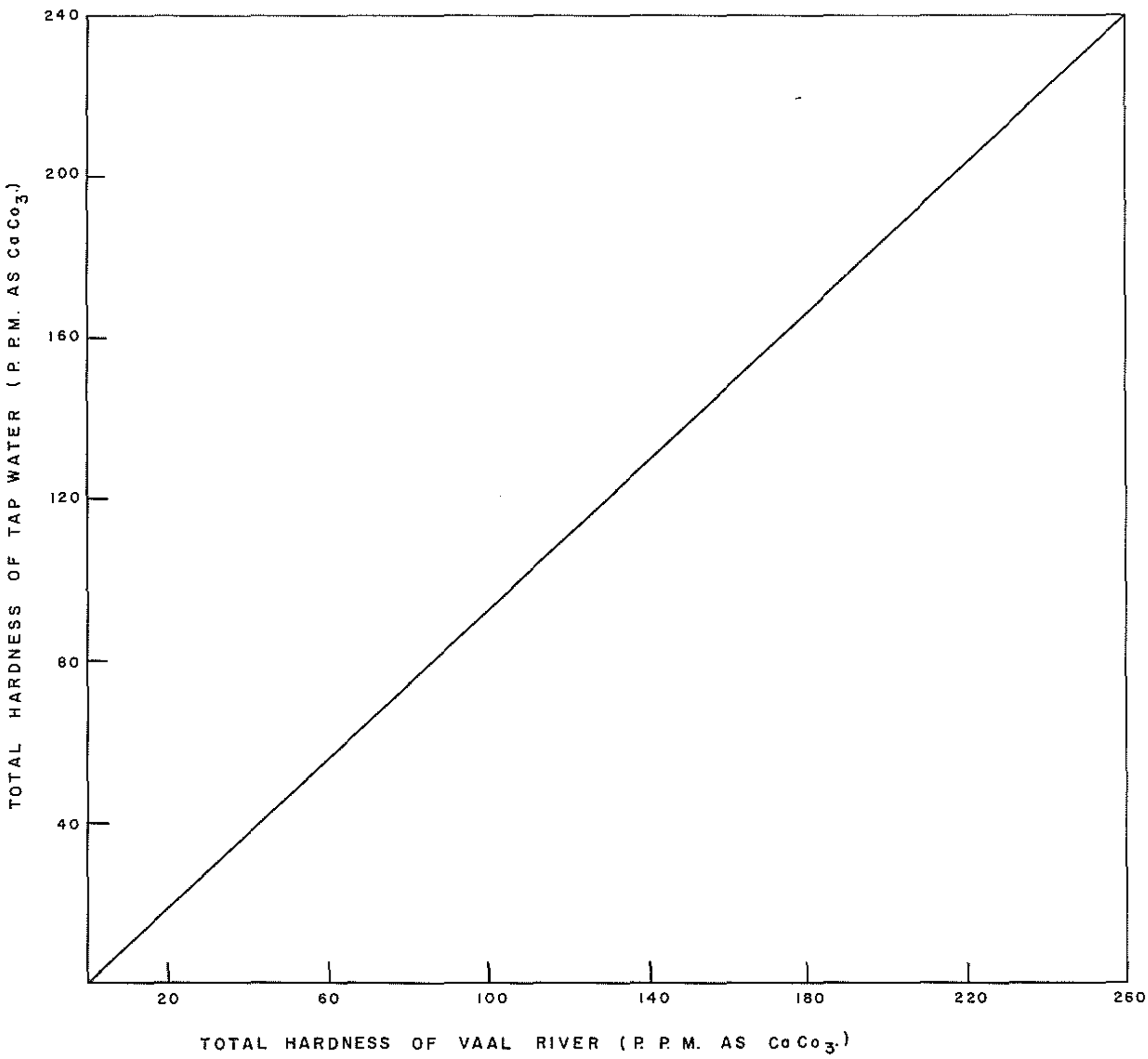


FIG. 17. RELATION BETWEEN TOTAL HARDNESS OF VAAL RIVER & TOTAL HARDNESS OF WATER SUPPLIED TO THE WITWATERSRAND.

