CHAPTER 5

A SEWERAGE TREATMENT PARADIGM

By the time that engineers were forced, by public opinion, to consider installing treatment at the main ocean outfalls in Sydney, the range of possible treatments and the arguments over their relative efficiencies had been severely curtailed. Whilst sewage treatment had been the subject of fierce public debate, many letters to the editor and rivalry in the nineteenth century, the twentieth century saw the choice of treatment method reduced to a routine selection by Water Board engineers of a standard first stage process. A sewerage treatment paradigm had been set and consensus achieved by the engineering community.

Thomas Kuhn postulated in 1962 that science progresses through periods of 'normal science' and periods of scientific revolution. 'Normal science' occurs when scientists do research based upon one or more past scientific achievements which they all agree are fundamental to their work and scientific revolutions occur when that consensus is shattered and radically new theories are put forward. The scientific achievements on which 'normal science' are based serve to define the problems and methods for research and "to attract an enduring group of adherents". These scientific achievements, together with the "law, theory, application and instrumentation" that they incorporate, form the basis of a scientific paradigm. It is this paradigm which is studied in universities as preparation for students to join the scientific community.[1]

Kuhn argues that the acquisition of a paradigm "is a sign of maturity in the development of any given scientific field."[2] Before such a paradigm is formed there is a continual competition between various views of nature that are all more or less "scientific" but represent incommensurable ways of seeing the world.[3] The early developmental stages of sciences have similarities with the early developmental stage of sewerage treatment engineering. The competition between treatment technologies could not be resolved whilst there was no engineering consensus. The incommensurable ways of seeing the world that Kuhn refers to in science are similar to the differing objectives (to utilise the sewage or to minimise land usage) that occur in engineering and which arise from different ways of seeing the world.

In the nineteenth century researchers had aimed for an ideal treatment solution that would completely, or almost completely, purify the effluent leaving no awkward by-products and no smell. The existence and discovery of new treatment methods did not end the research or settle disputes since there was always a better treatment to strive for and no agreement could be reached about the efficacy of new treatment methods. The major factors in the formation of a paradigm for sewage treatment methods were the attainment of consensus amongst engineers about which treatment technologies were adequate and the discarding of the search for an ideal solution. Both of these conditions, which were interrelated, were made possible by the British Royal Commission into Sewage Disposal of 1898-1915.

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[1] Thomas Kuhn, The Structure of Scientific Revolutions, 2nd ed, University of Chicago Press, 1970, pp10-11.

[2] ibid., p11.

[3] ibid., p4.

Several major parameters for the paradigm had been set in place by the time the Royal Commission sat. The use of water carriage and the consequent reliance on waterways for disposal were significant developments. As was discussed in chapter 2, the triumph of water carriage over dry conservancy methods of sewage collection and removal gave a measure of control to the governing authorities and pushed the field of sewage management more firmly into the domain of the engineers. The competing technologies of the late nineteenth century were therefore developed to deal with a diluted waste stream carried by gravity to a waterway. The sewage treatment technologies were designed, usually by the responsible governing authorities and the engineers who worked for them, to reduce the pollution of the waterways which had become a matter of public concern. Since the ocean was much more difficult to pollute than a river, engineers and governments preferred ocean disposal and treatment methods were not developed for ocean outfalls.

