Swan River Reference Committee

Report by

SUB-COMMITTEE

on

POLLUTION

of

SWAN RIVER

PERTH WESTERN AUSTRALIA

Contents

Foreword

The Swan River Reference Committee was originally formed in September, 1943, and reconstituted in 1948 to advise the Hon. Minister for Works in Western Australia in regard to all matters relating to the control of the Swan River—particularly as to the problem of maintaining the River in a clean and healthy condition. The Committee comprises representatives of the various Government Departments in any way associated with river administration and develoment as well as of those Departments able to render general assistance and advice. The Committee also included representatives from Local Authorities whose Districts covered River Foreshore, from the Commonwealth Scientific and Industrial Research Organization, and Sporting Bodies.

During the years it has operated the Committee has been handicapped by absence of legislative authority and plenary powers but the members—who function in an honorary capacity—have carried out useful work in co-ordinating the efforts of the several authorities interested in River development and control, and have been instrumental in effecting many improvements.

In May, 1952, the Swan River Reference Committee appointed a Sub-Committee—comprising the following members to investigate the problem of pollution of the Swan River:—

W. S. Davidson, M.B. Ch. B., D.P.H. (Aberd.), Deputy Commissioner of Public Health (Convener).

F. M. Kenworthy, B.E., LL.B., A.M.I.C.E., M.I.E. (Aust), Chief Engineer, Metropolitan Water Supply, Sewerage and Drainage Department.

J. C. Hood, B.E.M., F.R.A.C.I., Deputy Government Analyst.

The terms of Reference were:—

(a) Define pollution;
(b) Suggest methods of control.

In order that its report might be authoritative and enlightening, the Sub-Committee approached several experts in various sciences with a request for assistance. This assistance was freely and generously given and was of extreme value.

The Sub-Committee expresses its gratitude and indebtedness to the contributors of the scientific essays forming various chapters in the report.

This Report is printed by direction of the Hon. John T. Tonkin, Minister for Works in Western Australia.

R. J. BOND,
Chairman Swan River Reference Committee,
Under Secretary for Works.

Perth, Western Australia.
February, 1955.

Introduction

River Pollution is a problem facing most civilised countries today, and exercising the minds of expert committees and scientists throughout the world.

The magnitude of the problem will be more appreciated in this State as the population of Western Australia increases and industry expands.

The confining of research to the local problems of the Swan River, and subsequent solutions, would entail a great deal of work, which would require repetition in other areas similarly affected by industry and man-made interference. The Sub-Committee has therefore endeavoured to set out in its report, not only a means of meeting the problem in the Swan River, but a means of meeting it in any waterway or foreshore.

In its report the Sub-Committee has collected and arranged much information which is not restricted in its application to the Swan River; it therefore should be of assistance to any authority responsible for purity of waterways. As the need for these authorities will gradually increase, the Sub-Committee has attempted to visualise the problem as a whole, and to devise a form of legislation for control of the Swan River that will serve as a model for other similar waterways, and integrate the whole so that there is a form of local control subject to some degree of central authority.

With this broader objective in view therefore, the Sub-Committee set out to—

(a) Define Pollution in the Swan River;

(b) Ascertain a means of control.

The method of approach was as follows:—

(a) Examine the history of complaints regarding the River to ascertain the popular conception of Pollution.

(b) Examine the physical, chemical and biological constituents of the River to ascertain by some scientific standard the amount of this Pollution.

(c) Examine reports, legislation, and literature of other countries and states to ascertain standards and methods adopted elsewhere.

(d) With the information thus collected to propound ways and means of producing adequate control of River Pollution.

Subsequent chapters and appendices show to what extent the Sub-Committee has succeeded in its task. These chapters and appendices are largely summaries of extensive data. As, however, they are themselves of no mean extent, the Sub-Committee has summarised its findings under the next heading of "Summary and Conclusions".

Summary and Conclusions

The most popular concept of "Pollution" concerns itself with odour.

Malodorous gases arising from the River have occasioned most complaints. It is said they have turned red paint black, have been alleged to have driven people from their homes, and have been accused of causing ill health.

As decaying algae give off offensive odours, the algae themselves have been considered "Pollution" and, next to odours take precedence as chief contributors to pollution.

As, however, algae require food to satisfy their biological demands, it was an easy step for the public to include as "Pollution" any excess of nutrient added to the stream.

In this way industrial and sewage wastes and effluents came finally to be the "causa belli" to most complainants.

Sewage having been incriminated, a search was made for bacteria. The discovery of various species of bacteria broadened the "Pollution" menace from a nuisance, and a cause of ill health, to the spreading of disease. Bathers have held it responsible for skin diseases, bad ears, sore throats, inflamed eyes, and common colds but rarely, if ever, for such recognised water-borne diseases as enteritis.

This, then, is the evolution of the complaint of "Pollution" and it is alleged that the pollution is of comparatively recent origin; is increasing, and can and should be controlled.

The researches of the Sub-Committee indicate that much of this concept of pollution is fallacious. The main factors involved have been in existence long before living memory and are natural phenomena of the River.

Industrial wastes and sewage play little or no part in the growth of algae; the algae receive adequate sustenance from the natural waters of the River. The diseases suffered by swimmers are normal concomitants of swimming in confined pools and are largely the result of infection introduced by swimmers themselves.

There is, at present, some evidence of a change of algae flora and of a possible increase in numbers. Whether this change or increase is a true one or merely part of a normal cycle of change is impossible to say. There is, however, ample evidence that flood waters bring down alluvial soil and fertilizing agents, including nitrogen and phosphorus in considerable quantities, and it is obvious that increased agricultural developments in the upper reaches are producing in the River a richer nutrient medium for the growth of algae.

Algae in the River are a natural phenomenon. They have an important function to perform and any increase that has taken place in their numbers is largely due to agricultural development, and cannot be obviated. There is no practicable means of removing them, and total removal is undesirable. Their nuisance value, however, is largely concerned with their death and decay on foreshore and in shallow waters. It would therefore seem that the only solution is in carefully planned reclamation, and construction of retaining banks in such a way that dead algae do not accumulate in these places, and where this is unavoidable, to remove the algae before decay takes place.

Uncontrolled discharge of effluents and wastes into a river can, however, radically alter its character and produce undesirable results. It is therefore necessary to ensure control over such agencies to prevent undesirable characteristics developing in the River in the future. The Sub-Committee recommends the adoption of control measures without undue delay to preserve the purity of the River, and prevent the deterioration of rivers common in industrial countries.

Control should be in the hands of a statutory body representing various interested portions of the population. This body could be reproduced in various localities where the need arose for control of waterways and foreshores. A central authority is required to exercise supervision of controlling bodies and to provide technical assistance. It is suggested that this central authority should be the Minister for Works and Water Supply, assisted by a committee of technical officers of various Departments.

The Controlling Body of the Swan River may decide that no effluent will be admitted to the River. This would simplify control and reduce it to a matter of policing. It would, however, mean the removal of many industries elsewhere and might interfere with the normal development of the area. This, to a large extent, is a matter of Government policy and Town Planning and the Minister, as Central Authority, can influence the decision of the controlling body.

A policy of complete removal of effluents would have little effect on the overall purity of the River because of the large body of water contained in the estuary, and its constant change from fresh intake and tidal ebb and flow. The estuary is capable of dealing with considerable quantities of suitable effluent. The purity of the River is much more affected by natural drainage from agricultural areas in the upper reaches and built-up areas around the estuary. It is inevitable that the River must accept this drainage, and as these areas increase their development, so they will increase their potential for adding pollutants to the River.

It may therefore be desirable to accept certain effluents to the River, in which case the controlling body must ensure that they comply with certain standards.

There are technical difficulties in setting standards and these difficulties do not appear to have been overcome in other countries investigating this problem. In the chapter on "Pollution Control" a general standard for the River is recommended, and a possible means suggested for maintaining this standard by controlled acceptance of effluents. The calculations given are merely intended as a suggested guide to a method to be adopted. Every case must be examined critically on its merits.

A Controlling Body must therefore decide:—

1. Whether it will accept any effluents at all.
2. If accepting effluents, the standard of purity to be maintained in the River.
3. If there are any alternative means of disposal for individual effluents.
4. Whether the effluent will affect the standard of purity in the River.

If the effluent is acceptable, the Controlling Body might issue a Permit. All persons wishing to discharge effluent or waste must apply for and obtain this permit before discharging to the River.

Permits, standards, controlling bodies, central authority and legislation are dealt with more fully in the chapter on Pollution Control.

Suggested boundaries of the Swan River for the jurisdiction of the Swan River Controlling Body are:—

Eastern boundary of harbour.
Junction Southern River and Canning River.
Scott Street Bridge, Helena River.
Middle Swan Road Bridge, Swan River.

chapter i

Pollution of Swan River Historical

Before attempting to control "pollution" it is necessary to form some idea of what it is we seek to control. In references to the Swan River, "pollution" is a very much overworked word. Everyone using it has a very definite idea of what he means until he is asked to define it, and the chances are that, should he succeed in expressing himself, his definition will not agree with that of anyone else. The truth is that the River is viewed from different aspects according to the use we make of it. Consequently pollution will be the unnatural interference with the particular use an individual has for the River and will change from individual to individual, according to changes in the circumstances of his life. Thus the bather is concerned about harmful bacteria, the paddler about algae and black mud, the yachtsman about silt, the fisherman about effluents that destroy fish, the nearby resident about odour, and the casual passerby about a host of things that offend his eye, including the flotsam and jetsam of orange peel and empty bottles.

The unconscious adaptability of human memory is a frailty on which we cannot wholly rely when estimating an increase or decrease in pollution. We remember best what we wish to remember, and forget that which is unsuitable to our purpose. Thus it is that in our youth the beaches were all yellow sands free of algae and stench, and now the River is choked with algae and stinking mud. We see only that part of it which is bad today, and remember only the part that was good in our youth.

The truth is that the River is a part of living Nature full of variation and change from place to place, and time to time, subject to influences, natural and artificial, that may be progressive or return in cycles, influences that affect the life it sustains, the course it runs, the quality of the waters, and the mud under the waters.

We must determine how much these influences have affected the River during the history of our acquaintance with it; how much these influences have been detrimental to our enjoyment of the River, and to what extent detrimental influences are preventable. We must ascertain the nature of the complaints made about the River, the evolution of these complaints, and determine the cause from which they have arisen. Having determined the cause we must seek the influences inducing it, and determine to what extent they are natural or man-made, and irrespective of whether they are natural or otherwise, decide to what extent their eradication is practicable and desirable.

A brief review of the history of recorded complaints about the River will assist in the forming of an opinion concerning the conception of pollution in the public mind, and to what extent such may justifiably be considered pollution. In 1801 Monsieur Bailly undertook an exploration of the River and in an account of his experiences published in "A Voyage of Discovery to the Southern Hemisphere" (1809), in describing the River in the vicinity of the present Causeway, states:—

> On the 18th of June, at the break of day, we re-embarked to continue our voyage. On leaving the place where we had spent the night, we again met with great numbers of pelicans, which came and flew about us; we killed two of them, after which pursuing our way for about half an hour we found ourselves aground on a shoal of soft mud, extremely greasy and sticky; we had much difficulty in dragging our boat off this shoal, which at length we did after much labour.

On their way down the River they again ran aground at this spot and—

> For above 13 hours we had been in the mud up to the waist, striving ineffectively the whole time to save our boat.

It would therefore seem that there were mud troubles before the advent of the white man.

The following are extracts from a local newspaper of 1870:—

"THE INQUIRER AND COMMERCIAL NEWS," Wednesday, March 23, 1870.

Local and General News. Page 3, Column A.

Our attention has been called to the accumulation of large masses of seaweed in the river, extending from Mill Street to William Street jetties from which most intolerable stenches arise. This is a matter requiring the immediate attention of the Inspector of Nuisances.

"THE INQUIRER AND COMMERCIAL NEWS," Wednesday, March 30, 1870.

"Health of Perth."

Mr. Editor,

I, as a citizen, felt extremely obliged to you last week for calling the attention of the Inspector of Nuisances to the fact of the existence of a large collection of seaweed in the river near Mill Street jetty, from which arose a most abominable stench, to the annoyance of the dwellers in the neighbourhood and even to many residing as far back as Murray Street.

Sergeant Dale, active, and ever willing to do all in his power to fulfil the arduous and sometimes very unpleasant duties of his office, I can testify, took immediate steps on the matter being thus brought to his notice, and with the cooperation of our worthy Chairman of the City Council, very soon put an end to a nuisance which, if disregarded, might have remained in our memory to our sorrow. This, Sir, affords a proof of the necessity of every one, whether directly interested, or I may say, annoyed, as some will have it, or not, to inform the Inspector of any accumulation of deleterious matter which may be injurious to the health of the people. "Cleanliness" it is well said "is next to godliness"; and from the natural result of climatic influences, with no very great anxiety for cleanliness in some localities in the city, it behoves us one and all to assist Sergt. Dale in every possible manner, if we would have ourselves and our neighbours enjoy good health. Etc., etc.

"Perthite."

The algae nuisance is then not a new thing, and few of us have youthful impressions of the River prior to 1870. We cannot however but regret that Sergt. Dale is no longer with us and that history has not seen fit to describe his methods in more detail.

The following literary effort appears in "The West Australian" of 7th January, 1904:—

THE POLLUTION OF THE SWAN RIVER.

To the Editor.

Sir,

Despite the flexibility of the English language and its power of expression, it would appear that a fresh stock of adjectives was an imperative necessity to enable the average individual to express himself or herself with propriety, tempered by a moderate amount of protestation. For instance, what used to be called pure air often appears under the guise of "God's glorious oxygen" and occasionally manifests itself—when in a state of unusual activity—as "ozone". It is then usually heralded by superlatives of infinite power of qualification. The other evening I walked along the Swan River, where it is joined by other tributary streams, (notably those upon the banks of which are built the Swan and Stanely Breweries). The tide was very low, and I was almost paralysed by the amount of good able-bodied "ozone" I encountered. Seriously, it is a pity that Mt. Eliza, with its unrivalled background of a natural park, with its locomotive facilities for all kinds of vehicles, its views of forest glade and river to gladden the eyes and heart of man, should have issuing from its base such foulness and impurity as may be seen and felt by anyone who walks along Mounts Bay Road and thinks what it might have been and what it is. In reading Mr. Charles Faber's letter in "The West Australian" in which he confidentially expresses his ability to have certain obstructions removed along the foreshore, one thinks of the doubt expressed in the eyes and voice of Captain Cuttle, at Susan Nipper's expressed desire to deal violently with his landlady, Mrs. MacStinger, "Would or will you really, my dear?" I quote from memory.

Yours etc.,

J. M. KELLY.

Perth, December 5.

Thus fifty years ago the vicinity of the Swan Brewery was suspect of even more pollution than it is today.

The following extract from "The West Australian" of 13th August, 1908, is reproduced among other things for the encouragement it may give to a much maligned organisation and to indicate at least one improvement on Nature that the White Man has performed on the River.

"THE WEST AUSTRALIAN," 13th August, 1908, Page 6, Col. D.

THE SWAN RIVER FORESHORE.

To the Editor.

Sir,

With regard to the alleged desecration of the foreshore of Perth Water, I think it is about time that someone took up the cudgels for the Public Works Department and pointed out to the public of Perth the good work that they are doing. For some time past we have been reading criticisms from the city councillors and remarks that the beauties of the River were being destroyed. But it might interest the ratepayers if they were made aware of a few facts of the case, and it were pointed out to them what the Public Works Department had done and what the City Council had not.

At that time the Council claimed that the boundaries of the municipality were the South bank of the river and therefore the North foreshore was under their control. What was the state of affairs then? The foreshore consisted of mud-banks for the most part, and from Barrack Street, East, there stretched a beautiful straight line of dilapidated back fences, and the only people who had access to that part of the river were the fortunate property holders in St. George's Terrace. The Public Works Department came to the rescue and their first desecration was the splendid Esplanade Recreation Ground as existing at present, which is the resort and pleasure grounds of thousands of Perth's citizens; then the beautiful Barrack Street square, with the imposing boat-houses, which make the river approach to Perth one of the finest of any city in the States. Both of these have been handed to the City of Perth to be held in trust for the citizens for ever.

Then Eastward of Barrack Street was resumed a large area which will be one of the finest promenades in any city in Australia; the rowing clubs were compelled to put up sheds which are a credit to the city instead of an eyesore as they were before, and the ground resumed between Barrack Street and Victoria Avenue handed likewise over to the City Council to be held in trust for the people and instead of that portion of the river being inaccessible to, it is now available for, the public, and instead of malodorous mud-banks ending in a backyard, we have clean water owing to the retaining wall which has been built and the dredging which has been done by the alleged vandals, the Public Works Department.

Now let us see what the Council, who propose to keep intact the beauties of the river, have done. As I said before, the resumed land between Barrack Street and Victoria Avenue has been handed over to them. Certainly they have planted a few trees on it, and in addition have enclosed a portion of it with a high fence to keep out the public to whom it belongs, in order that it might be utilised by an emu which looks so miserably lonesome I think it might be presented to the Zoo, and the other portion does not want fencing, as it is a barren sand waste, which only requires levelling and covered with street sweepings and planted with couch and we will have immediately another playing ground for our young people equal to the Esplanade itself.

I should now like the public of Perth to say which they would rather have, the straight line of dilapidated back fences which keep the people away from their birthright—the beautiful river—and the low malodorous mud-banks, or, as it should be at present, the grand stretch of garden and playground with the fine promenade and the river kept clean by means of the retaining wall and dredging?

It is a pity for the residents of Claremont and Peppermint Grove that the later authorities in the Government had not the foresight of Captain Roe and made it possible by the wording of the titles that steps could be taken to reclaim more of the river in Freshwater Bay.

Yours etc.,

PERTHITE.

Perth, December 12.

In 1912 the effluent from the sewage treatment plant at Burswood was discharged to the river at that point above the Causeway.

This was a form of pollution easily appreciated by the general public and served as a focus for all their complaints about the River for many years. When the sewage was re-directed to the ocean outfall in 1936 complaints were still voiced but attention drawn to other influences and malpractices which were said to affect the condition of the river.

In February, 1913, Inspector Rodd of the Maylands Local Board of Health wrote to the Acting Commissioner of Health as follows:—

Dear Sir,

I would draw your attention to the polluted condition of the River fronting Kirkham Hill Terrace at Maylands, some half mile of foreshore is covered with a filthy green vegetable growth, and the decaying matter in connection with same is covered with millions of flies and also maggots, the stench arising from this place is causing great complaint by the residents in the vicinity. The oldest settlers never remember anything like it. Mr. Berryman and others who have built fine residences, and have been living here for some seven years also testify to the fact, that only since the filter beds were placed at their present position has the nuisance occurred. I am sending a sample of what is to be found at the place in question. Trusting something may be done to abate this fearful nuisance.

I remain, etc.,

J. A. RODD.

And again in March, 1913:—

To the Deputy Commissioner of Public Health.

Dear Sir,

For your information regarding the question recently brought under your notice concerning the pollution of the River foreshore at Maylands. The following is a copy of letter received by my Board from Mr. J. Shaw of the Railway Department and who has a residence facing the river. He says, omitting the first part of the letter. "The matter accumulating comes from the vicinity of the Septic Tanks. It has a most offensive smell. The peculiar effect caused by the vapours arising has changed the colour of the inside of my rowing boat which was Red to Black. The other day I noticed that the offensive matter complained of was being stirred up near the Tanks, and on Sunday the 2nd it could be seen floating up the river in patches." I thought the above information might be valuable in connection with any inquiries being made.

Yours etc.,

J. A. RODD, Secretary and Inspector.

A Health Department Inspector visited the area and reported—

The complaint of a nuisance is well founded, and is caused by large masses of vegetable growth which have apparently drifted into shallow waters of that locality and evolve offensive gases.

Dr. F. Stoward of the Agricultural Department was asked to investigate this vegetable growth. He did so with considerable thoroughness, and in August, 1913, issued an extensive report which is still of considerable interest to this day. His report is given at length in Appendix I, but in brief he formed the opinion that the smell arose from decaying algae, that the algae decayed because of seasonal changes in the River, that calm waters favoured their growth, and shallow backwaters their collection and decay. He considered that sewage effluent might stimulate their growth but that even without such effluent the topography of the River in that area was such that recurrent algae growths would occur.

He suggested that improvement might be brought about by removing barriers to the flow of the River and by treating the algae with copper sulphate.

In 1913, the complaints spread, and were received in addition to Maylands, from Perth Road Board and from the Council of Victoria Park. The complaints however referred to the same stretch of river, and in November of that year a deputation waited on the Minister for Works with objections to the filter beds and their effluent.

Thus a little more than a year from the institution of the filter beds there commenced a controversy which was carried on with considerable bitterness by Local Authorities, private individuals and the press against various Governments and their Departmental officers. In vain did scientists and technical experts express opinions in favour of the system. For 20 years every evil of the River was a result of the filter beds. The War of 1914-1918 brought no respite; the war on the River and the filter beds went on unmitigated and oblivious.

It says much for the courage and capabilities of the Departmental Engineers that they refused to give way to the constant propaganda levelled against them, or adopt one of the precarious alternatives constantly being proposed by those with little technical knowledge for making such decisions.

In May, 1916, a meeting of the following Local Authorities was held, Perth City Council, South Perth, and Victoria Park Councils, Perth and Maylands Road Boards.

They decided to obtain an injunction against the Minister to abate the nuisance and allow only clean discharge into the River. The Attorney General however refused to take action and the matter was put in abeyance by a change of Government. With a fine discrimination of political neutrality however the River continued to give off offensive odours—and so the war went on. During the 1916-17 period the role of the algae seems to have been lost sight of and many interested persons spent considerable time investigating the filter beds to ascertain the source of the offensive odours, but without success.

Amid all the pedantic claims of amateur investigators a letter to the Minister of Water Supply from a lady in West Perth indicates a more realistic approach to the problem.

West Perth,

May 10th, 1917.

Sir,

I think you are probably quite right in thinking that the smells at Burswood may have nothing to do with the Septic Tanks. I do not know if you have ever been to Weston-super-Mare in England, but the smell there at low tide is simply awful, and yet it is one of the healthiest seaside resorts in England.

To come nearer home, when the wind is South, there is a most dreadful stench at Cottesloe Beach—a lady who stayed there for the first time this summer was horrified at first and thought of leaving, but I told her it had been just the same for 17 years that I know of and no one seemed any the worse.

Of course, not being an expert, I cannot say there is nothing wrong with the tanks, still the two cases noted above may lead to some light on the subject.

Yours faithfully,

L.B.S.

P.S.: It would not be a bad plan to find out from the health officer if typhoid and such kindred diseases are more prevalent in East Perth than in other parts of the City.

In August, 1919, the Town Clerk of the Municipality of South Perth wrote the following letter to the Government Analyst:—

Dear Sir,

A weed growing in the Swan River has recently been giving rise to very offensive smells and my Council would be glad if you could advise as to means of eradicating it or preventing its spread.

The nuisance is noticeable just now at the Victoria Park end of the Causeway where a lot of the weed has accumulated and is decomposing on the banks.

Naturally at low tide the trouble is most in evidence because the sun acts directly on the accumulated stuff.

If the growth is not checked or the offensive smell overcome, it will seriously affect the river surroundings, and the Council's object in writing is to ascertain whether you would be good enough to investigate this matter, examine the weed, and report upon the best means of eradicating it.

Trusting to hear from you at your early convenience,

I am,

Yours etc.,

RAY CARGEEG,

Town Clerk.

The Government Analyst had nothing to add to Dr. Stoward's report except that he thought that during cold weather the sewage effluent might stimulate the algae, and in the hot weather kill it off by oxygen deprivation. The Commissioner of Public Health and the Government Analyst then embarked on a series of tests of the river water at Bunbury Bridge and Mill Point to determine the amounts of dissolved oxygen. Nothing very conclusive seems to have arisen from those tests, except that there was more oxygen in the water when a breeze blew and the water remained cool.

Although nothing further appears on the files until early 1922 one gathers that the antipathy towards "pollution" grew and spread, because on the 7th March of that year a "Conference re Alleged Pollution of Swan River" was held in the Council Chamber, Town Hall, Perth. Mr. J. W. Paterson, Chairman of South Perth Road Board was in the Chair and the members numbering no less than 34 represented Local Authorities and Aquatic Clubs throughout most of the length and breadth of the Swan and Canning estuaries. The scientific aspect of the question was not neglected and was represented by Prof. E. Nicholls, Dr. E. Atkinson, Commissioner of Public Health, Mr. F. W. Lawson, Eng. M.W.S.S. & D. Department, Mr. E. Simpson, Government Analyst. The proceedings of this meeting along with reports presented by Prof. E. Nicholls, Dr. Atkinson and Mr. Lawson are given in Appendix II and are worthy of study because of the interesting light they throw on the attitude towards the problem 30 years ago.

The technical experts clearly expressed their views but the Local Authority representatives maintained that the offensive weed had only arisen since the construction of the Burswood Septic Tanks, and the trouble would not abate until the sewage was carried out to sea.

This claim found little or no support in the reports of Prof. Nicholls, Dr. Atkinson, or Mr. Lawson. It is not without interest to note that from 1913 to 1919 the complaints had been confined to the area of the Causeway and filter beds, yet in 1922 Authorities all up and down the River were represented at the Conference, and in Prof. Nicholls' report it will be seen that there was abundant weed or algae growing and floating throughout the salt water reaches of both the Swan and Canning Rivers. If the algae were a disease spreading from the filter beds, it is difficult to understand this sudden jump in the extent of infestation from 1919 to 1922, and how even the strongest critic of the filter beds could reconcile the vast spreading of algae to Fremantle and far up the Canning estuary in the 10 years that had elapsed since the effluent from the Burswood treatment plant was first discharged into the River.

Of special interest is a Swan River Conservancy Board recommended by Dr. Atkinson and supported by Mr. Lawson. The Board was to have Statutory powers for the prevention of pollution and for river improvement. Surprisingly enough when put to the vote this suggestion was rejected. The records give no indication as to the reason.

The Conference however appointed a sub-committee of seven members (five from local authorities, and two from Yacht Clubs) to obtain full information on the subject under discussion and report to a further Conference meeting. Although the Pollution Conference or a section of its members seems to have remained active for several months, and led at least one deputation to the Acting Premier, there is no record of the information collected by the sub-committee, and further activity by this body seems to have been curtailed by the advent of Col. Longley.

In the interim, however, a specimen of the black foul smelling mud from the River was examined and reported on by the Government Mineralogist and Analyst. His report in Appendix III may do much to discredit the popular belief that this mud is an accumulation of waste discharged from State Industries.

Colonel F. F. Longley was assigned by the International Health Board of the Rockfeller Foundation to the newly created Commonwealth Department of Health as an "Advisory Expert in Sanitary Engineering" to assist in the development of Health administration in Australia. His services were offered free of charge to the W.A. Government.

A letter from the Acting Premier to the Prime Minister dated 11th July, 1922, gives in a few sentences a very clear picture of the situation at that time thus—

July 11, 1922.

The Right Honourable,
The Prime Minister of the Commonwealth,
MELBOURNE.

Dear Sir,

With reference to your circular letter in regard to the availability of certain Advisory Experts, I have to advise you that there is one problem in regard to which it appears that this State might well accept the offer made by you, and that is in connection with the alleged pollution of the Swan River by the filtrate from the septic tank and filter bed system of sewage disposal which operates in the metropolitan area of Perth.

This pollution is not so much alleged to be directly due to the filtrate as to the growth of Algae said to be encouraged by it.

For some years a strenuous controversy has gone on between the public and departmental officers, receiving a new impetus each year, when, in the summer, the weed dies, becomes detached, and is washed up in a putrid state upon the foreshore, where considerable nuisance results.

It is claimed by departmental officers that, with the extension of settlement and cultivation along the river and its tributaries, the river acquires from the silt and drainage brought down quite sufficient nutritive material to maintain the growth of algae, quite apart from that which enters from the septic tank system, and they claim further that only the deepening of the river channel and the reclamation of the extensive shallows which act as incubation beds, will bring about the disappearance of the weed.

The public, on the other hand, will not accept this statement, and place the whole blame with the filtrate from the sewage system.

As its river is Perth's greatest asset you can well imagine that this state of affairs is causing considerable concern, not only to the citizens but to the Government. At the same time, the latter does not wish to see condemned, and perhaps unjustly incriminated, a system of sewage disposal which has been installed at enormous cost and which gives good results as regards purification. For a non-putrescible filtrate with a low "solids" content alone reaches the river, where considerable dilution occurs.

A stage has now been reached which is virtually a deadlock, and all parties concerned would welcome an independent, unbiassed, expert opinion, which your offer appears to make possible at small cost to the State.

With a view to your expert acquainting himself fully with the position, I am submitting, under separate cover, a file which contains both press cuttings and official reports covering the whole controversy, together with a map of the Swan River showing soundings, etc., and other necessary information.

If, after perusal of these papers, your expert is prepared to visit this State and advise, I need hardly say that his opinion will be much appreciated, whilst every effort will be made by State officials to assist him in arriving at a conclusion which shall represent the true position and be generally accepted as a guide to future action.

Yours faithfully,

ACTING PREMIER.

Colonel Longley paid his first visit towards the end of September, 1922, and his second and last visit in January, 1924. An atmosphere of restraint prevailed during this period while awaiting his report. It was obvious however, that the rediscovery of the algae had spread far and wide. South Perth Road Board spent considerable sums on cleaning algae from Como Beach, and a deputation from Claremont Council on River Algae was seen by the Commissioner of Public Health. A member of the Legislative Council requested the Premier to grant Government assistance to Local Authorities for clearing weed on the basis of £ for £.

The interim between the two visits of Col. Longley was taken up in the collection of a great amount of analytical data requested by him. Unfortunately for his purpose this data was incomplete because of the lack of equipment and staff to obtain it. The Government steadfastly refused to grant the £600 required to obtain this data, maintaining in spite of the arguments of the general public and departmental officers, that it was the responsibility of the local authorities to find the money, an attitude which caused some adverse criticism in the "Sunday Times" of 17th December, 1922, under the sub-title "A Stagnant Government".

Colonel Longley's report was received in January, 1924, and is reproduced in Appendix IV. In brief his opinion was that the sewage effluent played little part in the formation of algae, and that the vast expense of an ocean outfall was unjustified as it would not remove the nuisance. He suggested that deepening and straightening the channel could be done at a fraction of the cost of providing an ocean outfall, and that the land thus reclaimed would develop a value far in excess of the cost of reclamation.

An air of comparative calm prevailed until 1928 when once again the opposition to the Burswood filter beds broke forth in all its erstwhile fury. The only difference now being that instead of being the direct cause of the odours they were the agent responsible for the growth of the algae. Consequently complaints against them were not confined to the region of the Causeway, but to the length and breadth of the Swan and Canning Estuaries; wherever the algae grew they were the direct result of the filter beds.

The following letter by a prominent citizen in "The West Australian" of 1/2/28, passed unheeded by the general population.

ALGAE NUISANCE.

Not a New Trouble.

To the Editor.

Sir,

I have hesitated to participate in the controversy over the cause of the algae nuisance and the means that should be adopted to minimise or overcome it, but the possibility of public sentiment being moved to such an extent by the assertions of many of your correspondents as to force the Government, against the opinion of their scientific advisers, to concentrate on the Burswood filter beds as the sole cause of the trouble and spend the people's money in a project that will probably leave the weed growing and accumulating in the protected bays of the river just as vigorously as now, prompts me to put in a plea for a more searching inquiry before definite action is taken.

The statements made, that the trouble was unknown prior to the date when the sewage of Perth was conveyed to the septic tanks at East Perth and the effluent finally treated by filtration at Burswood are untrue. Upwards of a quarter of a century ago, that is, before the septic treatment was designed, the Claremont Council was inundated with complaints from residents along the foreshore of Freshwater Bay, where the accumulation of algae, then known by the less euphonious name of "rotten seaweed", was very much in evidence. Questions arose as to whether it was the duty of the council to keep the foreshore clean or whether the residents themselves, whose Southern boundary it was claimed extended to the water, should be "held responsible for keeping their frontages free from the offensive matter. The Council, however, failing to enforce the latter course, employed a man with a horse and cart regularly during the summer months to rake up and remove the weed twice a week. At a later date, but still long before deep drainage was introduced in the city, the Claremont Council, acting on the advice of its then engineer, Mr. Brockway, removed numerous small rocks from the shallow water between the jetty and the college baths and constructed a rough retaining wall near the deeper water. This minimised the trouble, but the weed still continued to accumulate East of the wall, where the natural wash of the river is checked.

I was surprised to notice in your report of the politicians' meeting yesterday that, notwithstanding expert opinion to the contrary and their early day experience, old residents like Messrs. Clydesdale, Lovekin and Nicholson, Dr. Saw and others still apparently conclude that the effluent from the Burswood filter beds is the main cause of the present trouble.

It may be true that the growth of the weed is more prolific now than it was 25 years ago; personally, I doubt it. I distinctly remember crossing the Causeway in the early seventies and noticed the swans selected the clear water between the patches of floating green weed which covered a considerable area of the river East of the Causeway then, and I have carefully compared conditions at

Claremont now with what they were 30 years ago and can see little, if any, difference. If the growth has been stimulated during the past 10 years, rather than accept the prejudiced view of the man in the street, I would suggest consideration of the theory of Mr. Brockway, who attributes the cause to the fact that in 1917 an exceptionally heavy rainfall raised the level of the fresh water in the lakes and flats adjacent to the river higher than it had been for 40 years previously, and that percolation to the river was now through strata charged with vegetable matter containing all the ingredients necessary to stimulate plant life.

It must not be forgotten that another factor affecting the present situation is the number of people residing in the odorous areas, for every person holding his nose and anathematising the authorities 25 years ago, there are at least a thousand now and the volume of complaint is correspondingly greater.

If Mr. Clydesdale's barge raking suggestion were carried out, aided by small reclamation schemes in those sheltered portions of the river where the accumulation is most offensive, I think we could give the filter beds a rest for a season or two.

If members of Parliament care to get an object lesson in the effect of inexpensive reclamation on a small scale, I suggest a visit of inspection of the foreshore immediately East of the Claremont baths.

Yours etc.,

G. P. STEVENS,
Claremont Avenue,
Fremantle, Feb. 2.

In July, 1928, the Engineer in Chief presented the following memo to the Under Secretary for Works:—

1. There is at present no authority controlling the Swan River above the point to which the jurisdiction of the Fremantle Harbour Commissioner extends.

2. It seems desirable that the question of constituting such an authority, as a Swan River Conservancy Commission, should be considered. As time goes on the need for such an authority will become more and more evident and the duties more widespread.

3. The main duty at the present time would be to control the points at which discharges to the river are made and ensure adequate purification before discharge.

4. At present no real control exists, City Council connections are made to M.W.S. storm water drains and trade wastes thus brought in, probably without the knowledge of the latter Department.

5. Neither the Chief Harbour Master, this Department, nor the Commissioner of Public Health have the power to act, nor is it the business of anybody to take action, even though very undesirable effluents may be discharged to the river.

6. The most useful constitution for any new authority is not clear at the present time and possibly the best course at the moment would be to call a conference of those interested. These would include, in addition to this Department, the Harbour and Light, and the Public Health Departments, the Metropolitan Water Supply and probably also the City Council.

The Under Secretary for Works asked the Commissioner of Public Health to nominate an officer for the above.

The Commissioner replied that he would be pleased to attend himself. No record can be found of any further action on the subject.

The Harbour and Light Department and Local Authorities then endeavoured to remove the weed by mechanical means, dredges, rakes and carts. The Government in 1928 granted £1,000 towards this effort. Hundreds of tons of algae were removed with some local improvement but little permanent effect.

In March, 1928, an experiment was carried out by the Chief Inspector of Fisheries, the Economic Botanist and Pathologist, the Engineer for Metropolitan Water Supply, Sewerage and Drainage, and the Government Mineriologist and Analyst.

They tested areas of algae in the river with applications of sulphur dioxide and with copper sulphate. They summarise their report thus:—

> After considering the matter carefully in all its aspects the Committee is of the opinion that it is impracticable to reduce the growth of weed, or lessen the nuisance it creates, by treating the shallows with sulphur dioxide or other plant poison as suggested by Mr. Gillies.

The following optimistic note appears in "The West Australian" of 12/5/28:—

> REMOVAL OF ALGAE.
>
> The work of removing algae from the Swan River in the vicinity of Bunbury railway bridge has ceased for the season. Nearly 400 tons of algae were removed, and it is claimed by the Public Works Department that the situation that existed during last summer has been very materially relieved, by an expenditure of £300 of the £1,000 allotted for the purpose by the Premier. The first flood waters it is considered, will afford further relief by carrying what is left of the algae into the ocean. The work of clearing the algae will probably have to be repeated annually, it is thought, until the dredging has progressed sufficiently to rid the river of the algae growth.

The algae, however, continued to flourish and year by year the outcry went on unabated against the algae and the filter beds that were popularly thought to induce their growth. Apart from smells the algae and the filter beds were also blamed for sore throats, bad ears and infected sores. An extract from "The Mirror" of January, 1932, sums up the popular opinion:—

RUINING THE RIVER.

Practical people have become tired of the conflicting testimony of experts on the subject of the pollution of the Swan River.

Much evidence—not absolutely convincing—has been called to show that the effluent from the filter beds has not introduced a means of infection into the Swan River and that, furthermore, it is not a menace to health.

On every occasion when the condition of the Swan comes up for discussion this testimony is quoted as if it were the last word on the subject.

But it isn't.

Even if we believe those experts who say that the algae in the Swan is not a menace to health, and ignore those on the other hand who maintain that it is, we have not reached a settlement.

The plain fact that still faces us is that before the instalment of the filter beds there was no filthy looking green slime and other offensive matter spoiling the beauty of the river, and there was no nauseating smell arising from the water.

Today both of these objectionable features exist, and they are destroying the comfort of dwellers in what were once our most charming riverside spots, and at the same time seriously menacing the assets of property owners in several suburbs.

If the charge of being a menace to health is still disproved as far as the filter beds are concerned, it is still quite obvious that they are ruining the river.

With the increasing burden placed on this system, its effect on the river is becoming worse each year, and before long the Swan that was once Perth's greatest asset, will become its chief eyesore.

There is only one remedy. The sewage must be diverted into the ocean and there will never be any solution of the present problem until the ocean outlet is made possible.

In March, 1933, a resolution was passed at the annual meeting of South Perth ratepayers recommending to the Road Board that the Government be asked to remove the sewage filter beds in the Swan River. Speakers declared that the beds were largely responsible for the accumulation of algae, because the beaches at South Perth and Como years ago had been perfectly clean, but now were polluted with algae.

By this time extensions of the sewerage system were getting beyond the capacity for the beds and the Government was faced with expensive additions to them, or an alternative means of disposal. The Government very wisely decided to proceed with an ocean outfall, thereby acceding to the popular demand and at the same time giving employment to a large number of men during the critical depression years.

With due ceremony and public rejoicing the new system was officially inaugurated on 27th November, 1936, and the filter beds were a thing of the past, the last effluent reached the River from them on 21st December of that year. The algae, however, are still with us.

The ensuing peace on the river front was extremely brief.

In April, 1937, a letter from the Local Government Association to the Under Secretary for Health contained the following:—

> At the last general meeting of the Association, as the result of a letter received from the South Perth Road Board, consideration was given to the prevailing large algae nuisance, particularly along the foreshores of the Swan River.
>
> As the result of the discussion I was asked to write and advise you of the receipt of the complaints and ask that the Department might make scientific inquiry into the cause and remedy of the trouble.