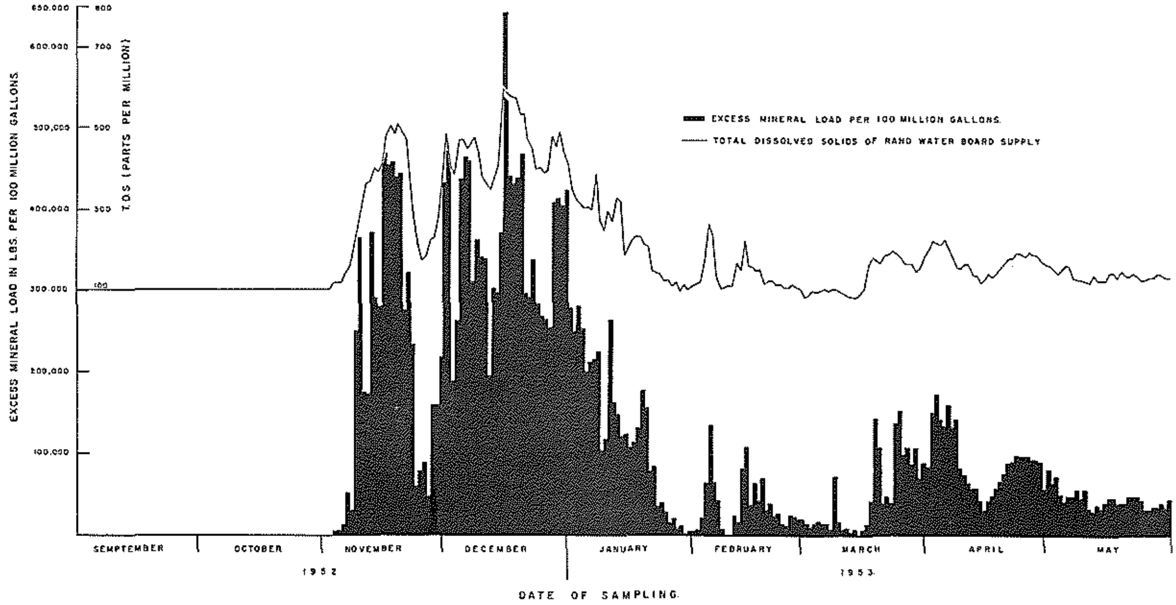


FIG. 18. EXCESS MINERAL LOAD PER 100 MILLION GALLONS OF VAAL RIVER WATER SUPPLIED TO THE WITWATERSRAND.