In view of the fact that scientific opinion had been derided for 20 years, and bearing in mind the dogmatic reasons for growth of algae given in the last report of affairs in the South Perth Road Board—reasons which had been extensively used as a lever to force the Government into an expensive undertaking—it is somewhat astonishing to find that a scientific investigation was now requested.

World War II intervened before an organised discussion in any one particular direction could develop and complaints during that period were desultory and not sustained. With the end of the war, men's minds again turned to the problem of the prevention of despoilation of the River. Complaints however, have never reached the intensity or unity of purpose of the filter bed era. Whether this is due to an actual improvement in the River, or due to a lack of focus on which to direct an attack, is difficult to assess.

During the time of the filter beds, whether the complaint was of odour, algae or sore throats the cause invariably given was the filter beds. Now various sources of pollution were hunted out and decried with varying popularity from time to time.

The most popular were the harbour with its ships and wharf latrines, the wool scouring at Fremantle, the abattoir and workshops at Midland Junction, various stormwater drains that carried industrial effluent, the Gas Works' industrial and septic tank effluent, the acid in discharges from superphosphate works and the effluents from breweries. Occasionally reports are received of masses of faeces seen floating in the river, particularly near the exits of storm water drains, or in back creeks. When examined more expertly and dispassionately, they almost invariably prove to be algae.

In addition to concern regarding odour, algae and infection of bathers there has also arisen a more positive drive to improve the beauty of the river by channeling, reclamation, and prevention of unsightly contamination and discolouration by flotsam and jetsam and industrial effluent. Most important of all it has eventually been realised that the degree of purity and beauty demanded by the public for the River must influence the whole manner of development of the Metropolitan area, its roads, buildings, drainage and siting of industries. Purity of the River in other words is an integral part of, and inseparable from, Town Planning of the Metropolis.

In view of the plan to be hereafter suggested the following memo dated 12th February, 1948, from the Commissioner of Public Health to the Under Secretary for Works is of considerable interest:—

> I am returning herewith your file on pollution of the Swan River.
>
> I am of the opinion that no intelligent determination of this matter is possible until a complete survey by competent officers has been made of the sources of pollution throughout the River's length.
>
> Confronted with this data it would be possible to tabulate the varieties of pollution reaching the River and to study practicable means of eliminating them or for arranging alternative methods of disposal. Where this is impossible, the amount of dilution to which pollution is subject could be estimated with a view to determining the risk likely to be occasioned by it.
>
> Apropos of this matter I should like to take this opportunity of calling your attention to the pollution of rivers in W.A. other than the Swan, and to invite your views upon the setting up of an authority which will be responsible for controlling river pollution throughout the State.

In his reply the Under Secretary for Works said—

> You are no doubt aware that £300 has been voted to enable preliminary investigations to be made and data secured to formulate plans for combating the nuisance. It is felt that the Swan River Reference Committee in which are representatives of most institutions having direct interests in the Swan River and on which it is hoped a representative of your Department will sit, is a satisfactory organ to carry out such preliminary investigation and make recommendations.
>
> It is noted that you have advocated that the control of all rivers in the State should be under one authority, but I would in this connection, state that the Director of Works is doubtful if the time has yet arrived for rivers other than the Swan to be closely studied with regard to pollution.

The Swan River Reference Committee which had recently been formed to discuss matters appertaining to the River other than pollution was expanded towards the end of 1948 to include technical officers from the Health Department and Chemical Laboratories, and an increased representation from Local Authorities. The main subject of its deliberations from then on has been the control of pollution.

As regards its activities concerning pollution and in addition to the survey of the condition of the waters which will be dealt with in another chapter, the following improvements have been brought about largely through the instrumentality of the Reference Committee.

1. The wharf side latrines have been connected to septic tanks.

2. Gas works industrial wastes treated and all effluent along with septic tank effluent wholly disposed of in the sewer.

3. The majority of noxious trade wastes removed from storm water drains and disposed of in sewers after suitable treatment.

4. Superphosphate works discharges treated to reduce acidity to acceptable level for discharge to river.

5. Abattoir effluents disposal of on the land until such time as new construction now in hand permits of more satisfactory disposal.

6. Financial assistance to local authorities for the removal of algae from the foreshores and an Inspector has been employed during the summer months to patrol the river.

7. Testing of mechanical methods for removal of algae.

8. Sewers have been extended as in Midland Junction thereby reducing contamination from improperly functioning septic tanks. Wherever possible all known septic tank effluent entering the river has been disposed of otherwise.

9. Samples of river water have been regularly taken from selected points and subjected to chemical and bacteriological analysis.

10. In addition to these there has been a continued slow progress of reclamation going on along the river and building of sea walls, thereby reducing the shallows and beaches in which the algae collect and decay.

All this has led to a great improvement in the quality of the river water but on the debit side must remain the increasing size and density of the Metropolitan population, and the increased drainage from the areas inhabited and the industries maintained. Above all is the effect of intensive cultivation and increase.in the use of fertilizers in the drainage basin.

From all this it will be seen that, in the main, the popular conception of pollution concerns itself with algae and the smell arising from them and from the mud, infection of bathers and contamination from industrial wastes.

These matters will be dealt with in separate chapters.

chapter ii

A description of part of the Swan River system and factors influencing its character

G. H. LOW, B.Sc., *Geologist,*
Geological Surveys Branch, Mines Department, Perth, W.A.

The popular name for the waterway which lends such scenic beauty to Perth and its environs is the Swan River. To be technically accurate the term river requires qualification. Actually in its lower reaches, at least as far as Perth, and possibly as far as Guildford, it should be termed an estuary. The same applies to the Canning up as far as Riverton Bridge. Beyond Guildford and Riverton, the Swan and Canning are intermittent rivers, since they flow only at times of flood. However, for briefness in this report, the word intermittent will be omitted, and the terms river, stream, and brook, used without immediate qualification.

The name Swan-Avon River will be used to refer to the Swan above Guildford and to its extension, the Avon, as far as its source near Wickepin. The Swan River System, or the Swan System, means the Swan River with all its tributaries, the Swan Estuary, and the Canning with its tributaries. When reference is made to the Canning, it means the entire course of that waterway down to its junction with the estuary at Riverton.

There are several factors which have influence on a river's character. These are termed environmental factors and it will be as well to consider them briefly before examining the Swan System in detail. The factors concerned are physiography, diastrophism, climate, fire, close-pasturage, cultivation, and geology.

Physiography has a great influence on stream velocity and the position of the water table. Where the relief is rugged, and providing the rocks are pervious, the water table will ordinarily be far below the surface of the higher parts, with the result that there is a thick zone given over to soil water, and a consequent increase in the amount of leaching and removal of colloids and solubles. Under these conditions stream velocities are strong and the waters are better able to gather and transport all types of sedimentary material; that is, they have maximum competencies and capacities.

Where the relief is low, movement of the surface waters is sluggish, and they have correspondingly low competencies and capacities. The water table is then close to the surface and the depth of weathering is not great.

There are three stages in physiographic development. These are physiographic youth, maturity, and old age. In physiographic youth rivers are young and fast flowing in narrow and often straight channels. In maturity, streams wander through their valleys, which are broad and gently sloping. They often overflow their banks to deposit alluvium on flood plains. In old age, streams meander slowly through their own flood plains. In this latter stage the suspended and tractional load is negligible except in time of flood.

The physiography of the coast line, both from the point of view of its elevation above sea level, and its irregularities, has great influence on the nature of the sediments deposited in the lower reaches of the river, and on the marine life there. Where the sea has transgressed across a flat land, as is the case on the Coastal Plain, the shore line is regular and even. Coastal waters are liable to be shallow for some distance from the shore. Unless rivers flowing on to such a coast are young and vigorous, their estuaries tend to become filled with sediment. There will, however, be certain areas protected against the entry of much sediment, at least during part of the year, and these areas are likely to support luxuriant floras and faunas. Where sedimentation is rapid or prolonged or where currents are strong, the waters will be almost barren of life.

Diastrophism, or earth movement, is an important factor. It is this which has, by elevation of the plateau, brought youthfulness to certain sections of the Swan System. Submergence of the coast line caused the transformation of the lower parts of the Swan and Canning into an estuary.

Climate is important as it governs the rainfall, and also affects the rate of production of sediments. In the case of the area under consideration, the climate is one of seasonal dryness. During the time of no rains, the ground becomes thoroughly dry and cracks open to variable depths. This results in a reduction in level of the water table, and makes for easier soaking up of early rains.

Vegetation, which depends upon the climate, has an important bearing on flooding. A good cover of vegetation will prevent the too rapid run off of excess surface water into the streams, thereby giving them a chance to drain the area without overflowing their banks. Regions that had constantly flowing streams before the removal of natural timbers may be devoid of perennial streams after cultivation.

Fire, close pasturage, and cultivation must be considered as factors liable to influence a river's character. A forest fire may kill not only the trees, but also the accumulation of vegetable litter on top of the soil. This makes possible the rapid removal of the loose soil cover, particularly on the slopes where the rooting system is in itself not sufficient to arrest erosion. Close pasturage and cultivation have essentially the same effect as fire, in that they render the soil cover more liable to erosion by removal of its natural protection.

River valleys and flood plains are favoured areas for the grazing of stock. Consequently there has been, since the advent of settlement, a greater concentration of animal droppings and refuse in the immediate neighbourhood of river channels. All soluble compounds from these find ready access to the streams and considerably increase the concentration of such compounds already present from other sources.

Up to the point where they flow on to the Coastal Plain the various members of the Swan River System constitute the drainage of an area which is composed of a complex of granites, gneisses, schists, and basic intrusives. This area, except where it is exposed by erosion, is covered by weathering derivatives in the form of soil, or by a layer of laterite, both of which vary considerably in depth. Waters draining such country commonly carry in solution the ions CI, SO_4, CO_3, and Na. Other ions such as K, Mg, Fe and SiO_2, are generally present in lesser amounts. These crystalline rocks are, for the most part, massive, and except for openings provided by joints and cracks, are generally impervious. The cover of soil and weathered rock contains many openings which may contain water, but since this cover is relatively thin, the quantity of water held in this fashion is not great. The result is that the underground water which supplies the springs at the heads of tributaries is rapidly exhausted after the cessation of rains and the streams "run-dry".

After leaving the crystalline complex of the Plateau in the neighbourhood of Upper Swan, the Swan Avon River flows out on to the pervious sediments of the Swan Coastal Plain. It enters the sea at Fremantle after flowing some 30 miles with a drop in elevation of about 40 feet, practically all of which is before it reaches Guildford.

A considerable quantity of water is lost from the streams as they flow on to the Coastal Plain. A. Gibb Maitland, writing in 1919 on the artesian water resources of Western Australia, reported that gauging stations on the Helena River at Midland Junction and Greenmount showed the river to be losing a calculated amount of 22,000,000,000 gallons annually between these two points. The river at Midland is flowing on the sedimentary deposits of the Plain, while at Greenmount it is still on the crystalline rocks of the plateau.

It is reasonable to assume that a considerable amount of water from other streams, including the Swan itself, and the Canning, disappears underground near where they flow off the crystalline rocks. Although no figures are available, it is possible that further away from the scarp the streams may not lose so much water in this manner. Near the scarp many of the sediments consist of coarse material such as sands, grits, gravels, and conglomerates, which, due to the larger spaces between individual particles, are extremely pervious. The finer sediments such as silts and clays which are less pervious, or even impervious, can be expected to occur in increasing quantities towards the coastline.

In the succeeding paragraphs, the Swan-Avon River will be briefly traced from its course to the sea. Other major streams such as the Brockman, Helena, and Canning will not be treated in the same way, since the general description of conditions along the Swan-Avon mostly applies to those also.

The Swan-Avon River arises near Wickepin, on the Plateau, at a height of approximately 1,100 feet above sea level. This area receives, on an average, 15 to 18 inches of rain annually. The greater part of the length of the river receives from 18 to 30 inches annually. There are favoured spots near the top of the Scarp which receive up to as much as 45 inches. This considerable rainfall falls mostly between the months of April and August, the average number of wet days per year being about 90.

The river flows off the Scarp and on to the Coastal Plain at a point about two miles East of the township of Upper Swan. The distance between this point and its source is approximately 110 air miles, or about 180 miles as the river flows. From Upper Swan to the sea at Fremantle is 25 miles in a direct line, or about 31 miles along the river channel. The area drained by the Swan is some 13,000 square miles, the much greater portion of which is on the crystalline complex of the Great Plateau.

The principal tributaries in the North are the Brockman River, the Toodyay Brook, and the Mortlock River; and in the South the Helena River, the Canning River, and the Dale River.

In tracing the river from its source to the sea, the following broad classification prevails: Youth, from approximately Wickepin to Yealering; Maturity, from Yealering to approximately Northam; Youth again from Northam to Coastal Plain near Upper Swan: and old age from Upper Swan to the sea.

From Wickepin the stream follows a fairly straight course in a North-Easterly direction to about four miles past Yealering, where it enters Noonalling Lake. During the wet season the tributaries in the Wickepin area are slowly proceeding with headward erosion in a South-Westerly direction towards the headwaters of the South branch of the Avon. Although this section of the river is young, the volume of water carried is not sufficient to permit rapid or severe erosion.

From Yealering to the vicinity of Northam the stream meanders across the plateau falling only about 440 feet in a distance of some 90 odd miles. The country through which it passes is mostly open agricultural land from which a good deal of the natural vegetation has been removed. The stream, when flowing, may be either degrading or aggrading, and flows in wide, shallow valleys, meandering through flats of its own alluvium. The South branch of the Avon joins the major stream about 10 miles North of Brookton after flowing for some 45 miles in a North-North-Westerly direction from near Debeling Rock.

At Northam and Toodyay the river meanders through wide valleys, which have gently sloping sides, but from a few miles past Northam to Toodyay, and from just North-West of Toodyay to where it reaches the Coastal Plain, the river channel is a gorge. On this stretch, a distance of about 50 miles, the river falls approximately 450 feet. In some localities the grade is quite acute over a short distance and there is a development of rapids, and even falls. The disturbed water at these parts becomes aerated to a certain degree and is subsequently sweetened. The Swan-Avon River is joined by the Brockman, which flows in from the North, about 10 miles from its entry on to the plain. The tributaries assume the character of the Swan-Avon at that part of the river which they join.

Studies of the movements of both surface and underground waters North of the Swan on the Coastal Plain show that at least as far North as Wanneru, the regional trend of drainage is to the South-West. For a shorter distance South of the Swan the drainage is to the North-West. This is to be expected since all coastal unconfined waters in the neighbourhood of Perth, which have no direct outlet to the sea, must ultimately enter the Swan, either by surface run off, or by the less obvious method of lateral percolation.

These waters carry into the Swan the elements of any soluble compounds they meet on the way. Important sources are soluble or colloidal size inorganic matter, refuse dumps, open sewers, the products of vegetable decay, and decaying remains of animals. Some of the peat swamps of the metropolitan area are a prolific source of solubles derived from the decay and resultant breakdown of vegetable matter. Waters from a number of swamps North-West of Upper Swan are drained directly into the Swan by Henley and Ellen Brooks, and there is a number of other swamps from which overflow waters enter the Swan.

When the Swan is flowing these solubles are effectively dispersed but when the Swan is not flowing, or is barely so, there must be local areas when the concentration is quite high.

As previously stated the lower reaches of the Swan are estuarine in character. The effect of sea tides is easily observed as far up the river as Perth, while bottom waters near the bridge at Guildford approximate the sea in salinity. The broad expanses of water in the lower Swan and lower Canning are largely due to their being drowned rivers. This was brought about by a relative increase in elevation of sea level, with a resultant inflow of sea waters. The Canning may be regarded as a drowned river to approximately the Riverton Bridge, and the Swan to about as far as the Belmont Racecourse.

In physiographic old age streams meander across their valley flood plains. Such is the case of the Swan and the Canning on the Coastal Plain. Bends tend to travel downstream which means that each meander loop sweeps slowly forward, advance being made during the time of flood. This movement is brought about by the streams alternatively impinging on opposite banks, the threads of maximum velocity following a more twisted course than the stream channel. The thread of greatest velocity is on the convex side of the current and is thus directed against the concave bank. It crosses the channel between concave banks. Thus the concave side of the channel is eroded, while in the quieter waters of the opposite side deposition takes place.

This is quite clearly happening at Maylands during flood times. After passing under Garratt Road bridge, the river impinges against the concave bank North-East of the Maylands Airport. If it were permitted to proceed without interruption the river would eventually break through North of the airport, short circuiting that part of the meander which swings around to the South. This same sort of thing is happening in Melville Water and Freshwater Bay but is not so obvious since the meanderings of the stream channel have been obscured by the drowning of the river. In Freshwater Bay the old channel around the North of Karrakatta Bank is not now followed by the river in times of moderate flow. The channel now being used curves from Melville Water between the North end of a sand spit running North-Westerly from Point Walter and Karrakatta Bank, into Mosman Bay.

Where waters are shallow and the current gentle, the tendency is for fine sediments to be rolled from the shoals into the deeps. During floods or where a current or tide is strong, the deeps are scoured and deposition takes place in the shallows.

The effect of sea tides on the Swan during the summer months may be considerable at or near the surface, but it is probable that they are of little consequence in the deeper parts of the channel, although in the absence of figures this cannot be stated definitely. During winter months when the river is flowing, they will be more effective. Rising tides hold back the stream waters, the quantity held back depending upon the height of the tide. When the tides reverse the stored energy forces the water out.

The tide will be more effective in the narrower parts of the estuary, such as Blackwall Reach and in Fremantle Harbour itself, since a funnel like effect is created by the wider expanses of water upstream being compressed into a narrow channel. For an estuary to be of much consequence as such the tidal range should be considerable.

While the Swan and Canning are flowing, the influx of fresh waters into the estuary from the higher reaches produces an extremely unstable environment in which only the hardier varieties of organisms can survive. Among these are the Diatoms and the Algae. During summer months however, conditions are fairly stable and all forms of estuarine life flourish, particularly in the quieter back stretches such as Melville and Perth Waters, and in the estuary near Bulls Creek and up to Clontarf.

The organisms of the estuary will be unlike in different parts. Fresh water forms live above the influence of the salt water, and salt water forms below the influence of the fresh water. Those forms which have established themselves in the salt water during the summer months and cannot adapt themselves to the drastic change of conditions will be killed off with the sudden change in salinity when the rivers commence to flow in winter. Fresh water forms will also suffer from the increase in turbidity and cloudiness.

Algae, which are to be found in considerable quantity in the estuary, will not be found in equal quantity all the year even should the salinity remain constant. Many disappear more or less completely during the winter months, while others become scarce in summer. The different species of algae commonly succeed one another. This periodicity is governed by a number of factors, the most important of which probably are temperature and illumination. The quantity of light available for a plant's photosynthetic process depends upon the depth and the cloudiness of the water. Where the water is continually cloudy with suspended organic or inorganic silts, the algae are obliged to live in shallower parts.

Excepting the free floating types, algae (which includes the sea weeds) are very firmly attached. The freedom of water movement may therefore be checked and as a result the rate of deposition of water borne particles accelerated.

Particles of colloidal dimension may be precipitated under the influence of sea water by a process called flocculation or coagulation. Colloidal particles are small enough to be independent of velocity and do not settle in response to gravity until several unite to form a larger particle. Colloids carry an electrical charge which may be either positive or negative sign. Colloids of minerals which are easily oxidised carry positive charges, whereas minerals not readily oxidised carry negative charges. Lime, magnesia, alumina, ferric oxide, and many hydroxides are examples of the former; while silica, clay minerals and humus are examples of the latter. Flocculation is brought about by the union of colloids carrying opposite charges, or by the union of colloids with oppositely charged particles in solution.

From this discussion it is seen that the predominant process on the crystalline rocks of the plateau is erosion, the products of which are deposited on or near the beds of the rivers, particularly where they flow on the Coastal Plain. Coarser sediments such as gravels, and sands are deposited nearer to the Scarp, while the finer sediments such as silts and clays are deposited farther away in the estuary, or in the sea near Fremantle, or on the flood plains of the rivers.

The environment up the Swan to Guildford and up the Canning to Riverton is estuarine, and the life existing therein is largely controlled by the seasonal influx of waters from the upper reaches.

Between Perth and Fremantle there is a relatively narrow channel, varying between 10 and 30 feet in depth, which winds between extensive submerged mud flats and sand spits, over which the depth of water is from a few inches to perhaps six feet. The winding nature of this channel reduces the value of the tide as a scouring agent; apart from which the tidal extremes are hardly sufficient to make it of much consequence, except in the river channel just above Fremantle, and in the Harbour itself.

chapter iii

A description of some aspects of the hydrology of Swan-Avon River system

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The Swan-Avon River arises near Wickepin which is approximately 140 air miles from the sea or 200 odd miles as the river flows. It drains an estimated area of 10,000 square miles, the average rainfall of which varies from 15-18 inches annually near its source to 40-45 inches in areas near the top of the Scarp. At Northam the principle Northern tributary, the Mortlock River, flows into the Swan-Avon below the Northam Weir. Further downstream the other Northern tributaries, Toodyay Brook, Brockman River enter the Swan-Avon before it leaves the Scarp. After dropping on to the coastal plain the system is enlarged by Ellens Brook from the North and Helena River and Canning River from the South. Both of these latter are dammed, the Helena by Mundaring Weir and the Canning by Canning Dam. The Mundaring Weir was completed in 1902 and until 1951 had a capacity of 4,650 million gallons. In 1951 the retaining wall was raised and the capacity increased to the vicinity of 15,000 million gallons.

For Mundaring Weir data are available since 1902 showing, inflow into weir, loss by evaporation, amount used, etc., and they reveal the surprising fact that of all the water which has flowed into the Weir, namely 650,000 million gallons, only 20% has been retained and the remaining 80% has either overflowed or been released through scour pipes and has found its way into the Swan.

The Canning Dam which was completed in 1940 has a capacity of 20,550 million gallons and here again data are available since its completion and show that of the 200,000 million gallons inflow approximately 50% has passed over the retaining wall.

Data are available for the estimated quantity of water passing over the Avon Weir at Northam for 1946-1953 inclusive, and they yield an average annual flow of approximately 65,000 million gallons.

On considering the period 1946-1952 inclusive, for which data for Canning Dam, Mundaring Weir and Avon River at Northam are available, we find that a total of approximately 400,000 million gallons passed over the Northam Weir. During this same period 82,000 million gallons was retained by both Canning Dam and Mundaring Weir which is about one fifth of the flow of the Avon at Northam. When it is considered that:

(1) after leaving the Northam Weir the river flows for about 80 miles through a 30-35 inch rainfall belt,

and (2) it is joined by the Mortlock River, Toodyay Brook, Brockman River, Ellen's Brook, the latter two of which are the Northern analogues, although smaller, of the Helena and Canning Rivers; it seems reasonable to assume that the volume of water which finds its way to the sea from the Swan-Avon system must be very much greater than that flowing over the Avon Weir at Northam.

If the volume is only doubled after leaving Northam, and a rough calculation of catchment area and rainfall show this is quite likely to be, at least, the case, it would mean that even if the dams were removed from Helena and Canning Rivers the annual flow to the sea would be increased by only about 10% of the volume of water being contributed by the Swan-Avon system. Further it must be remembered that the water being held by the dams is only about 35% of the water which flows down those rivers. If cognisance is taken of this fact the percentage of waters held by the weirs would be something less than 10% of water flowing into the sea. Thus it appears that the erection of the dams has made little difference to the amount of fresh water which flows into the sea, the Swan-Avon and its Northern tributaries being by far the greatest contributor.

Note.—These figures are only approximate but they give some idea of the percentage of water being retained by the reservoirs.

Swan River Basin.—The Swan River shows typical estuarine properties at least as far upstream as Maylands on the main branch and as far as Riverton up the Canning Branch. An estuary can be defined as an enclosed basin with free access to a limitless amount of salt water at its mouth and receiving continuous accessions of fresh water at its inner end. If we draw a line across the estuary at the narrows and at Canning Bridge and again at Fremantle Bridge we enclose an interesting area which may be termed the "Swan River Basin".

This basin consists of an area of approximately 10½ square miles and of average depth 13½ ft., including the banks. The channel has a depth of 10 ft. at the Narrows, 18ft. at Crawley Bay, 35 ft. at Applecross and reaches a maximum depth of 70 ft. in the Freshwater Bay area. The depth decreases from Freshwater Bay downstream until at the Fremantle traffic bridge it is 15 ft. This shallowing at the seaward end and the maximum depth occurring somewhere near halfway up the basin are responsible for some very interesting features of the Swan River Basin. The volume of water contained by the basin is in the vicinity of 25,000 million gallons with a daily variation of approximately 2,000 million gallons if the average daily tidal range is taken as one foot. As is well known the tidal range is by no means uniform and is greatly affected by atmospheric conditions.

The hydrological conditions (i.e., distribution of salinity, oxygen, nutrients, etc.) in the basin, show marked seasonal variations and a typical annual cycle is described below.

From January to the onset of the fresh water run-off, usually in June, the basin waters are most stable, the salinity and other chemical properties approximates very closely to sea-water and there is very little change in salinity and temperature with depth. Thus the basin appears to be filled with freely circulating sea water.

The onset of the run-off is indicated by a marked drop in temperature and salinity, an increase in nutrients salts such as phosphate and nitrate and a pronounced muddy colouration of the surface waters in the upper reaches of the basin. If favourable rains continue a sheet of almost fresh water with comparatively high concentrations of above nutrient salts and carrying a heavy silt load covers the surface of the basin at least as far downstream as Bicton. The depth of this fresh water layer is dependent upon the volume of fresh water coming down the rivers, being deepest when the discharge is greatest. Below Bicton a certain amount of mixing of the fresh water with sea water appears to take place but the salinity of the surface waters is still very much lower than sea water as far downstream as the Mole.

Since considerable energy is required to mix liquids of different density there is surprisingly little mixing across the fresh water, salt water interface in the basin and the salinity will vary from that of sea water (salinity about 35 parts per thousand) to almost fresh water (salinity about 2 parts/1,000) over a boundary of something like a foot. Over this same interface there exists a temperature gradient of as much as 5° Centigrade being perhaps 13°C. in fresh water layer and 18°C. in underlying salt water.

This fresh water layer overlying the salt water in the basin has the effect of isolating the bottom waters from the atmosphere and apparently preventing the normal summer type of circulation from taking place, with the result that as the winter proceeds the isolated bottom waters appear to remain stationary, except perhaps for some movement up or downstream of the whole body, there being very little, if any, vertical circulation.

The chemical composition of this isolated and almost stationary body of water then begins to alter with a marked depletion of oxygen and increase in both phosphate and nitrate content until after a time the upper basin stations show complete lack of oxygen at some level between the bottom and the fresh water, salt water interface. This deoxygenation proceeds both upwards and downwards through the water column and also downstream until, if run-off is persistent, the whole of the isolated bottom waters becomes completely deoxygenated. Accompanying deoxygenation is an increase in phosphate and nitrate content and when the oxygen tension reaches zero at any station there is considerable hydrogen sulphide production. When this stage is reached it means that the bottom waters are virtually uninhabitable except by anaerobic organisms. All aerobic organisms will suffer both from lack of oxygen and the toxic effect of the hydrogen sulphide produced.

All this time there is a sheet of fresh water of varying depth with high oxygen, phosphate and nitrate content and low temperature flowing over the surface of the basin; the depth is dependent on the amount of fresh water finding its way into the system. The high phosphate and nitrate is probably gained by leaching from the cultivated soil over which it passes before entering the rivers. For example, in the middle of June, 1953, the fresh water layer reached the bottom at Crawley Bay (a depth of 18 ft.) and tapered upwards to a depth of 6 ft. at Billygoat Farm. The following week however, apparently due to a slackening of the run off, the fresh water layer was only 12 ft. thick at Crawley Bay, the lower 6 ft. being occupied by the stagnant bottom waters once more. This re-introduction of bottom water can be explained by an oscillation of the isolated basin waters as a whole.

Throughout the period of run-off there is a constant tidal pressure operating on the seaward end of the basin and as the run-off slackens its effect is felt by a wedge-like body of sea water penetrating the system from the lower end. This wedge slowly moves upstream and as it does so vertical mixing must occur since the basin waters suffer an increase in oxygen content and a decrease in nutrient content. (Sea water being saturated in oxygen and low in nutrients.)

After the cessation of the run-off the wedge penetrates further upstream accompanied by vertical mixing until finally the whole basin is back in its initial stable summer state.

The stages of the cycle outlined above vary in both time of commencement and duration from year to year and are probably affected by prevailing winds, atmospheric conditions, extent and distribution of rainfall, etc.

chapter iv

Algae of the Swan River

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The group of plants known technically as Algae, are predominantly aquatic plants of simple structure without differentiation into leaf, stem and root, almost entirely lacking in conducting tissues, and reproducing by vegetative division or by means of spores of various types. A number of true flowering plants (Angiosperms) are also aquatic in habit and are to be found in most large tracts of water, growing in close association with the true algae. From the popular point of view, all plants which grow entirely submerged in water are regarded as algae, irrespective of their true relationships.

THE ROLE OF ALGAE IN NATURE.

It is probably correct to say that no body of water of any size can remain for long without the development of an aquatic flora of some sort, and it is equally true that no water which lacks a flora can support animal life. In the biological cycle of a lake or river, the vegetable life performs a two-fold function. In their normal growth processes, plants absorb carbon dioxide and liberate oxygen into the surrounding water, but they also absorb a certain amount of oxygen in respiration. During the hours of daylight, however, the production of oxygen in the process of food synthesis, greatly exceeds that used up in respiration, and the excess is absorbed by the water.

This oxygen is essential to the health of the local fish population, and without it animal life would cease. Moreover, animals are dependent, directly or indirectly, on plants for their sustenance; vegetarian forms feed directly on them and carnivores feed on other animals which are themselves plant feeders. Both plant and animal after death are broken down into organic and mineral constituents which are in their turn available for the continuation of further plant life. This interdependence of all living things is very unstable and the balance is easily disturbed, particularly by the interference of man.

ALGAL FORMS.

(a) General.

The variation in life form of the terrestrial plants finds its counterpart in the aquatic flora. In sheltered areas and small enclosed pools, minute unicellular plants occur in great numbers and multiply by simple division of the cell. In some of the forms, the cells do not separate after division, but remain joined in a simple unbranched filament, whilst in others the filaments branch freely, and give a bushy appearance to the plant. Other species grow by the division of their cells in two planes, thus forming a thin flat sheet-like thallus or plant body. The majority of algae, however, are more complex in structure, and are analogous to terrestrial herbs, possessing a thallus which branches freely either according to a definite plan, or without any apparent system, and sometimes attaining a considerable size.

(b) Swan River Flora.

The epiphytic Diatom population of the river waters is high in comparison with are well represented, both as free living plants and as epiphytes on the larger algae and on stones and other solid objects. The so-called Blue-Green algae of the Class Cyanophyceae occur mainly in the region between high and low tide levels, but it is probable that few would recognise them as plants. The Green algae included in the Class Chlorophyceae, contain the same green pigments as land plants and generally occur close to the river bank in comparatively shallow water, in order to obtain the maximum amount of sunlight. The Brown algae (Class Phaeophyceae) contain brown pigments as well as the normal green, in a combination which permits the plants to grow at a greater depth than those which possess only the green pigments, whilst algae of the Class Rhodophyceae contain red pigments in addition, and are able to grow successfully to a depth where little light penetrates.

THE ALGAL FLORA OF THE SWAN RIVER.

(a) Bacillariophyceae.

Of the free-living plants the most obvious and possibly the most abundant is very little is known about them from the point of view of systematics. They are single-celled plants, brown or greenish in colour, each being provided with a cell wall which is richly impregnated with silica, and usually bearing a symmetrical and often highly elaborate pattern of sculptured markings. It is this external pattern which forms the main criteria for classification within the group.

Although the Bacillariophyceae or Diatoms are very abundant in the Swan River, *Melosira,* which is colonial or filamentous in habit, and occurs in dense masses in shallow waters during the summer months. When free floating it appears as a dense brown cloud in the water, but when tangled on twigs or some other obstruction it resembles an ordinary filamentous alga. It is particularly abundant in the neighbourhood of the Causeway, and extends through the Narrows at Mill Point into Melville Water and beyond.

In the waters of the Swan River the microscopic forms of algae such as Diatoms, that of the ocean, and few specimens of the larger algae examined under the microscope fail to reveal an abundance of Diatoms attached to the thallus. Small though these plants are individually, they have an important bearing on the utilisation of river algae for agar production, and also on the question of pollution.

(b) Cyanophyceae.

On every rocky headland, and all reclamation walls along the foreshore, the average level of the water is marked by a dark brown line. This is caused largely by the presence of considerable numbers of algae, the majority of which are microscopic forms of the Cyanophyceae or Blue Green Algae. These plants consist of single cells or short cellular filaments surrounded by a gelatinous sheath and occur in extensive areas on rocks, posts and other objects at or near the surface of the water. Species of *Ocillatoria* and *Lyngbya* have been identified from this band, and although they have little real significance from the point of view of river pollution, their gelatinous nature constitutes a distinct hazard for those who would attempt to walk over rocks near the water's edge.

(c) Chlorophyceae.

Below the line of discolouration on the rocks of the foreshore, there occurs a broad band of Green Algae (Chlorophyceae). It extends outwards into the river to a depth of one to two feet, and where sandbanks are developed, the plants may be found some distance from the beach. The so-called Hair Weed, *Chaetomorphs aerea,* festoons the rocks, and when the tide is low, hangs down from ledges and projections like miniature stalactites. A very coarse, large-celled form of this plant grows in tangled masses attached to the larger grains of sand in depths of up to two feet. Intermixed with this plant on the rocks, are the two species *Enteromorpha intestinalis* and *E. compressa.* These plants differ from the filamentous *Chaetomorpha* in having a multi-cellular thallus which is tubular in structure. Some forms are very fine and hair-like and are easily mistaken for Hair Weed, but, typically, *Enteromorpha* is coarser and more or less inflated. A third species of *Enteromorpha* showing a regular type of branching habit occurs in the deep water, and is washed up on the beaches during the winter and early summer. It is interesting to note that these species are normally found growing in great abundance on ocean-going liners as well as on river craft, and it is no doubt due to this fact that they have been recorded as being cosmopolitan in distribution.

In the deeper water, and not usually found above low tide mark, there occur several other species. One of these, *Ulva lactuca,* is common throughout the lower reaches of the river, and typically possesses a broad green thallus with crisped edges not unlike a lettuce leaf, hence its common name of Sea Lettuce. It varies considerably in size and shape, but in general the broader forms occur in the calmer areas such as Perth and Melville Waters, while in the narrower portions of the river bed at Fremantle and Blackwall Reach the thallus is commonly narrow and ribbon-like, frequently twisted and with the edges abundantly and closely undulate. Smaller and less obvious plants of the shallows, but ones which are quite common and extremely important, are the much-branched bushy species of *Cladophora.*

The larger and systematically more advanced members of the Chlorophyceae are represented by the two species *Caulerpa cylindracea* and *Codium Muelleri.* Both of these genera are typically marine in distribution, and the presence of these two species at least as far up the river as Melville Water, is both interesting and significant.

Codium Muelleri, as it occurs in the river waters, is of a darker green and much more intricate branching habit than its marine form, while *Caulerpa cylindracea*, too, assumes a modified form in the river, and in general appearance is quite unlike the marine specimen. It is more spindly in habit, and the fronds are more or less profusely branched, while the ramenta, or lateral branchlets, are longer, thinner, more widely spaced, and disposed in two vertical ranks, instead of being borne on all sides of the frond. Both these plants occur in the deeper water and would probably be found over the greater part of the river bed.

(d) Phaeophyceae.

The Brown Algae or Phaeophyceae are represented in the river by no fewer than five genera. *Ectocarpus confervoides* is a small gelatinous filamentous plant, brown or olive-green in colour, and strongly resembling a mass of *Melosira*. It is commonly found mixed with the Blue Green Algae on rocks, posts, etc., as well as free-living in the water. Along the base of retaining walls in deeper water and on rocks, posts, etc., away from the shallow banks, there is usually to be found a strong growth of *Cystophyllum muricatum*. The thallus of this plant is characterised by the development of lateral branchlets bearing numerous air-filled vesicles, the purpose of which is to give the plant the buoyancy necessary for its successful growth. In contrast to the compact plants of the turbulent waters on marine reefs, those of the river are frequently as much as two feet in length.

From the deeper water *Colpomenia sinuosa* and two species of *Dictyota* are frequently washed up on the beaches. *Colpomenia* is a brown sac-like bladdery plant growing from a broad attachment, while *Dictyota* has a flat much-branched thallus, the branches arising in a dichotomous manner resulting in a characteristic fan-shaped thallus. Another bladdery or sac-like plant, *Asperococcus bullosus*, is at times very abundant occurring as an epiphyte on other algae or on barnacles and rocks, etc. It is smaller and finer than *Colpomenia* and develops from a short solid attachment.

(e) Rhodophyceae.

Although probably more numerous in the river water than are the Green and Brown Algae, the Rhodophyceae or Red Algae, are perhaps less conspicuous, due to the fact that a considerable proportion are minute epiphytes, whilst the larger species are usually very dark in colour, and do not assume the attractive red colouration so common among drift weed on ocean beaches. Among the smaller forms, *Bangia fusco-purpurea* is wide spread. It occurs gregariously as red patches on the face of rocks near high water mark, in association with the Blue-Green Algae and other species of the mid-littoral zone.

Among the macroscopic forms, *Gracilaria confervoides* is the most abundant, and grows thickly over the river bed at least as far upstream as the Causeway. The thallus is fine, much branched, cartilaginous and terete, or round in cross section, while the branches and branchlets are narrowed into fine filiform points. *Hypnea musciformis* is a plant which somewhat resembles *Gracilaria* in general habit and is found associated with that species over the greater part of the river bed. The thallus is more brittle and softer in texture, while the branches and branchlets are beset with short lateral processes or ramuli, and are not narrowed into filiform points. These two species frequently carry a heavy burden of epiphytic red algae, whose short filamentous thalli give the larger plants a strong resemblance to *Spiridia spinella,* a plant which also occurs in the deeper water, but not as abundantly as *Gracilaria* and *Hypnea.*

Often associated with barnacles, but also found on small stones and piles, *Centroceras clavulatum* occurs as dense dark purple tufts one to two inches in height over most of the shallow waters of the river. The thallus is fine and hair-like, branches freely, and shows conspicuous transverse bands of light and dark colour. Much coarser and of a reddish-brown colour, *Monospora australis* occurs in the deeper water. The thallus is more brittle and turgid than *Centroceras* and does not exhibit the transverse markings.

THE ANGIOSPERM FLORA OF THE SWAN RIVER.

The angiosperm (or flowering plant) flora of the river bed is small as regards numbers of species, but is found over an extensive area. By far the most common species, and one which occurs in large beds over the shallow banks throughout the lower course of the river, is *Halophila ovalis.* It possesses a creeping stem which produces a number of roots and leaves at each node. The leaf blades are oval in shape, are borne on elongated petioles or leaf stalks, and show the typical feather-like venation with a midrib and fine oblique lateral veins so common in land plants. The flowers are quite inconspicuous, and are enclosed in small bracts along the stem. Occurring in the beds with *Halophila,* but less abundant and less conspicuous is *Ruppia maritima.* This plant, too, develops from a creeping stem, from the nodes of which arise roots and leafy stems. These are up to a foot or more in length, and carry a number of fine filiform leaves which are dilated into broad sheathing bases. The flowers are borne within the sheaths of terminal leaves and when mature they are carried to the surface of the water by the elongation of the peduncle or flower stalk.