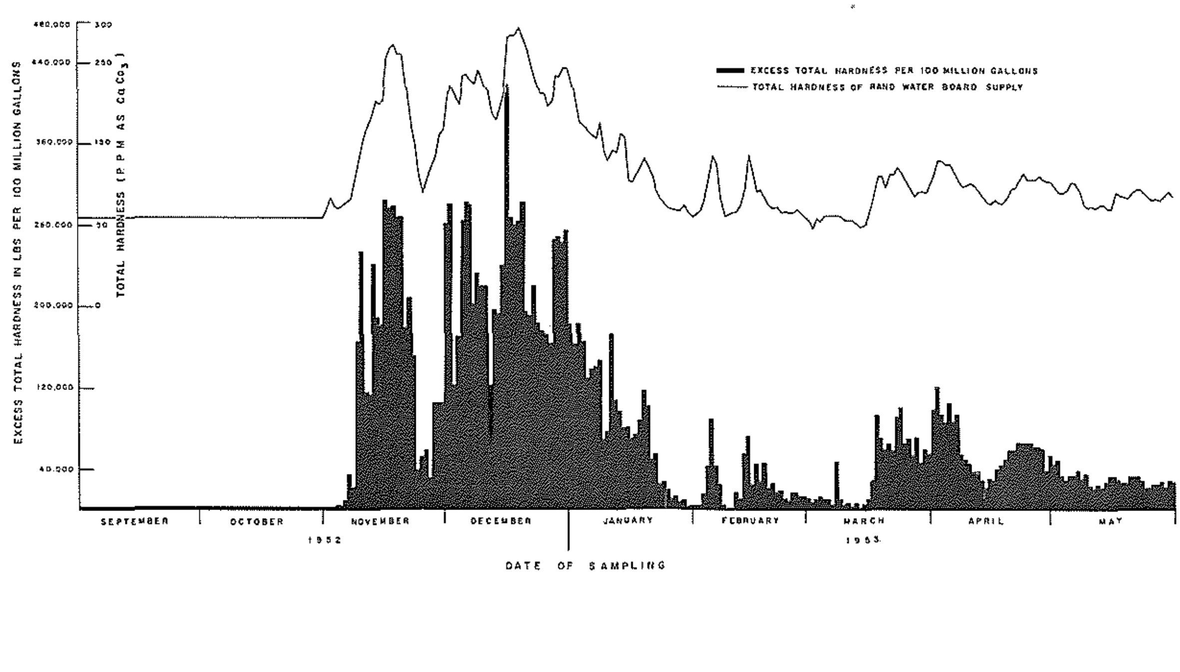


FIG. 19. EXCESS TOTAL HARDNESS PER 100 MILLION GALLONS OF VAAL RIVER WATER SUPPLIED TO THE WITWATERSRAND.