THE PERIODICITY OF THE ALGAL FLORA.

Just as the varying seasonal conditions produce a succession in terrestrial plant life, so algae show a marked periodicity of occurrence. This is evident in all streams which experience a regular seasonal alternation between fresh and salt water conditions. Certain species flourish in the fresh water during the wet season, but as soon as the salinity of the water increases, these plants are killed off and the more marine types of algae take their place. These in turn are destroyed as the concentration of salt is reduced in the following season. In streams which experience a daily alternation between fresh and saline conditions, most species of algae experience difficulty in establishing themselves.

In the Swan River, the growth of species of Cyanophyceae and of the smaller members of the other three main Orders of Algae is largely controlled by the average height of the tide, so that the growth takes place only during the winter months when the plants are kept moist by frequent inundation or by splash from waves, and ceases during the hot dry period of the summer months.

The majority the Green Algae of the shallows also flourish in the winter, but those near the low water mark are soon killed off as the average water level drops and leaves them exposed for lengthy periods. Those in the comparatively deeper water are not exposed between tides, and continue vigorous growth until the middle of summer, when they become detached, and are washed away to accumulate on the beaches. The Angiosperms of the shallows also make vigorous winter growth, but the late winter storms very largely defoliate the plants, and the beaches are frequently carpeted with leaves and plants torn from the bottom during August and September.

In contrast to the Green Algae of the shallower water, the majority of the plants of the deeper regions, mainly Phaeophyceae and Rhodophyceae, either continue growth throughout the year, or reach their maximum development in summer. Such plants as *Colpomenia sinuosa, Cystophyllum muricatum, Gracilaris confervoides,* and *Hypnea musciformis* are washed up on the beaches at all seasons of the year, and do not appear to be more abundant in one season than in another. On the other hand, *Asperococcus bullosus* develops during the winter months and is normally not very abundant, although in some seasons when conditions are suitable, it may appear in great numbers. Other winter growing species of the deep water are *Caulerpa cylindracea* and *Codium Muelleri.* In the late winter months, these plants become detached during storms and drift into the shallows where they mostly become entangled in the beds of *Gracilaris, Halophila* and *Chaetomorpha.* They eventually die as the summer advances and wash up on the beaches.

CHANGES IN THE ALGAL FLORA OF THE RIVER.

During the many centuries since the Swan River first flowed into the sea along its present course, an algal flora has been built up in complete harmony with its environment. The flora has undoubtedly been altered or modified by varying conditions during this period, but there is no doubt that the stream has always contained vegetable life. The flora as it exists today contains many marine species which have probably invaded the area since the geologically recent drowning of the lower reaches of the river.

The presence of *Caulerpa* and *Codium* in the river is interesting since it aptly illustrates the changing character of the flora. Before the arrival of Europeans, the algal flora was undoubtedly more or less stable. The destruction of vegetation resulted in increased run-off, and with the agricultural activities this water carried large quantities of silt and fertilising ingredients. These chemicals probably stimulated algal growth while the silt produced alterations to the river contours, modifications which were still further aggravated by the digging of channels in the river bed, and the erection of bridges, and retaining walls.

Thus over the past 120 years the environmental conditions in the river have been somewhat altered, and the growth of some forms of algae has been stimulated. Thus, at the present time, the area covered by beds of *Halophila* and *Gracilaria* is increasing throughout the estuary, while new elements are being added to the flora. *Codium* is apparently not yet very plentiful and is of infrequent occurrence in the drift weed on the beaches. *Caulerpa,* on the other hand, is becoming plentiful in Freshwater Bay and Melville water, and is the more obvious indicator of the changing face of the algal flora. It is probable that *Spyridia* and *Asperococcus* are also comparatively recent immigrants from the ocean, and it is quite possible that new environmental factors may eventually cause further marine migration. On the other hand it may be a purely cyclic occurrence, and the present incursion merely one phase of the whole sequence.

THE SO-CALLED ALGAL POLLUTION.

Much has been said and written during recent years concerning pollution of the Swan River, and it is evident that there are many different conceptions of what constitutes pollution. To perhaps the majority of people, the smell of algae rotting on the beach, and even the algae themselves, are synonymous with pollution. To the naturalist, however, this is far from the truth. It cannot be too strongly emphasised that algae are essential to the river, and without them life in the river would cease. The rotting of their organic remains is just as natural as is the decay of gum leaves in the forest.

On the other hand, true pollution is caused by anything which disturbs the balance of nature, anything which introduces an environmental factor not present in the river under natural conditions, or anything which alters the status quo of any or all of the living organisms in the water. The effect of these substances is reflected in the quantity and quality of the growth of plant and animal, and in so far as these organisms vary from their natural conditions, they act as an index of pollution, but should not be confused with the pollution itself.

At all seasons of the year algae are dying or being uprooted by various natural agencies to drift with tide and waves, eventually being stranded on the beaches. In the winter months, although at times the quantities are considerable, particularly after storms, the weeds gradually disappear without any disagreeable odours, as the high tides, together with the strong winds and the accompanying waves, keep them in a state of constant motion and gradually disintegrate them. During the warmer weather, however, when the water level is lower the plants accumulate in masses at high tide level.

As pointed out above, it is the Chlorophyceae which are most affected by the summer temperatures, and it is these plants which comprise the bulk of the summer drift. The species of *Cladophora* and *Chaetomorpha* undoubtedly constitute the greater part of this material, while the numerous other species play a lesser role in making up the bulk. Even more significant than the masses of macroscopic algae, are the very numerous diatoms, both epiphytic and free-living forms, and particularly the so-called "gas forming" group to which the abundant *Melosira* belongs. At the time that these plants are accumulating, conditions of temperature and moisture approach the optimum for bacterial activity, and offensive odours are quickly generated, particularly if the weed is disturbed.

It is this odour which constitutes the nuisance of algae, and which is branded by most people as "pollution". The algae themselves, as has been pointed out, have existed in the river for centuries, and must remain an esential and integral part of the biological set-up in the water. For centuries, too, the plants have been dying and rotting on the beaches. In some years the net effect of all factors controlling the algal flora, has produced exceptional accumulation of plants on the beaches with resultant abnormally strong odours. In other years very little accumulation occurs, and the smell scarcely arouses public comment. It is probably true, however, that in any such "good" year there will be some stretch of the foreshore, which for some reason, such as local dredging operations or unusual winds, will experience a bad accumulation of weed, although little trouble is experienced in other parts of the river.

DRAINAGE WATER AND ALGAL GROWTH.

It would appear that the most important factor in river pollution is not the algae themselves, but the admixture of drainage water in the river. Drainage water is of two types which, for convenience, may be referred to as industrial effluent and agricultural effluent.

(a) Industrial Effluent.

Practically every industrial concern produces a greater or lesser quantity of effluent. If discharged into the river, some of these would be detrimental, and contribute to pollution, while others would be harmless.

A proportion of this waste contains organic matter, and if excessive amounts of this type of liquid are poured into the river they are liable to produce some disturbances of river life. The water normally contains a large amount of organic matter from natural sources, and with these added substances the intensified bacterial activity necessary to purify the water by the breaking down of the organic matter, results in the excessive utilisation of oxygen supplies so that less is available for algae and fish. Under these conditions of low oxygen content, organic matter tends to be deposited as a black mud on the bed of the river.

Among other industrial effluents are those containing acids and alkalis which have a toxic action in the water. Under normal conditions these substances are discharged close to the bank, and dilution would be a progressive process. In the area immediately surrounding any such outlet the effects on algal growth could possibly be considerable, while the discharge of harmful effluent may entirely destroy the plants of the area. These effects would be only local, and although of little consequence to the question of algal growth over the whole river, could have some bearing on the so-called algal pollution in small localised areas.

(b) Agricultural Effluent.

The surface water entering the stream in the agricultural hinterland, presumably contains a certain amount of fertilising chemicals which will eventually enter the sea at Fremantle, unless utilised by plant life at some point on the journey. Extensive work carried out by the C.S.I.R.O. Division of Fisheries (1) has demonstrated conclusively that the concentration of phosphorus and nitrogen in the waters of the Swan River shows considerable variation. This is true for any one day over the length of the river, for any one locality throughout the year, and at any time for the surface water as compared with the deeper layers. Seasonal variation, too, is very marked, and appears to be independent of seasonal conditions.

This variation is consistent over the whole length of the river tested, whilst there is no significant difference between the figures derived from samples obtained above the Causeway, and those from stations between the Causeway and Fremantle Harbour. It would appear, therefore, that despite the popular conviction, the bulk of the phosphorus, nitrogen and other substances necessary to maintain plant growth, enters the river by way of the streams and rivulets in the agricultural headwaters, rather than from the drains in its lower course. Such chemicals as are contained in the effluent from these drains in the lower reaches are ultimately diluted, and their contribution to the river water as a whole is so small that no significant difference can be detected by chemical analysis.

It has been further shown by D. J. Rochford (2) of C.S.I.R.O., Cronulla, that the winter influx of fresh water into the Swan River flows as a surface layer, and that the lower layers of saline water are relatively stable.

Thus it is that the added chemicals are carried in the zone of water in which the Angiospermae and Chlorophyceae, as well as the Diatoms, normally thrive, and these Orders contain plants which are capable of deriving rapid benefit from the fertilising chemicals. The apparent irregularity of the concentration of nutrient materials in the water as demonstrated by the analyses, is of little importance to the growth of the algae, as it is largely compensated by the constant movement of the water.

The importance of this surface concentration of chemicals lies in the fact that the plants which normally occur in the upper layers of the water are the ones which occur most freely in the summer drift. Any trend in this concentration, either over a long period of years, or from season to season, would be expected to be reflected in the amount of summer drift, and hence "pollution".

POSSIBLE CONTROL MEASURES.

It is quite evident that little can be done to prevent the leaching of the chemical substances from the agricultural areas. However, a great deal can be done, and has been done, to prevent the discharge of harmful industrial effluent into the river.

It is not feasible to eliminate the algae completely even over small areas by the use of copper sulphate, as has been proposed, since the relief is only temporary, and the plants quickly re-establish themselves over the treated area. Their presence in the water is essential since they play a vital role in the life of the river, and it is a natural corollary of life that death must follow. Hence accumulation of drift is a natural process, and the unpleasantness of summer odours emanating from rotting weeds cannot easily be overcome while the greater part of the river foreshore remains as natural beaches which offer such ideal areas for the accumulation of drift.

The erection of retaining walls so that no beach is exposed at summer low tide, and the straightening out of the foreshore in conformity as much as possible with water currents, are probably the most effective methods of combating the offensiveness of algae. The erection of these retaining walls would not prevent the growth of the algae as has been suggested, but would tend to keep the weed in the water and in motion, thus preventing its decay in masses.

The elimination of the natural beaches would certainly meet with opposition from a section of the public, and it has been suggested that contouring the beaches by a system of groins may be sufficient to keep the drift moving away from the shallows. It seems certain that the aesthetic value of the natural river, and the economics of extensive foreshore reclamation are subjects which will have to be weighed very carfully in the near future against the inconvenience and odour which the presence of algae in the river must necessarily produce.

SUMMARY.

The algal flora of the Swan River has played a vital part in maintaining the life of the water since the stream was first formed. Its role in the biological set-up is one which is peculiarly its own, and one which cannot readily be performed by any other agency.

The algae themselves do not constitute pollution, but to most people the smell of rotting plants on the beaches is objectionable, and is synonymous with pollution.

Any substances which disturb the biological balance of the river organisms are harmful and constitute pollution. Such substances are largely the product of Man's activities. By far the greatest pollutant is the alluvial mud brought down from agricultural areas which is rich in nutrient fertilisers such as nitrogen and phosphorous.

Industrial effluents are of little importance because of the great dilution to which they are subject.

In addition to supervision of industrial wastes, some degree of control over evil smelling algal deposits might be obtained by the erection of retaining walls to conform as much as possible with water currents, or by contouring the beaches by a system of groins, to prevent, as far as possible, the accumulation of rotting algae in the shallow waters.

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chapter v

The bacteriological control of drinking water

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Introduction.

Water as well as soil may be regarded as primary reservoirs for all living objects including bacteria. Water bacteria are found in lakes, rivers, swamps, streams, deep and surface wells and the sea. The great majority of water bacteria are saprophytic, living upon inorganic elements and compounds and upon the dead residues of plant and animal life. The water bacteria in natural waters bear the same relation to the constant and recurrent transformation of organic matter as the process taking place in the soil, and are an integral part of the aquatic life.

Other micro-organisms are of parasitic nature and flourish on living tissues of plants and animals, from where they find their way into water. The water bacteria usually only multiply slowly except under conditions where fresh plant and animal residue are added to the water.

The bacteria native to fresh waters are sulphur—and iron—bacteria, spiral forms, pigment producing bacteria, such as B. prodigiosum, B. violaceum, B. aurescens, flourescent bacteria, thermophilic bacteria, aerobic non-pathogenic spore bearers, pigmented or non-pigmented cocci, nitrogen-fixing and nitrifying bacteria, etc.

Sea water contains similar bacteria including the nitrogen-fixing, flourescent bactera and various pigmented forms.

Some water bacteria are difficult to cultivate on laboratory media. The optimum temperature for the growth of many of these bacteria is at 20-22°C. and they do not grow at 37°C. They are mainly saprophytic types, which are non-pathogenic to human beings. While bacteria developing at 37° are mainly parasitic or potentially parasitic types, derived from soil, sewage, or excreta. High bacterial counts at 37°C. frequently indicate the influx of sewage in to the water. Some of the bacteria derived from the soil and also from excreta are non-pathogenic or potentially pathogenic anaerobic spore bearers.

Water Pollution.

Waters are subject at some stage to sewage or manurial contamination. If the pollution is of human origin there is always a possibility that excreta of carriers of enteric fever (typhoid and paratyphoid) or dysentery contaminate the waters and the consumption of such water may result in an outbreak of the disease. Disease producing organisms have also been found in the faeces of domestic animals and birds. As the detection of pathogenic bacteria in drinking waters is technically impracticable as a routine procedure owing to their relatively small numbers, the aim of the bacteriological examination is to detect the normal inhabitants of faeces of either man, animals or birds, i.e., the coliform bacteria which always greatly outnumber in faeces or sewage the pathogenic organisms. The ratio of coliform organisms to pathogenic organisms in water is never less than 1,000 to 1. The presence of coliform organism in drinking waters is therefore always an *indicator* of a potential danger of the presence of pathogenic enteric bacteria in the water. The detection of faecal bacteria, first of all the coliform bacteria, is therefore of great hygienic value as evidence of recent contamination. A further point in favour of the examination for coliform bacteria is that typhoid bacilli die out fairly rapidly in water, so it is improbable that after the lapse of time the bacteria can be isolated from water at all.

Besides the coliform bacteria, two other types of bacteria, the anaerobe Cl. welchii and the entero-cocci, are constantly present in the human intestine and are used to demonstrate excretal pollution. In some waters it may be advantageous to test for the presence of these organisms, but the modern tendency is to rely more and more upon the examination for the coliform bacteria and to prefer repeated simple examinations of this kind to less frequent elaborate investigations.

Faecal B. Coli.

The main component of the coliform bacteria in the faeces is the faecal B. coli type 1, and the remaining smaller percentage is composed of other types (B. aerogenes, intermediate and other types) which are not exclusively associated with faeces. For instance B. aerogenes is often found in the soil and on vegetation, and survives in water long after the B. coli has disappeared. When they are found in water they must for safety be regarded as possible faecal indicators. Unfortunately they acquired the term "non-faecal" to distinguish them from the more certainly "faecal B. coli". If the above differentiation is used it should only indicate that "non-faecal" B. coli without faecal B. coli means the possibility of a less recent faecal contamination.

Bacterial Count.

The estimation of the general bacterial content by the plate count technique does not give sufficient information in ordinary routine control. It has only a limited value, when carried out on the same supply at regular intervals over long periods. An increased count may indicate the influx of storm water, of other polluted surface or soil water, or direct contamination by dust or animals.

A high 22°C. count may often be met with in water free from dangerous pollution. Sometimes in pure water, such as deep well waters, counts of thousands per ml may be obtained and usually can be ignored, unless they occur in waters which have previously given low counts.

It should be remembered that upland surface waters may have a high count at 37°C. sometimes exceeding 1,000 per ml, in the complete absence of excretal pollution. The ratio of a count at 22°C. to that of 37°C. helps to explain a sudden fluctuation in the bacterial content of a water; the higher the ratio the more probable it is that the bacteria are clean soil and water saprophytes and therefore of small significance. In unpolluted water, the ratio of the 22°C. count to the 37°C. count is usually 10 or more to one. In polluted waters it is usually below 10. The bacteriological examination indicates the purity or pollution of the water supply. It is a check of the efficiency of the purification. It is a more delicate test than any chemical test and therefore more importance is attached to the bacteriological than to the chemical findings.

Sampling.

The sampling for bacteriological examination should be done with the *utmost* care to avoid introduction of coliform or other bacteria in the samples from sources unconnected with the water under test.

The sampling should be done in special bottles, supplied already sterilised by the Public Health Laboratory and these should not be opened until the moment of sampling. If the sample is taken from the tap, the water should be run to waste for a few minutes. then the tap sterilised with a blow-lamp or a spirit lamp, which can be improvised. Samples from a spring, lake, reservoir, shallow pool or stream are taken by holding the just opened bottle by the bottom. The bottle should be plunged neck downwards below the surface, usually for a distance of about one foot, the bottle is then rotated until the neck points slightly upwards, the mouth directed up stream. In reservoirs the current should be artificially created by moving the bottle horizontally in a direction away from the hand. When the bottle is full it should be immediately re-stoppered. The samples should be transmitted to the laboratory with the minimum possible delay, packed in *ice-filled* containers. Water samples treated with chlorine or chloramine should be collected in containers sterilised after adding crystals of sodium thiosulphate to neutralise the effect of the chlorine on the bacteria.

Examination for Coliform Bacteria.

The bacteriological examination is performed in the laboratory. As the coliform bacteria are not present, in pure culture, selective methods are used for their detection. These media inhibit the growth of most of the other bacteria and types. The presence of coliform bacteria is indicated by production of acid and gas by fermenting the lactose in the media. Measured quantities of the water to be examined are inoculated into several tubes of fluid media. These are incubated at 37°C. under appropriate conditions and observed for signs of growth. Provided a proportion of the inoculated tubes remain sterile, it is assumed that every tube in which growth is manifest received an inoculation of at least one living bacillus. From the number of tubes showing growth with gas formation in relation to the total number inoculated, it is possible by suitable probability tables to estimate the approximate number of organisms in the original sample.

From the number of tubes showing acid and gas after incubation at body temperature the probable number of coliform bacteria present in 100 ml. of the sample is calculated, i.e., the presumptive coliform count. By sub-culture of the positive tubes to fresh tubes which are incubated at a higher temperature (44°C.) the probable number of faecal B. coli in 100 ml. sample can be estimated.

It is important that frequent sampling is performed as the operation of a water purification plant can only be accurately controlled by continued routine examinations. There is always a possibility that a water supply is exposed to contaminations which can be overlooked, unless its quality is regularly followed by laboratory examination.

Classification of Drinking Water.

At present the following classifications for piped water supplies, based on the presumptive coliform count results for 100 ml. is suggested:—

Class	1—Highly satisfactory less than	1.
„	2—Satisfactory	1-2.
„	3—Suspicious	3-10.
„	4—Unsatisfactory greater than	10.

Throughout the year 50% of samples should fall into Class 1; 80% should not fall below Class 2; the remainder should not fall below Class 3. In chlorinated water, piped supplies ought to be in Class 1.

For rural districts where piped water is unobtainable, everything possible should be done to prevent the access of pollution to the water. By routine simple measures it should be usually possible to restrict the coliform count, for water from a shallow well, to a level between 10 and 25 per 100 ml.

Water-borne Diseases.

The most important water-borne diseases are typhoid fever and cholera. Water can also be the vehicle for bacillary dysentery, leptospiral infection, tularemia, infective jaundice, poliomyelitis, amoebic dysentery and worm infections. The most important, typhoid and cholera, should be dealt with in detail.

Typhoid bacilli, as a rule, do not live long in water, perhaps only for a few weeks. They live longer in clean than in contaminated water. They do not multiply in water. Their survival is influenced by the degree of contamination of the water, the saprophytic bacteria in the water are apparently responsible for the destruction of the pathogens. Typhoid bacteria survive in water at lower temperatures longer than in higher temperatures. An epidemic reaches its maximum in winter, autumn and spring, when the cold water tends to prolong the period of their survival.

Cholera vibrio have been found alive in drinking waters after several days and they may remain alive for weeks in water reservoirs. It has been shown by experiment that cholera vibrio may multiply to some extent in sterilised river water or well water. In river waters and other natural waters they may survive for weeks, but some grossly contaminated rivers, such as the Ganges, are unfavourable to their survival. Cholera vibrios were found in sea water, although their survival there is limited. They may live there for three weeks. The optimal survival conditions were found where the sea water was diluted with about equal parts of fresh water and at a temperature of 15°C.

chapter vi

Bacteriological examinations of the river—general survey

Since 1948 the River has been systematically sampled for chemical and bacteriological analyses.

These samples were taken with the object of determining sources of pollution. Known and suspected sources of pollution were examined by sampling the River close to the point of entrance of the polluting influence.

By the year 1949-50 (June to June) 35 of these sampling points had been established. It must be clearly understood that indications of pollution in these samples bear no relation to the condition of the main body of water. The number of samples taken in the immediate vicinity of pollutants entering the stream are out of all proportion to the amount of water these pollutants represent in the vast body of water in the Estuary. Any average or mean derived from these samples will therefore be considerably worse as regards indications of pollution than the River really is.

This fact must be clearly borne in mind when comparisons are made with other waters from which truly representative samples are taken.

The samples have been examined for the presence of B. Coli in 1 c.c. and in 0.1 c.c. B. Coli in water is not a pathogen, that is, it does not cause disease. The reason for determining the B. Coli content has been indicated by Dr. Kovacs. It exists in huge numbers in every mammalian bowel, including those of whales examined at Point Cloates. It is therefore used as an indicator of faecal contamination, the inference being that if B. Coli are present faecal contamination has taken place and other intestinal bacteria, which may be pathogens, may also be present. These pathogenic bacteria may cause typhoid, paratyphoid, dysentery, enteritis, cholera and other intestinal diseases. The following relationship, however, must be borne in mind to keep the B. Coli count in its true perspective. B. Coli are present in large numbers in every intestine, pathogens, as above, are present in very few. Even in a person suffering with the above diseases, B. Coli still vastly outnumber the pathogens. Sea water kills off both B. Coli and pathogens but B. Coli survive much longer than the others. By virtue of their large numbers and long survival, B. Coli will therefore be found very frequently where no pathogens exist.

In addition to bacteria, intestinal parasites and pathogenic viruses must also be considered. Parasites or their ova are as a rule more resistant than bacteria but a close look-out is kept for persons suffering from such parasites by the Health Department and those of a serious nature are practically non-existent in the metropolitan area.

Their numbers when passed by a carrier are extremely few and in the vast dilution of the Estuary are a negligible hazard.

Viruses such as those of hepatitis and poliomyelitis are to a great extent an unknown quantity. There are indications that their persistence in water may be relatively long compared with pathogenic bacteria and infected water has been blamed for spread of the disease. Viruses have, however, a widespread distribution and the succumbing to infection is more a matter of personal immunity than anything else.

When B. Coli are found in the River is does not necessarily mean that there is direct sewage contamination from sewer or septic tank. B. Coli are widespread as they survive outside the bowel for considerable periods. They are contained in street washings, and run-offs from paddocks or agricultural land. Considerable B. Coli content may be found in rivers or lakes from the excreta of aquatic birds.

It may therefore be asked what, with all these limitations and side issues, is the use of the B. Coli analyses.

Its function is to indicate possible sources of pollution so that they may be critically examined in situ and an evaluation made of any danger that may exist. A further function is to obtain from a series of tests an idea as to the consistency or extent of the pollution and whether or not it is increasing. Action to be taken will depend on the source of pollution, the use of the water and available means for minimising the pollution.

If we now refer to the table we can study the results of the sampling from the 35 points from 1949/50 to 1953/54.

The denominator of each fraction indicates the number of samples taken and the numerator the number of these that were positive. An attempt has been made to simplify the scrutiny of these by totalling the results for each sampling point and also for all sampling points for each year. These totals represented in fractions have been turned to decimals and the decimals representing 1 c.c. and 0.1 c.c. added together to give a simple index. As, theoretically, a positive in 0.1 c.c. is 10 times as bad as a positive in 1 c.c. only, the decimal point for 0.1 c.c. has been shifted one place to the right before adding to form the index. The index therefore means that a sample that was positive in all 1 c.c. and all 0.1 c.c. examinations would score an index of 11 and a sample that was consistently negative in all 1 c.c. and 0.1 c.c. examinations would have an index of zero.

This is not a very scientific method of evaluating bacterial pollution but it is the best that can be done with the material at hand and will serve as a useful measure for purposes of comparison.

It will be seen from the table that the mean index for all this sampling of the River is 1.682 and by glancing down the index column the indices for the various sampling points may be studied and compared with the mean. The worst offenders are the three industrial effluents—

Swan Brewery	7.331
Gasworks	6.309
Industrial Extracts	5.361

These are followed by two drains—

Woodbridge Creek	4.108
Spring Street	4.049

It is interesting to note the improvement in the Gasworks effluent since trade and septic tank effluent have been diverted to the sewer. The high index of 6.309 is entirely due to the early years as from 1949/50 to 1953/54 the annual indices for the fractions shown on the table for the Gasworks are respectively 8.272, 7.416, 8.416, 3.833, 1.984. This big improvement is shown diagramatically on the graph. Septic tank effluents were diverted to the sewer on 8/9/52 and trade wastes on 16/10/52.

The indices and the diagram also show the general overall improvement in sampling results towards the mouth of the Estuary where tidal effects are greater. There is no evidence that the harbour contributes materially to the bacterial pollution of the Estuary.

The index line at the foot of the table gives the overall index for the successive years showing a slight rise and fall before and after 1951-52.

To obtain some comparison for the overall index of 1.682 we might consider the following figures:—

Leschenault Estuary—

85 Samples from 24 Sampling Points from Aug. '52 - Feb. '53.

B. Coli in 1 cc. in 24 = 24/85
B. Coli in 0·1 cc. in 9 = 9/85

Index 1.341.

It must be emphasised that in contrast to the sampling from the Swan River, the above are representative samples of the Leschenault Estuary without any favouring of pollution sources. Similar sampling of the Swan Estuary would give a vastly improved index.

City and Wembley Beaches—

45 Samples taken from Three Sampling Points from Feb. '51 - Jan. '52.

B. Coli in 1 cc. in 12 = 12/45
B. Coli in 0·1 cc. in 8 = 8/45

Index 2.044.

Wongan Pipe Head—

41 Samples taken from January to December, 1951.

B. Coli in 1 cc. in 8 = 8/41
B. Coli in 0·1 cc. in 4 = 4/41

Index 1.170.

Victoria Reservoir—

42 Samples taken from January to December, 1951.

B. Coli in 1 cc. in 4 = 4/42
B. Coli in 0·1 cc. in 2 = 2/42

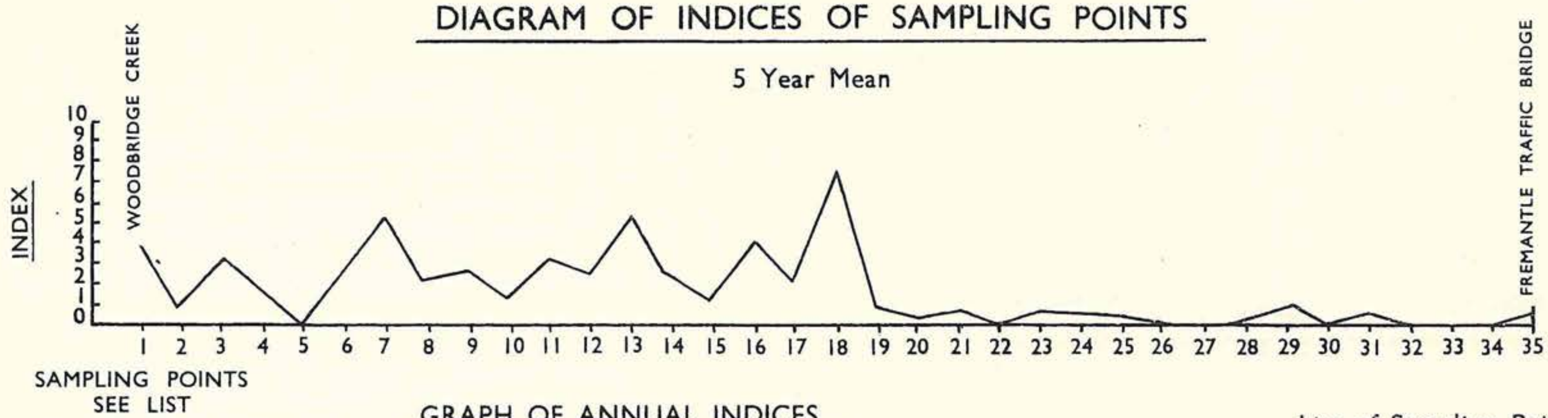
Index 0.574.

We therefore find that in sampling the Swan River selectively to favour pollution areas, our samples are little worse bacteriologically than the overall condition of the Leschenault Estuary and slightly better than the City and Wembley Beaches.

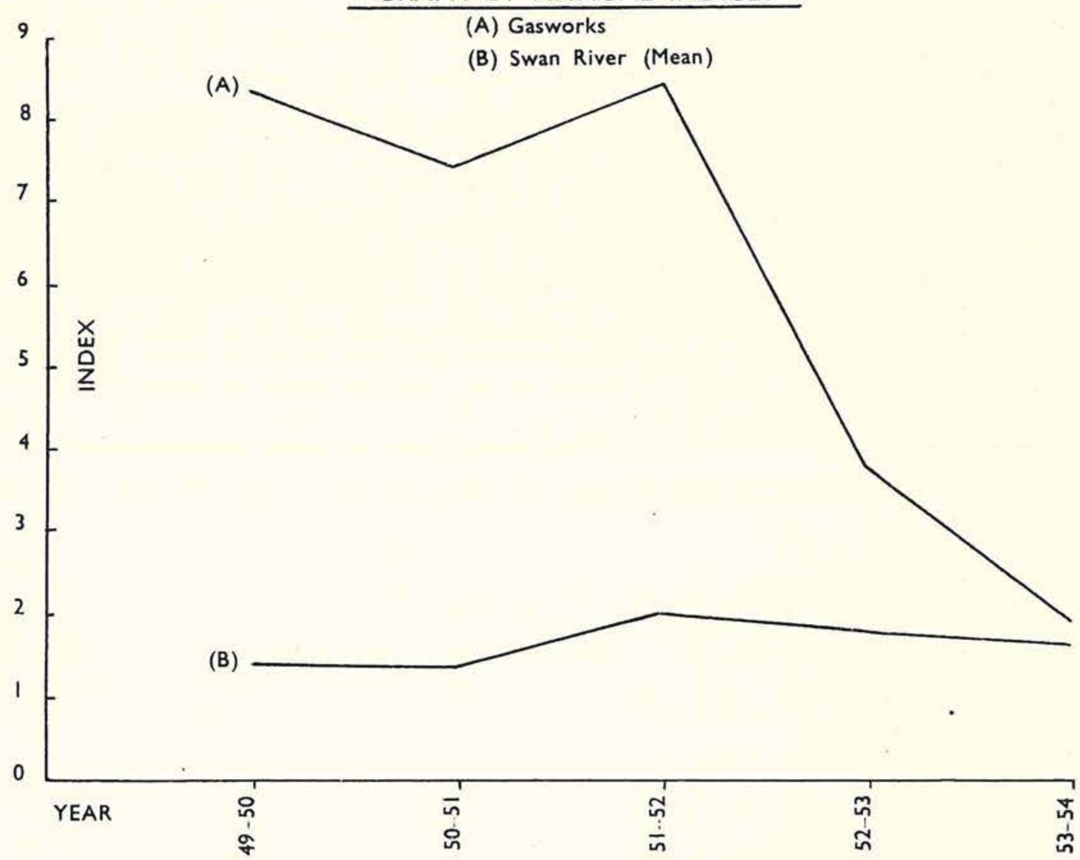
The difference between the River samples and those of our drinking water supplies at Wongan Pipe Head and Victoria Reservoir when examined statistically are not significant. That is, if we consider the number of positives and negatives in each and put them to a X^2 test we find P values for Wongan of somewhere between .50 and .30 for both 1 c.c. and .1 c.c. results and for Victoria Reservoir between .20 and .10. Admittedly, these water supplies are not of the best and the water is chlorinated before being passed into circulation; but if sampling of pollution areas in the River can give us bacteriological results not significantly different from our unchlorinated water supplies we are justified in asuming that by processes of dilution and natural purification the general body of water in the Estuary is, bacteriologically speaking, as good as our drinking water.

DIAGRAM OF INDICES OF SAMPLING POINTS

5 Year Mean



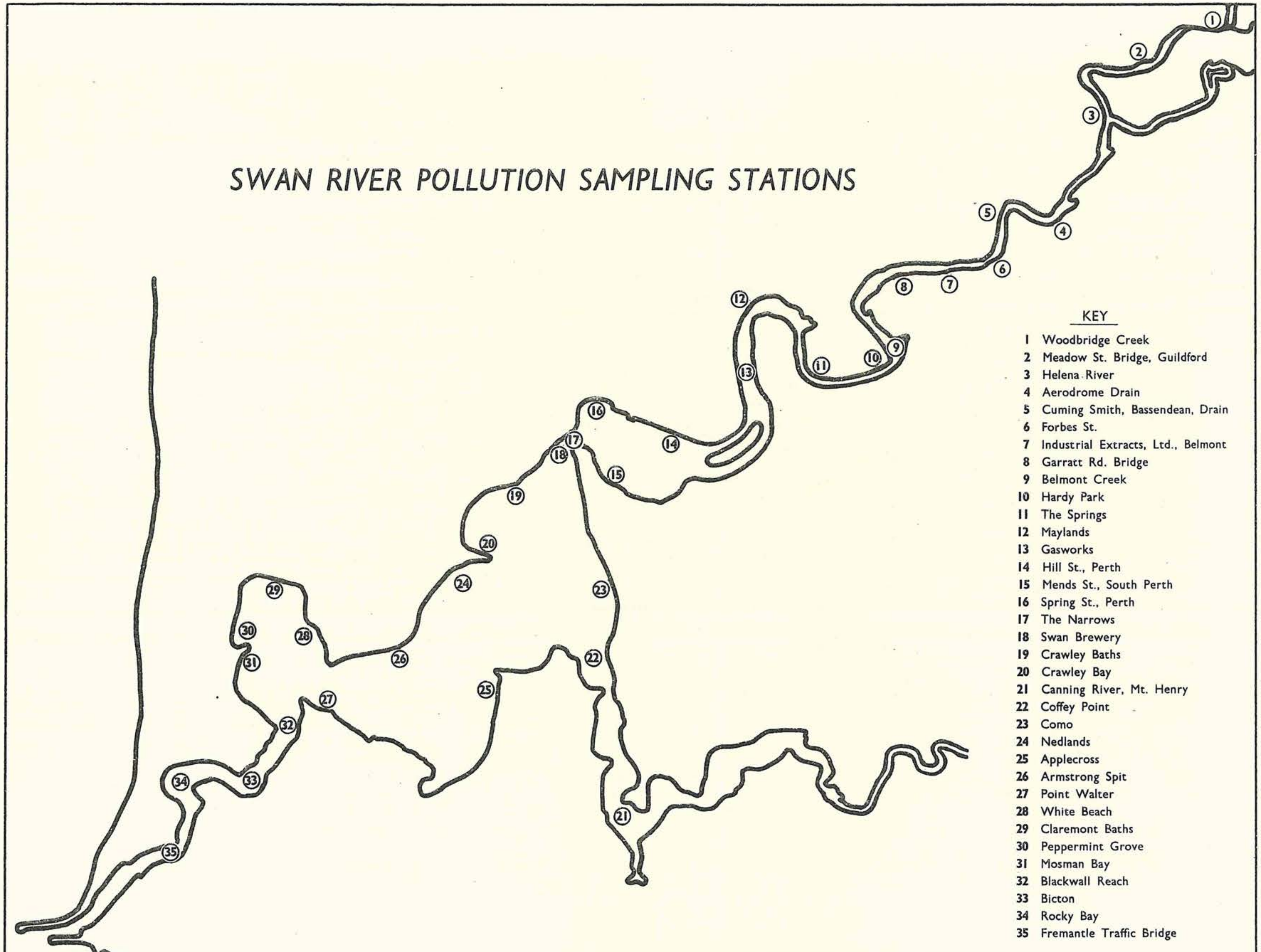
GRAPH OF ANNUAL INDICES



List of Sampling Points

1 Woodbridge Creek
2 Meadow St.
3 Helena R
4 Aerodrome Drain
5 Cuming Smith
6 Forbes St.
7 Industrial Ex.
8 Garratt R. B.
9 Belmont Ck.
10 Hardy Park
11 The Springs
12 Maylands
13 Gasworks
14 Hill St.
15 Mends St.
16 Spring St.
17 Narrows
18 Swan Brewery
19 Crawley Baths
20 Crawley Bay
21 Canning R., Mt. Henry
22 Coffey Pt.
23 Como
24 Nedlands
25 Applecross
26 Armstrong Spit
27 Pt. Walter
28 White Beach
29 Claremont Baths
30 Peppermint Grove
31 Mosman Bay
32 Blackwall Reach
33 Bicton
34 Rocky Bay
35 Fremantle Traffic Bridge

SWAN RIVER POLLUTION SAMPLING STATIONS



KEY

1 Woodbridge Creek
2 Meadow St. Bridge, Guildford
3 Helena River
4 Aerodrome Drain
5 Cuming Smith, Bassendean, Drain
6 Forbes St.
7 Industrial Extracts, Ltd., Belmont
8 Garratt Rd. Bridge
9 Belmont Creek
10 Hardy Park
11 The Springs
12 Maylands
13 Gasworks
14 Hill St., Perth
15 Mends St., South Perth
16 Spring St., Perth
17 The Narrows
18 Swan Brewery
19 Crawley Baths
20 Crawley Bay
21 Canning River, Mt. Henry
22 Coffey Point
23 Como
24 Nedlands
25 Applecross
26 Armstrong Spit
27 Point Walter
28 White Beach
29 Claremont Baths
30 Peppermint Grove
31 Mosman Bay
32 Blackwall Reach
33 Bicton
34 Rocky Bay
35 Fremantle Traffic Bridge

Table showing Bacteriological Results from Samples taken from Thirty-five Points in the Swan River from the Year 1949/50 to the Year 1953/54 inclusive.

B. Coli	1 cc.	·1 cc.	1 cc.	·1 cc.	1 cc.	·1 cc.	1 cc.	·1 cc.	1 cc.	·1 cc.	Totals.		Decimal Totals.		INDEX.
Sampling Points.	1949–50.		1950–51.		1951–52.		1952–53.		1953–54.		1 cc.	·1 cc.	1 cc.	·1 cc.	
Woodbridge Creek	1/3	1/3	1/4	0/4	2/3	1/3	3/4	2/4	3/3	2/3	10/17	6/17	·588	·352	4·108
Meadow Street	2/4	1/4	0/0	0/0	0/4	0/4	1/4	0/4	0/3	0/3	3/15	1/15	·200	·066	·860
Helena River	2/4	1/4	1/4	0/4	3/4	2/4	3/4	2/4	2/3	0/3	11/19	5/19	·578	·263	3·208
Aerodrome Road	2/4	1/4	2/4	0/4	3/4	1/4	2/4	0/4	3/3	0/3	12/19	2/19	·631	·105	1·681
Cuming Smith	1/4	0/4	0/0	0/0	0/4	0/4	0/4	0/4	0/3	0/3	1/15	0/15	·066	·000	·066
Forbes Street	3/4	0/4	1/4	0/4	3/4	2/4	2/4	2/4	0/3	0/3	9/19	4/19	·473	·209	2·563
Industrial Extracts	3/4	0/4	1/4	1/4	2/4	2/4	3/4	3/4	3/3	3/3	12/19	9/19	·631	·473	5·361
Garrett Road Bridge	2/4	0/4	1/4	0/4	2/4	2/4	2/4	1/4	1/3	0/3	8/19	3/19	·421	·157	1·991
Belmont Crescent	0/4	0/4	1/4	0/4	1/4	1/4	2/4	2/4	1/3	1/3	5/19	4/19	·263	·209	2·353
Hardy Park	1/4	0/4	1/4	0/4	2/4	1/4	2/4	1/4	0/3	0/3	6/19	2/19	·315	·105	1·365
The Springs	2/4	1/4	0/4	0/4	2/4	2/4	4/4	2/4	0/3	0/3	8/19	5/19	·421	·263	3·051
Maylands	3/4	2/4	0/4	0/4	2/4	2/4	2/4	0/4	2/3	0/3	9/19	4/19	·473	·209	2·563
Gasworks	11/11	8/11	9/12	8/12	11/12	9/12	6/12	4/12	4/7	1/7	41/54	30/54	·759	·555	6·309
Hill Street	6/10	4/10	4/11	2/11	1/12	0/12	5/12	2/12	4/7	1/7	20/52	9/52	·384	·173	2·114
Mends Street, South Perth	2/7	0/7	3/7	2/7	0/8	0/8	3/8	1/8	0/3	0/3	8/33	3/33	·242	·090	1·142
Spring Street	5/8	2/8	6/12	1/12	5/12	7/12	6/12	4/12	5/7	4/7	27/51	18/51	·529	·352	4·049
Narrows	5/11	3/11	4/12	1/12	4/12	2/12	3/12	1/12	3/7	2/7	19/54	9/54	·351	·166	2·011
Swan Brewery	11/11	6/11	9/12	6/12	10/12	9/12	9/12	8/12	7/7	6/7	46/54	35/54	·851	·648	7·331
Crawley Baths	3/8	0/8	1/8	1/8	1/8	1/8	4/8	0/8	0/4	0/4	9/36	2/36	·250	·055	·800
Crawley Bay	0/8	0/8	1/8	1/8	0/8	0/8	1/8	0/8	1/4	0/4	3/36	1/36	·083	·026	·343
Canning River, Mt. Henry	0/8	0/8	2/8	2/8	0/8	0/8	2/8	0/8	0/3	0/3	4/35	2/35	·114	·057	·684
Coffee Point	0/8	0/8	1/8	0/8	0/8	0/8	1/8	0/8	1/4	0/4	3/36	0/36	·083	·000	·083
Como	1/8	0/8	1/8	1/8	0/8	0/8	0/8	0/8	0/4	0/4	2/36	1/36	·055	·026	·315
Nedlands	0/8	0/8	1/8	0/8	0/8	0/8	1/8	1/8	0/4	0/4	2/36	1/36	·055	·026	·315
Applecross	0/8	0/8	0/8	0/8	0/8	0/8	1/8	1/8	0/4	0/4	1/36	1/36	·026	·026	·326
Armstrong Spit	0/8	0/8	1/8	1/8	0/8	0/8	1/8	0/8	0/4	0/4	2/36	1/36	·055	·026	·315
Point Walter	1/8	0/8	0/8	0/8	1/8	0/8	0/8	0/8	0/4	0/4	2/36	0/36	·055	·000	·055
White Beach	1/8	0/8	0/8	0/8	0/8	0/8	1/8	0/8	0/4	0/4	2/36	0/36	·055	·000	·055
Claremont Baths	1/8	0/8	2/8	2/8	0/8	0/8	1/8	1/8	0/4	0/4	4/36	3/36	·111	·083	·941
Peppermint Grove	0/8	0/8	0/8	0/8	1/8	1/8	0/8	0/8	0/4	0/4	1/36	1/36	·026	·026	·286
Mosman Bay	1/8	0/8	0/8	0/8	1/8	1/8	0/8	0/8	0/4	0/4	2/36	1/36	·055	·026	·315
Blackwall Reach	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/4	0/4	0/36	0/36	·000	·000	·000
Bicton	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/8	0/4	0/4	0/36	0/36	·000	·000	·000
Rocky Bay	0/8	0/8	0/8	0/8	0/8	0/8	1/8	0/8	0/4	0/4	1/36	0/36	·026	·000	·026
Fremantle Traffic Bridge	0/8	0/8	1/8	0/8	1/8	1/8	0/8	0/8	0/4	0/4	2/36	1/36	·055	·026	·315
Fraction Totals	70/252	30/252	55/240	29/240	55/241	44/241	73/252	38/262	40/143	20/143	296/1128	161/1128	·262	·142	1·682
Decimals	·277	·119	·229	·120	·240	·182	·289	·150	·279	·139	·262	·142	....	....	....
Index	1·467		1·429		2·060		1·789		1·669		1·682		....	....	....

chapter vii

Chemical tests—general survey

Systematic chemical testing of the waters of the Swan River as an index of "pollution" is of comparative recent introduction, the earliest recorded assessments being individual and public observations associated with visible offences and odours and with only a single degree of classification, namely "bad".

The part played by soluble nutrients received from the head waters and agricultural areas adjoining the tributaries of the Swan River in fertilising marine growth was not early realised. Nutrients however received full publicity as a source of pollution when received into the river as a filtrate from the Burswood Island Sewage Treatment Works. The ultimate removal of this filtrate from the river has caused the relatively few industrial effluents now discharging into the river to carry the blame for the largest share of man-made pollution.

Over a period of years numerous chemical analyses of single samples of the Swan River have been made for one reason or another but without continuity, or sufficient data to use as a yardstick to gauge changing estuarine conditions, or the increase in degree of pollution in terms of chemical constituents.

The first recorded analysis which might be used for comparison was taken under the Bunbury Bridge in 1905.

Analysis—transposed to parts per million.

	Bunbury Bridge. 10/3/05.	Sample near same location. 23/3/53.
Free ammonia	1.5	0.7
Organic matter .... (Oxygen absorbed from $KMnO_4$)	10.7	3.1
Chlorides (Cl)	14,040	13,080
*Solids in suspension	510	—

*The nature of the solids in suspension was not recorded but by present day standards the amount would indicate a grossly polluted condition.

Analyses of River Waters for Dissolved Oxygen, 1917-1920.

Probably as the result of complaints from local residents of the pollution caused by the discharge of filtrates from the sewage treatment plant established on Burswood Island in 1912, a survey for dissolved oxygen was carried out in the years 1917, 1919 and 1920.

It would appear that the purpose was to ascertain if a serious depletion of oxygen occurred in river locations adjacent to the sewage discharge and downstream into Perth waters. Samples were also taken at control points upstream to the Springs at Belmont, but it is to be regretted that the sampling points were not extended further downstream at least to Crawley.

The survey showed only slight depletion in oxygen saturation near the filter beds and rapidly recovering to near oxygen saturation progressively at points downstream to Perth waters. The results indicated that by dilution and the natural recuperative processes and oxidation, evidence of actual pollution was almost entirely removed in Perth Waters.

The actual values for dissolved oxygen obtained were similar to those shown in Perth Waters by the systematic surveys carried out since 1948.

Salinity of River.

An over-all increase in the salinity of the Swan River as opposed to seasonal variations has frequently been proposed as one of the factors responsible for a changing marine and algae flora in the river and contributing to wider distribution of types and increased growth. Undoubtedly the character of the Swan River changed materially following the removal about 1898 of the bar which marked the entrance of the river into the sea and more recently in the lower reaches at least by the "weir" effect of the emergency stone protection work around the piles of the railway bridge following the phenomenal flood of 1926.

No scientific observations relating to marine growth, chemical composition or salinity were recorded in those early days.

A systematic series of analyses of the river in Perth water taken at 10-day intervals at Mends Street Jetty, South Perth, was started in March, 1922, and continued to April, 1925.

The figures for chloride (C1) in parts per million plotted on graphs together with analyses from approximately the same positions taken at monthly intervals from July, 1948, to March, 1954, showed almost identical peaks of increasing salinity rising rapidly from October to the maxima in March-April during which time the salinity approaches and sometimes exceeds that of the ocean. Subject to seasonal variation the minimum concentrations in both series are from July-October and are of similar order over the ensuing 26 years.

Fertilisation of Algae Growth.

The growth of algae is a natural phenomena of the estuaries and inlets of the West Australian coast. The estuarine waters of the Swan River provide a favourable habitat with regard to water temperatures and large relatively shallow areas, where the penetration of light is adequate to complete the photo-synthetic processes of growth. It is considered that the natural waters of the river have probably always brought down sufficient nutrients to sustain vigorous algae growth.

Additional fertilising agents have undoubtedly added to the nutrients available to river flora. These have been derived from the run-off from increased agricultural development and settlement of land adjoining the upper reaches of the river and its tributaries.

The part played by industrial wastes in this build-up is comparatively small.

Again early records are lacking in providing a means of gauging the increase of fertilising agents in terms of nitrogen and phosphorus. A brief analytical survey of selected points on the river was carried out during 1923 at the request of Colonel Langley, a U.S.A. health expert lent by the Commonwealth Government, to report on the system of sewage disposal and river pollution generally. Figures obtained during this survey may be used for comparison with those from approximately similar points in the 1948-1953 Survey.

It should be noted that in 1923 the river was receiving discharge from the Burswood Island filter beds and continued to do so until 1936.

	Survey 22nd January, 1923 to 27th November, 1923. Parts per Million.				Survey 6th July, 1948 to 21st September, 1953. Parts per Million.		
	Free Ammonia.	Oxygen absorbed (4 hours.) from $KMnO_4$.	Phosphorus.		Free Ammonia.	Oxygen absorbed	Phosphorus.
Guildford—				Guildford (Sampling point 3)			
Maximum	·90	7·4	·21	Maximum	·7	6·4	1·0
Minimum	·04	1·0	·03	Minimum	·1	2·0	·01
Average	·24	5·0	·09	Average	·37	3·7	·05
Causeway—				Maylands (Sampling point 12)—			
Maximum	·87	6·7	·29	Maximum	·9	8·4	·12
Minimum	·02	1·5	·09	Minimum	·2	1·6	·01
Average	·43	4·2	·19	Average	·52	3·8	·05
Narrows—				Narrows (Sampling point 17)			
Maximum	·78	6·4	·19	Maximum	1·8	8·4	1·0
Minimum	*Nil*	1·0	·04	Minimum	·1	·7	·02
Average	·21	3·5	·10	Average	·44	2·9	·05
Claremont—				Claremont (Sampling point 29)—			
Maximum	·91	5·4	·13	Maximum	·8	6·4	·12
Minimum	*Nil*	·5	·04	Minimum	·1	·6	·01
Average	·14	2·5	·08	Average	·31	2·0	·03

The figures although not statistically comparable would show that there has been an apparent increase in the free ammonia content, little change in the soluble organic matter and a decrease in the phosphorus content of the river at these isolated positions.

During 1948 much Press publicity was given to the pollution of the Swan River which some writers claimed had reached an unprecedented level, and for which the disposal of trade wastes and man-made pollution was entirely responsible.

To ascertain the facts a survey was undertaken for the Swan River Reference Committee to include chemical and bacteriological testing. Started as a preliminary survey samples were taken initially from nineteen selected points, adjacent to bathing beaches, public utilities, known sources of pollution and positions serving as controls and situated from Blackwall Reach through Perth Waters to Maylands. Subsequently the survey was extended to 36 points including additional positions downstream to the Traffic Bridge at Fremantle and upstream to Woodbridge Creek beyond Guildford.

Pollution recent or remote can be inferred if excessive amounts of ammonia, phosphorus and organic matter are found by chemical analysis but the ultimate assessment should only be considered in conjunction with the more delicate bacteriological methods.

Free ammonia may be derived from various sources, some of which are harmless in origin. Excessive amounts together with high organic matter may indicate contamination with sewage or drainage from manured land.

Organic matter is measured by the oxygen absorbed in a test under standard conditions. The biological-oxygen-demand (B.O.D.) is another oxygen consuming test which in this survey is determined by the difference in the immediate dissolved oxygen of samples, and after five days at retained constant temperature. This test is of value as indicating the extent an effluent entering the river can remove the dissolved oxygen therein destroying plant and fish life and if in sufficient quantity causing the locality to become foul and putrid.

The systematic sampling and analyses under this survey together with field observations have permitted a monthly appraisal of the condition of the river and seasonal variations to be assessed. Collectively, in conjunction with the bacteriological examinations, the chemical analyses present with some limitations an overall picture of the purity of the river and the sources and extent of pollution from Fremantle Traffic Bridge to Woodbridge Creek.

Generally the river from Fremantle Traffic Bridge to Crawley and including the Canning River to Mt. Henry shows little evidence of pollution judged by chemical standards. The dissolved oxygen content of the river also shows an overall high degree of saturation particularly from Freshwater Bay downstream and the residual oxygen after five days incubation (B.O.D.) not seriously depleted indicating that, contrary to some opinions, little upstream pollution occurs from Fremantle harbour.

The dissolved oxygen shows a quick recovery when partially depleted by polluting wastes entering the river at the Swan Brewery and in the vicinity of discharge from Industrial Extracts Limited at Belmont.

Although the locality of the Gasworks at East Perth has always shown a high ammonia figure, high values for B.O.D. and phosphorus, consistent with the pollutional effect of an unpurified gas works effluent the figures have been inflated as the result of the nearby entry into the Swan River of the Claisebrook Drain. This drain which is one of the main storm water drains also receives some trade wastes from small factories and establishments not yet connected to the sewerage system.

A noticeable improvement occurred in this locality following the diversion of the gas works effluent after suitable treatment to sewerage disposal, but the drain still constitutes one of the major pollution points of the river. The pollutional effect of effluents from the Emu Brewery and the Spring Street drain are also noticeable in analyses of samples taken at Point 16 in Perth Water, particularly during the winter and late summer months.

The results of the tests compiled in the 1948-53 Chemical Survey of the Swan River shows that it should not be difficult for existing industrial effluents received into the Swan River to meet or receive the necessary treatment to meet the requirements proposed by the Sub-Committee on Standards of the Swan River Reference Committee.

chapter viii

Odours of the Swan River—general survey

General.

The senses particularly associated with the olefactory organs appear to be the criteria mainly utilised by the public to assess pollution of the Swan River. Although the river is obviously more polluted in the winter months public complaint is confined to the mid-summer months and centres around decomposing algae upon the foreshores.

Odours do not lend themselves to precise classification and this applies also to those which have their origin in the Swan River and which may be of natural origin or as the result of industrial effluents.

ODOURS OF NATURAL ORIGIN.

Algae.

The algae which are responsible for the offending emanations grow in relatively shallow water, where altering conditions of salinity from winter to summer may create an unfavourable environment. Following a succession of low tides the algae may be killed by prolonged exposure to the sun and subsequently become detached by wave and wind action. When thrown on the beaches the weather conditions prevailing may hasten decomposition and cause sulphur-assimilating diatoms growing or attached to it, to die.

A product of this death and decomposition, common to organic matter containing sulphur, is the familiar "rotten-egg" odour associated with hydrogen sulphide. The gaseous emanations undoubtedly contain other sulphides such as ammonium sulphides, methyl sulphide together with amines and minute traces of complex sulphur and nitrogenous gases.

The period of offense is of comparatively short duration, being usually manifest about the first week of December and recurring until the beginning of February by which time most of the detached algae have drifted to shores to decompose or to be removed as the result of governmental or local governmental action.

Muds.

The river being the natural draining basin of the Swan valley receives in addition to the surface run-off, drainage in the form of colloidal matter and products of vegetable and animal decay. Bordering swamp lands yield considerable soluble organic matter and partially broken down organic silts. Following the usual pattern of river erosion the Swan has deposited eroded matter on flats to which flood waters have added their quota of suspended organic matter and tractional loads of silt.

It is known that the black mud formed from decomposing organic vegetable consists of complex compounds such as humic acid, organic residuums not easily fermentable or putrescible and even free carbon. In the muds of the Swan River in addition to these compounds there is much ferrous sulphide present as minute flakes and granules and also associated with fibrous organic matter. In the slightly alkaline condition of the river ferrous sulphide is very slowly oxidised to sulphate in shallow water without the evolution of gaseous sulphides. Removed from the water, the muds have a mouldy, slightly putrescent odour which intensifies on exposure to the atmosphere over a period.

As the result of phenomenal low tides and Easterly winds therefore, the mud flats may become malodorous with the altered conditions. The odours are a combination usually associated with putrescible nitrogenous matter, decaying crustacea and some hydrogen sulphide. When the mud flats are again covered the process of normal oxidation in shallow water is re-established with little or no evidence of odour from the river.

Odours of Industrial Effluents.

The Swan River from Guildford to the Traffic Bridge at Fremantle receives the natural drainage, drainage from built-up areas and a limited and reducing number of trade wastes through some 25 storm water drains and possibly effluents direct from 14 industrial establishments. Of these some are in the nature of cooling water returned to the river at an elevated temperature but otherwise without tangible contamination or discernible odour.

Effluents and drainage containing much organic matter (both in solution and suspension) discharged into the river may be sources of pollution in that they deplete or reduce the dissolved oxygen necessary to maintain a healthy and clean river.

Many of these discharges are not inherently odorous and their pollutional effects are almost removed by natural processes and oxidation, and the enormous dilution provided by the large expanses of Matilda Bay, Melville Water and Freshwater Bay.

Abattoir waste which formerly gave offence as a malodorous discharge into the Helena River has now been given satisfactory treatment and is no longer an offensive effluent.

The gas works formerly contributed an odorous effluent variously described as pungent, acrid and phenolic. Whilst not offensive or putrescent it constituted one of the most potent sources of river pollution. Since 1952 however this discharge has been diverted to the Perth sewerage system.

Brewery wastes when discharged are malty or yeasty in odour and although high in suspended and soluble organic matter are not offensively odorous. Through their avidity for oxygen, these effluents are potentially a major source of industrial pollution of the river.

In the vicinity of North Fremantle a laundry discharges a fluid containing soap, etc., which is not normally offensive but at periods may become slightly nauseating.

An effluent containing non-settable solids in suspension, manural matter, grease and excess alkali is discharged by Woolscouring Works into the river centre reputedly on an outgoing tide. Dispersion by this agency is not always complete and shallows and mud flats adjoining become malodorous with a fetid, foul odour.

chapter ix

Swan River Reference Committee Algae clearance

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Harbours and Rivers

The problem of algae clearance by mechanical means is one that has received considerable attention by technical officers associated with the above Committee and it has been found that serious difficulties arise because of the peculiar circumstances apertaining to the growth of algae in the Swan River.

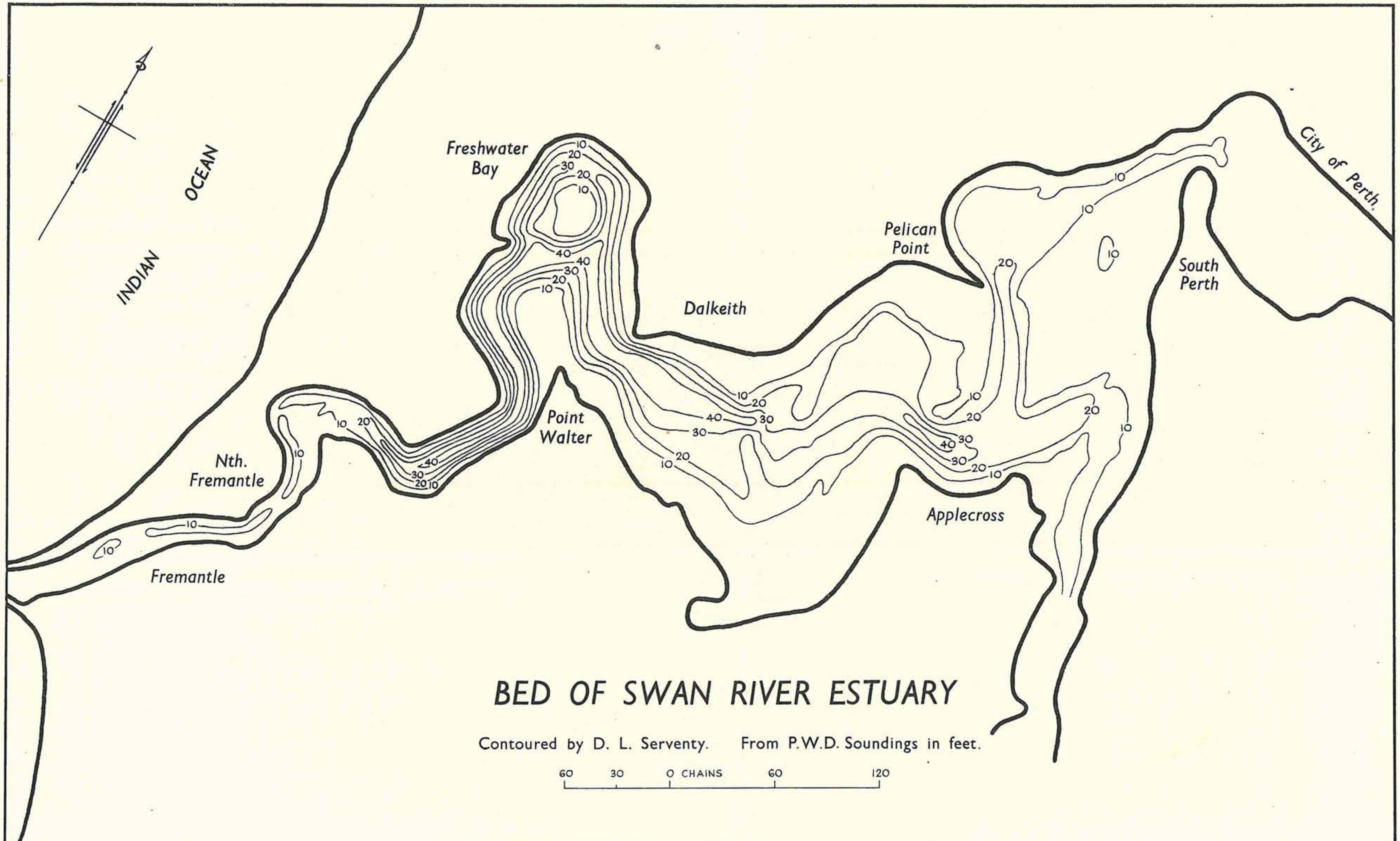
Generally, algae clearance is necessary extending from Mosmans Bay on the right bank of the river and to Lucky Bay on the left, with a roadway separating distances of some 14-15 miles. Hence a mechanical unit demands high mobility because of the extensive zone to be treated.

It is found that the condition of the river bed in the zone concerned has greatly different characteristics adjacent to the various foreshores. In some, a clean white sand beach is presented which offers sufficient stability to permit of the operation of mechanical tractors either wheeled or caterpillar tracked. However, the use of such mechanical equipment in salt water causes high maintenance costs and furthermore, such practice is not acceptable for plant under the control of the Mechanical and Plant Engineer.

In other sections of the zone where algae clearance is required, the river bed is unstable and will not support any wheeled or caterpillar tracked mechanical device for removal of algae. Many parts of the foreshores requiring treatment have numerous obstructions on the river bed and it may be said that all areas requiring treatment have insufficient depth of water to provide flotation for floating plant of sufficient size to be of value in effectively dealing with the problem.

One of the main sources of the algae nuisance is an extensive area on the South Perth foreshore extending from Mill Point to Como and having an area of 120 acres with 12 inches or less depth of water. It has been estimated that in parts of this area there is an algae growth of 50 to 100 cubic yards per acre. Tests indicated also that, on clearance of selected areas under control, regrowth was rapid.

It has also been established that the offending algae is that located in shallow areas which are subject to drying or near drying when low summer tides prevail and temperatures are sufficiently high to kill the growth, thus permitting the algae to float



BED OF SWAN RIVER ESTUARY

Contoured by D. L. Serventy. From P.W.D. Soundings in feet.

and then eventually be washed ashore on beaches affecting those vulnerable, as determined by the direction of the prevailing wind. Operation of floating plant is not practicable to remove algae in such limited depth of water. Very limited sections of the river bed will permit the operations of any mechanical wheel or caterpillar equipment for the removal of algae at its source of growth because of river bed instability.

During November of 1953 a number of experiments were carried out by the Harbours and Rivers Branch of the Public Works Department to ascertain any promising method of algae collection and disposal. A chain some 100 feet long fitted with tynes was drawn along the river bed between two tractors, over extensive beds of algae, opposite the Royal Perth Yacht Club at South Perth. This method was quite ineffective and discarded. A "Mitchell" harrow with stump jump cultivating points was also used, but again results were not encouraging. It was found that the algae collected between the tynes, quickly built up a barrier completely sealing the passage of water between the tynes. As a result a wave was formed in front of the machine as soon as this blocking up resulted and in consequence induced the flow of algae away from the collecting medium instead of into it.

The Department has examined two mechanical devices submitted by outside interests. Both were identical in type with pump operation and an expanded suction to operate on the vacuum cleaner method. Both ideas fail because the enlarged suction area reduced the velocity of approach to such low limits as to be ineffective in inducing a flow of algae through the pump or intercepting screen. For successful operation, any method such as this, demands a large dimensioned pump with heavy and powerful prime mover. In effect a suction dredge becomes the answer. In such case a depth of water is demanded greater than provided in areas to be treated at the source of growth and furthermore, the exclusive removal of algae without sand, mud, etc., forming the river bed would not be possible. Dredging of the sources of algae growth to provide sufficient depth of water, i.e., four feet for flotation and to a depth of water where algae growth would have no nuisance value, is beyond the economic ability of the State. The cost of dredging the 120 acres previously referred to would cost in the vicinity of £100,000.

It is my opinion, therefore, that the existing method of hand raking of affected beaches by Local Authorities and the Public Works Department, is the most effective and economic method of treatment.

chapter x

The Fauna of the Swan River Estuary

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I.—INTRODUCTION AND SUMMARY.

The fauna of the estuarine compartment of the Swan River presents a strikingly different character in the summer from that which occurs there in the winter, and the animal communities of the estuary cannot be discussed without relation to the chemical and physical conditions—salinity, oxygen content and temperature—existing at the time. The transition from the summer conditions to those of the winter is often associated with phenomena which, to a superficial observer, may erroneously recall some of the consequences of pollution. However, at no stage and in no part of the Swan River, except in extremely localised spots, does the condition of the fauna provide any indication of the effects of man-made pollution.

In the summer months, when there is no flow of fresh water into the estuarine basins, the boardwaters may be fittingly described as an arm of the sea, populated with an exclusively marine fauna. All of the widespread animal phyla, with the exception of the Echinodermata, are represented.

During the winter months, from the beginning of July, or when the up-stream waters begin to flow, the estuary freshens, either gradually or suddenly, A skin of fresh water comes to lie over the entire estuarine system, varying in depth according to the severity of the winter floods. The wedge of bottom marine water, sealed off from the atmosphere, rapidly loses its oxygen, and consequently the deeper portions of the estuary become untenable for animal life.

The freshening of the upper layer, accompanied by a lowering of the temperature, and the de-oxygenation of the bottom salt water, has a catastrophic effect on the marine organisms which flourished in the summer and autumn. The attached and slow-moving invertebrates perish in a wholesale manner and there is an extensive seaward exodus of fishes. It should be emphasised that this calamity is in no sense due to pollution. It has been an annual event in the river since the present climatic and physiographic regime was established, existing for a vast period prior to white colonisation, and its severity varies with the nature of the season.

The replacing fresh water fauna in the upper layer is extremely sparse compared with the rich assemblage of summer organisms. Most of the fauna is planktonic and hence consists of minute forms which do not readily impress themselves on the notice of the average naturalist or collector. Some of the marine forms, which are more or less tolerant of brackish or fresh water conditions, may continue to exist over the winter, and the degree of this survival also varies with the intensity of the winter floods.

As the summer salinities return and the stratification of the estuary is destroyed, the marine organisms begin to re-populate the estuary. By October or November the typical summer conditions are re-established, but the full climax of this fauna may not be reached until late summer.

Conditions in the estuary were not always so. The wealth of sub-fossil marine Mollusca, associated with Echinoderms, demonstrates that the Swan River estuary in Sub-Recent times was a permanent marine basin which could not have been materially subject to the seasonal freshening which now operates.

The present seasonal variations in the composition of the estuarine fauna, and the conditions under which it exists, may now be considered in rather more detail.

II.—THE ESTUARY IN THE SUMMER.

The environment in the summer months is far from uniform, temperatures and salinities fluctuating, both exceeding the maxima to be met with in the sea outside the moles at Fremantle. The fauna, however, is always rich. Minor fluctuations in salinity appear to have little effect on the abundance of the plankton which at times is so plentiful that the water assumes a "pea soup" appearance because of the abundance of microscopic life. However as temperatures fall in the autumn the plankton diminishes, even though the salinity remains high.

The Diatoms of the estuary include a variety of forms, the genera *Chaetoceras, Melosira, Synedra, Coscinodiscus* and certain Naviculoid groups being prominently represented in tow-nettings made at Crawley Bay. Species of the first two genera may be present in such numbers as to dominate the plankton at times, great quantities occurring in late summer and autumn.

Among the Dinoflagellates a form of *Ceratium furca* is an abundant constituent of the summer plankton and in the autumn it may occur in such enormous numbers as to dominate the plankton. A form of *Peridinium* occurs regularly with it.

One of the most interesting Protozoans from the popular point of view is a large Tintinnid which appears to be associated with the phosphorescence in the estuary, as first noted by Professor W. J. Dakin (1916, p. 17). In the spring it does not appear until the chlorinity reaches 1.2% and may persist until June or until the final eclipse of the marine plankton by the winter floods.

Two Jellyfish are abundant in the plankton, the pellucid, pale *Aurelia aurita* and the large brown *Phyllorhiza punctata,* both surviving well into the winter if the floods are late. A Ctenophore also occurs.

The attached forms include Sponges; the branched and bushy Polyzoan, *Bugula neritina;* the Barnacles, *Balanus nigrescens* and *B. amphitrite;* the Edible Mussel, *Mytilus planulatus;* and dense growths of the Ascidian, *Ciona intestinalis* and of the Polychaete, *Mercierella enigmatica.*

Among them shelter a variety of animals including a large Turbellarian, *Leptoplana;* large numbers of Caprellid Amphipods and the Hymenosomid Crab, *Halicarcinus australis.* Some of these creatures are also found in seaweed patches, of which *Gracilaria confervoides* is very abundant. In the shelter of this alga Amphipods and the Shrimp, *Palaemonetes australis,* are particularly plentiful. Further downstream, *Leander intermedius* is common among algae in Freshwater Bay, where the fauna has been specially studied by Thomson (1946, p. 55).

The burrowing forms comprise several Crustaceans, including *Corophium* in the sandy mud, and the boring Isopod, *Sphaeroma quoyana,* which tunnels both in the sandstone rock in the Freshwater Bay area and the jetty piles. There is also the boring bivalve, *Venerubius crenata.* The common Polychaetes are *Harmothoe waahli, Leonnates ehlersi, Nereis oxypoda, Ceratonereis erythraeensis, Haploscoloplos kerguelensis* and *Demonax leucaspis,* some of which are dug for bait by anglers.

Larger benthic and swimming Crustaceans include several Prawns of which the most plentiful is *Penaeus latisulcatus,* and the Blue Swimming Crab, *Neptunus pelagicus,* all of which form the basis of a worthwhile fishery, both for professionals and amateurs.

A striking feature of the composition of the estuary fauna is the absence of Echinoderms and the poverty in species of the Molluscs. Of the latter some five species only are reasonably common. The Edible Mussel, *Mytilus planulatus,* and *Venerubius crenata,* have already been referred to. The Window Pane Oyster, *Monia ione,* is very numerous on the lower levels of the shallow banks. The only common Gastropod is *Velacumantus australis,* and towards the mouth of the estuary the Bubble Shell, *Quibulla tenuissima,* is common, though it extends at least as far up the estuary as Crawley. This remarkable poverty of Molluscs contrasts with the richness of forms in the sub-fossil shell beds already mentioned (see Glauert, 1925, p. 65 for a representative list of species), and which are of such extent that they are dredged as a basis for cement manufacture. The locality, "Swan River", given in the checklist by Hedley (1916, p. 152) refers to the district of the Swan River Colony and not to the present living fauna of the estuary.

Fishes are abundant and in 1953 supported 18 commercial fishermen who marketed 67,000 lb. of fish and 37,000 lb. of prawns and crabs. The commercial fish were mainly Mullet (*Mugil dobula*), 44,000 lb.; Yellow-eyed Mullet (*Agonostomus forsteri*), 6,000 lb.; Tailer (*Pomatomus pedica),* 5,000 lb.; Cobbler (*Cnidoglanis macrocephalus),* 4,000 lb.; Black Bream (*Acanthopagrus butcheri),* 3,500 lb.; and Flathead (*Platycephalus bassensis*), 2,000 lb. In addition considerable quantities of fish and crustaceans were taken by amateurs. Other commercial or potentially commercial fish in the estuary include the Perth

Herring (*Nematalosa erebi*), Scaly Mackerel (*Amblygaster posterus*), Anchovy (*Engraulis australis*), River Garfish (*Reporhamphus regularis*), Yellow-tail (*Therapon caudavittatus*), Trumpeter (*Helotes sexlineatus*), Skipjack (*Caranx georgianus*), River Kingfish (*Sciaena antarctica*) and Flounder (*Pseudorhombus jenynsii*). The Whaler Shark in the estuary has been described as a distinctive species, *Galeolamna mekaili*, but it occurs also over a considerable length of the Western Australian coastline.

Of the non-commercial fish species the better-known ones are Gobbleguts (*Apogon ruppellii*), Hardyheads or Smelt (*Pranesus endrachtensis*), and Gobies (*Glossogobius suppositus*), all of which figure prominently in the dietary of the four species of Cormorants found on the estuary. None of these birds breed around the estuary but three species feed on the shallows in very great numbers. These are the Pied Cormorant (*Phalacrocorax varius*), a marine species nesting on the islands outside; the Little Pied Cormorant (*P. melanoleucus*), and the Little Black Cormorant (*P. sulcirostris*), both nesting in the fresh water swamps north and south of the estuary. The last-named cormorant has a community-fishing technique by which large companies of densely-packed birds, of up to a thousand or more individuals, operate on the shoals of Hardyheads and Anchovies. The large Black Cormorant (*P. carbo*) is an infrequent visitor to the estuary, more common in some years than others, and is more likely to take commercially important fish than the other species, but its effect on the fish stocks is negligible. However, though of no importance as predators on important fish species these birds have aroused criticism from yacht-owners because they foul the boats while perched on them.

The estuary supports other fish-eating birds, including four species of terns, of which the Crested (*Sterna bergii*) is the commonest, and a moderate number of Pelicans (*Pelecanus conspicillatus*). There is a large population of Silver Gulls (*Larus novae-hollandiae*). On the foreshores waders are numerous, and some 35 species of migratory sandpipers, plovers and dotterels have been recorded. There are also flocks of Avocets (*Recurvirostra novae-hollandiae*) and White-headed Stilts (*Himantopus himantopus*). The only local breeder is the Red-capped Dotterel (*Charadrius ruficapillus*), which nests at Pelican Point. Riverside development is, however, reducing the habitats of all these species.

Ducks are plentiful in numbers but not in species. The most abundant is the Grey Teal (*Anas gibberifrons*) which might be seen in flocks of many hundreds at Pelican Point, Como and Lucky Bay. Black Swans (*Cygnus atratus*), after which the river was named by the first Dutch explorers, are hardly ever seen on the broadwaters, except at Lucky Bay, but are plentiful enough above the Causeway and in the Canning River. The infrequency of the birds in Perth and Melville Waters has often aroused comment, and even advanced as evidence of pollution. However, as Whittell has pointed out (1954, p. 60), the records of the early explorers suggest that this has always been the case. At the end of the last century birds were captured from elsewhere and held pinioned in Perth Water. It appears that many of these fell victims to Avian Aspergillosis.

The Common Dolphin (*Delphinus delphis*) ascends the estuary not infrequently as far upstream as the Causeway, and has been known to feed on the Perth Herring. The Western Water-Rat (*Hydromys fuliginosus*), though essentially a fresh water species, can exist under marine conditions and formerly inhabited the banks of the estuary. It may still do so in the more secluded reaches as dead specimens are occasionally seen on the foreshore in winter. These may, however, have come down in the winter floods.

III.—THE ESTUARY IN WINTER.

With the deterioration of physical conditions in the winter months profound changes occur in the fauna and a temporary fresh water community of animals exists in the surface water during this period. Temperatures decline during the autumn and drop from the high levels of summer (about 23 to 26° C.) to about 13° C. in mid-winter at the surface. The bottom temperatures do not fall so rapidly in the autumn nor rise as rapidly in the spring, so the bottom water is decidedly warmer in the winter than at the surface and colder in the spring and early summer.

However, considerably more drastic to the summer fauna are the salinity changes. With the first heavy winter rains, fresh water begins to flow into what has been an essentially marine basin during the summer. As a rule no profound effects are apparent until about late June or July, when a stratum of brown silt-laden freshened water develops over the clear salt water remaining in the estuary. This may be gradually attained, or in years of heavy floods, the situation is established with catastrophic suddenness. The degree of surface freshening, and the depth of the surface layer of fresh water varies with the nature of the season. In 1930 the stratum of fresh water was eight feet deep at Crawley Bay and in 1935 it was five to six feet. In years of particularly severe floods, the whole of the estuarine basins may become fresh, and the salt water entirely scoured out, as happened in 1946, but in low rainfall years the surface may remain of moderately high salinity throughout the winter, as was the case in 1949.

The bottom salt water, blanketted off from the surface, becomes progressively de-oxygenated and the degree of this also varies with the intensity of the stratification. The bulk of this stagnant bottom water, fouled also with hydrogen sulphide, is confined to the deep channel or trench in the estuary, which is covered with soft black mud, but the considerable expanse of sandy shallow flats, less than 10 feet in depth, may escape being covered with de-oxygenated water.

Following these drastic changes in temperature, salinity and oxygen content, the marine fauna is rapidly killed off, and when the floods come down suddenly the alterations in faunal composition of the estuary may be established within a few days. The attached animals such as the Ascidians, tubicolous worms and barnacles die off and remain for a time as putrifying masses. Often fish, unable to accommodate themselves quickly to the altered conditions, perish and are washed up on the beaches. These include River Kingfish, Cobblers, Perth Herring, Gobbleguts and Hardyheads. Others, like Pipefishes (*Stigmatopora argus*) forsake their weedy harbours and swim about in so moribund a fashion that they can be easily taken by hand. Fishermen using sunk nets in the winter often bring up dead crabs and prawns below certain depths.