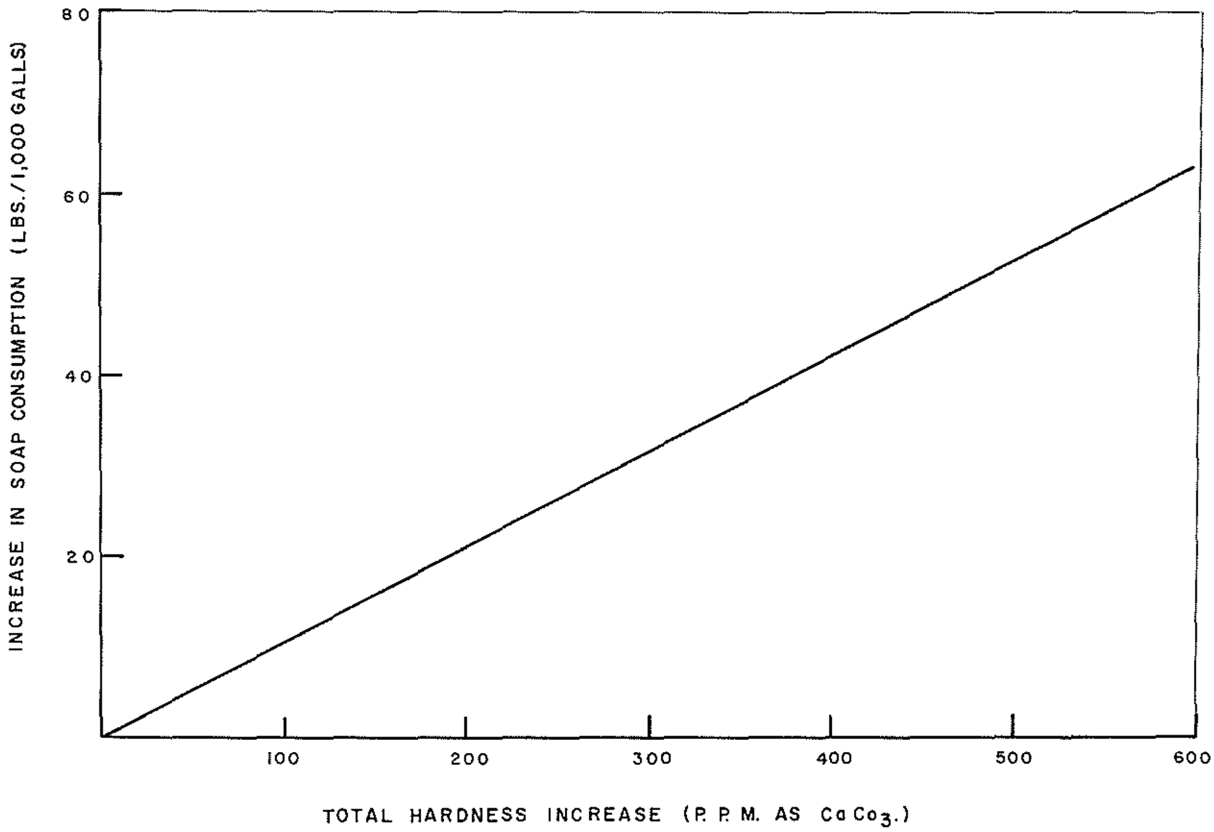


FIG. 20 RELATION BETWEEN INCREASE IN TOTAL HARDNESS OF WATER & INCREASE IN SOAP CONSUMPTION.