Generally speaking, however, the crustaceans and many of the fish tend to move out of the estuary to the sea when the winter freshets start. The aboriginals used to take advantage of this movement by constructing fish weirs, or mungurs, where the situation was practicable. None have been reported on the Swan River but a notable one existed near the mouth of the Serpentine River at Barragup, of which detailed descriptions are available (Hammond, 1933, p. 46; Fraser, 1953, p. 186). So effective was the operation of this "very destructive engine for fish capture" (Thompson, 1898, p. 4) that the fisheries authorities of the day procured its demolition. Mullet, being an anadromus species, are not incommoded by salinity changes but they share in this downstream movement because they spawn in the autumn and with the first rains leave the fresh river and lake waters, which are the preferred habitats of the adult fish, for the sea. Throughout the winter fry and immature Mullet may be found in the estuary but a considerable movement of these into the estuaries takes place in the spring. Black Bream, another euryhaline species, which, however, breeds in the estuaries, is common in the upstream reaches in the summer and in the winter extends its distribution downstream into Melville Water. Another species which remains in the winter is the Flounder and commercial fishermen take it with sunk nets on banks which lie above the de-oxygenated zone.

A few of the marine invertebrate elements may survive during the winter months. These include some Amphipods; the burrowing Isopod, *Sphaeroma quoyana;* the Shrimp *Palaemonetes australis;* the Mussel, *Mytilus planulatus,* and the Crab, *Halicarcinus australis.* On the shallow banks in the brackish water zone the Blue-swimming Crab, *Neptunus pelagicus,* and sometimes the Common Jellyfish, *Aurelia aurita,* may contrive to exist.

The temporary fresh water fauna of the upper water zone comprises mostly planktonic organisms, all derived from the inland fresh water streams and swamps. This community includes characteristic fresh water Protozoans such as *Euglena, Volvox* and *Pandorina,* and, more rarely, the Desmid *Closterium.* The Rotifer, *Brachionus,* is plentiful. Crustacea include Boeckellid and Cyclopid Copepods, and several species of Cladocera, including the common South-West species, *Daphnia thomsoni,* and others of the genera *Simocephalus, Ceriodaphnia* and *Moina.* Mosquito larvae are abundant, and *Aedes camptorhynchus,* a common local species in the winter, has been identified. Tadpole larvae of Frogs are plentiful and probably several species occur.

No fresh water fishes become temporarily established in the estuary though the Pigmy Perch (*Nannoperca vittata*) may occasionally stray as far as the Bunbury Railway Bridge and to the junction of Bull's Creek and the Canning River. The fresh water Long-necked Tortoise (*Chelodina oblonga*) may be found as far as Pelican Point.

Among the birds the most noteworthy difference from summer conditions is the dearth of waders. The Northern Hemisphere breeders are, of course, absent on migration but even the true Australian species such as the Red-capped Dotterel, are scarce. Probably the scarcity of surface and burrowing invertebrates is the cause. There is, however, a striking new addition to the bird fauna of the winter months, the Hoary-headed Grebe

(*Podiceps poliocephalus*), fleets of which are dotted all over the shallow reaches of Melville Water. In the aggregate there must be many thousands of these birds present. The Cormorants still occur in seemingly undiminished numbers.

Numerically (in number of individuals) and in variety (in number of species) the winter fresh water fauna is far inferior to that existing in the summer. This is demonstrated in the illuminating graph of plants and animals given by Thomson (1946, p. 68) of his investigations of Freshwater Bay, Claremont.

Conditions favouring the existence of the fresh water fauna are of comparatively short duration, and they may endure some 10 to 12 weeks. In some wet years with prolonged rain, the period may be much longer; thus in 1907 "the freshet was strong, and lasted four months" (Abjornsson, 1908). As explained in Chapter III as the fresh water run-off slackens the constant tidal pressure at the mouth of the estuary moves the wedge of bottom sea water further upstream and vertical mixing breaks down the winter stratification. Fresh water organisms tend to disappear about the end of September and during October the marine fauna begins to re-establish itself. This transition is later in wet years, and in the case of the flood year of 1945 the winter conditions persisted until the end of October or early November, after which they rather rapidly reverted to those characteristic of the summer.

IV.—LONG-TERM FLUCTUATIONS IN THE FAUNA.

As is the case with the faunal composition of other environments long-term cycles of abundance and scarcity are apparent in the case of certain species in the Swan River estuary. Where these are conspicuous or have economic importance public opinion is too ready to ascribe the explanation to man-caused influences, such as pollution or over-fishing. There is evidence, however, that these events have been of long standing in the history of the Swan River estuary. Some of the more interesting cases of long-period cycles may be mentioned.

During the summer of 1947-48 a large jellyfish appeared on the estuary and became as abundant as the familiar Common Jellyfish, *Aurelia aurita*. It re-appeared each successive summer and still exists, exceeding at times in numbers that of the Common Jellyfish. The new jellyfish attracted considerable speculation at the time of its appearance and a favourite hypothesis was that it had been introduced on the floats of Catalina aircraft from Northern waters. Specimens were identified by Dr. M. Blackburn, of the Fisheries Division of the C.S.I.R.O., as the Rhizostome, *Phyllorhiza punctata*, described by von Lendenfeld from New South Wales and not hitherto recorded in the literature outside of that State. However it appears to have been long a resident of Western Australian waters. It had been seen previously in the Swan River and an occasional individual was observed in 1930. Over a century ago, in 1838, the naturalist James Backhouse, noted that two species of jellyfish were abundant at that time in the estuary and he gives recognisable figures of both (1843, p. 548). It appears that some time after his visit *Phyllorhiza* disappeared from local waters as a common species and made a sudden revival in 1947.

Up to a couple of decades ago Swan River anglers were greatly troubled by a small Blowfish (*Spheroides pleurogramma*) which was present in the broadwaters in excessive numbers. It, however, made a sudden disappearance and this phenomenon likewise has caused much speculation. The author found the Blowfish plentiful in the estuary in 1937, when he left the State. On his return in 1943 it was absent. No specimens were again recorded until the summer of 1954-55, when the species re-populated the estuary.

Two other fishes in the estuary are noteworthy for their long-term presences and absences. These are the Clupeoid "Scaly Mackerel" (*Amblygaster posterus*) and the Perth Herring (*Nematalosa come*). There is some evidence that these species tend to replace each other as common elements in the estuary. The Perth Herring was an abundant species locally until 1950 and it formed a small but important war-time canning industry. According to fishermen "Scaly Mackerel" were observed at Applecross in 1952. This was the first time that the species had been observed for many years. A similar fluctuation has been observed in the Peel Inlet, Mandurah. The disappearance of the Perth Herring as a common species there in 1910 caused the closing down of a local cannery.

It is impossible at present to correlate these fluctuations with other varying factors, biotic or physical, in the estuary, or, indeed, to be sure that the cause lies wholly in conditions inside the estuary. There are several other species whose irregular presence in the estuary appears to be certainly due to what might be termed "outside" causes, notably variations in their population strengths in their main centres of distribution elsewhere. Thus between 1903 and 1907 the West coast was visited by considerable shoals of the Southern fish, the Barracouta (*Thysites atun*) and in the autumn of 1903 they invaded the estuary as far as the Narrows. There has been no record of a similar visitation since. The irregular variations in numbers of the Black Cormorant (*Phalacrocorax carbo*) on the estuary are also probably due to some outside cause and not concerned with the availability of estuarine food supplies. Pelicans are usually present in minimal numbers in the estuary in winter but in some years, as in 1952, they may occur in strength throughout the year; there is evidence that this is correlated with adverse environmental conditions in other parts of the State, resulting in a greater irruption into the South-West.

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chapter xi

Pollution Control

This problem will be discussed under four sub-divisions.

1. The type of Administrative Body or Bodies required to carry out control.
2. Standards to be set with regard to permissible pollution of the River.
3. Laws to be enacted to empower the Administration to maintain these Standards.
4. Revenue.

The legislation of other States and countries has been examined to ascertain how these four sub-divisions of the problem have been approached, and what answers have been obtained.

Probably the most extensive recent examinations of the problem have taken place in Great Britain and in California. In these two countries years of investigation by special committees have produced reports that have led to considerable administrative changes and redrafting of legislation. The reports prepared by these committees and the laws, etc., that have arisen from them were concerned with the prevention of pollution in all rivers and waterways, tidal and otherwise. The legislative and administrative machinery for preventing pollution in fresh water rivers, that may be sources of drinking water supply, is exactly the same as that required for tidal waters, the only difference being in the standard of pollution to be considered permissible.

It is therefore relevant to examine the application of the new British and Californian administrative processes to our own problem of the Swan River. The objective of the Sub-Committee is to incorporate in its examination and solution of the Swan River problem, a plan that will be applicable to all rivers and waterways in the State. The standard of pollution permitted will depend on whether the water is to be used for drinking, or otherwise.

Following on the Report of the Rivers Pollution Sub-Committee of the Central Advisory Water Committee, Great Britain introduced the River Boards Act, 1948, and the Rivers (Prevention of Pollution) Act, 1951. These Acts are applicable to England and Wales, with certain areas excluded.

After the publication of the "Dickey, Fact-Finding Report" California legislature enacted 11 Bills to control Pollution—Dickey Bills 1949.

ADMINISTRATIVE BODIES.

In England the Minister for Health and the Minister for Agriculture and Fisheries divided the country into Regions. Where navigable waterways were included in a Region the Minister for Transport was also concerned. To each Region a Board was appointed to control all matters pertaining to Rivers and Waterways. Regional Boards consisted of from 3/5 to 2/3 local authority representatives and the remainder represented the Ministers.

The Minister for Health was mainly concerned with pollution; the Minister for Transport with navigation and the Minister for Agriculture and Fisheries with the remaining aspects of River Control. Regional Boards were empowered to appoint permanent paid staff and they were requested to consult all authorities and interested bodies when formulating their policy. Such was the position brought about by the River Board Act, 1948. The 1951 Act concerned itself mainly with Pollution and for some reason or other was placed under the direction of the Minister for Local Government. It placed under the control of the River Boards all matters of pollution which, hitherto had been the responsibility of various authorities. The Act does not, however, repeal certain clauses of the Health Act dealing with River Pollution. Local health authorities therefore retain the power and the responsibility for direct action on their own behalf, when they consider that a nuisance is being created that will endanger health by virtue of water pollution.

The 1951 Act requires the Regional Boards to set up Standards and controls for effluents entering the rivers, and to produce by-laws approved by the Minister for Local Government and the Minister of Agriculture and Fisheries. A person may appeal to the Minister against a decision of a Board regarding an effluent he is discharging or wishes to discharge into the river. The Minister has also power to intervene where he considers that a Regional Board is not adequately carrying out its duties.

The State of California under the new laws has been divided into nine Regions for Control of Water Pollution. The supreme authority is the State Water Pollution Control Board.

The State Water Pollution Control Board consists of nine members appointed by the Governor and the following officers of the State, or their nominees.

(a) The Director of Public Health.

(b) The State Engineer.

(c) The Director of Natural Resources.

(d) The Director of Agriculture.

Of the nine members appointed by the Governor, at least one shall be selected from qualified persons engaged in each of the following fields:—

(a) Production and supply of domestic water.

(b) Irrigated agriculture.

(c) Industrial water use.

(d) Production of industrial waste.

(e) Public sewage disposal.

(f) City government.

(g) Country government.

Insofar as reasonably practicable the Governor shall appoint a member from each of the nine "regions".

"A Regional Board, consisting of the following members shall be appointed by the Governor for each of the regions":—

(a) One person associated with organisations dealing with water supply, conservation, or production;

(b) one person associated with irrigated agriculture who is an owner or manager of a farm in the region;

(c) one person selected from persons acting in an executive or administrative capacity in industries producing industrial waste in the region;

(d) one person associated with the municipalities in the region;

(e) one person associated with the counties in the region.

State and Regional Boards appoint their own chairman; members obtain only necessary expenses incurred on official business. Each Board is required to appoint an executive officer and necessary staff.

The State Board administers general State wide policy, finance and research in the control of pollution. It acts as an appeal board and may also give instructions to a Regional Board or take over the latter's functions where the Regional Board has failed to carry out its duty.

The State and Regional Boards deal with "Pollution" and "Nuisance" where these are not actual hazards to health. Where "contamination" of the water creates an actual hazard to health, the situation is dealt with by local or State health officers under the authority of the Health and Safety Code.

We see, therefore, a remarkable similarity between the English and Californian form of Administration; in England a central authority of the Ministries of Health, Agriculture and Fisheries, Transport and Local Government; in California the chief technical officers of similar departments plus technical representatives from the regions. Both countries are divided into regions to correspond to a geographical distribution of the waters, and to each region a local board is appointed consisting of men conversant with the problem in their region.

In both countries there is recognition that matters directly affecting health should not be left entirely to the jurisdiction of such boards and that it is necessary to allow the health officer liberty of action when a hazard threatening health is involved.

The re-organisation of administrative control in England and California arose from the necessity to remove the confusion of multiplicity of control under the old methods. The confusion arose in two ways. Firstly authorities interested in different aspects of river usage produced different laws and standards for the same part of the river. Secondly local authorities were geographically arranged in a pattern completely dissociated from the geographical pattern of rivers and streams. Water therefore flowed from one local authority area to the next, and local authorities down stream were dependent for the quality of their water on the vigilance or neglect of the authorities upstream.

It may now be advantageous to examine the general position in Western Australia to ascertain how far it is satisfactory or otherwise for local conditions and to what extent application of English or Californian principles might be profitable to this State.

In general, streams and waterways as regards pollution, are under the control of Local Authorities by virtue of authority derived from Health Act, Road Districts Act and Municipal Corporations Act. There are however, a number of water supply systems, both drinking water and irrigation water that were Government projects and are controlled by the Minister for Works.

Legislation exists under the Water Boards Act to permit of the setting up of local boards of control for rural community water supplies. Two committees advise the Minister in the control of State Water Supply systems; namely The Metropolitan and The Country Water Purity Committees. These committees are formed from officers of the Public Health Department, Agriculture and Forests Departments, Government Chemical Laboratory, and water and sanitary engineers of the Public Works Department.

The committees have no statutory authority. Until recently control of these water supplies was largely a matter of control of catchment and reservoir, and as the catchment was largely State forest or unalienated land, the matter of control did not involve interests outside Government Departments. With, however, the advent of the Wellington Dam as a drinking water supply, we found ourselves suddenly face to face with the same problem as England, California and all other industrial countries. We had, in fact, an industrial town situated on the banks of the river a few miles above its entry to the reservoir. It was to meet this situation that the Country Water Purity Committee was formed. The committee recommended a plan for sewerage and development in the basin and produced by-laws to protect the quality of the water. The general principles of the committee's policy while framing the by-laws are given in appendix V.

This committee consists of Government representatives only. To be in line with English and Californian legislation it would be necessary to include representatives of local interests.

There is one feature that English, Californian and Western Australian administration have in common. That is the position of the health authority, and the recognition of that authority's paramount position in regard to hazards threatening health.

The Acts protecting water supplies in Western Australia from which the Minister for Works and Water Supplies derives his authority, obtain their measures protecting health from the Health Act and in administering them the Minister has the powers of the local health authority. By this means the Commissioner of Health is still in a position to intervene if hazards affecting health arise.

This may all seem a very round-about approach to the Control of Pollution in the Swan River, but it is our contention that the problem in that river is merely part of a much larger problem, and in order to understand that part thoroughly it is necessary to know something of the whole. It is our purpose to integrate the Swan River problem with that in the whole State, so that the solution for the Swan River will eventually fit, without modification or adaptation, into a future integrated plan for pollution control in all our streams, waterways and foreshores. By visualising the whole plan now we can more accurately form the pieces that will fit the pattern of the whole, and avoid a patchwork development that will eventually require intensive investigation and revolutionary adjustments, such as have recently been found necessary in England and California.

Control of pollution of the Swan River is vested in the Local Authorities by virtue of the Health, Road Districts and Municipality Corporation Acts. Some legal doubt seems to arise as to the extent of this jurisdiction, if it is held that the river is Crown property outside the limits of the local authority. But irrespective of this, most pollution can be corrected before it reaches the River so that one way or another the local authorities cannot escape the responsibility The Health Department has the same prerogative, as in other waters, to interfere where a health hazard occurs, but as the Swan River is virtually sea water this power is almost entirely limited to health hazards affecting recognised swimming pools.

With some 20 local authorities abutting on the river, any form of uniform control has been totally impracticable, the position being similar to that in England before the advent of the River Boards. To attain some unity of purpose the Swan River Reference Committee was formed, its purpose being to advise the Government and to endeavour to prevent pollution by stimulating the various bodies and departments represented on it to take action within the jurisdiction of their respective Acts. The Reference Committee consists of representatives of various Government Departments with interests in the river, private organisations (sporting bodies) using the river and from the local authorities.

The diversity of Acts and legislation that this process entails is reminiscent of the position in California before the setting up of Regional Boards, except that in California the complaint would appear to have been that a number of Authorities were giving different directions to correct each source of pollution, whereas with the Swan River there is a reluctance to take on the responsibility of correcting any source of pollution. Whatever exaggeration there may be in this statement it is obvious that the absence of a clear cut overall authority and responsibility is detrimental to adequate control, and therefore the Reference Committee or analogous body must be given authority corresponding to the Regional Boards of California, or the River Boards of England.

With an increase in population in the State, development of industry and a demand for water borne sewage, one can look forward to the time when control of water supplies and streams will be decentralised to Regional Boards who will be subject to the overall jurisdiction of a Central Board of Control largely consisting of technical officers acting on behalf of the Minister. The controlling body for the Swan River will naturally be one of these Regional Boards.

It should therefore consist of persons representing interests in the use of the river, i.e., departmental officers whose departments are intimately concerned with the river, representatives from local authorities on the shore of the river, and from industrialists and others, such as sporting bodies to whom the river is an important asset in their work or sport. This Regional Board would have statutory authority to control pollution and other matters appertaining to the best use of the river. The Minister, advised by the Central Board or Committee of technical officers, would act as a Court of Appeal, would give technical advice and assistance and could when necessary direct the Regional Board, when he considered that the latter was not carrying out its duty towards obtaining the best use of the river. This Regional Board would require an Executive Officer and staff to carry on the day to day work of administering its policy and laws. As it is doubtful if the project is big enough to warrant full time officers for this task it would seem reasonable, at least in the beginning, to obtain them from the staff of a Government Department.

By such a process of reasoning we therefore conclude that the administration and control of the Swan River should be vested in the following bodies:—

1. Central Body for control of State Waterways, water supplies, etc.,
   Minister for Works,

   acting in conformity with the advice of his Advisory Committee consisting of:—

   Chief Engineer Water and Sewerage Departments.
   Commissioner of Public Health.
   Director Chemical Laboratories.
   Director of Agriculture.
   Director of Industrial Development.

   or the nominees of the above.

   This Central Body to act as an Appeal Board and to have power to advise and to direct Regional Boards.

2. Regional Board for the Swan River to consist of a member representing each of the following:—

    Local Authorities.

    Medical Officer of Health or Health Inspector for Local Health Authorities.

    Local Authority Engineer conversant with drainage problems.

    River Sporting Activities.

    Government Departments concerned with River Navigation and Harbour Management.

    Department of Industrial Development.

    Department of Fisheries.

    Town Planning Board.

This Regional Board will carry out its policy through the agency of a salaried Executive Officer and whatever paid staff he requires.

In the beginning the Executive Officer may be appointed by the Minister for Works and maybe an officer in a Government Department concerned with development of the Swan River area. His staff may also be found in that Department. Such work as he performs for the Regional Board would be in addition to Departmental duties.

In process of time as the Regional Board establishes its policy and revenue accrues it may be advisable for it to appoint and maintain its own Executive Officer.

STANDARDS.

It is not the task of a controlling authority to maintain a natural stream or waterway in a state of absolute purity. To do so would restrict activity and strangle development in the whole drainage area.

The Controlling Authority's task is to set a standard for the water that is compatible with its future use, and to regulate the quantity and quality of pollutants for the adequate maintainance of this standard.

In setting standards for rivers, waterways, etc., and for effluents entering them, the Controlling Authority finds itself in the greatest difficulty, which is seldom fully appreciated by those without sound technical knowledge and experience of such matters. It is apparent that the fact finding commissioners and committees in California and England, and the bodies constituted under their recommendation, developed a greater appreciation of this difficulty as the knowledge of the subject increased.

There are, broadly speaking, three methods of legislative control of effluents

Firstly the "Permit Method" which requires anyone desiring to discharge an effluent into the river to first obtain a permit from the controlling authority, which will examine the proposed effluent and state whether or not it may be permitted.

Secondly there is the "Standard Method" whereby the controlling authority lays down standards for effluents, and anyone wishing to discharge an effluent may do so provided it is within the required standard.

Thirdly there is the "Combined Standard and Permit Method" wherein only a generalised form of standards is laid down as a guide, and a permit is obtained from the controlling authority when it is satisfied that such standards are to be obtained.

Prior to the Dickey Bills, Californian waters were controlled by the Permit System.

It would appear that the Fact Finding Commission was impressed with the iniquities of the Permit System. Permits were required from different authorities for the same effluent; having spent large sums of money on industrial plant the owner was in danger of losing all because no permit was forthcoming for the effluent; the Health Authority included in its permit the right to dictate the manner in which the effluent would be treated, in addition to a mere acceptance of the final effluent.

The Commission is almost self-congratulatory over its recommendations to abolish this method and establish a Standard Method whereby industrialists would know before planning their manufactory what the requirements for the effluents were, and whereby the industrialist, etc., would not be dictated to regarding the manner of treatment of the effluent, provided that in its final form it complied with the Standards.

The impression is obtained that the Commission regarded this as a revolutionary conception of control with which it was well pleased. Then the technical difficulties arose, the inescapable mathematics and the ingenuity of the modern chemist and industrialist.

The standard with which we are essentially concerned is that of the whole body of water, and standards for effluents are devised to maintain this overall condition. The degree of pollution of the water will depend on four things; the quantity of water, the rate of change of this water, the quality of the effluents and the quantity of the effluents. The first two may be calculated with reasonable accuracy, but the latter two are constant variables, and herein lies the difficulty and the insurmountable defect of any hard and fast standard system applied to effluents.

There would appear to be a little confusion in the minds of some, concerning the standards laid down by the Royal Commission on Sewage Disposal.

This Royal Commission carried out an exhaustive inquiry between 1898 and 1915 when it isued its Tenth and Final Report. It laid down standards for solid content and oxygen demand in effluents and indicated the means of calculating the permissible proportion that the effluent should bear to the flow of water in the stream. The Commission, however, was only concerned with sewage disposal, and its standards are largely inapplicable to complex effluents of modern industry. It is for this reason that the whole situation has again been reviewed in the United Kingdom.

Any set standard that confines itself to elements or simple compounds is hopelessly inadequate. Chemists and particularly manufacturing chemists almost daily add to an ever increasing number, some compound of complex formula with characteristics of little resemblance to the properties of its elemental constituents. Further even than this we are concerned in this atomic age not only with such compounds and natural isotopes of the elements but also with the manufactured radio active isotopes.

The expanding use in industry of such isotopes may lead to further complications in standards for effluents.

It is obvious then that even were it possible to lay down standards for the host of known pollutants, such standards would be inadequate because of the continual increase to the number of such pollutants. Many of the new substances used are concerned with processes in the nature of trade secrets which the manufacturer does not wish publicised, and the controlling authority would ever be behind in its appreciation of the presence and need for standards in respect of such substances.

So much for the quality of pollutants. It stands to reason that if we do not know the quality we cannot set standards for the quantity. It may, however, be suggested that we set standards for quantity of known pollutants. There is, however, this difficulty. The Controlling Authority is concerned with the overall standard of the body of water, but it must give to the industrialist a standard for his effluent. The Controlling Authority cannot expect the industrialist to calculate the effect of his effluent on the water in conjunction with all other effluents.

The Controlling Authority must calculate the total permissible pollutant acceptable to the stream and allow each industrialist to contribute to that total on some equitable basis. Further, having allotted amounts, the controlling authority must be prepared to review them and reduce them from time to time to make way for additional industrialists with similar polluting effluents. There is therefore no permanency in such standardisation.

It is also inequitable to divide equally among the industrialists the amount of pollutant they contribute by setting a fixed standard. This apparent contradiction may most easily be explained as follows. Suppose X to be the pollutant for which a Standard is to be fixed. It is decided that the stream can absorb 3X. Then if three industrialists, A B and C, desire to add this pollutant to the stream we may say that each industrialist shall add not more than 1X to the stream and therefore 1X is the standard. This standard will have to be reduced if further industrialists enter the field. But this standard is inequitable because B and C can, without much difficulty or expense reduce the pollutant to $\frac{1}{2}$X, whereas A cannot maintain his industry without discharging $1\frac{1}{2}$X. It would therefore be more equitable to set the standard for B and C at $\frac{1}{2}$X and for A at $1\frac{1}{2}$X allowing a further $\frac{1}{2}$X for future expansion of similar industries.

If we admit that such an arrangement is more equitable, we admit finally that set standards are impracticable and detrimental to the best use of the stream. In other words, it is essential to consider each effluent individually and decide the standard to which it will comply and this standard will be liable to review from time to time depending on growing demands on the use of the river.

The Californian authorities despite their initial enthusiasm in repealing the "Permit Law" and endeavouring to substitute the "Standard Method" seem to have realised the difficulties and to have come to the conclusion that the situation can only be met by a "Case by Case Study of the Problem". Amongst the "General Powers and Duties" of a Regional Board we find the following:—

> 13054.—Any person proposing to discharge sewage or industrial waste within any region, other than into a community sewer system, shall file with the regional board of that region a report of such proposed discharge. The regional board, after any necessary hearing, shall prescribe requirements as to the nature of such discharge with relation to the conditions existing from time to time in the disposal area or receiving waters upon or into which the discharge is proposed, and notify the person proposing the discharge of its action. Such requirements may be revised from time to time. After receipt of such notice, the person so notified shall provide adequate facilities to meet any such requirements with respect to the discharge of sewage and industrial waste.

It is very difficult to see in what way this does not constitute a permit system.

Some slight difficulty also seems to have been encountered in the resolution to confine the jurisdiction of the boards to the standard of the effluent, and to disallow any interference into the individuals method of obtaining this standard. The obvious difficulty here arose in the case of small private sewage plants and septic systems.

It is totally impracticable to set a bacteriological and chemical standard for private septic systems and expect the owner to be capable of working out the problem and maintaining the standards by a series of examinations. We find therefore that the Attorney General was under the necessity of issuing the following in an Opinion of Act, 1950.

> Thus in an area where a local ordinance or regulation establishes disposal criteria for small installations, which, in the judgment of the regional board, provide reasonable safeguards against pollution and nuisance, the regional board may simply require that the installation shall comply with the local ordinance or regulations. Where no local requirement is in force the regional board may instead of passing upon individual proposals, provide in advance a set of standard requirements to which all installations shall adhere. Such advance requirements may be simple or detailed, depending on physical factors which may vary from one area to another. It may be anticipated that in some areas the statutory objective will be satisfied by a simple requirement that the effluent be kept underground.

Having already experienced this difficulty it is likely that the boards will encounter many more of a similar nature among industrial effluents from small plants and backyard industries, wherein it is far more practicable and satisfactory to lay down the method of treatment rather than the standard to be attained. One feels that the Californian legislation would have been more practicable if it had provided for qualifying the amount of direction a board would give on the method of treatment, rather than abolishing this prerogative entirely.

If we turn for a moment and consider briefly how the problem is being faced in England we find that years of work by special committees led to the Rivers Boards Act, 1948, and the Rivers (Prevention of Pollution) Act, 1951.

The expert investigators in these committees disentangled the jumble of Acts and Authorities dealing with water pollution, but the Acts which they have apparently instigated quietly side step the major problem—the setting of standards. Instead the Rivers (Prevention of Pollution) Act throws the whole responsibility on the River Boards thus—

> 5.—(1) A river board may by bye-laws make such provision as respects any stream or part of a stream in their area as appears to them expedient—
>
> (2) for prescribing standards for the purpose of determining when matter is to be treated as poisonous, noxious or polluting for the purposes of this Act.

Some three years later we are still awaiting the publication of these bye-laws. We are therefore unable to say what method will be adopted, although a recent circular from the Ministry of Local Government (Appendix VI*) indicates that the matter is still testing the ingenuity of an expert committee.

The sum total of all this then, is that it is desirable to set maximum standards for effluents, so that all persons intending to use the river for disposal of effluent know exactly where they are, but in practice this is not possible and it is necessary to consider each effluent on its own merit and to decide on the standard it will maintain and, if necessary, how it will be treated.

In an endeavour to obtain as far as possible the advantages of both systems the Combined Method of control is to be considered.

This sets a generalised standard for the whole body of receiving water and permits are issued for effluents which are considered not to jeopardise this standard.

It seems that some of the Californian Regional Boards have come round to this interpretation of their new legislation. For example, the Regional Board for San Francisco Bay, a similar body of water to the Swan River, made specific standards for sewage plant effluents but considered that these standards were met if the bay retained certain characteristics of relative purity.

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Extracts from the San Francisco Bay Regional Board resolutions are as follows:—

Therefore, Be It Resolved, that this Regional Water Pollution Control Board prescribe the following requirements for the sewage plant effluent which the Cities of .... propose to discharge at the place and in the amount stated above:—

B.O.D.	200 P.P.M.	Maximum.
Suspended Solids	130 P.P.M.	Maximum.
Grease	10 P.P.M.	Maximum.

No objectionable odours of sewage origin.

Be It Further Resolved: That if the Cities of ...... are able to maintain the following conditions in the receiving waters of San Francisco Bay Easterly from the mouth of the existing ship canal and provided that no nuisance arises from the discharge of sewage or industrial waste into the ship canal or tributary slough, the Board will consider the above requirements as being met:

No formation of sludge deposits.

No noticeable grease, scum or other floating material of sewage origin.

No objectionable odours of sewage origin.

Dissolved oxygen 3 P.P.M. Minimum.

Be It Further Resolved: That if conditions should change materially at some time in the future, it may be necessary to revise the above requirements and in such event the Board will take up the matter with the Cities at that time.

The Combined Method gives some guide to all users of the river concerning the state of purity they can expect to enjoy or are expected to maintain and at the same time permits of complete supervision and adequate flexibility in control. It is therefore, the method to be recommended.

We must now give careful consideration to the principles which will guide us in setting up this general standard, and the standards and conditions for individual effluents for which permits are to be issued.

To quote the "Dickey" Report: "In its broadest terms water pollution may be defined as an impairment of the quality of natural waters by the addition of foreign materials to a degree which limits the further use of such water."

This limitation or the factors causing this limitation may be:—

(a) Dangerous to health.
(b) Injurious to fish.
(c) Detrimental to irrigation.
(d) Prevent watering of stock.
(e) Impair its usefulness to industry.
(f) Interfere with navigation.
(g) An aesthetic nuisance, i.e., a nuisance by virtue of unsightliness or evil odour, not amounting to a health hazard.

The Swan River being sea water, certain exclusions must be made to the above list—

(a) is limited to influences on swimming and bathing.

(c) does not apply.

(d) does not apply.

(e) will most likely only concern industries using sea water for cooling.

Our standards need therefore only concern themselves with maintaining suitable conditions for the list modified by these exclusions. In making the standards we must bear in mind that over restriction of pollutants may impair the use of the river as much or more than the pollutants would themselves do if left unrestricted.

This attitude towards pollution is emphasised in all recent approaches to the problem, e.g.:—

In the British Rivers (Prevention of Pollution) Act, 1951, Section 2 (3)—

> Subject to section five of this Act, the said subsection shall not, by virtue of paragraph (a) thereof, penalise the discharge into a stream of any trade effluent or any effluent from the sewage disposal or sewerage works of a local authority, if—
>
> (a) it is not reasonably practicable to dispose of the effluent otherwise than by discharging it (directly or indirectly) into that or some other stream;
>
> and
>
> (b) all reasonably practicable steps are taken to prevent the effluent being unnecessarily poisonous, noxious or polluting.

This, of course, does not detract from the power under the Health Act to take action where a hazard dangerous to health is involved.

In January, 1950, the Californian State Board adopted a preliminary statement of objective and policy. A portion of this statement reads as follows:—

> The objective of the State Water Pollution Control Board is the prevention and control of pollution and contamination of the waters of the State at a minimum of expense consistent with obtaining this objective. In achieving this objective, it will be the policy of this Board that its actions and those of the Regional Water Pollution Control Boards shall be so directed as to secure that degree of care in the planning and operation of works for the treatment and disposal of sewage and industrial wastes as will adequately protect the public health and all the beneficial uses of waters in this State, and at the same time permit the legitimate planned usage of those waters for receiving suitably prepared wastes so that an orderly growth and expansion of cities and industries may be possible.

The "Report of the Inter-Department Committee on the Pollution of Waters in New Zealand," August, 1952, after summing up the evils of unnecessary industrial waste pollution, continues:—

> On the other hand there is need for appreciation by the community of these points:—
>
> (1) That the contamination of great quantities of water in industrial processes is unavoidable.
>
> (2) That, in general, fluid wastes from industry must be discharged to inland or coastal waters.
>
> (3) That natural waters, by dilution and biochemical processes, can assimilate reasonable quantities of industrial waste liquors.
>
> (4) That restraints on industry should be the minimum restraints necessary to safeguard the interests of different sections of the community in the waters to which the wastes are discharged.
>
> (5) It would be harmful to industry directly and indirectly to the country's economy—to impose harsh restraints on industry by sudden legislative process. Any change to be fair and effective, should allow reasonable time for remedial measures.

With all this in mind and with the Tables A and B as an indication of standards in other countries, we are in a position to formulate our standards.

We can say that, in general, effluents will meet the requirements of our standards if in the main body of the Swan River effluents do not cause:—

(1) Any formation of sludge deposits.

(2) Any noticeable grease scum or other floating material of effluent origin.

(3) Any objectionable odours.

(4) Any discolouration.

(5) The dissolved oxygen to be below 6.5 p.p.m. average; 5.0 p.p.m. minimum.

(6) The B.O.D. to rise above 2.5 p.p.m. average; 3.5 p.p.m. maximum.

(7) P.H. value to be outside maximum 8.6—minimum 6.0.

(8) Phenols to rise above .005 p.p.m. maximum.

(9) Coliform organisms to be more than 5 per ml. average; 10 per ml. maximum. or more than occasionally found in .1 ml.

(10) Any undue increase in Phosphorous or nitrogen content.

(11) The Radioactivity to be higher than limits normally found in such a River.

(12) The presence of any toxic substance in sufficient quantity to constitute a hazard to the health of persons bathing in the stream or to be inimical to fish life in the River.

This is the standard we hope to maintain in the river; it is necessary now to decide how far from the effluent outfall we desire this standard to be reached. Here a number of local considerations will have to be taken into account, and each situation and effluent considered on its own merit. For example it is obviously inequitable to set the same distance for an outfall that is adjacent to oyster beds or swimming pool, as for one that is situated on an unfrequented part of the River. Local habitation, local use of the river, prevailing currents, etc., must be taken into account when setting the distance from the outfall where our standards will have to be met.

Each effluent then has to be considered on its merits in the following manner:—

(1) Ascertain the concentration of substances in it affecting the standards of the river.
(2) Calculate the volume of effluent in 24 hours, = Ve.
(3) Decide on the distance applicable to this particular effluent at which our standards are to be obtained.
(4) Calculate the volume of water into which the effluent will be dispersed before reaching this distance, with due regard to prevailing currents, = Vw.
(5) Calculate degree of variation of this volume of water in 24 hours.

In addition, the concentration of substances in the receiving body of river water must be determined.

There will frequently be difficulty in calculating the quantity of water into which the effluent is dispersed, but a rough approximation can be obtained by supposing the stream to be devoid of current, and the effluent to disperse evenly in a radial direction, so as to be represented as a semicircle with the diameter the bank, and the centre the effluent outfall.

The dispersal in depth may be taken as "t" feet which will be an average dispersal depth over the theoretical semicircle, and is influenced by such factors as tidal range, salinity, temperature, etc., as well as topography in the neighbourhood of the effluent drain. This depth "t" will vary from place to place in the river estuary.

If the distance decided on in which a particular effluent must comply with the proposed standards is "x" feet, then the volume of water into which it will be dispersed is

$$\frac{\pi x^2}{2} \times t \times d \text{ gallons (with d gallons} = 1 \text{ c. ft.)}$$

which is very closely = 10 x^2t gallons = Vw gallons.

and if number of changes per day of Vw = n.

then total volume of water for dispersal per day = 10 ntx^2 gallons. Knowing the volume of effluent (Ve) in gallons discharged each 24 hours, it is possible to determine the dilution that occurs, and may be expressed as a dilution factor.

$$= \frac{n\ Vw}{Ve} \quad \ldots\ldots\ldots\ldots (1)$$

or

$$= \frac{10ntx^2}{Ve} \quad \ldots\ldots\ldots\ldots (2)$$

As the receiving body of water will be polluted to some extent before discharge of effluent occurs, allowance must be made for the quantity of pollutants already present. Using the dilution factor, theoretical maximum and/or minimum values for effluent can then be calculated.

This method does not allow for re-aeration which cannot be ignored without requiring effluents to be of an unnecessarily high standard.

Re-aeration depends on turbulence, temperature, depth, time, sunlight and the rate of deoxygenation of the liquid. For most cases it will be necessary to compute coefficient of re-aeration from direct observations of dissolved oxygen and B.O.D. at various critical points. Future conditions can then be predicted from these observations.

An approximation of the rate of oxygen absorption by water from air and from plants can be obtained from the attached graph. For initial calculation of quantity of oxygen absorbed, it is advisable to work from the full line shown on the graph.

Assuming that an industry wishes to discharge effluent to the River, the following method will give a rough indication of the standard required for that effluent, for say B.O.D.

Let B.O.D. of receiving water $= Bw$ p.p.m.

Let B.O.D. effluent water $= Be$ p.p.m.

and B.O.D. as max. allowed by standard $= 2.5$ p.p.m.

with dilution factor $= \frac{n\,Vw}{Ve}$

then B.O.D. allowable for effluent is

$$Be = (2.5 - Bw)\frac{n\,Vw}{Ve} \text{ p.p.m.}$$

Available B.O.D. in Receiving Water $= (2.5\text{-}Bw)\ n\ Vw\ 10^{-5}$ lbs./day.

From graph, determine oxygen absorbed (R) in lbs. per day, then total available B.O.D.

$$= (2.5\text{-}Bw)\ n\ Vw\ 10^{-5} + R \text{ lbs/day.}$$

$$= (2.5\text{-}Bw)\ \frac{n\,Vw}{Ve} + \frac{R\ 10^{5}}{Ve} \text{ p.p.m.}$$

With Vw and Ve expressed in gallons.

(For further information on re-aeration reference may be made to Sewerage and Sewage Treatment by Harold E. Babbitt.)

If the quantity of receiving water is large compared to quantity of effluent, then the resulting temperature, dissolved oxygen content, B.O.D. etc. of the mixture can be computed from the general expression.

$$Cm = \frac{Ce\ Ve + Cw\ Vw}{ve + Vw} \quad \text{where}$$

Cm = the particular characteristics of the mixture desired e.g. temperature.

Ce = corresponding characteristic of the effluent.

Cw = corresponding characteristic of diluting water.

Ve = volume of effluent in the mixture.

Vw = volume of diluting water in the mixture.

This formula is not strictly correct if conditions at a point "x" feet from point of discharge are being considered, unless it is assumed that original quantity of diluting water remains in dispersal area after effluent is added.

Allowance for re-aeration should be made as previously.

Where prevailing currents are such as to limit the dispersal of the effluent before it reaches point "x" feet from discharge, a limiting factor will have to be introduced to the amount of pollutant discharged to correspond to the limitation in dispersal.

Experiments will require to be carried out with pollutants for which permits are requested, to find at what concentration they comply with the generalised requirements of producing no sludge, discolouration, floating objectionable matter, etc. Having decided on the distance at which the standard will apply, the amount of daily discharge may then be calculated.

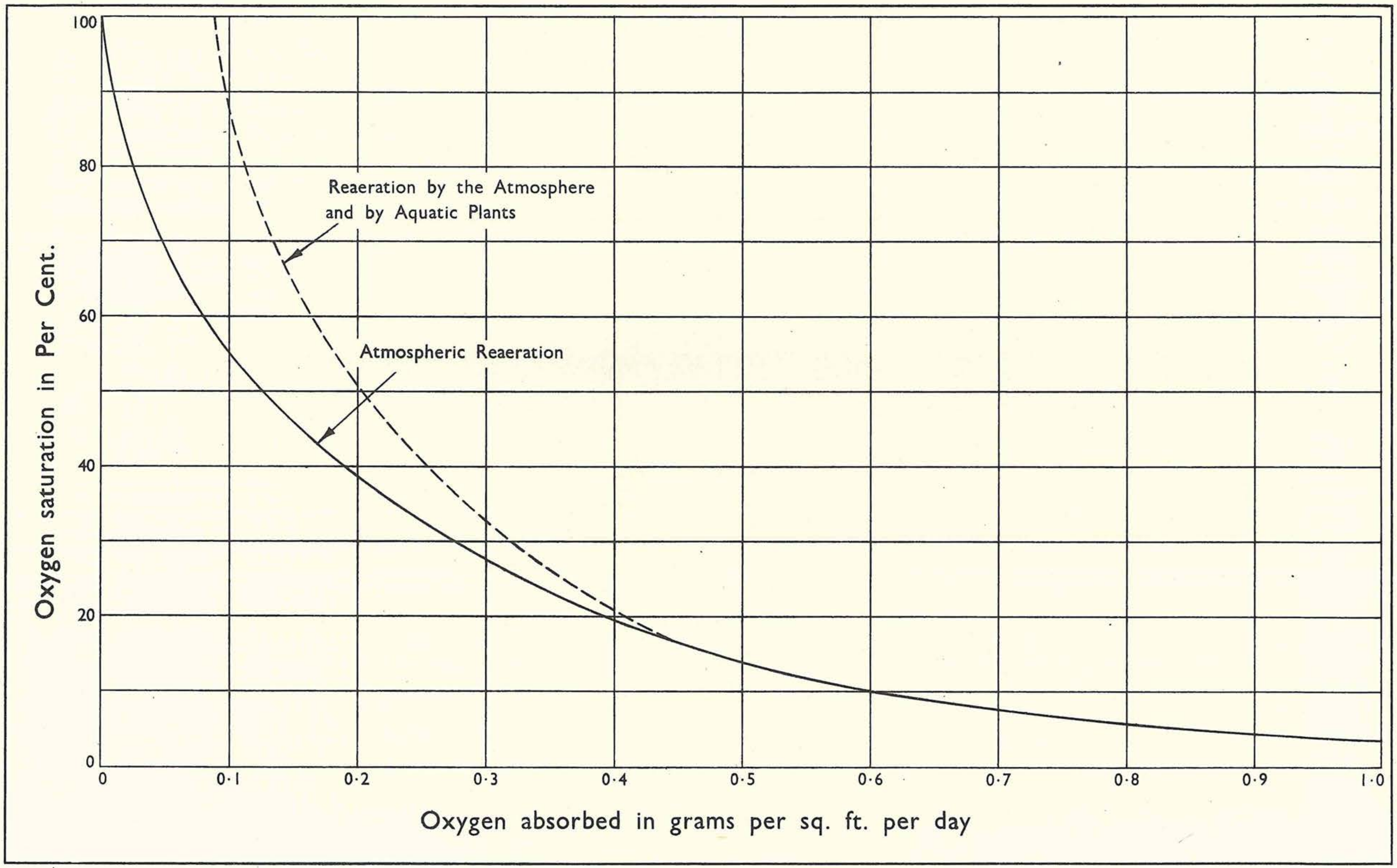
There are, however, two additional sets of circumstances which must be borne in mind when considering the permit for an effluent. These apply to the effluent at the outfall, and are not covered by our standards for the river. They are:

(1) Concentrations of acids or alkalis or other substances that may be harmful to persons entering the water adjacent to the effluent outfall, but which with normal dilution would be within our standards at distance X.

A similar danger may arise from high temperature of an effluent.

The permit may safeguard against this by stipulating Ph values and maximum temperature at the outfall or by arranging for the exclusion of the public from the river and river bank adjacent to the outfall.

(2) The pollutant may be of such a nature that it is fixed or precipitated instead of being dispersed. The effluent would then conform with our general standards, but there would be an objectionable accumulation on the river bed adjacent to the outfall. Such circumstances would arise when insoluble material was present in large particles in the effluent. It may also occur



Reaeration by the Atmosphere and by Aquatic Plants
Atmospheric Reaeration
Oxygen saturation in Per Cent.
100
80
60
40
20
0
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
Oxygen absorbed in grams per sq. ft. per day

by chemical fixation with normal constituents of the river. This chemical fixation may be particularly dangerous where radio-active material is concerned, leading to dangerous local concentration.

Such things can only be dealt with by individual examination of every proposed effluent.

Standards have been suggested for radioactive materials in drinking water supplies and discharges into sewers. The position regarding these substances is at present in a stage of rapid evolution, and their control requires specialised knowledge of a nature not expected of water control authorities.

It is therefore advisable that in all cases where a permit is sought for the discharge of an effluent suspected to contain radioactive substances that the matter be referred to the State Council controlling the use of radio-active materials.

The same principles as the above may be applied to a stream used as a drinking water supply. In such a stream we have the choice of two points from which to measure the distance X, namely the effluent outfall and the water supply intake. Our standards at that point will be higher than those set for the Swan River and in addition to odour, pollutants will be required to cause no detectable taste. The standards may vary in accordance to the purification treatment to be given the water before being turned into the drinking supply.

LEGISLATION.

Apart from Acts dealing with Navigation in rivers, the use, etc., of rivers, streams, waterways, reservoirs and catchment areas is dealt with under the following Acts:—

Health Act, 1911-1954.

Metropolitan Water Supply, Sewerage and Drainage Act, 1909-1951.

Country Areas Water Supply Act, 1947-1951.

Water Boards Act, 1904-1953.

The Rights in Water and Irrigation Act, 1914-1951.

The Road Districts Act, 1919-1951.

The Municipal Corporations Act, 1906-1953.

The Land Drainage Act, 1925-1941.

There is an overlapping of these Acts but in general they are a means of applying some principles of pollution control to different bodies of water.

Any legislation for the Control of the Swan River should anticipate a similar evolution of control laws in this State, as is taking place elsewhere, and be drafted so as to fit into the scheme of things if these Acts or the relevant portions of them, are subsequently co-ordinated and incorporated in our Regional Water Pollution Control.

We would therefore suggest that a Regional Water Pollution Control Act should be drafted which would apply to the Swan River, and which could be extended from time to time by legislation to cover other similar areas as Regional Water Pollution Control areas.

The Act to be administered by the Minister for Works and Water Supplies with the assistance of a State Board or Council.

The State Board to be composed of members as previously indicated in this chapter.

The State Board to be mainly advisory but to have power to direct or when the Minister so decides to take over the functions of a Regional Board. It will also be a Board of Appeal.

The Act will appoint Regional Boards composed of members as previously indicated, and allow for their policy to be carried out through the agency of an Executive Officer.

The Act will empower the Regional Board to control effluents and wastes discharged into the water or likely to gain access to the water; and to take any other action as may be specified in the Act to promote or preserve the purity of the water.

The Regional Board will be empowered to take action and to make by-laws or regulations to protect or improve the quality of the water, to set standards for the water and for effluents and wastes to be discharged into the water. The Act will prohibit pollution of the water and misuse of the water.

It will empower the Regional Board to make by-laws or Regulations concerning the issue of permits for discharge of effluents and wastes and for any other purposes prescribed in the Act.

The Act will allow the Regional Board to obtain funds from the Government and from Local Authorities in its area and to raise charges for granting of various permits.

The Regional Board will be authorised to expend these monies on any, or all, matters appertaining to its function of regional control of rivers, waters etc.

Any person with a grievance against a decision by the Regional Board may have the right of appeal to the Minister.

Nothing in this Act should restrict the application of the powers of the Health Act by the appropriate authority where a circumstance constituting a danger to health arises or is likely to arise.

REVENUE.

Regional Boards will require funds for carring out their functions.

As their work will bestow both a national and local benefit it is right that they should acquire funds from both the Government and from Local Authorities.

As also benefits will be conferred on private individuals and industrial concerns in the acceptance of wastes and effluents it is fitting that a charge should be levied for such use of the water, and for the issue of the necessary permit. It is very difficult to fix equitable charges for the discharge of effluents because of their variation in quality as well as quantity. As however every effluent will have to be treated by the industry producing it to comply with a standard considered satisfactory for the general condition of the river, it would seem equitable to make a standard rate for every 1,000 gallons discharged, with a flexible scale of over-charges for industries that produce noxious effluents which limit the use of that section of the river for other industrial effluents.

This method would allow case by case examination and rating at the time of granting the permit, and at the same time would allow industrialists to make a close estimation of the charge likely to be levied on them before they undertake the development of their industry.

It would also allow the Minister to define maximum ratings to be made by Regional Boards.

TABLE A.

Standards in operation in other countries are as follows:—

U.S.A.*

Stream Quality and Uses.	Standard†	Class.	Coliforms/ml.		Dissolved Oxygen (p.p.m.)		5-Day B.O.D. (p.p.m.)		pH Value		Phenols (p.p.b.), (U.S.A.).
			Ave.	Max.	Ave.	Min.	Ave.	Max.	Min.	Max.	
Excellent.											
Recreation (Bathing), Water Supplies (Chlorination)	Ohio R.B.	AA	0·5	....	....	....	....	....	6·5	8·6	....
	T.V.A.	I	0·5	....	7·0	....	1·0	2·0	6·5	8·6	....
	W.V.	AA	1·0	....	7·5	6·5	0·75	1·0	6·3	7·7	0·0
	P.R.B.	A	0·5	....	7·5	6·5	....	....	6·0	8·0	....
Desirable.											
Recreation (Bathing), Fish Life	Ohio R.B.	A	1·0	10·0	6·5	5·0	3·0	....	6·5	8·6	1·0
	T.V.A.	II	5·0	10·0	7·0	5·5	1·5	3·0	6·5	8·6	....
	W.V.	A	10·0	....	6·0	5·0	2·5	3·5	5·8	9·0	5·0
	P.R.B.	B	5·0	10·0	6·5	5·0	1·5	3·0	6·0	8·5	....
Desirable.											
Water Supplies (Filtration)	Ohio R.B.	A	50·0	....	6·5	5·0	3·0	....	6·5	8·6	....
	T.V.A.	II	50·0	....	6·5	5·0	2·0	4·0	6·5	8·6	....
	W.V.	A	10·0	....	6·0	5·0	2·5	3·5	5·8	9·0	5·0
	P.R.B.	B	50·0	....	6·5	5·0	2·0	4·0	6·0	8·5	....
Doubtful.											
Water Supplies (Aux. Treatment), Recreation, Fish Life	Ohio R.B.	B	200·0	....	5·0	3·0	5·0	....	4·0	9·5	10·0
	T.V.A.	III	200·0	....	5·5	4·0	4·0	6·0	5·0	9·5	....
	W.V.	B	100·0	....	4·0	2·0	6·0	7·0	3·8	10·5	25·0
	P.R.B.....	C	....	....	4·0	3·0	3·0	5·0	6·0	8·5	....
Unsuitable.			Over		Under	Under	Over	Over	Under	Over	Over
Water Supplies, Recreation, Fish Life	Ohio, R.B.	C	200·0	....	5·0	3·0	5·0	....	4·0	9·5	10·0
	T.V.A.	IV	200·0	....	5·5	4·0	4·0	6·0	5·0	9·5	....
	W.V.	C	200·0	....	3·0	2·0	6·0	10·0	3·8	10·5	25·0
	P.R.B.	D	....	....	4·0	3·0	....	....	6·0	8·5	....

†Key :—Ohio = Ohio River Basin. T.V.A. = Tennessee Valley Authority. W.V. = West Virginia Water Commission. P.R.B. = Potomac River Basin Commission.

* H. W. Streeter; Sewage Works Journal, January. 1949.

Remarks:

(1) Each classification specifies that no organic sludge deposits shall be present in streams of "excellent" or "desirable" qualities. For "doubtful" class, slight to moderate deposits permitted.

(2) All except Ohio River Basin classification specify limiting amounts of colour and turbidity in streams of "excellent" and "desirable" quality.

(3) All classifications provide that no toxic substances, oils, tar or free acids, floating solids, debris (except from natural sources), or taste—or odour-producing substances, shall be present in streams of "doubtful" or better quality. T.V.A. standards also provide that in such streams the water shall be free from irritation to swimmers, and that treated waters shall meet the physical and chemical characteristics of the U.S. Public Health Service Drinking Water Standards.

TABLE B.

† U.S.S.R.

The standards for the discharge of industrial wastes to public water courses are:—

		Stream.	Classification.
Type of Pollution	Used as source of water supply and located in the 2nd Zone of protection or adjacent to a state fish hatchery.	Used as a source of water by unorganised groups, as water for domestic or industrial purposes or food establishment and sections with larger spawning areas.	Sections located in the centre built-up areas, but not used for domestic purposes, but for wide-spread bathing and artistic uses (fountains, etc.), and used for fish culture or located on streams used as passages for fish to spawning areas.
Suspended Solids	After mixing, the suspended solids contents should not exceed :—		
	0·25 mg./l.	0·75 mg./l.	1·5 mg./l.
	Remark :—In receiving streams carrying more than 30 mg./l natural suspended matter and during the period when wastes are discharged during high water or during accidental discharges, when it is impossible to obtain the required levels by ordinary means, the conditions under which wastes may be discharged shall be set up by the State Sanitary Inspection Service.		
Tastes and Odours	After dilution, no taste or odour should be detectable in the waste itself or after chlorination.		
Dissolved Oxygen	After mixing, the wastes should not reduce the stream D.O., to a value below 4 mg./l per day during the summer season.		
B.O.D. 5-Day	2 mg./l.	4 mg./l.	No value established.
pH	Wastes should not lower pH below 6·5 or increase pH above 8·5.		
Colour	Mixing the wastes with distilled water, on the same basis that the wastes will be diluted in the stream, no visible colour should be noticeable in a depth of liquid of :—		
	20 cm.	10 cm.	5 cm.
Pathogenic Organisms	Wastes from slaughterhouses, tanneries, leather factories, hair or wool washing, biological factories, etc. :—		
	Discharge prohibited.		Before discharge and after primary clarification wastes should be chlorinated.

† Sewage and Industrial Wastes, July, 1951. Abstract of article by Teodor Kirkor, "Protecting Public Waters from Pollution in the U.S.S.R."

appendix i

Report on Algal Pollution of the Swan River in the vicinity of the Bunbury Bridge

DR. F. STOWARD,
11th August, 1913

In reply to your letter of March 6th. last re algal pollution of the Swan River in the neighbourhood of the Bunbury Bridge, rather than deal with this matter in a casual way I have delayed my reply pending a detailed examination of the question, and now beg to hand you herewith my report on this subject.

Algal pollution of bodies of water in small lakes, ponds, storage reservoirs and streams in which, at certain season of the year there are stretches of semi-stagnant water, is not of unfrequent occurrence.

In the case now under report the conditions encountered presented certain special features and as a consequence investigation of the matter has involved the collection and examination of a considerable amount of material.

IDENTIFICATION OF ALGAL MATERIAL.

The green "weed" which, during the warmer season of the present year, was reported as flourishing on the surface of the river near the Bunbury Bridge and in the neighbourhood of the sewage effluent, is an aquatic plant—an Alga—belonging to the genus Cladophora.

Examination of this material showed that while chiefly composed of a species of Cladophora, it also included species of two other closely allied genera, viz; Choetophora and Rhizoclonium.

As these types belong to the same Algal Family, although not strictly morphologically similar, are in all probability physiologically identical, it will, for the purpose of this report, only be necessary to refer in detail to the Cladophora species, this representing by far the greater mass of the material submitted for examination.

This Alga, it may be specially mentioned, is a *free floating form,* i.e. it is not attached to the substratum of ooze which at this part of the river constitutes its bed. Consequently it may be readily washed ashore or down stream by such agencies as winds and water-currents.

The species under consideration is evidently one which is capable of flourishing in strongly saline or brackish water, as my analyses of the salt-content of a sample collected on March 11th last at a point near the sewage effluent show that it contains an amount of Chlorine equivalent to 3.39 grams Sodium Chloride per 100 c.c.

TOPOGRAPHY OF LOCALITY.

It is essential briefly to outline the topography of the locality because environmental conditions contribute in no small degree to the growth and also the decay of algal flora.

Extending from the Bunbury Bridge to a point a short distance beyond the sewage effluent there is an expanse of water which, sometime prior to and in March last, was shallow, saline, and comparatively quiescent or even in parts quite stagnant.

This stretch of shallow water extended, roughly speaking, to perhaps one half the width of the river in this neighbourhood.

At the Bunbury Bridge is a mud-bank unbroken in its continuity, except here and there, which serves, especially during the latter part of the summer, as a barrier to the movement of the main body of water on the left side of the river.

At or near the filter beds is a submerged main through which flows the sewage from the septic tanks on the opposite bank of the river to the filter beds.

This submerged main and the barrier at the Bunbury Bridge both tend to obstruct the flow of the river and the expanse of water between these two barriers forms a kind of reservoir into which the sewage issuing from the filter beds flows.

Added to this is the fact that there is discharged daily into this reservoir a volume of treated sewage containing products capable of being utilised, in a nutritive sense, by the aquatic flora with which the river water and ooze teems.

These environmental conditions, together with the nutritive elements derived from the treated sewage, are particularly favourable therefore to the growth of the "weed" or alga referred to, as well as other types of algal life, and at a later stage, to their decay.

The "weed" (Cladophora sp.) as already stated, is a free floating form and, apart from the question of the nutritive value to it of the treated sewage, could without difficulty establish itself in such a favourable habitat during the earlier part of the summer, when the river is low and there is little or an insufficient flow of water to carry it down stream.

While the alga is not wholly dependent on the nutritive material derived from the treated sewage it may be assumed that this material is contributive to algal development.

These environmental conditions—shallowness of water, salients, comparative stagnation, and of nutritive substances—all contribute to the growth and spread of the species incriminated and others also during the earlier part of the summer.

The change in the environmental condition during the latter part of the summer, on the other hand, brings about decay of the alga and the consequent production of objectionable odours during its decomposition.

ALGAL GROWTH AND DECAY.

In addition to the favourable environmental conditions above referred to there are other factors to which it is desirable to direct attention, and which bear chiefly on the growth and decay of this aquatic plant.

Algal growth, during the earlier part of the summer, is favoured by the less intense light conditions and more moderate warmth which then prevail. As a result the plant grows rapidly during this period of the year; this may continue, in the absence of any disturbing or retarding influence, until practically the whole available surface of an expanse of water may be almost completely covered with the plants.

This stage of rapid growth is generally unaccompanied by any pollution or the marked production of objectionable odours.

As the summer advances, the more intense light and its more prolonged duration, together with the higher average temperature of the water, tend to retard growth, and to prove fatal to those portions of this plant which are either at or just beneath the surface of this water.

Added to this may be the circumstance that the great abundance of the alga itself eventually inhibits its further development.

Then commences the period of algal decomposition and the steady generation of unpleasant smelling products.

These two chief phases in the life of the plant, namely growth and decay, progress during the various intervals in such a way that the one stage, growth or decay, predominates, whilst during intermediate intervals these processes may progress at the same rate.

The final condition of affairs, however, is that in which processes of decay predominate and it is then that an algal growth under the habitat conditions described becomes troublesome; it may give rise to products of decomposition of an obnoxious character, the smell of which is frequently referred to as "fishy" and is particularly offensive.

EXAMINATION OF SAMPLES OF SEWAGE COLLECTED AT THE EFFLUENT.

Samples of sewage were collected at the effluent; portions of these immediately after receipt at the laboratory were distributed in varying bulks into a series of wide-mouthed open vessels, and either simply exposed to the air, or a current of air, was bubbled through the liquids.

In either case it was noted that within a comparatively short space of time it was possible, particularly by the latter method, to displace the volatile products to which the objectionable sewage smell was due in these samples.

Other portions of these samples were placed in securely stoppered flasks. Under these conditions the sewage smell did not so readily disappear and a faint reaction for sulphureatted hydrogen was noted in these even during the final interval.

It is unnecessary to dwell upon this portion of the subject as it is evident that the sewage, after having passed through the filter-beds, had not undergone that stage of purification which would result in its complete deodorisation. This point it is necessary to emphasise, however, because some evidence will be advanced in support of the view that the alga is capable of entangling the particulate matter in the discharged sewage, and this tends to further hinder its deodorisation.

Lastly it may be mentioned that qualitative tests have shown that citrates, nitrates, sulphates, chlorides and phosphates are present in the treated sewage.

THE ENTANGLEMENT OF SEWAGE PRODUCTS BY THE ALGA.

A sample of the alga was received from Mr. Greenhill on March 6th last.

A portion of this material was mixed and thoroughly stirred with sterilised tap-water and the water at once decanted. This procedure was repeated a second and a third time. The three lots of decanted water were placed in separate wide-mouthed glass vessels and these examined in regard to their odours at once, and after the lapse of 24 and 48 hours.

The results of this method of treatment and examination are given beneath:—

No. of Washing.	Odour of Wash-water.		
	At once.	After 24 hours standing.	After 48 hours standing.
1st	Strong smell of sewage	Slight smell of sewage	Strong seaweed odour
2nd	Slight sewage smell and seaweed odour	Seaweed odour only	Strong seaweed odour
3rd	Seaweed odour	Seaweed odour only	Seaweed odour only.

As a result of subjecting the alga to successive washings with perfectly odourless, sterilised water, it will be noted that in the first and second washings of the material the sewage smell was distinct, especially in the washings when examined at once, and not recognisable in the third washing. After twenty-four hours standing the sewage smell was only slight in the first washing and absent in the second and third at the close of this interval.

After 48 hours standing the sewage smell had vanished from all the washings and was succeeded by a pronounced seaweed odour.

These experimental results point to the conclusion that at one stage or another the algal growth entangles some of the particulate matter in the material discharged at the sewage effluent, and also that the sewage adheres more or less tenaciously to the algal filaments which in this respect behave something like a sponge.

It is necessary to point out that the material received from Mr. Greenhill was chiefly composed of dead or dying algal filaments, as indicated by the fact that the application of vitality tests only afforded indefinite results.

The seaweed odour which was detected in the second and third washings at first, and in all the washings after the 24 and 48 hours standing, is attributable to the presence of products associated with algal decay, and characteristic of that phenomenon in its earlier stages.

These two odours may be differentiated with reasonable exactitude by the sense of smell; that due to sewage is apparently limited in amount and disappears with comparative rapidity: that which results from algal decay in its earlier stages is less volatile, more persisent, is generated with comparative slowness, and is succeeded by another more objectionable odour when decomposition proceeds to its more advanced stages.

This far it will be understood that this mixture of odours is not to be attributed to the sewage or to the alga alone, but is a product or mixture of products in the generation of which both are to be regarded as contributive factors.

During the late summer, when, as already mentioned, the process of algal decay overshadows that of algal growth, then the alga in this environment may become a source of trouble even in the absence of sewage contamination.

INVESTIGATION OF VARIOUS SAMPLES OF ALGAL MATERIAL COLLECTED IN APRIL LAST.

In order to follow more closely the various phases of algal decay further samples of various types of material were collected in April last.

These comprised: samples of the effluent liquid, of living algae (Cladophora sp. and the more closely allied Rhizoclonium sp.), of the ooze in the immediate neighbourhood of the effluent and at a point some distance from it, and also material from the boggy depressions on the mainland near the site of the filter-beds.

Portion of these various samples, which were placed under two sets of conditions, i.e. open and closed vessels, have been at intervals during the past two and a half months carefully examined microscopically and also in regard to the character of the odours evolved during the progress of the process of decomposition which ensued.

The object of these examinations was to determine as far as possible, the principal types of organisms present in the various samples, and their possible share in the production of offensive odours over a period of time of sufficient duration to admit of this being accomplished.

In the course of these experiments it must be admitted that it was not possible precisely to match natural conditions, nevertheless the results have closely indicated certain useful facts, namely:—

(1) That neither the effluent liquid nor the ooze from either source abovementioned have on keeping, developed anything but a very slight earthy odour.

(2) That the algal material—both living and dead Cladophora—as well as that from the mainland, which comprised several species, during decomposition evolved a distinctly offensive "fishy" odour.

Unquestionably these algal types in decomposing give rise to this unpleasant odour, and under suitable conditions, especially towards the close of the summer, may constitute a source of pollution of an objectionable character.

REMEDIAL MEASURES.

Algal growth may be retarded, if not completely suppressed, by one or other of the following means:—

(1) By extending the effluent so that discharge of the treated sewage may take place into the moving body of water on the opposite side of the river. This would obviate the discharge into semi-stagnant water of sewage containing substances capable of contributing to, and stimulating algal growth, when, as in the late summer, the water of the river in the immediate vicinity of the effluent, is low.

(2) By cutting through the barrier at the Bunbury Bridge and thus possibly removing an impediment to the flow of water on this side of the river.

(3) By treatment of the expanse of water in the vicinity of the effluent with Copper Sulphate or Bluestone.

The practicability of the first and second methods suggested are matters which will require consideration before being carried into effect.

The application of the third method depends on the susceptibility of the alga under consideration, as well as other types of these organisms, to copper salts in solution, and I venture to recommend that it should receive full consideration.

Experimental work elsewhere in connection with the algicidal properties of Copper Sulphate indicate that each alga, as Cladophora and Oscillatoria, may be kept under control in reservoirs containing fresh water and used for human consumption by treating it with one part (by weight) of Copper Sulphate to 1,000,000 parts (by weight) and 5,000,000 parts (by weight) of water respectively.

In a highly saline water one part of Copper Sulphate (by weight) in 5,000,000 parts of water (by weight) is stated to be sufficient, the Copper salt being more effective under these conditions. As my analyses establish the fact that the water of the Swan in this neighbourhood possesses a high degree of salinity in the summer it follows, if this were desirable on the score of economy, that this weaker concentration might be employed. In view of the fact that this water does not serve as a source for domestic supply, there are practically no limitations to the quantity of Copper Sulphate which may be used and it would, in my opinion, be advisable to double or even treble the above-mentioned proportionate amounts.

Increase in the amount of Copper salt would, in the circumstances, lead to increased effectiveness in the destruction of the algae.

The application of the copper salt, when the approximate volume of water to be treated has been determined, is easily carried out.

The required weight of Copper Sulphate is placed in a coarse gunny sack which is attached to the stern of a rowboat near the surface of the water. This boat is rowed backward and forward over the stretch of water and on each trip the course of the boat is kept within 10 to 20 feet of the previous path traversed.

As temperature has a very marked influence on the effect of Copper Sulphate upon polluting, forms, a warm day should be selected on which to apply this treatment.

It must be clearly understood that the application of the Copper Sulphate should be made early in the season before algal growth commences, as, if applied when this has set in and progressed for some time, it would simply hasten the decomposition of a large mass of material without minimising the offensive odours, which would thereby be produced.

appendix ii

South Perth Road Board

Conference re alleged pollution of Swan River

The meeeting was held in the Council Chamber, Town Hall, Perth, at 8 p.m. on

In the Chair: Mr. J. W. Paterson, Chairman of the South Perth Road Board.
Tuesday, the 7th March, 1922.

Present:

Name District or Club Represented.

(1) F. M. Stone—South Perth Road Board.
J. A. Loader—South Perth Road Board.
E. E. Humphrey—Canning Road Board.
T. J. Smith—Fremantle Municipality.
H. T. Haynes—Fremantle Town Engineer.
H. Woodhouse—East Fremantle.
F. D. Sewell—Perth Flying Squadron.
H. Carew-Reid—Royal Perth Yacht Club.
A. W. Berryman—Perth City Council.
J. A. McDermott—North Fremantle Municipality.
W. S. Finey—Claremont Road Board.
T. J. Myers—Claremont Road Board.
J. H. Simpson—Melville Road Board.
E. M. Wild—Melville Road Board.
H. L. Marsh—Swan River Rowing Club.
J. P. Sheedy—A.N.A. Aquatic Club.
V. H. Nevile—A.N.A. Aquatic Club.
Geo. E. Nicholls—Professor of Biology.
H. W. Mills—Perth City Council.
J. H. Harvey—Perth City Council (Victoria Park)
T. G. Halbert—Subiaco Council.
V. R. Trenaman—Subiaco Council.
Everitt Atkinson—Commissioner of Public Health.
F. W. Lawson—Met. Water Supply & Sewerage Dept.
Ed. S. Simpson—Government Analyst.
C. Alday—Peppermint Grove Road Board.

Name District or Club Represented.

N. J. Church—Peppermint Grove Road Board.
D. W. Whitehead—President Mounts Bay Sailing Club.
Louis E. Joubert—Commodore Mounts Bay Sailing Club.
J. G. Hay—Scientist.
A. Clydesdale—Member for Canning.
W. Kingsmill—Met. Suburban Province.
J. Duffell—Met. Suburban Province.
A. Sanderson—Met. Suburban Province.

(2) The Chairman introduced the subject and suggested that a general discussion should take place before any motions were put forward. He stated that a Report by Professor Nicholls was available and copies has been supplied to each representative present.

(3) The Chairman invited Dr. Nicholls to address the meeting and the Doctor in response stated (inter alia) that various causes, such as wast material from the Power House, city drains, drainage from cultivated land as well as the effluent or filtrate from the septic tanks, contributed fertiliser to the weeds growing in the river. Continuing, he quoted from his report and said that it was apparent that the filtrate from the Burswood Filter Beds could not at this stage be solely blamed for the excessive growth of weed in the river and only exhaustive experiment and research could prove the cause and possibly find a remedy.

(4) Mr. F. Mends Stone (South Perth) spoke on the subject of the offensive weed which he stated had only made its appearance since the inception of the Burswood Filter Beds.

(5) He stated that he had opposed the construction of the Burswood Septic Tanks because he believed the system was bad. He claimed a thorough knowledge of the whole of the Swan and Canning Rivers extending over very many years, and he was supported in his contention (i.e., that the filter beds were responsible for the present trouble) by fishermen who earned their living on the river, and had spent most of their lives upon the Swan or in its precincts.

(6) Other speakers were: Hon. W. Kingsmill, M.L.C., Crs. Mills and Harvey (Perth), Messrs. E. E. Humphrey (Canning Road Board), J. H. Simpson and E. M. Wild (Melville Road Board), Cr. Y. G. Halbert (Subiaco), H. Carew-Reid (Royal Perth Yacht Club).

(7) *Mr. J. G. Hay* referred to masses of black slimy ooze in the Canning River near Clontarf which, he claimed, contained allum phosphates brought down from phosphatic rocks in the hills. In his opinion, reclamation and the scour it would cause, would prove the most satisfactory solution to the existing nuisance.

(8) *Cr. Berryman* (Perth) stated that he lived in Mt. Lawley and was familiar with the awful stench which was caused by the septic tanks or filter beds. He believed the Government had done their best to remedy the troubles and complaints which had arisen from time to time, but their system was bad and would never be satisfactory until sewage was carried out to sea.

(9) Statements were made by Dr. Atkinson (Commissioner of Public Health) and Mr. F. W. Lawson (Chief Engineer for Water Supply and Sewerage).

(10) *Dr. Atkinson* said that the offensive smell caused by decomposing sea-weed was not dangerous to health, and that it was impossible for crude sewage material to get into the river with the effluent from the filter beds, and recommended the appointment of a River Conservancy Board.

(11) *Mr. F. W. Lawson* stated that the Swan River was going through the process of pollution common to all streams upon the banks of which settlement takes place and which receives the drainage from towns and cultivated or occupied land. He added that an eminent British engineer and scientist (Sir Maurice Fitzmaurice) has approved of the present system. Mr. Lawson gave his assurance that the filter beds, tanks, etc. were thoroughly stable and the purification as revealed by analyses was steadily improving and the system was based on the most approved modern practice. Conveyance of the sewage to the sea would cost £300,000. He supported Dr. Atkinson's suggestion for the appointment of a "River Conservancy Board".

(12) Mr. A. Clydesdale moved "That a deputation from this meeting wait on the Government and request that a 'River Conservancy Board' be appointed". The motion was seconded by Cr. T. G. Halbert, but on being put to the vote, was *lost.*

(13) *Cr. Mills* (Perth) moved "That a Committee of seven members be appointed from this Conference to take all necessary steps to obtain full information on the subject under discussion and report to a subsequent meeting." The motion was seconded by Mr. Stone and carried.

(14) The following gentlemen were then nominated and appointed to act as the committee:—

(15) A. Clydesdale.
W. Kingsmill.
H. W. Mills.
H. Carew-Reid.
J. Loader.
F. Sewell.
J. W. Paterson.

(16) Cr. Mills moved, Mr. A. Clydesdale seconded, that the Chairman (Mr. J. W. Paterson) be Convener of the Committee and Conference. (Carried.)

(17) Cr. Mills moved, Mr. Simpson seconded, after a vote of thanks to the Chairman and to Dr. Nicholls, Dr. Atkinson and Mr. Lawson, that the Conference be adjourned until a later date, pending the report of the Committee. (Carried.)

(18) The meeting then adjourned *sine die.*

POLLUTION OF SWAN RIVER.

REPORT TO A CONFERENCE OF LOCAL GOVERNING BODIES

7th MARCH, 1922.

(By Professor G. E. Nicholls, Biologist.)

At the outset, I should state that I find no reason for believing that "pollution," in the common acceptation of that word, is taking place to any important extent in the Swan River. I cannot assert, of course, that there is nowhere entering the stream, organic matter that should not be allowed to reach the river, but I have little positive evidence upon that head.

In so far as the principal suspected source is concerned, viz,—The sewage works at Claisebrook and Burswood Island, although, as I have previously indicated, I do not consider myself qualified to speak authoritatively upon *sewage treatment,* I can say that the results of the analyses of the filtrate (as published in the Annual Reports) indicate a degree of purification which would be likely to amply satisfy the requirements of Health Authorities anywhere. This would, I believe, be true even if the filtrates were destined to be discharged into a freshwater stream from which, lower down, water for drinking and domestic purposes were to be obtained, which of course is not the case here.

As to the suitability, under local conditions, of the method of purification actually adopted at the sewage works, I am not required to express an opinion. The position of the present outlet of the works is a matter upon which, what I have to state under another heading will have some bearing.

Turning to that aspect of the matter upon which I, as a biologist, am more directly concerned, viz,—the nature of the material upon the foreshore, and the conditions under which it is produced and thrives; material floating, stranded upon the shore, and collected while still living, attached and growing, was obtained upon a number of occasions, and from a variety of situations. (List I.)

This was examined by myself and submitted to two other botanists and proved to contain a number of different Algae, belonging to three of the four principal divisions of that group of lowly weeds. Abundant in certain areas was a plant belonging to the higher (Flowering) plants. The latter appears to be a species of *Lepilaena.* This was found to be very plentiful in the upper (brackish and fresh-water) regions of Canning and Swan Rivers, Bennett Brook etc. It is no doubt the form whose occurrence has given rise to the statement made to me, that the weeds grow as abundantly at Guildford as in Perth water. It grows in large and obvious masses, in a depth of several feet of water, but it is firmly rooted and not likely to become detached. Nowhere did I find any floating freely, and it may be dismissed from further consideration.

The more important forms, seeming to make up the greater part of the decaying material, are green Algae; very abundant is a species of *Enteromorpha.* This is one of the Ulvales, which family includes Ulva, the excessive growth of which in Belfast Lough, some years since, was attributed to the stimulus supplied by the Belfast sewage effluent.

Also abundant are *Chaetomorpha sp* a confervoid form (which normally grows attached, but growing luxuriantly may break free, as do other of the Cladophoraceae) and *Polysiphonia sp.* The latter was found growing covered with epiphytic (encrusting) smaller confervoid forms. *Vaucheria* is more sparingly present.

In the floating masses, with offensive odour, were very abundant *Oscillatoria* and many kinds of diatoms (Cynedra, Navicula, &c.). *Oscillatoria* is often popularly supposed to be faecal matter which has escaped from sewage works.

In deeper water (4½ feet upwards) in the open parts of Melville Water, was found an abundant brown seaweed, which has not yet been identified. It does not appear to form any contribution to the material which is responsible for the odour complained of. It lives at a depth at which it is hardly likely to be killed by exposure to direct sun's rays or loosened by wave action. The depth at which algal life can be sustained is limited by the depth to which efficient sunlight will penetrate.

The material producing the odour seems to be composed almost wholly of the above named forms which grow, if attached, for the most part in shallow water, where, at low tide, it may be killed by prolonged exposure to the sun and then liberated by the decay, and wave movement. Decay may continue upon the water in the stranded material which is likely, presently, to refloat with a rising tide. With the floating debris is associated the living diatoms and *Oscillatoria* which probably benefit from the decomposition of larger forms.

In order to appreciate the effect of the effluent upon the growth of the weed, certain details connected with plant composition and nutrition must be understood. Any green plant will live and grow only if (i) it receives sufficient sunlight, (ii) it is maintained at a suitable temperature, and (iii) is provided with adequate food materials in the presence of moisture. Long periods of sunlight and the continuance of favourable temperature conditions will allow the plant to make the most of the food supply.

This food material consists of an atmospheric gas (Carbon dioxide) and inorganic (mineral) salts dissolved in water. The actual mineral salts appear to be of no great importance so long as certain ingredients are present in sufficient, but not in excessive quantities.

The essential ingredients (apart from the Carbon already mentioned, and Hydrogen and Oxygen always present as water) Nitrogen, Phosphorous and Sulphur, with Potassium, Calcium, Magnesium, Iron, Sodium, Silicon and Chlorine.

All of these exist, in various combinations, in the soil, in sea water and probably less abundantly in fresh water. Most of them are required only in most minute quantities and for some at least, substitutes exist. Many of the combinations (or salts as they are called) are very soluble, and are lost from the soil, not only by their withdrawal by the plant, but by washing out in water percolating through the soil: hence the necessity, in agricultural practice, of frequently adding to the soil certain manures or fertilisers to make good the losses of chemical substances essential to plant growth. Much of the material draining away ultimately reaches the sea, where it accumulates.

The sea, therefore, affords a most suitable growing place for such plants as are able to withstand the high degree of salinity. One food constituent, nitrogen, the sea contains only sparingly, the contained nitrates and ammonium salts furnishing but one part of nitrogen to every two million parts of sea water. Yet even this attenuation permits of a most luxuriant marine plant growth. Nearer the shore, the nitrogen is probably slightly more abundant, and we find thriving beds of seaweeds along the shores, between the levels. Now, one of the effects of an increased nitrogen supply is seen in an increased luxuriance of growth of the vegetative organs of the plant, and a tendency to refrain from fruiting.