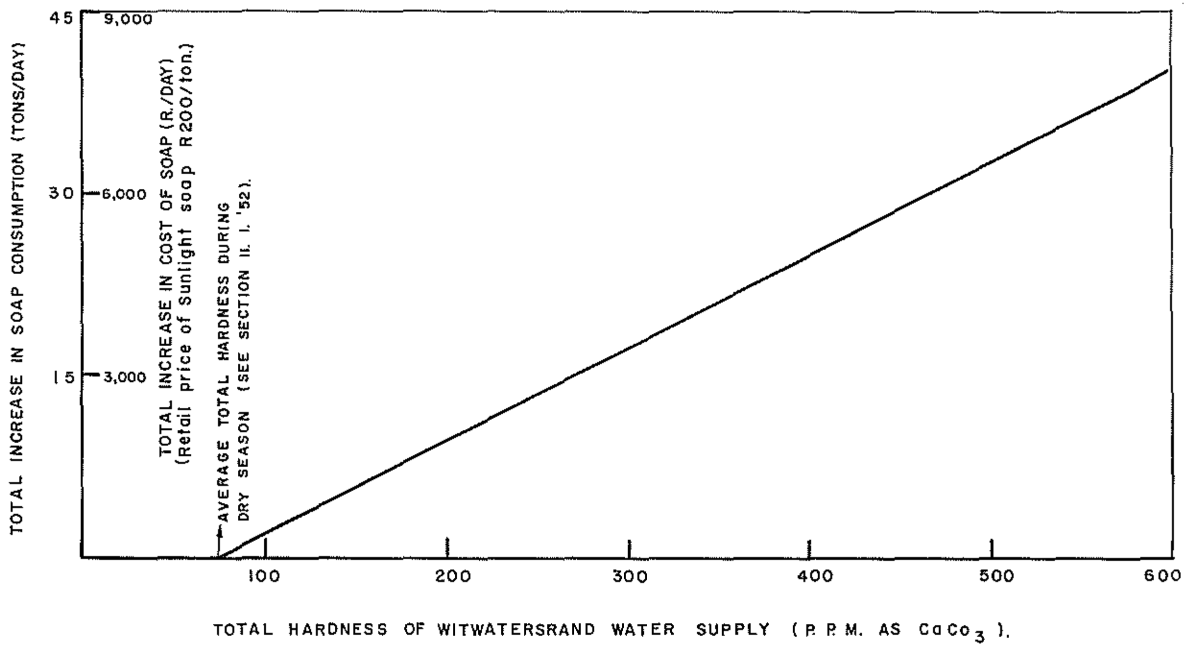
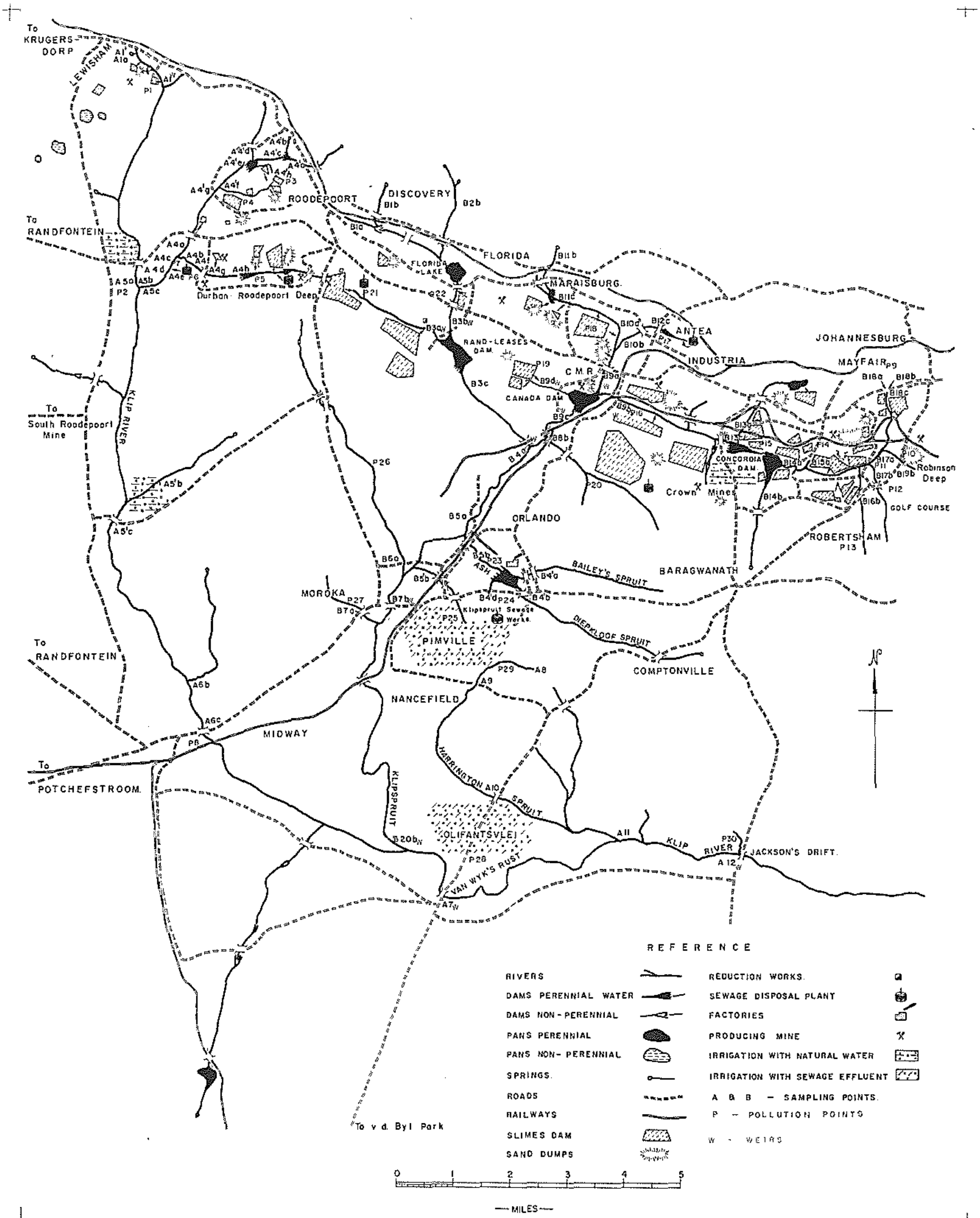