The nitrogen contents of a typical artificial culture solution will be seen in Table A (below); that of the waters of open sea, Swan River and sewage filtrate in Tables B, C, D. From a comparison of these it will appear that the Swan River is nearly fifteen times; the filtrate eighty times; and the culture solution one hundred and sixty times as rich in nitrogen as is the water of the open ocean. Up to such a strength increasing nitrogen favours growth, and not until nitrates are present to such an extent that nitrogen becomes more than 500 times as plentiful as it is in the sea, does the plant show any ill effects.

I am inclined to believe that the figures from which I have obtained Table C, may indicate a higher nitrogen content for the Swan River than is actually the case, but, until a series of analyses have been made of samples of river water taken at all times in the year and at a number of widely separated points, I can have no data for checking that estimate.

That is a matter of some importance, for, until further information is available, it is impossible to determine what proportion of the total nitrogen content of the river is to be regarded as derived from the sewage effluent (filtrate). Table E has been obtained by calculations made from official figures, and serves to show what has been the total annual output of nitrogen (as nitrates and ammonia) discharged from the river from the sewage works in the filtrate.

Sources of nitrogen, other than this, are the various stormwater outlets, the drainage from land under cultivation, and to a smaller extent perhaps, unauthorised outlets of organic matter from factory or works near the river.

With reference to land under cultivation, which is likely to be a factor of considerably increasing importance. It has been established that land tilled and cropped loses more nitrogen than is removed by the crop, while land tilled but not put under crops loses still more of the nitrate by washing out from the soil. Land covered with vegetation, which is undisturbed, tends, on the other hand, to slowly accumulate nitrogen. Increasing cultivation of the areas drained by Swan and Canning Rivers would, therefore, tend to augment in the river the abundance of this essential plant foodstuff. Similarly, increasing population, with its accompanying extension of roads, providing more organic material in the storm water, will become a matter of increasing moment. Only a series of actual experiments, and a systematic analysis of the waters contributing to the river, can apportion the responsibility for this superabundant alga, and provide an answer to the question of the likelihood of increasing sewage effluent being accompanied by still more abundant growth of weed.

As pointed out, in my preliminary statement, there exists no reliable data available for an accurate computation of the minimum average and maximum volume of water in the Swan River. Such a calculation would be affected by tidal factors, rainfall, wind etc. A rough estimate can, however, be made, and this has been kindly furnished me by the Engineer in charge of the Sewage Works (Table F). If that estimate is even approximately accurate and if the figures of analyses of river water are to be regarded as holding for the entire estuary, then the contribution from the sewage filtrate would become almost negligible in comparison with the huge bulk of nitrogen so estimated. (Table G.). The quality of moving water, too, seems to me to be a high estimate, but if accurate, even approximately, would suggest a daily loss of close upon two hundred tons of nitrogen (as nitrates and ammonia) from the river to the sea, an amount that seems to me incredible.

A more certain knowledge of these matters is essential before an opinion can safely be pronounced upon the relative importance of the sewage filtrate, as compared with other sources of nitrogen supply.

But, two other elementary substances exercise an important effect upon plant growth: these are potassium and phosphorus. It is a well established fact that, in the presence of an abundance of these, the plant will more readily take up the available nitrogen. With potassium we need not concern ourselves, for sea water (and we may therefore suppose Swan River water) contains 390 parts of this element per million of water.

Phosphorus (as phosphates) is an essential ingredient of artificial culture solutions of which it may form as much as 100 parts per million of water, whereas in sea water (in which it must exist as a trace) it is not even recorded as present in a typical analysis. Now, in a sewage filtrate, I should not be surprised to find a quite measurable quantity of phosphate.

It is an interesting fact in this connection that, in 1891, a sudden fouling of an immense volume of water in the reservoir supplying Bolton (Lancs.) with drinking water, was found to be due to a green Alga (*Conferva bombycina*). This growth was regarded as fostered by the presence in the water of phosphates derived from manure and sewage on the watershed area.

Lacking further information and data extending back over a number of years, a positive answer to several of the questions put to me is not possible. It is, however, beyond dispute that the algal growth and decay is responsible for the production of the smell which, though probably not harmful (directly) to health, is most unpleasant.

Such a growth is rendered possible by the existence of shallow banks in the river, and by the prevalence of sunshine, and a moderately high temperature and warm water. It is likely to be accentuated by the abundance of foodstuffs, of which it is probable that nitrogen is, in this connection, the most important. An added stimulus may be given by the presence of other substances in solution in the water, which stimulus may be perhaps out of all proportion to the actual quantitative occurrence. The existence of such substances (bicarbonates, phosphates, potassium salts) in unusual quantities can be detected by water analyses, but such data do not at present exist.

The occurrence of abundant nitrogen is admitted; an appreciable quantity is daily added in the filtrate from the sewage, but it is not at present possible to say exactly what proportion this bears to the whole. Much of course is lost tidally; in winter much must be scoured out to sea. How much, is again a question for investigation.

The greater abundance of the weed as the filter beds are neared, and the occurrence of abundant Ulvales suggests that, in any case there is a direct connection between the weed growth and the discharged substance in the filtrate, but this effect may possibly be produced only in the presence of some other substance, normally or occasionally present in the stream water, whose existence is not certainly known, or perhaps not even suspected. An investigation, including a series of experimental cultures, would perhaps clear up that point.

Undoubtedly the river does offer abundant matter for plant growth, far and near, for the vigorous growth of reeds in many places is contributing actively to natural reclamation. One has only to stir the river bottom in many parts to get a marked fouling of the water from the abundant black silt which, also, must contribute much valuable plant food.

Dredging away the shallow banks, or reclamation, or a combination of both, would be practically certain to do much to abate the nuisance, whatever part the sewage filtrate may play in the matter. If the filtrate were to be proved to be largely responsible, the substitution of some other method of treating the sewage, or the provision of a sea outfall, might effect a considerable improvement.

I would repeat that, at the present time, there is not available the necessary information to permit of a safe conclusion, and rash generalisations or hasty action are to be deprecated. Only a complete investigation, carried out carefully on strictly scientific lines, is to be recommended. If such a course be decided upon, it should be started upon as soon as possible, for such problems do not always permit of prompt solution. In any case, it is probable that at least a year must elapse before a knowledge could be gained of the life cycles of the plants concerned.

I would recall to memory the fact that a Royal Commission on Sewage Disposal was set up in England, and continued to investigate for years before arriving at definite conclusions. Here our problems are beset with very different conditions, of which little reliable information is to be had, and almost all is to seek.

In conclusion, I desire gratefully to acknowledge the receipt of help in various ways, from Engineers in Charge of Water and Sewage (Messrs. Lawson and Hillman), from the Inspector of Fisheries (Mr. Aldrich); and I have also to thank Professor Osborn of Adelaide and Miss E. R. L. Reed of the University of Western Australia for their assistance in the identification of the Algae concerned.

LIST 1.

A list of places from which material was collected, or observed, with the dates and notes as to relative abundance and character of the of the growth.

Date.	Place.	Remarks.
1922.		
Feb. 18	South Perth from Mends Street to Mill Point	Weed abundant, stranded, floating and growing; mostly mixture of green algae.
	Perth, around Barrack Street Jetties	Similar material, growing and floating.
	About half mile North-East of Burswood Station	In shallow water: Enteromorpha less abundant. Growth generally less. Smell more attenuate. Very little thrown up on sandy stretch.
Feb. 19	Como and the West bank of Canning River to head of Bull's Creek	Similar to that found around Mill Point. Near Canning Bridge, and indeed, in every little bay, floating material drifted in large quantity. Abundant growing weed. Low tide and prevailing easterly wind.
Feb. 20	Claisebrook and Burswood Island, and river in vicinity	By the kindness of Engineers in charge taken over Sewage Works. My visit coincided with the occasion of the emptying of a tank. Examined river bed to South-West, West and North of Island. Everywhere shallow water showed a most luxuriant growth of weed. North of island and also against Maylands shore large areas covered with floating weed.
Feb. 24	Perth Water	Higher tide after some days of low tide. Large area of the water covered with masses of floating weed, largely decomposed but mingled with great quantity of Oscillatoria.
Feb. 25	Fremantle	River between Bridges carefully examined. Left bank, water clear and with little weed, of types usual on sea shore. Right bank, behind a sandy spit, lies a nearly stagnant backwater, receiving the contents of a foul-smelling ditch. Weeds quite abundant, but not present on the other side of the bank towards the river.
Feb. 28	Banks of Shore from Narrows to Como and Canning River	Shallow areas clothed with abundant weed of type described. Visible as black patches in water to 4 ft. in depth. often quite obscuring sandy floor of river.
Feb. 28	Canning River to its navigable limit (just below Nicholson Road Bridge)	Growth of weed abundant to West and South of Mt. Henry; less marked in the channel. In the brackish water further up, this weed no longer occurs, but its place in the water is taken by an innocuous flowering plant (*Lepilaena*).
	Coffee Point	Shallows, occupied by weeds growing very freely.
	Frenchman's Bay and Lucky Bay	The landward side of banks not too freely covered, in shallow areas with weed of same type; on the seaward (westward) side this gave place to a moderate growth of brown seaweed which passed into deeper water. Towards Alfred Cove the green Algae became more evident again.
	Curries Spit (off Pelican Point)	As off Como.
	Perth Water (towards Coode Street)	Water too turbid to permit of observation, but abundant weed brought up in depths of 4 feet and less.
Mar. 4	Guildford (between the bridges)	No evidence of the green seaweeds except for a solitary patch of *Nitella*. Abundant *Lepilaena*.
	Bennet Brook	Stagnant water. *Lepilaena*; a little confervoid.

TABLE A.

Constituents of typical Water Culture Solution.

Substance.	Amount.	Porportion in parts per million of water.
Water	Grammes. 5,000	
Calcium Nitrate	2	Nitrogen 68 parts per million.
Potassium Nitrate	0·5	Nitrogen 14 parts per million.
Magnesium Sulphate	0·5	Total Nitrogen 82 parts per million.
Potassium dihydrogen phosphate	0·5	Phosphorus 23 parts per million.
Iron	Trace	

TABLE B.

Composition of Sea Water.

Substance.	Amount.	Proportion in parts per million of water.
Sea Water	Grammes. 1,000	
Sodium Chloride	26·44	
Potassium Chloride	0·75	Potassium 390 parts per million.
Magnesium Chloride	3·15	
Magnesium Bromide	0·70	
Magnesium Sulphate	2·07	
Magnesium Carbonate	Traces	
Magnesium Nitrate	0·002	Total Nitrogen one-half part per million.
Ammonium Chloride	0·0004	
Calcium Sulphate	1·33	
Calcium Carbonate	0·047	
Lithium Chloride	Traces	
Iron Carbonate	0·005	
Oxide of Silicon	Traces	

TABLE C.

Analyses of Swan River Water.

Samples taken at Jetty at Claisebrook. Numbers = Grains per gallon.

Year.	Suspended Solids.	Ammonia.		Nitrogen as Nitrates.	Oxygen absorbed 24 hours.
		Free.	Organic.		
1914	2·75	0·25	0·84§	0·094	0·42
1914–15	Figures	two months	only.	....	....
1915–16	Incomplete	....	....	....	....
1916–17	1·05	0·13	0·15	0·044	0·31
1917–18	2·43	0·29	0·26	0·042	0·39
1918–19	1·76	0·17	0·51	0·047	0·34
1919–20	0·93*	0·22	0·45	0·072	0·31
1920–21	†	0·26	0·37	0·042	0·50
1916–21 Average	1·41‡	0·21	0·35	0·049	0·37
		Ammonia.			
In parts per 100,000	2·01	0·30	0·50	0·07	0·53
		Nitrogen 0·66			

Total Nitrogen = 0·66 + 0·07 = 0·73 parts per 100,000.

* Figures for four months only. † No figures; estimation presumably discontinued. ‡ Average for three periods, 1916–20. § Average for five months. Exceptional figures for December, 1914. These results are not included in average figures which relate only to years 1916–21.

TABLE D.

Metropolitan Sewerage—Claisebrook Treatment Works.

Analysis of Effluent (Filtrate).

Year.	Solids.		Ammonia.		Oxygen absorbed in 4 hours.	Nitrogen as Nitrates.
	Dissolved.	Suspended.	Free.	Organic.		
1914	....	9·40	3·13	1·40	1·87	·431
1914–15	....	6·82	1·66	1·78	1·72	·792
1915–16	....	6·73	2·01	2·59	1·36	·458
1916–17	....	6·19	1·99	0·58	1·31	·791
1917–18	....	5·14	1·75	·60	1·10	·562
1918–19	....	6·93	1·60	·85	1·07	·443
1919–20	....	6·81	1·58	·77	1·20	·269
1920–21	....	5·94	1·37	·53	·88	·45
Average 1914–21	....	6·36	1·71	1·06	1·23	0·538

The figures are expressed in grains per gallon.

Converted in to parts per 100,000 they would appear :—

9·08	2·44	1·51	1·76	0·77
	= as Nitrogen 3·25		Total Nitrogen 3·25 + 0·77 = 4·02	

TABLE E.

Estimated *annual* output (in tons) of solids, nitrogen etc. contained in effluent.

Year.	Quantity of Filtrate in millions of gallons.	Solids in suspension tons.	Nitrogen as Ammonia in tons.	Nitrogen in Nitrates in tons.	Total Nitrogen tons.
1917–18	513	168·1	63·3	18·32	81·6
1918–19	530	234·2	68·2	14·97	83·1
1919–20	557	241·7	68·7	9·56	78·2
1920–21	624	236·4	62·2	17·92	80·1

It may be explained that 80 tons of Nitrogen in combination as a Nitrate such as Chili Nitre would be equivalent to 485 tons of that fertiliser ; as Sulphate of Ammonia, perhaps a little more than 375 tons.

TABLE F.

Estimated total quantity of water between the Narrows and a point above Bunbury Bridge.

At low tide	979,000,000 gallons	3 Square miles
At high tide	2,646,000,000 gallons	
At average tide	1,812,000,000 gallons	
Moving water	1,667,000,000 gallons	

Estimated total quantity of water between Narrows and a line between Pt. Resolution and Pt. Walter.

At low tide	17,972,000,000 gallons	5 Square miles
At high tide	22,232,000,000 gallons	
At average tide	20,102,000,000 gallons	
Moving water	4,260,000,000 gallons	

Estimated total quantity of water between a point above the Bunbury Bridge and a line between Pts. Resolution and Walter.

At low tide	18,950,000,000 gallons	8 Square miles
At high tide	24,877,000,000 gallons	
At average tide	21,914,000,000 gallons	
Moving water	5,927,000,000 gallons	

TABLE G.

Taking average figure, 21,914,000,000 and accepting Nitrogen estimated for Swan River, the total Nitrogen contents would be about 4,000 tons Nitrogen.

Accepting 6,000,000,000 as correct for tidal water moving out to sea and becoming diluted to same strength as sea water, the daily loss of Nitrogen would be 180 tons. These figures I find difficult of acceptance.

POLLUTION OF THE SWAN RIVER.

REPORT TO CONFERENCE OF LOCAL BODIES.

(By Dr. E. Atkinson, Commissioner of Public Health, on 7th March, 1922.)

There has been popular tendency for some years past, to place the blame for everything unpleasant that emanates from the Swan River, upon the Septic Tanks and filter beds.

There was perhaps some justification for this in the days of the old filter beds, for the reason that they did not work properly as a result of the subsidence of their foundations.

As now constructed, however, there can be no recurrence of the old trouble and indeed the whole present system is constructed on sound modern lines with the result that an extremely efficient purification of sewage which varies from 90 to 99 per cent. is effected.

The effluent passes into the river and has been accused of (1) polluting the stream, (2) encouraging the growth of weed in the river, and (3) being washed up on the shores and beaches either as solid excreta or as a black slime, and pestilence has been prophesied as a result.

Now, there are one or two points in regard to sewage effluents and this one in particular which I should like to stress:—

(1) That no solid recognisable faecal matter can reach the river by means of the effluent, for the reason that none reaches the filter beds.

(2) That a good effluent, that is one from an efficient system in which proper chemical changes have taken place, is not putrescible and, therefore, cannot produce smells after leaving the beds.

(3) That to a great extent pathogenic or disease producing bacteria do not survive the septic tank and filter bed process of purification and even should some do so, provided they pass into such a volume of water as to cause a considerable dilution of the effluent that carries them, the danger from them is infinitesimal even supposing the water to be subsequently used for human consumption.

Under certain conditions, then, an effluent of this nature should not, of itself, cause pollution to the extent of either producing nuisance such as smells or accumulations, or of rendering the water capable of producing disease on account of the pathogenic bacteria it contains. Those conditions are:—

(a) That it shall be of a certain chemical standard of purity and stability.

(b) That it shall discharge into a stream of sufficient volume to dilute it adequately.

As regards the first condition I am able to say with confidence after studying carefully a large number of analyses of the Burswood Island effluents, that a good, stable, non-putrescible effluent is the rule.

As regards the second condition, now that the effluent is carried across the river and discharged into the deep channel, I feel confident that there is very adequate dilution of it. If this were not so, and if, as has been suggested, there be stagnation of the water between the Bunbury Bridge and the Causeway then analyses of the water in various parts of the river should give evidence of that stagnation and concentration of pollution.

With the object of determining this point, which by the way has previously on more than one occasion been done, I recently took a number of samples of water from the river at the following points:—

(1) about three miles above the Bunbury Bridge;
(2) from the stream opposite the outflow of the effluent from the filter beds;
(3) at the Causeway;
(4) at the Narrows;
(5) in Melville water about 200 yards from the South Perth shore.

These samples were submitted to Analysis with the following result:—

There is shown in the neighbourhood of the effluent outflow an increase in nitrogen which, however, was not maintained and was actually less in quantity at the Causeway than at the Narrows. Much more extensive investigation is, however, necessary to determine the exact fate and distribution of the nitrogen.

The figures further support some tests made last year into the absorption of the dissolved oxygen by organic matter in the river and go to show, as did these, that there is no pollution of the river by the effluent in the ordinary accepted sense of the word.

I have been able to obtain, moreover, an analysis of the river water near the Bunbury Bridge made in 1905, that is before the Septic Tank system was installed and to my astonishment I find that this water gives figures considerably less satisfactory than those referred to above.

Three samples of water were also taken for bacteriological examination at the following points:—

(1) about three miles above the Bunbury Bridge;
(2) midway between Barrack Street Jetty and South Perth Jetty;
(3) at the Narrows.

In only one of these samples and strangely enough, that taken three miles above the Bunbury Bridge was the Bacillus Coli, the index of pollution by the excreta of man or animals, found. Other bacteria of water were not present in undue numbers for the time of year.

As the Bacillus Coli is present in enormous numbers in crude sewage its presence should be readily detected, were gross sewage pollution present.

Whilst there I have failed to find evidence of pollution of the river by the sewage effluent which enters it, there is no denying the fact that weed is very abundant in the river and that it is causing very considerable nuisance in certain areas.

When dead and decaying it gives off most offensive odours for which the septic tank effluent is sometimes blamed. There is no doubt also that the black slime deposited upon some of the beaches is a product of the decay of this weed and is most certainly not a product of the filter beds.

On the other hand it has been said that the weed is fertilised by the effluent from the filter beds and to the extent that this contributes some nitrogen to the river water, this cannot be denied. On the other hand, however, it is to be noted that the increase in nitrogen in the river water is not very considerable even opposite the outfall whilst it diminishes considerably below the Causeway where it is less even than in the upper reaches.

It may be that this diminution is due to the removal of nitrogen by the weeds below this point.

In admitting that to some extent the effluent may act as a fertiliser to the river weeds I think, in justice to that effluent, it should be recognised that this is not by any means the only supplier of nitrogen to the river water.

It is, indeed, only one of a number of contributing factors. In this area we have a large storm water drain bringing down street sweepings and the washings of a closely populated area. This contains a large amount of fertilising material and in a much more putrescible and unstable form.

From the gas works the river probably receives ammoniacal products whilst another large storm water drain enters at the foot of Spring Street, and two breweries no doubt discharge waste into the river lower down.

Numerous drains empty into the upper reaches of the river whilst both the Swan and the Canning bring down large quantities of silt from cultivated land. It is difficult, therefore, to justly ascribe the whole, or even the major part of the responsibility to the effluent when so many factors are involved.

I am firmly of the opinion that one of the great contributing factors to the growth of algae in the river is the existence of shallow backwaters and flats and that these probably act as incubators for the general supply of weed. One typical such area is that conglomeration of small islands, inlets and swamps beside the Causeway.

It has been stated that the weed in question does not grow in waters deeper than three or four feet so that reclamation and dredging would probably do much to mitigate the nuisance, and incidently also deal with the mosquito and to some extent the rat problem.

Professor Nichols has already done some good work in connection with this question and could he extend his investigations it is probable that he would be able to locate the main incubation areas of the growth.

If this could be done, concentrated action upon these areas might do much in reducing it and treatment by Copper Sulphate early in the season might have a marked effect. This method, however, has the disadvantage that it may poison fish and so produce nuisance in another form, though experiment might result in this being avoided.

There is no doubt that the question of this excessive algal growth needs at once the combined attention of all of us able to deal with any of its aspects, otherwise, from a sentimental point of view, we are going to detract from one of the finest attributes of the City of Perth.

And I am, therefore, going to suggest for your consideration the question of urging the appointment of a conservancy Board with statutory power to enquire into, and where deemed advisable to abate all undoubted causes of pollution of the Swan River and to exercise all necessary powers to preserve and enhance its beauty.

In conclusion I should like to repeat my opinion that there does not exist, in the present state of the river any danger to health whatever and, further, that I very much doubt that the exclusion of the Septic Tank effluent from it, would materially affect the growth of the weed, as I feel sure that it would thrive under present conditions on the nutriment available from other sources.

I do not wish it to be thought that I consider that this effluent is being disposed of in the best way possible, for I think it should go to the sea when the enormous cost involved can be met.

POLLUTION OF THE SWAN RIVER.

REPORT TO CONFERENCE OF LOCAL BODIES.

(By F. W. Lawson, Engineer, Metropolitan Water Supply & Sewerage Department, on 7th March, 1922.)

(1) The Swan River is, unfortunately, going through the experience that all rivers, along which settlement takes place go through, and this experience is not confined to Australia as a study of Engineering literature will show that it has happened in Great Britain, the Continent and America.

(2) Nearly all rivers, unless they have an extremely rapid fall become, in the course of time, polluted. Many instances of this could be given, but I consider it is sufficient for our purpose to mention the Thames, New York Harbour, Boston Harbour, and in Australia Sydney Harbour where for many years reclamations have been carried out at the heads of all bays, where the tidal water does not actively penetrate, or where, owing to the shallow depth a great many mud flats become uncovered at low tides.

(3) In Melbourne, the Yarra River has been confined to a comparatively narrow channel from Richmond to Williamstown or Port Melbourne, and the salt water river was undoubtedly badly polluted as far back as 1892/3.

(4) A famous instance of pollution of a stream is the Manchester Ship Canal where an authority has been set up to control this canal and a scientific staff permanently engaged to see that there is no undue pollution taking place.

(5) The Swan River above the Narrows has the appearance at first glance of containing a large body of water, yet the actual sounding shows that from the Narrows to the Causeway the average depth of water is only 2 feet, this including the dredged channels which in parts have been taken to a depth of 7 feet. It is therefore evident that in the natural course of events these shallow waters must, with the growth of settlement, become gradually silted up and the shore line, in the course of time, carried out into the flats, and nature will itself, if left long enough, confine the river into a channel which is only capable of taking the normal flood water. The experience of this is world wide, but I need only instance two well-known cases, the Delta of the Nile and that at the south of the Hooghli River, where the mud flats have been silted up and the river confined into narrow channels. Therefore it will be seen that the Swan River is no different in this respect to many other rivers. I have no hesitation in saying that at least above the Narrows the whole of the mud flats will either have to be dredged out, and the material so dredged deposited so as to reclaim the shallow water, or else in course of time the trouble which is now bad enough will become much more acute.

(6) In America it has been noticed in the large lakes, and one particular town, namely, that of Madison on Lake Monona the conditions which exist in the Swan River have existed there for many years and their trouble could be read in parallel columns with those of Perth.

SEWAGE TREATMENT WORKS.

(7) In reference to the Sewage Treatment Works, the location of these works was considered for some time, and the present site was recommended by Mr. C. R. S. Palmer, M.Inst.C.E., Engineer-in-Chief, by Mr. J. Davis, M.Inst.C.E., late Director of Public Works, New South Wales, and the Engineers at that time in charge of the Metropolitan Sewerage scheme. Therefore it will be seen that advice was obtained before the works were constructed. The Sewage Treatment Works were put into operation in 1910 and their earlier history is well known to most of the residents as, unfortunately, the first filter beds were erected on unstable foundations and undoubtedly caused a great deal of trouble. This matter was fully investigated by Sir Maurice Fitzmaurice in

1913 when certain questions were put to him by the Government and in his report it will be found that he stated that the site upon which the present filters were erected was quite suitable and that all precautions necessary to make the filter beds satisfactory had been carried out. In his report he stated that the method of sewage disposal adopted was in accordance with the best modern engineering practice and later on he also said that he considered it extremely undesirable to abandon the present system of sewage disposal for a sewage farm and he strongly denounced the Birmingham Sewage Farm which was the best design in England but was abandoned in 1902 because it turned "a once smiling valley into an evil smelling swamp".

(8) In regard to the sea outfall he estimated that this would cost anything between £2/300,000. In his report Sir Maurice Fitzmaurice also dealt with the question of reclaiming the foreshore.

(9) I can give this conference my assurance that the present works are stable in every respect. There has never been any leakage from the septic tanks since they have been put into use and the present filter beds have shown no signs of any subsidence since their erection. Levels have been taken very frequently and they proved beyond doubt that the structures are permanently stable. Therefore, I would ask you to dismiss the thought that the works are in any way liable to get out of order through faulty construction.

(10) In reference to the efficiency of these works, if any of the members of this Conference have read the Annual Report of the Department they will see therein a table of purification effected by the Sewage Works given on page 48 where it will be seen that the percentage of purification based on oxygen absorbed in four hours for the year 1920-21 averaged 99.29 per cent. and based on the organic ammonia 99.21 per cent. At page 49 it will be seen that the purification has risen from 1912-13:—

PURIFICATION OF SEWAGE.

Year.	Per cent. of Purification by Organic Nitrogen.	Per cent. of Purification by Oxygen absorbed in four hours
1912–13	60·9	49·5
1913–14	77·0	79·9
1914–15	83·4	92·7
1915–16	84·48	95·18
1916–17	97·10	97·07
1917–18	96·61	97·25
1918–19	96·24	97·61
1919–20	97·12	98·49
1920–21	99·21	99·29

(11) I think, therefore, that I am justified in claiming that the percentage of purification effected by the present works has been brought up to such a state of efficiency that there can be no undue pollution of the river. Further, I would like to add

that the method adopted for working the tanks and the filters is the very latest possible, as at the conclusion of the war my Assistants and myself took the opportunity of visiting all the large important sewage works in England and Scotland, spending some days at Birmingham, Manchester and some of the works at larger towns and anything learnt there for the improvement of our system has been freely used to benefit the works in Perth.

(12) It is a mistake to say that the works are septic tanks and filters, as a matter of fact, the old method of working the tanks has been entirely discarded and the tanks are now more sedimentation and settling tanks than septic tanks, the object being to prevent, as far as possible, the ultimate purification changes which take place with a 24 hour contact in the tanks and reduce the time of settlement or sedimentation in the tanks so that the effluent therefrom is not over septic or in other words that the process has not been carried further than is necessary. With this object in view the time of contact has been brought down to about eight hours this having been found quite sufficient for our purpose.

(13) In reference to the filter beds, these are on the most modern lines both of English and American practice and the percentage of purification is the best index of their efficiency. In addition to treating the sewage in the tanks, as before described, it is oxidized in the filter beds. Settling pits have been constructed to retain any sediment that finds its way through the filters and this has proved so successful that in spite of the fact that the sewage from Perth is dense and much above the ordinary strength the crucial test by the solids in suspension in the filtrate discharged into the river when compared with the standard laid down by the Royal Commission on sewage disposal cannot be regarded other than satisfactory as the last Annual Report shows that the filtrate contained on the average for the year 5.94 grains per gallon.

(14) It has been stated by irresponsible persons that crude sewage has been discharged from the sewage works into the river. I can with every assurance say to this Conference that such has never taken place whilst I have been in charge of the Treatment Works, and it is, under present conditions, almost impossible for this to happen, and could only take place if the men employed at the Treatment Works went to considerable trouble to wrongly manipulate the valves, and to do this they know would mean instant dismissal.

(15) It has also been stated that sludge from the septic tanks has been discharged into the river. This statement is made without any foundation whatsoever, as the sludge has been deposited at Burswood Island, and within recent years the Department has found a ready sale for this sludge as one of the component parts of a fertiliser which is being manufactured at the present time adjacent to the filter beds, and during the year ending 1921, 2233 cubic yards of sludge were removed from the Perth septic tanks and sold to the Company at a profit of over £500 to the Department. Therefore, it is not reasonable to think that the Department would throw away a source of revenue by allowing the sludge to go into the river.

ALGAE IN THE RIVER.

(16) I have read the report of Professor Nichols in reference to the algae in the river, but I would draw the attention of the members of this Conference to the fact that many of the inhabitants of Perth are well aware that for many years past there has been at various times very considerable growth of algae noticed in the river, and this was especially so at the foot of Barrack and William Streets and along the foreshore as far as the Causeway before reclamation was undertaken, and very shortly after my arrival in this State, and before the filter beds were put into use I noticed the very large growth of algae between the Bunbury Bridge and the Causeway. This was in 1906, and I do not consider that the present growth is very much more abundant or larger in area than it was at that date. The conditions of the mud flats and the shallow waters along the Swan River are very ideal for the growth of algae, and some temperatures taken during the past month showed that in the river channel near the Treatment Works the temperature of the water was 78°, whereas in the shallows anywhere between the Treatment Works and Maylands the temperature of the water was 82°, and it appears to me that, with a temperature as high as the latter figure, the conditions are very suitable for the growth of algae.

(17) A few figures in reference to the quantity of water in the Swan River may be of interest, and, from calculations made, I estimate from the amount of water above the Bunbury Bridge to where the river narrows in, that at low tide there are 979,000,000 gallons of water, whereas at high tide there are 2,646,000,000 gallons of water. In other words, there is a movement of water of 1,667,000,000 gallons taking place as the tides vary. Some years ago I had very careful records taken of the water passing under the Bunbury Bridge with the change of tides, and also due to the discharges of the various rivers, and came to the conclusion that the volume of water discharged by the Helena River, the Swan River, and the tributaries thereto and passing under the Bunbury Bridge throughout the year averaged approximately 200,000,000 gallons per day. This would include the time when the river was in flood, when the volume would be very much more, and the months of January, February and March, when the change of water would be very little indeed owing to most of the streams having dried up.

(18) I have also made some calculations in reference to the main stormwater drains discharging into the river above the Narrows, and as the average rainfall of Perth is 33.91, say 34 inches, and the area served by the stormwater drains is 2,622 acres with a 20 per cent. run off, which is very low, the discharge from the stormwater drains would equal 1,100,000 gallons as a daily average. Analyses show that this stormwater contains about 4.5 grains of solid material per gallon, which is equal to approximately 115 tons of solids per annum. I would remind you that these solids contain a great deal of material undoubtedly of such a nature as to pollute the river, as the washings from the streets during the first run off are recognised by all authorities as being equally offensive as crude sewage.

DISPOSAL OF SEWAGE INTO THE SEA.

(19) No Engineer who has been connected with sewage schemes for any length of time would have any hesitation at all in saying that the first method of sewage disposal to be considered for any city is discharge into the sea, but, like every other method of disposal, this must be adopted with caution, and so far back as the time when the late Mr. C. Y. O'Connor was considering the sewage scheme for Perth, he had floats put in the ocean in the vicinity of Cottesloe and Cottesloe Beach, and it was found that these floats would stay just off the coast for many days at a time, and there was no decided current to warrant crude sewage being discharged into the sea at this point. As a matter of fact, it was realised that the discharge at this point would mean the contamination of the whole of our ocean beaches.

(20) In order that this matter may be further investigated, I have obtained the consent of the Hon. Minister to making further experiments in another direction to see whether there is any possibility of a suitable outfall position being obtained to allow of any of the crude sewage from Perth or the effluent from sedimentation tanks being discharged into the ocean without offence. As already pointed out, this proposal will be a costly one, as I estimate the cost somewhere in the vicinity of £300,000. This, of course, will be the capital expenditure, but there will be an annual cost of a pumping plant to deal with that portion of Perth already sewered. In conclusion, Gentlemen, I would venture to remind you that the present administration is not responsible for the position of the Perth sewage works which was decided on long before the present officers had control of the work. What has been done by the present administration is to make the best of the conditions they found, and I am satisfied that an independent judgment given at the present date would be the same as that of Sir Maurice Fitzmaurice, against whom no possible exception can be taken as he is undoubtedly one of the highest authorities on engineering works throughout the British Empire. In saying this, I do not wish you to think that I am in any way stating that in my opinion the present position of the works is unsuitable, when the main consideration is taken into account, namely, the ability of the present population to pay for a sewage scheme. What I want to convey is that the works have been made as efficient as possible, and I am satisfied that even if they were removed from their present position and some other method (which in my opinion could only be a sea outfall) adopted, that the pollution of the river would still continue, and this, Gentlemen, I am convinced will go on until such time as the river is confined to a channel, and the depth is so increased that there will not be the high temperatures and conditions suitable for the growth of the algae, which undoubtedly is the present cause of the trouble. Although it is not in my jurisdiction to put up any scheme for the reclamation of the river or the improvement thereof, much could be done to improve the conditions of the river and at the same time beautify the surroundings of Perth and South Perth, and would commend some such proposal to the authorities controlling the river, and strongly support the proposal put forth by Dr. Atkinson of the formation of the River Conservation Board as being a great step forward in the solution of this problem, because I am satisfied that no one can have the slightest desire to do anything that would tend in any way to pollute such a great heritage, as the Swan River is undoubtedly to the people of Perth and its surroundings.

appendix iii

Report on Swan River Pollution—Sand with black sediment

The Commissioner of Public Health,
PERTH.

I have examined the sample from the South Perth foreshore (Lab. Np. 9028E) submitted by you on the 15th instant. This consisted of a coarse white sand mixed with much black sediment, and covered with salt water. On opening the container there was apparent a strong smell of hydrogen sulphide, which continued to be evolved from the water after filtering it from the solid matters.

Portion of the well washed solids was decolorised immediately by adding a little very dilute hydrochloric acid, H_2S being given off and ferrous chloride going into solution. The black substance was therefore ferrous sulphide. It was found to exist in pure granules and as an impregnation of loose fibres and clots of filamentous algae associated with numerous diatoms. After removing all H_2S and adding a drop of nitric acid to prevent its further formation, the hot mixture of water and solids had a disagreeable odour like boiling glue.

On exposing some of the mixed sand and ferrous sulphide to the air under a thin covering of clean water, the black colour disappeared completely in two days, all the ferrous sulphide oxidising to ferrous sulphate without any H_2S being evolved. The residue, however, had a strong smell of dead curstacea, indicating the evolution of methyl amines, etc. from the organic remains.

The examination of this sample shows that hydrogen sulphide is being freely exolved from a mixture of decomposing algae, etc. with river water containing abundant sulphates. This is a common phenomenon calcium sulphate being readily reduced to calcium sulphide by oxidisable organic matter, and water acting on calcium sulphide to produce hydrogen sulphide. The presence of iron in the water seeping out from the shore converts part of the hydrogen sulphide into solid ferrous sulphide which in the alkaline water of the river is slowly oxidised to sulphate without giving off any unpleasant gas. To the extent that iron is present therefore the nuisance is reduced. There are still present, however, putrescible organic remains giving off various disagreeable organic gases as well as maintaining as long as they last the production of H_2S from the sulphates of the water.

The causation of "the black colour which so often develops in decomposing organic matter" is due to several things particularly (a) the formation of new organic compounds of low transparency, e.g. humic acids; (b) the formation of free carbon; (c) the formation under suitable conditions of iron sulphide, as illustrated in this case.

(Sgd.) E. S. SIMPSON,
Government Mineralogist and Analyst.

21st March, 1922.

appendix iv

Report on objectionable odours arising from the Swan River, Perth

by F. F. LONGLEY, *Adviser in Sanitary Engineering Commonwealth Department of Health.*

January 15th, 1924.

In the letter from the Honorable the Premier of Western Australia, dated 11th July, 1922, addressed to the Right Honorable the Prime Minister of the Commonwealth, Melbourne, the case of the objectionable odours arising from the Swan River was presented as an appropriate case for study by the Division of Sanitary Engineering of the Commonwealth Department of Health. In accordance with this invitation the undersigned went to Perth in September, 1922, and spent some time investigating the local conditions relating to the problem. Before leaving Perth at that time a memorandum was presented to the Honorable the Premier setting forth an outline of the situation, indicating certain measures which might be applied for the temporary amelioration of the conditions, and emphasising the point that the evidence available to give a satisfactory answer to the various questions arising was quite insufficient. (Memorandum dated 6th October, 1922). A schedule of information required was set forth in that memorandum. Some of this has been obtained. Some of it, including portions which would have been most significant, have not been obtained.

Somewhat more than a year has passed since the above memorandum was submitted. The available data have recently been brought together and studied with a view to seeing what conclusions could be drawn therefrom.

In the memorandum of 6th October, 1922, four questions were set forth which appeared to require answers. These questions were partly answered in that memorandum and certain parts were left for future consideration. I will repeat the four questions and give my conclusions regarding each in concise form and will then discuss certain of the points more at length.

The first question.

The first question in the memorandum of 6th October, 1922, was as follows:—

> What measures can be taken to prevent a nuisance during the coming summer due to the presence in the shore waters of the Swan River of prolific growth of algae?

The following quotation from that memorandum gives an answer to this question:—

> For the abatement of this nuisance for the coming summer it is necessary to do two things—
>
> (1) The algae growths which are thrown up upon the beaches must be regularly gathered up, removed, and effectively disposed of, and thus completely prevented from accumulating and decomposing on the beaches.
>
> (2) The effort must be made to kill the algae growths throughout the shallow waters and to prevent them from prolific development by means of chemical treatment or otherwise.

Further comment regarding this point will be found in that memorandum. Measures of the sort referred to, it must be remembered, are suitable primarily for emergency use. They should not be considered a sufficient or satisfactory permanent remedy.

The second question.

The second question was as follows:—

> What measures can be taken to assure a permanent abatement of the nuisance arising from the presence of prolific algae growths in the waters of the Swan River?

The only measure which appears to promise a permanent abatement of this nuisance is the deepening of the waters in the shallows of the Swan River to about 3.5 feet below zero of the gauge, that is to say, about 5 feet below low tide in Perth Waters. The work of deepening these extensive shallow areas would result in the reclaiming of several hundred acres of swamp land at present of practically no value but which would then have a large realisable value.

The third question.

The third question was as follows:—

> Is the effluent from the sewage treatment plant responsible for the prolific algae growths in the waters of the Swan River, and should this effluent be prevented from flowing into the River and disposed of elsewhere?

The question is really in two parts. The answer to the first part is that the sewage effluent may be to some extent responsible for the prolific growths but it is not entirely responsible. The reasons for this may be briefly stated as follows:—

(1) Quantities of nitrogen and of phosphorus enter the waters of the Swan River in the effluent from the sewage treatment works. Those quantities are great enough so that, if the water plants growing therein needed materials of this sort to make their growth prolific, they could obtain them from this source.

(2) Quantities of nitrogen and of phosphorus already exist in the waters of the Swan River before the sewage effluent enters. These quantities are great enough, without the addition of more from the sewage effluent, to permit the prolific growth of plant life in these waters.

The answer to the second part is that the sewage effluent should not be diverted from the River and disposed of, as at some time proposed, through an ocean outfall, for the following reasons:—

(1) The removal of the sewage effluent from the Swan River, if this could in some way be accomplished, could not be depended upon to result in a disappearance of the water plants whose decay upon the beaches is the cause, at times, of objectionable odours.

(2) The cost of an ocean outfall, which would not result in a complete remedy of the objectionable odours, would cost many times as much as the deepening of the shallow waters, and this latter would result in a complete remedy.

The fourth question.

The fourth question was as follows:—

> Is the sewage treatment plant responsible for objectionable odours, and does sewage flow into the river without going through the full process of treatment?

The first part of this question is answered in the memorandum of 6th October, 1922, as follows:—

> While it cannot be claimed that the Perth sewage treatment works are odourless, nevertheless, comparing them with many other municipal sewage works, I can state that the results of operation are good, and that the works as measured by customary standards are well and carefully operated, and are less offensive than the average in the production of odours.

The answer to the second part of this question is given in the memorandum of 6th October, 1922, as follows:—

> From my examination of the treatment works and of the conditions of operation I am entirely convinced that no untreated sewage goes into the River, but that it all goes through the successive steps of the treatment process, and the only thing which gets into the River is the effluent which the State Analyst's examinations show to be of excellent quality for a sewage effluent.

A DISCUSSION OF CERTAIN POINTS.

In discussing certain phases of the above questions in more detail I will first take up the third question.

The principal data which have been accumulated during the past year have been sanitary chemical analyses of the waters of the Swan River taken at five points, and also the water of Monger's Lake, a nearby fresh water lake not connected with the River. The five sampling points in the Swan River are as follows:—Guildford, The Causeway, The Narrows, Claremont and Fremantle Harbour. These analyses have been made by the Government Analyst. From January 23 to November 27, 1923, there have been 19 sets of samples taken for analysis.

Guildford was included among the sampling points in the belief that the water taken at that point would be free from any trace of the sewage effluent. This is true part of the time—but not all the time. An examination of the salinity of the Guildford samples shows that from January 23 to June 13 a measurable quantity of salinity from the sea was present in the samples. From June 27 to November 27, however, the salinity of the Guildford samples was so low as to make it clear that the fresh water coming downstream was great enough in quantity to keep back the salinity of the sea and therefore also the sewage effluent. The influence of the various constituents of the water upon plant growth is therefore considered for the period June 27 to November 27, as well as for the whole period covered by the analyses.

Nitrogen is well known as a fertiliser as it is one of the elements most vital to plant growth. It has long been recognised that the effluent flowing from the sewage treatment works at Claisebrook carries a considerable amount of nitrogenous organic matter into the River. It is, therefore, useful to examine the nitrogen content of the water of the Swan River at the several points above mentioned. The mean values of the 19 analyses at these several points at intervals during the entire period are as follows:—

Mean Values of Nitrogen Determinations for the Period January 23 to November 27, inclusive, 1923.

(p.p. 100,000.)

	Guildford.	Causeway.	Narrows.	Claremont.	Fremantle.	Monger's Lake.
Free Ammonia	·025	·044	·020	·027	·015	·020
Organic Nitrogen	·127	·147	·128	·114	·113	·160
Nitrates	·043	·059	·044	·050	·042	·049
Nitrates	T	·010	T	T	T	T
Total Nitrogen	·195	·260	·192	·191	·170	·229

The mean values of the nine analyses made at intervals during the time that fresh water was running at Guildford, are as follows:—

Mean Values of Nitrogen Determinations for the Period June 27 to November 27, inclusive, 1923.
(p.p. 100,000.)

	Guildford.	Causeway.	Narrows.	Claremont.	Fremantle.	Monger's Lake.
Free Ammonia	·024	·040	·021	·021	·014	·030
Organic Nitrogen	·118	·124	·124	·112	·103	·118
Nitrates	·024	·053	·045	·035	·026	·040
Total Nitrogen	·166	·217	·190	·168	·143	·188

Consider now what these figures represent in terms of a nitrogen fertiliser, such as sulphate of ammonia. An amount of nitrogen indicated by the figure .100 p.p. 100,000, which is somewhat less than any of the figures for total nitrogen given above, is equivalent to about 5 lbs. of nitrogen per acre in a depth of water 2 feet. 5 lbs. of nitrogen is about the amount of that element found in 24 lbs. of sulphate of ammonia.

Using this figure, the values given above for total nitrogen present in the water at the several sampling points may be converted into figures representing the equivalent amounts of a nitrogen fertiliser such as sulphate of ammonia, present in the water covering one acre of bottom at each of the sampling points.

Equivalents in pounds of Sulphate of Ammonia per Water Acre.

	Guildford.	Causeway.	Narrows.	Claremont.	Fremantle.	Monger's Lake.
Average for the entire sampling period, Jan. 23 to Nov. 27, 1923.	46	61	45	45	40	54
Averages for the period June 27, to Nov. 27, 1923, while fresh water running and Guildford samples contain no trace of sewage effluent.	39	51	45	39	34	44

This conversion into equavilent weights of sulphate of ammonia is made to help one to form a rational opinion of the fertilising effect of the nitrogen in the water. Those who are familiar with the use of nitrogenous fertilisers on land will realise that these quantities per acre, ever present in water, are ample to support a prolific growth of plant life. It is worth while to keep in mind the fact that in applying fertiliser to land, the entire dose for the season is applied at one time. In the water there is an ever present quantity, of the order above indicated, constantly replenished from various natural sources, and in the course of the entire growing season a quantity becomes available for plant life far greater in the aggregate than the figures stated above.

Even the smallest of these figures is ample to support prolific plant growth. In other words, the quantity present in the water at Guildford, while fresh water is running and while no trace of the Perth sewage effluent can be found there, equivalent to 39 lbs. of sulphate of ammonia per acre, is quite enough to account for a prolific growth of water plants without the addition of more nitrogen from the sewage effluent. It is of interest to note, too, that if the quantity of nitrogen in the water at Guildford, free of sewage effluent, be used as a basis of comparison, the excess over that quantity at each of the sampling points lower on the river, for the entire sampling period, is equivalent to *additional* amounts of sulphate of ammonia as follows:—

At Causeway, 22 lbs. additional per acre.

At Narrows, 6 lbs. additional per acre.

At Claremont, 6 lbs. additional per acre.

At Fremantle, 1 lb. additional per acre.

These quantities are small compared with the initial quantity present in the water, before the sewage effluent flows in, and this fact can not fail to throw doubt upon the statement sometimes made, that the prolific growths of water plants are caused by the fertilising material contributed by the sewage effluent alone.

It would be of great interest to know just what is the *degree* of influence upon plant growth, of the nitrogenous and other constituents of the water unmixed with sewage effluent, and on top of that, of the nitrogenous and other constituents contributed with the sewage effluent, in order to evaluate the true extent of influences exercised by the latter. This is not known, however, at present. There is only one way of determining it with certainty, and that is, to carry out some studies under scientific control and observation, using the river water, the river plants, and the sewage effluent under conditions subject to predetermined control. A recommendation to this general effect was made in the memorandum of 6th October, 1922, but the studies have not been made.

An interesting bit of collateral evidence appears in the figures for nitrogen in Monger's Lake. This lake receives no sewage effluent, as does the Swan River. The nitrogen therein is of the same general order of quantity as in the Swan River, lower than the high values and higher than the low, and this is sufficient to support a very prolific growth of a variety of water plants.

In waterworks practice, numerous reservoirs and lakes are known which contain only a small fraction of the quantity of nitrogen found in the Swan River, and yet which support vigorous growths of water plants which at times give the same kind of trouble from objectionable odours as is complained of in the Swan River.

Phosphorus is another element which is commonly recognised as a useful fertilising agent. The amounts of phosphorus present in the various samples of water have been determined, and may be summarised as follows:—

Mean Values of Phosphorus Determinations.
(p.p. 100,000.)

	Guildford.	Causeway.	Narrows.	Claremont.	Fremantle.	Monger's Lake.
Averages for the entire sampling period, Jan. 23 to Nov. 27, 1923.	·010	·019	·010	·008	·010	·012
Averages for the period June 27 to Nov. 27, 1923, while fresh water running, and Guildford samples contain no trace of sewage effluent.	·006	·017	·008	·007	·008	·007

A computation of the same sort as that made for nitrogen gives the following as equivalent amounts of phosphorous fertiliser, namely commercial tri-sodium phosphate, present in the water covering one acre of bottom at each of the sampling points:—

Equivalents in pounds of Tri-sodium Phosphate per Water Acre.

	Guildford.	Causeway.	Narrows.	Claremont.	Fremantle.	Monger's Lake.
Average for the entire sampling period Jan. 23, to Nov. 27, 1923.	6·1	11·6	6·1	4·9	6·1	7·3
Averages for the period June 27 to Nov. 27, 1923, while fresh water running and Guildford samples contain no trace of sewage effluent.	3·7	10·4	4·9	4·3	4·9	4·3

As in the case of the nitrogen, these amounts of phosphate fertiliser do not represent one annual dose, but a dose ever present and constantly replenished from various natural sources as well as the sewage effluent. The amount ever present in the water at Guildford, while free of all trace of the Perth sewage effluent, namely 3.7 lbs. per water acre, would have to be multiplied only by 20 to make 75 gallons per acre, which is a fair averaged dose of such a phosphate fertiliser applied to an acre of land. With the water constantly changing as it is, with fresh water coming down through half the year more or less and new sea water constantly diluting it at the lower end, the assumption that the 3.7 lbs. was replenished 20 times in the course of a year is certainly a conservative one.

It thus appears that the phosphorous, like the nitrogen is already present in the waters of the Swan River, before the intermixture of the sewage effluent, in quantity amply sufficient to supply water plants with food for prolific growth.

To return now to the second question. This relates to the permanent measures which might be taken to check the growths of water plants and thus eliminate the objectionable odours. If the prolific growths of water plants were caused entirely and solely by the presence of sewage effluent in the waters of the Swan River it would be natural to conclude that a removal of the sewage effluent from the river would result in a disappearance of the water plants and consequently a disappearance of the odours which at certain times have been so objectionable. As has been shown, however, the available evidence points convincingly to the fact that the presence of the sewage effluent in the waters of the Swan River is not completely and solely responsible for the prolific growth of water plants. Therefore its removal and discharge to some point other than the river cannot be counted upon to remedy the condition.

It is a well-known fact that the delicate forms of water plants which grow so prolifically on the shallow flats of the Swan River will not grow prolifically in considerable depths of water. Some careful observations have been made on the habits and growths of these plants in the Swan River. They have been found to grow prolifically in water not deeper than about 2½ feet. Some growths, although not nearly so prolific, have been found in water as deep as five feet at low tide. No growths of these plants have been observed in water deeper than five feet at low tide.

It thus appears that the deepening of the water to five feet at low tide would result in thoroughly discouraging the growth of these water plants, so that if they occur at all they would be inconspicuous.

The deepening of the shallow areas of the Swan River sounds like a formidable and expensive task. It would undoubtedly be a large task, but considered as a means of remedying once and for all the condition of plant growths and objectionable odours, it would cost very much less than to build the necessary works to carry the sewage of the city out to the open sea. The dredging, furthermore, would be a certain and permanent remedy. The diversion of the sewage effluent from the River, as already explained, could not be counted upon to assure a complete remedy.

Certain estimates which have been made of the cost of new works to deliver the sewage of Perth into the ocean indicate that it would cost about £750,000. The total volume of earth which would have to be moved to bring the depth of all the shallow waters of the Swan River above the Narrows down to five feet would be approximately 4,000,000 cubic yards. By building a dredge especially designed for this service, it would be possible to excavate this material at a cost not exceeding 3d. or 4d. per cubic yard. The total cost of excavation above the Narrows would therefore probably not exceed £65,000, or less than 10 per cent. of the cost of works to deliver the sewage into the ocean.

While this work is mentioned here primarily as a means of obtaining a permanent remedy for the bad odours from decomposing water plants, that would be only one of its benefits. There would be other important and material advantages resulting from this dredging work. The material dredged from the shallows would have to be discharged into other shallow areas, raising their level and thus reclaiming very large areas of ground which are now useless. It is estimated that the total area thus reclaimed above the Narrows would be about 500 acres. All of this reclaimed land, lying as it does close to the city and in the direction of some of its most promising development, would have a large value—a value which no doubt could be realised upon within a short term of years after the dredging and reclamation work had been done. It is easily conceivable that the value of the land thus reclaimed would more than pay for the entire improvement. This work would result, likewise, in the straightening of the river channel and the general improvement of the broad waters in front of Perth, a project which already exists on paper and which the development of the city will insistently call for sooner or later.

It will thus be seen that the remedy here suggested is sure, rational, and economically sound. It is a work of a sort which could advantageously be spread over a term of several years, so the total annual cost need not be heavy.

The improvement is most insistent above the Narrows, and that should be done first. The work below the Narrows would be smaller in magnitude, and could follow the completion of the other.

When Perth develops to considerably greater size than it is now, and the areas between it and the sea become more and more densely populated, there will undoubtedly be need for extensions of the sewerage system in that direction, and it may be that a logical feature of these extensions will be an ocean outfall. Should this be done, and all the sewage ultimately discharged into the ocean, there will still remain the necessity for deepening the great areas of shallow waters of the Swan River if the objectionable growth of water plants are to be put down.

The art of sewage treatment is in a stage of constant development. Methods of treatment accepted as the best a few years in the past have to be considered as susceptible to improvement. There have been developments in England in the past three or four years which may have a most useful application in connection with the sewage treatment problem at Perth, possibly permitting a reduction in the quantity of organic matter discharged with the sewage effluent into the Swan River, and at the same time a substantial saving in cost of construction of future extensions to the sewage treatment works. Some of the facts regarding these developments have been placed before the Metropolitan sewage authority for consideration. This office will be pleased to give such further assistance as it can in connection with the matter.

appendix v

Wellington Dam

Report by Water Purity Committee, Country Water Supplies, dated, 27th June, 1952

It was resolved that the Water Purity Committee considers it advisable to issue the following report on the Wellington Dam and its catchment in order to emphasise the national importance of this supply, the peculiarities and uncertainties that may provide many difficulties in the preservation of a safe water supply for all time. The report also indicates the committee's reasons for the advice it has given.

REPORT.

The terms of reference under which this Committee acts are expressed in general and somewhat indefinite terms. It is required to acquaint itself with the problems and advise regarding the safety of the Wellington Dam supply

Because of the peculiarities of catchment and streams that feed this supply, the task is one of considerable magnitude requiring extensive technical knowledge of water preservation technique and legislation.

The problem is so complicated by the intrusion of many variables and undeterminable influences, that the Committee in making any recommendation must proceed with the utmost caution, if it is to avoid the possibility of incurring vast and unnecessary private and public expense at some future date to preserve the purity of this supply, or if it is to avoid the possibility of ruining the supply from this or any neighbouring water supply for all time, or at least for many years.

The main peculiarity with which the Committee is faced is that the coalmining town of Collie is situated on the catchment area athwart the main feeding stream a few miles above the reservoir dam. By normal development Collie could be expected to grow rapidly to a large industrial city. The catchment itself, although at present little developed, is an extensive area with valuable agricultural potential.

The Committee, therefore, in its task of safeguarding the water supply is faced with the responsibility of advising with regard to the future development of Collie and the catchment generally. This problem involves economic and developmental interests of high importance to the State.

To be weighed against the future importance of Collie and the catchment area, is the future development around Bunbury and in the Great Southern area for which the Wellington Dam will be the main drinking water supply.

A further complication is the necessity to use the Wellington Dam not only as a source of domestic supply but also for irrigation and industrial purposes. Although it may at first appear that a water supply that is fit for human consumption is *ipso facto* fit for irrigation and industrial use, this is not altogether correct. A water supply may be rendered fit in certain circumstances for human consumption by chlorination, but the chlorination of large volumes of water for irrigation purposes is a matter of some considerable expense. Owing to the diverse uses to which irrigation water may be put, it is desirable that the water be maintained as pure as possible. If chlorination is not practicable, every reasonable effort must therefore be made to prevent pollution entering the supply.

Certain industrial processes are very sensitive to the chemical composition of the water employed and detrimental effects may be obtained in certain circumstances in much lower concentrations than will be apparent on human beings. The same applies to certain aspects of agriculture, and therefore, the access or accumulation of industrial waste in water or increasing salinity in water is a circumstance which as far as possible should be avoided.

A brief consideration of the variables and undeterminable influences, previously mentioned, will give some indication of the complexity of the task with which the Committee is faced and an outline of how it is proposed to meet the situation.

(1) The salinity of surface waters in Western Australia tends to increase with the clearing of the land and its cultivation. This increase in salinity varies from place to place and cannot be predetermined. It is therefore proposed as far as possible to restrict further agricultural development, until flow and salinity tests of the streams in the catchment in wet and dry periods indicate that restrictions can gradually be lifted in selected areas under careful supervision of the consequences.

(2) The rate and extent of the increase in population in Collie, and the rate and extent of the increase of industries and their qualitative variation together constitute the second undeterminable factor.

If we consider this in the first place under the possibility of disposing of sewage within the catchment area we find we are again face to face with a still further undeterminable factor, namely the rate of increase of pollution in the reservoir due to the re-use of the same water. In other words, from the cycle or reservoir to domestic and industrial supply and back through the sewage treatment plant to the stream, and so to the reservoir. This factor will increase not only from the accumulation in the re-used water but also from the increasing ratio of sewage effluent in proportion to fresh water in the stream as a result of the development of Collie.

With, therefore, an unknown quantity and quality of effluent to be dealt with in future years, and the unknown effect of accumulation from re-use the Committee was of the opinion that sooner or later pollution would reach the stream in such quantity that purifying processes for the water supply, and irrigation water supply, would become too expensive or even impossible. It was therefore decided that the safest procedure was to remove effluent from sewage treatment outside the catchment area by the most suitable and most economic route.

In considering the disposal of the effluent outside the catchment the Committee was again faced with the undeterminable factors of:

(a) the degree to which the effluent might encroach on the Preston and pollute that river; this cannot be determined without clarification of previous undetermined factors namely the extent of the growth of Collie and the quantity and quality of the effluent;

(b) the future use of the Preston River and consequently, the degree of pollution permissible.

The Committee decided to have regular samples of Preston River water taken as a guide for future comparison. It was considered that the discharge of effluent near the watershed would allow of much natural purification of the effluent to take place before the water entered the Preston if it should in fact ever reach that far. The degree of purification would depend on the rate of flow and therefore on the quantity and it would also depend on the chemical composition of the effluent as some industrial pollutants are of such a chemical nature that they will not be removed by natural purifying processes.

It is therefore evident that even with outside disposal of effluent the quantity and quality are important though much less so than for disposal of the effluent within the Collie catchment area. It is for this reason that the Committee has advised that the future development of Collie should be controlled and restricted to the mining industry and to secondary industries that have innocuous industrial waste effluents. By this means the Committee hopes that the quantity of effluent discharged to the Preston basin will be such that it will either never reach the Preston River or if it does its progress will be so slow that natural purification will take place to a satisfactory degree. By controlling the type of industries and their private treatment plants, the Committee hopes to prevent the discharge into the Preston valley of chemical pollutants that would not be removed by this natural purification.

(3) The third variable the Committee considered was the application in agricultural processes of various fertilisers, insecticides, vermicides etc. Their quantity would in a large measure be controlled by restriction on agriculture, but their qualitative variation is unpredictable. For this reason the Committee would allow the use of these articles only as permitted by the controlling authority. A list of permitted fertilisers etc. should be prepared and added to, as requested, and after due consideration of the effect on the

water supply. It is possible that permits may from time to time require to be modified because of the more extensive use and accumulating effect in the water of these chemical pollutants.

It is not the purpose of this report to discuss technical difficulties which can be overcome by appropriate engineering, chemical and biological processes, but to draw attention to the magnitude of the Committee's task in preparing the advice it offers for a safe water supply while in ignorance of the ultimate planned development in the area. The Committee wishes to provide a safe water supply with the minimum or restriction on industrial and agricultural development and natural enjoyment of the waterways by the people. But the importance of this supply, to vast territories far beyond the Collie basin, and to the general economy of the State impose the necessity for caution, lest such faults as increased salinity of the catchment, or contamination of the soil and the water with a harmful and irremovable chemical render the supply unusable for years or possibly for ever.

The Committee therefore recommends that control should be exercised not only over the waterways, the sewerage and discharge of effluents, but also over agricultural and industrial development, and also such ventures should have the prior consent of a controlling body before they are instigated.

The disposal of waste in an unsewered Collie is a problem which must always jeopardise the safety of the water supply. It is therefore important that the controlling body ensures that sewerage installations in Collie keep pace with development. It can only do this by having a voice in the control of both sewerage and development.

The By-laws prepared and advocated by the Committee and therefore designed to prevent pollution generally and also to allow to some extent for "case-by-case" consideration of certain aspects of pollution which may be considered permissible.

The By-laws for the catchment area contain no direct reference to control of development within the area by the water supply controlling body but the Committee has already indicated the necessity for this and this report largely concerns itself with the elaboration and clarification of its reasons.

It is obvious that the control of an institution of such national importance as the Wellington Dam water scheme requires the institution of a controlling body with specific statutory powers. The present Advisory Committee is well formed to constitute the technical part of such a controlling body but in order to formulate its policy, and to allow that policy to be more widely understood, representatives of Local Authorities and authorities responsible for Town Planning and Industrial Development should be included.

Such a Controlling Body may eventually control the water supplies of the State or form a pattern on which similar Controlling Bodies may be constituted.

SUMMARY.

In tendering advice the Committee has made the following its objectives:—

(1) To obtain a water supply that will be safe for domestic, agricultural and industrial purposes for all time.

(2) To restrict the normal industrial and agricultural development in the catchment area as little as possible, and to interfere to a minimum with the normal enjoyment of the waterways by the people.

To obtain these objectives it recommends the following:—

(1) The adoption of By-laws for the catchment as previously listed.

(2) The early sewerage of Collie.

(3) The discharge of sewage effluent out of the Wellington Dam catchment.

(4) The control of agricultural activities:—

(a) to prevent increased salinity;

(b) to prevent undesirable chemicals entering the water supply.

The restrictions under this control to be intelligently applied and to be lessened where experience shows them to be unnecessarily restrictive for the prevention of pollution.

(5) The control of industrial development to ensure that all waste effluents can be safely disposed of by the proposed sewerage system.

(6) The control of other development in Collie to ensure that sewerage systems increase in a proportion with the population that will ensure the safety of the water supply.

(7) That consideration be given to vesting this control in a body with statutory powers.

appendix vi

Circular on Rivers (Prevention of Pollution) Act, 1951

issued by Ministry of Housing and Local Government,
Whitehall, London, S.W.1
5th February, 1954.

I am directed by the Minister of Housing and Local Government to refer to paragraph II of his Circular No. 64/51, dated the 7th December, 1951, in which he mentioned that an informal expert committee is considering technical questions related to the framing of by-laws under Section 5 (1) (a) of the Rivers (Prevention of Pollution) Act, 1951. The Minister is now able to make available to those concerned in the administration of the Act the substance of the committee's first recommendations which deal with the way in which standards might be prescribed. No attempt has been made at this stage to formulate any general guidance on the quantity of polluting matter which might, in any given circumstance, be allowed to enter a stream. That is a question which will have to be considered in the light both of a comprehensive investigation of local conditions, and of experience elsewhere.

There are so many potentially harmful constituents of liquids discharged to rivers that standards based on concentrations of them taken individually would be impracticable, and could never embrace all possibilities. In specific cases and for routine purposes a special determination of a single constituent might admittedly be simple and useful, but for the most part is recommended that by-laws should be based on a series of tests, each of which will measure a general property of a polluting liquid. The basis of the Committee's suggestions is, therefore, the assumption that standards will be prescribed by reference to the results to be obtained when an effluent is subjected to one or more tests for a general property which can be described exactly, and carried out with ease and certainty. This assumption follows the views of the River Pollution Prevention Sub-Committee of the Central Advisory Water Committee. A series of tests which will completely cover the relevant properties of an effluent will not easily be devised, but some tests are well established and can be recommended now for adoption. These are referred to in Part I of the Appendix to this Circular. Part II of the Appendix contains notes on some of the further tests which have been or are being considered.

When the time comes to define standards in by-laws it will probably be found convenient, instead of setting out each test at length, to refer to some standard publication in which they are described in detail. One such work is the Departmental booklet entitled "Methods of Chemical Analysis as applied to Sewerage and Sewage Effluents". A new edition of this work is nearly complete and will be published as soon as possible.

APPENDIX.

Details of tests referred to in Circular Appendix VI.

PART I.

Tests for the following properties of effluents are thought to be suitable now for general adoption.

1. Solids in Suspension.

It has long been known that solids in suspension in an effluent are very important and the Royal Commission on Sewage Disposal recommended a standard for them. By-laws prescribing a limit for the content of suspended solids might, for the time being, adopt the test based on filtration through a Gooch crucible described in the 1929 edition of "Methods of Chemical Analysis as applied to Sewage and Sewage Effluents". When the new edition of this work is issued any alterations in technique could be incorporated in the standard test. For many liquids it may be convenient to adopt a quicker test, e.g. that based on the use of a certrifuge, for approximate and routine determinations.

2. Biochemical Oxygen Demand (see also paragraph 1 of Part II. of this Appendix.)

This is here taken to mean the amount of oxygen consumed in five days at 20°C. and is the second of the Royal Commission's two recommended tests. In carrying it out it is essential that a standard procedure should be followed. This will be described in the new edition of "Methods of Chemical Analysis as applied to Sewage and Sewage Effluents" referred to above. Until it is published, the American practice detailed in "Standard Methods for the Examination of Water and Sewage", latest edition, published by the American Public Health Association, New York, might be adopted.

It should be noted that the temperature of determination of 20°C. is slightly different from that recommended by the Royal Commission (19.3°C., 65°F.) The change will be incorporated in the new edition of the Ministry's publication mentioned above.

3. pH Value.

It is suggested that the British Standards Institution's standard pH scale (1647: 1950) should be used. For accurate results an electrometric procedure should be adopted and a description of it will be given in the new publication referred to above. It may also be found in many other places. For routine purposes and for approximate results indicators and either standard buffer solutions or tinted glasses may be used though they are not applicable to some effluents.

4. Temperature.

No comment is needed, save to suggest that the Centigrade scale should be used.

NOTE: The Committee recommended that any concentration specified in by-laws should be in parts per million, i.e. grams per million millilitres.

PART II.

The following notes refer to certain further tests for general properties for effluents considered by the Committee.

1. Organic Carbon or Oxygen absorption from potassium permanganate.

The former test gives a reasonably accurate measure of the organic matter present in an effluent, but little experience of its use is at present available. The latter test, in the absence of oxidising and reducing inorganic compounds, also gives an indication, but a misleading one in certain cases, of the amount of organic matter present. There is, however, a wider experience behind its use.

The necessity of a test of this kind in addition to that of B.O.D. may not always arise, but in this connection it is essential to bear in mind the differences in significance between the test for biochemical oxygen demand, that for organic carbon and that for oxygen absorption from potassium permanganate. The presence in an effluent of too great a quantity of matter amenable to biological oxidation may be objectionable for a number of reasons, depending on the nature of the material. It is always objectionable however because its oxidation in the stream tends to denude the water of its dissolved oxygen. The biochemical oxygen demand test, by simulating so far as can be done in the laboratory the conditions in the stream, provides a measure of this property, and is clearly of great importance. It is one of the two tests recommended by the Royal Commission on Sewage Disposal and it has been widely used since that recommendation was made. Its chief disadvantage is the time required, namely five days. Another disadvantage is that it may, on occasions, be profoundly affected by some other constituent of the effluent. For instance, some compound in a trade effluent might be toxic to bacteria and prevent biological oxidation altogether, in which case a highly polluting effluent might show a B.O.D. of zero. To provide for such circumstances, which are liable to arise with certain types of industrial waste, it might be desirable to have another test for organic matter which could not be influenced by the presence of such inhibiting agents. This additional test might be that for oxygen obsorption from permanganate or that for total organic carbon.

2. Toxicity to Fish.

No standard test can be recommended at the present time. A satisfactory test must not only give reliable and consistent results, but must also be so designed that the data obtained from the experiments can be related to the effect of the effluent on fish of all kinds in a river. Research into these problems is in progress. When satisfactory methods have been worked out the Ministry of Agriculture and Fisheries hope to set up a fish testing service available to river boards, local authorities and industry. A central testing service, if established, would not only ensure that tests are carried out on a uniform basis but would remove the need for the uneconomical duplication of apparatus and specially trained staff.

3. Colour.

A standard test for colour is under consideration, but none can be recommended yet.

4. Repression of Natural Self Purification Processes.

It may be important to determine whether effluents reduce the rate of self purification of river waters and some control of this property may be desirable. At present, however, no suitable test is in existence.

5. Liquids immiscible in water.

In certain cases a liquid immiscible with water may be present and may not affect the general properties of an effluent as gauged by the above tests. A special test may sometimes be necessary to cover this point.

appendix vii

Statement to the Press re the Swan River and Bathing

22nd January, 1954

from

Department of Public Health

Pathogenic bacteria, i.e. bacteria producing disease, have a limited life in water. Their life in sea water is shorter than in fresh river water. Consequently, the lower reaches of the estuary are much safer than the upper reaches because of the greater dilution and from the bacteriocidal effect of the sea water.

The Department has been under the necessity to indicate that certain bathing places in the upper reaches could not on bacteriological evidence be considered safe. There has, however, been no evidence of disease arising from infection with bacteria present in these waters. The Department has therefore not sought to prohibit the use of these pools, as many swimmers with full knowledge of the situation may consider the risk acceptable. The position, however, is closely watched and should any indication arise that disease was occurring because of the infected condition of a pool, immediate action would be taken to prevent its use.

The Department has informed interested authorities that because of increased development along the banks of streams it is illogical to expect improvement in the condition of these waters by any reasonable means, and therefore large sums of money should not be spent in improvements of up-river pools, but rather that the money should accumulate for provision of properly constructed Olympic pools.

All swimming pools, irrespective of the quality of the water, are from time to time associated with diseases of eyes, ears and the upper respiratory tract. These diseases are higher in a swimming community than in a non-swimming community however high the quality of the water.

The main factor in causation of such disease is a mechanical one.

Water washes away the protective secretions on mucous membrances, and washes bacteria into recesses of the upper respiratory tract from which they would normally be excluded if air-borne. By this means a person may develop sinusitis or middle ear disease from bacteria normally present in his nose. In congested pools bacteria may live long enough to be conveyed from one person to another by the water. It is obvious then that the swimmers introduce their own infective agents, and these play a far greater part in upper respiratory disease than any bacteria normally found in the pool.

It is well known that persons who specialise in diving suffer more from middle ear disease and sinusitis than other swimmers. This is the direct result of the forcing of the water into these recesses during the dive, and the carrying of bacteria from the nose into these more vulnerable areas.

Prolonged immersion in water has an effect on the skin which is most marked in the skin of the outer ear passage causing oedema, and reducing resistance to infection. Many swimmers consequently suffer from painful inflammatory swellings of the outer ear. The presence of sand in the water increases the mechanical irritation of the water and has most effect on ears and eyes.

Infections or irritations of eyes, ears and upper respiratory tract are therefore normal concomitants of swimming, they increase in proportion to the time spent in the water, the amount of diving done, the congestion of the pool, and the number of potential pathogenic bacteria harboured by the population at the time.

They are rarely an indication of bacteria in the water as supplied to a pool. Where disease arises because of bacterial contamination of a pool from outside sources, this disease is almost invariably of an intestinal nature such as dysentery and typhoid, or diseases arising from infected excreta. Such bacteria persist in water longer than most pathogens. They are not the bacteria associated with eye, ear and upper respiratory tract infections. Consequently, the Department is on the look-out mainly for bowel infections in association with swimming pools, rather than for those of the upper respiratory tract.

Thirty-six points on the river are regularly sampled by the Public Works Department, and the records are available to local authorities in that office. The Public Heath Department regularly samples a number of swimming areas in addition, and will assist local authorities in ascertaining the quality of their bathing places. The independent sampling by local authorities is not encouraged because of the redundant work this entails in the already overworked laboratories. Local authorities are therefore requested to make use of records already available at the Public Works and Public Health Departments, and to consult with the Public Health Department before embarking on any river sampling programme.

appendix viii

Pollution Points in Metropolitan Area

The following summary indicates sources of pollution in the estuary area which have caused comment or been the subject of complaint in recent years. Action taken to minimise the pollution is indicated.

Source of Pollution.	Action Taken.
MIDLAND JUNCTION COUNCIL.	
Bushby Street Drain.	
Collects stormwater drainage from foothills of Mundaring. Also liquid wastes from some houses (State Housing Commission) in the Hooley Road area.	Has been reconstructed and piped in some areas. State Housing Commission houses and rest of district being progressively sewered.
Drains to Blackadder Creek, to Woodbridge Creek, thence to Swan River.	Stormwater disposal methods being improved each year.
Few stagnant pools only during summer months.	
Woodbridge Creek.	
Discharges to the Swan River and for years was the " main sewer " for Midland Junction, *i.e.*, most of business premises were connected by a drainage system which has discharged liquid wastes directly to this creek.	This liquid wastes disposal system is gradually decreasing with the advent of sewerage in Midland Junction. Few premises now discharge to Woodbridge Creek.
Stock-holding paddocks located on banks of creek.	Stock has been excluded from creek in one or two instances.
State Government Abattoirs.	
Settling pits overflow, drainage from stock yards, manure and sludge drying beds.	
Overflow of liquid wastes from large " pooling " system situated on banks of Swan River. Numerous stock-holding paddocks.	
Effluents piped across Helena River from Abattoirs.	Some improvements initiated over the past two years.
Heavy pooling occurred in stock-holding paddocks immediately adjacent to the Helena River. Stock-holding paddocks followed course of Helena River for some distance.	Definite elimination of polluting area is doubtful. Conditions in stock paddocks unchanged.
W.A.G.R. Workshops.	
Septic tanks to large filter beds which had become inoperative.	Systems overhauled and filter beds reconstructed. Extra unit built.
Effluent flowed to Helena River, especially during winter months.	Included in sewerage programme.
Midland Junction Railway Station. Cattle Truck Washing Yards.	
Washing water discharged to Helena River.	Effluents now piped elsewhere.

Pollution Points in Metropolitan Area—continued

Source of Pollution.	Action Taken.
GUILDFORD COUNCIL.	
Old Women's Home, Woodbridge.	
Septic tank effluent and sullage waters discharged directly to Swan River.	Premises now connected to sewer.
Stock holding paddocks in some areas along the course of river.	
BASSENDEAN ROAD BOARD.	
Cuming Smith—Effluent Drain.	
Acid discharges.	Now corrected by adding alkali and lagooning.
King William Street, Stormwater Drain.	
Surface, seepage and stormwaters discharge through this drain to the Swan River.	
PERTH ROAD BOARD.	
Maylands Aerodrome.	
Septic tank effluents. Sullage waters, surface stormwater and oily washings from tarmac, etc., discharged to sump and pumped to river.	Effluents now discharged to French drains. Sullage waters only now reach the river bank.
Stormwater Drain (East Street Jetty).	
Drain 6 ft. in diameter. Drains stormwater from adjacent areas including drainage of swampy areas from parts of Inglewood.	
PERTH CITY COUNCIL.	
East Perth Power House.	
Septic tank effluent to river.	Now disposed of in sewer.
Trade waste to River.	Trade waste now treated and discharged to sewer.
Boat Sheds, Water Police, etc., Esplanade.	
Liquid wastes from showers, bar washings, hand basins, kitchen sinks, urinals discharge directly to river.	
River Boats, Ferries, etc.	
Faecal matter and liquid wastes dishcarged directly to river.	
Mill Street Drain.	
Stormwater disposal.	
Swan Brewery.	
Septic tank effluents to inoperative soak wells which seeped or flowed to river edge.	Soak wells renewed or repaired. Conditions satisfactory.
Floor washings, brewing wastes, etc.	Admission to sewer not at present practicable. Firm advised that treatment will be necessary when standards adopted.
Spring Street Stormwater Drain, 1953.	
In addition to stormwater this drain carried wastes from a number of factories, garages, etc.	Apart from Emu Brewery waste, major pollutants have now been deviated from this drain to the sewer.

Source of Pollution.	Action Taken.
CLAREMONT COUNCIL.	
Swimming Baths. Bath and kitchen wastes to River.	
Jetty Tea Rooms. Liquid wastes discharged to river.	
NORTH FREMANTLE COUNCIL.	
Wool Scours. Trade wastes discharge to river.	Centrifuging and settling of solids instituted and discharge in midstream at ebb tide of liquid waste. General position, however, still not satisfactory.
Pearse Bros. Boot Factory. Trade wastes discharge to river.	New settling tanks installed but position still not satisfactory.
A. M. McGilvray—Tannery. Trade wastes discharge to river.	New settling pits. Effluent to be taken out of river.
Joyce & Watkins—Tannery. Trade wastes discharge to river.	Effluent to river. Notice served by Local Authority.
Fremantle Steam Laundry. Trade wastes discharge to river.	Effluent to river. Notice served by Local Authority.
FREMANTLE CITY COUNCIL.	
Septic Tank Effluents (1950). Metropolitan Water Supply Yard, Beach Street. A. E. Tilley, Beach Street. Navy Store, Beach Street. Harbour Trust (4 tanks), Beach Street. South Slipway. Western End, Victoria Quay. Amenities Building.	
Crude Sewage (1950). Eight underwharf privies. Discharge directly to river.	Replaced by septic tanks on wharf area. Effluent disposal to Harbour (18-1-51), pending connection to sewer.
Harbour Shipping (1950). Raw sewage and liquid wastes discharge directly from ships to harbour.	Food wastes and rubbish discharged into barges and dumped at sea.
Fremantle Gas Co. (1950). Fifty thousand gallons water used for cooling purposes at Gas Co. Discharges to Council's drains.	
EAST FREMANTLE COUNCIL.	
Leeuwin—Navy Boat Shed. Raw sewage discharged directly to river.	Sani-pan fitted 30-10-53.

Pollution Points in Metropolitan Area—continued

Scource of Pollution.	Action Taken.
BELMONT ROADS BOARD.	
St. John of God Hospital. Sullage waters discharged to river 2–2–51.	Drainage overhauled and polluting point removed by 1952.
Industrial Extracts, Epsom Avenue. Discharge of trade wastes to river.	Under observation.
Forbes Street—Seepage waters and Stable polluted waters gain access to river. The "Springs" Swimming Pool adjacent. Horses swim regularly in river below swimming pool. Horse and stock holding paddocks border rivers edge along entire length of the Swan River within the boundaries of the Belmont Road Board. Boundary adjoins Swan Roads Board area at Guildford Bridge.	

notes