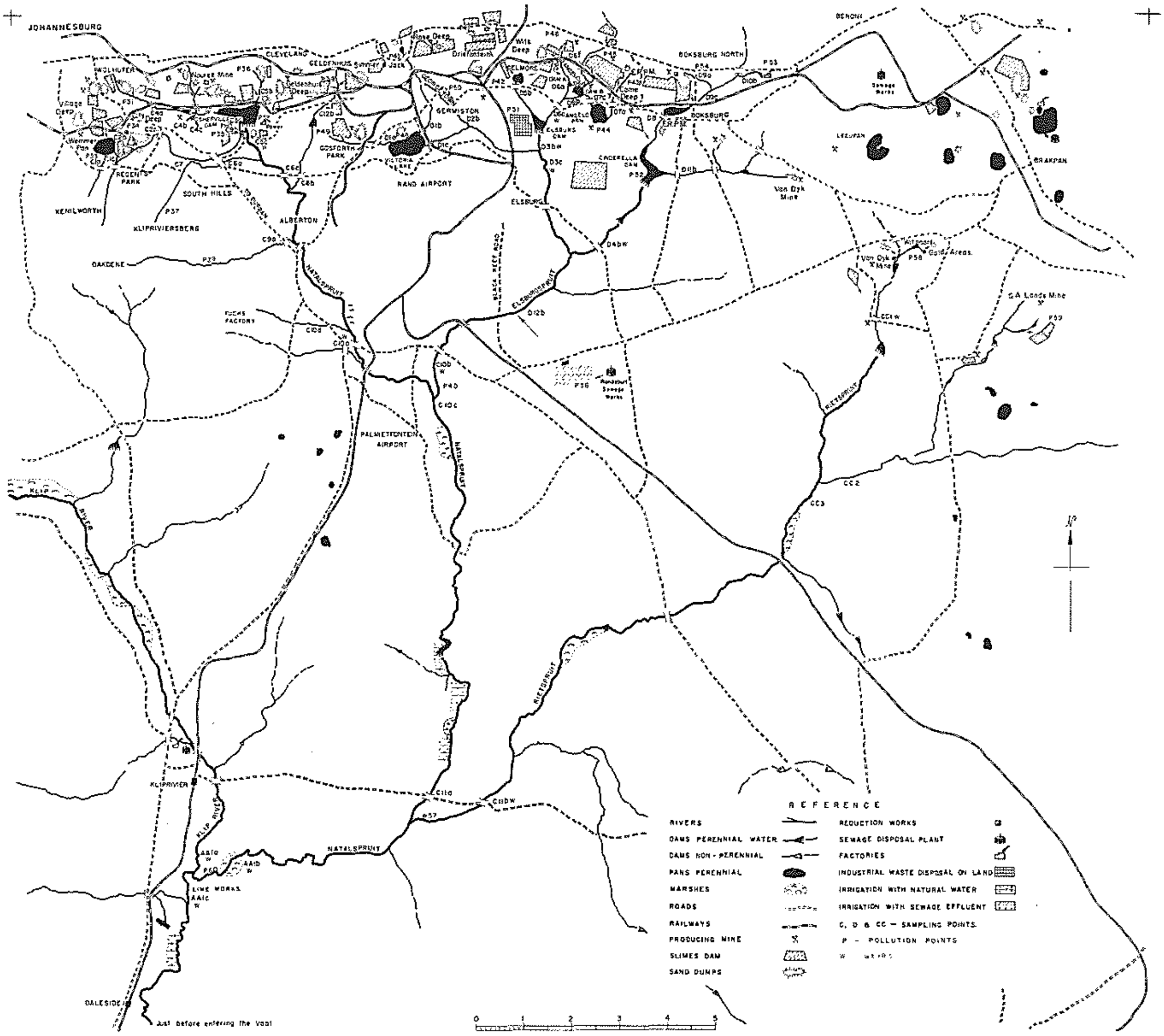


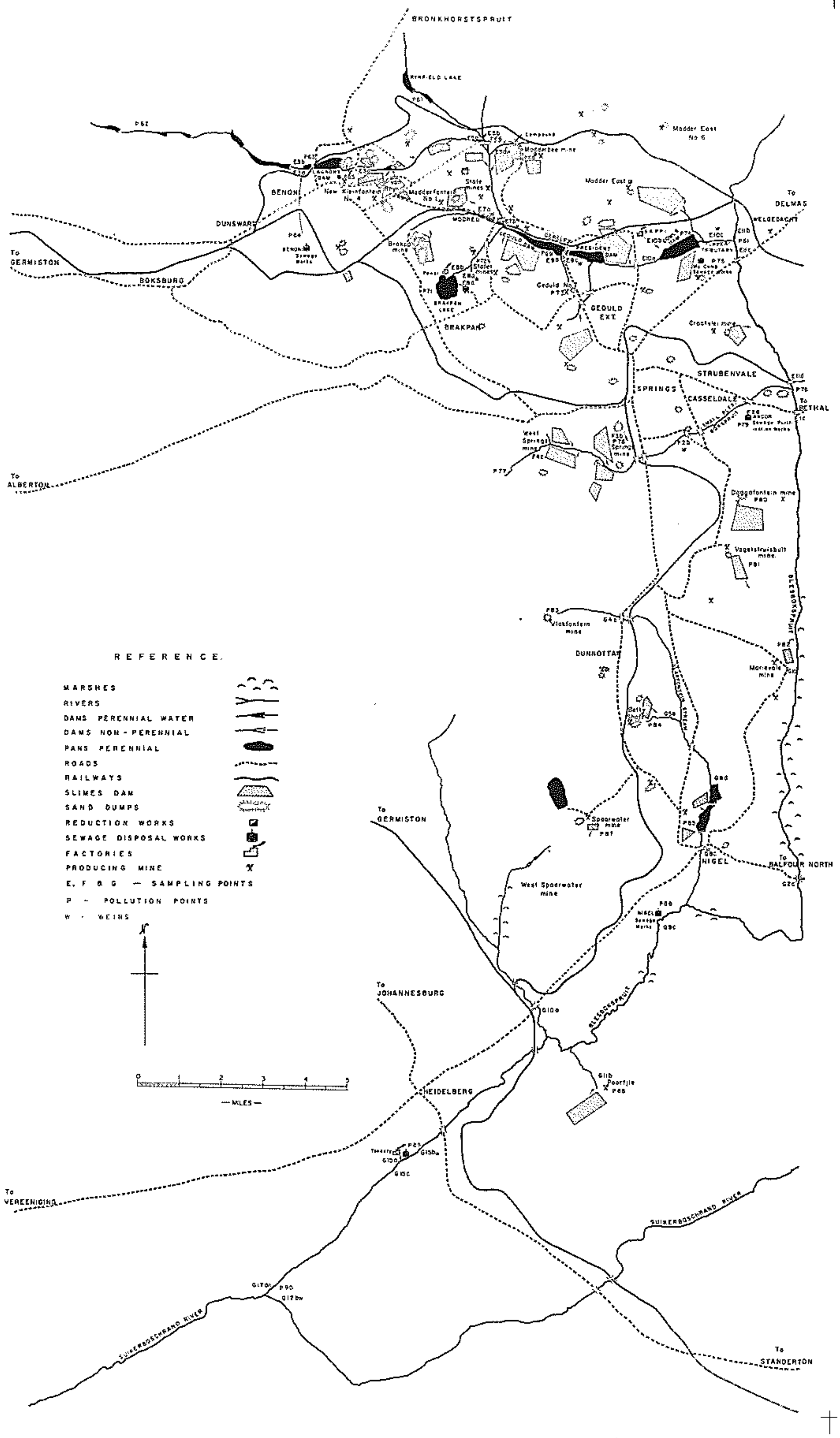
FIG 21. THE EFFECT OF INCREASE IN TOTAL HARDNESS OF THE RAND WATER SUPPLY ON SOAP CONSUMPTION FOR THE WHOLE WITWATERSRAND.



MAP No. 1. RIVER SURVEY. WITWATERSRAND CATCHMENT AREA. UPPER KLIP RIVER & KLIPSPRUIT CATCHMENT AREAS SECTIONS A & B. 1: 50,000.

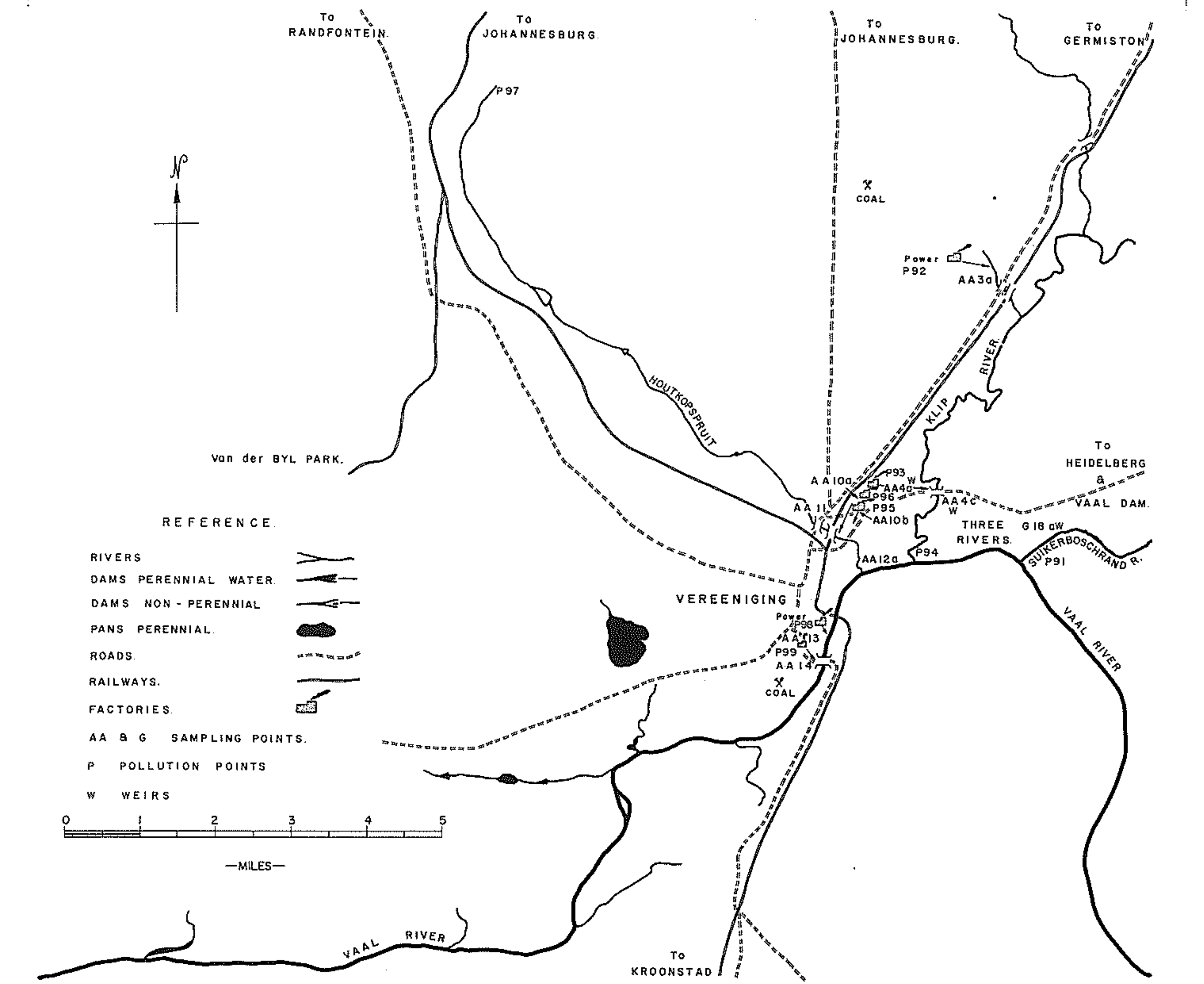


MAP No. 2 RIVER SURVEY: WITWATERSRAND CATCHMENT AREA NATALSPRUIT, ELSBURGSPRUIT & RIETSPRUIT CATCHMENT AREAS (SECTIONS C, D & CC) SCALE 1:50000



MAP No. 3. RIVER SURVEY: WITWATERSRAND CATCHMENT AREA. BLESBOKSPRUIT, SMALL BLESBOKSPRUIT & SUIKERBOSCHRAND RIVER. (SECTIONS E,F & G SCALE 1:50,000.

[redacted]



MAP No. 4 RIVER SURVEY: WITWATERSRAND CATCHMENT AREA. LOWER KLIP RIVER, SUIKERBOSCHRAND RIVER & THE VEREENIGING AREA. SECTION AA. 1:50,000.

MAP No. 5 KEY MAP TO MAPS 1, 2, 3 & 4 SHOWING THE DIFFERENT SECTIONS DISCUSSED IN THE TEXT SCALE: 1: 250,000.

INSET: MAP OF TRANSVAAL SHOWING THE WITWATERSRAND CATCHMENT AREA (SHADED) SCALE 1: 4,000,000.