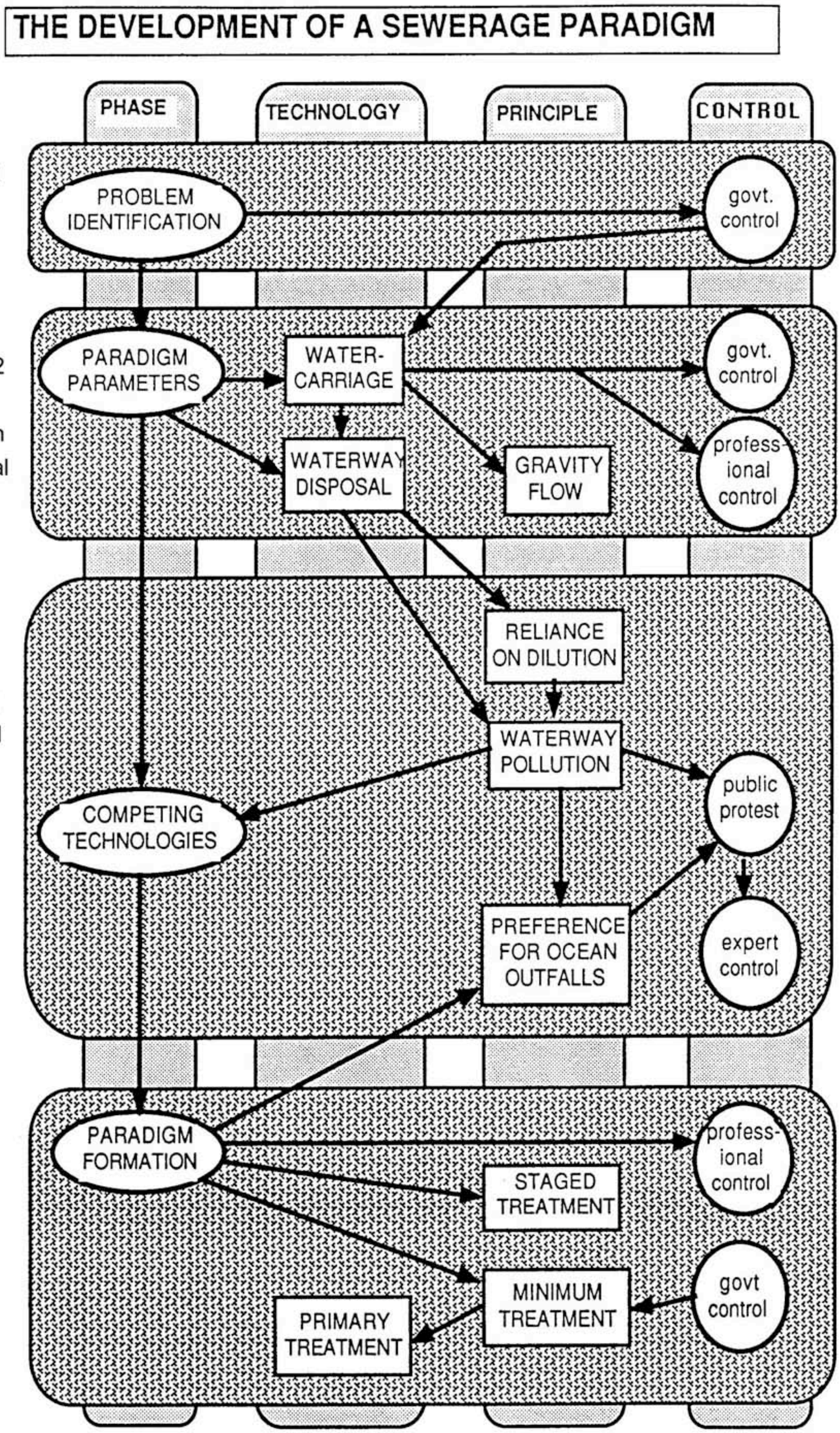
In this chapter we will be considering the role of the Royal Commission at the turn of the century in creating the conditions for paradigm formation in this area of engineering and in particular the concepts of staged treatment and minimum standards which emerged from the Commission. The paradigm ensured professional control over the range of treatment technologies that would be taken seriously and reduced government influence to that of supplying funds and defining standards.

The phases involved in reaching this point are illustrated in figure 5.1. The first phase in this process was the identification of a problem which was discussed in chapter 1 in terms of sanitary reform and the taking on of responsibility for waste disposal by the government. The next phase, which was described in chapter 2, involved the choice of water-carriage technology and the consequent reliance on waterways for sewage disposal. These decisions, which gave increased control to the engineering profession and to the governing authorities, also set the parameters which constrained the range of treatment technologies.

In chapters 3 and 4 various competing treatment technologies were considered. Despite the experimentation with competing technologies, ocean disposal continued to be preferred and this always influenced the way that those technological options were explored. The role of the public in this phase was reduced by the exertion of expert authority and rhetorical denial of problems.

This chapter describes the final stage in the formation of a sewerage engineering paradigm when a consensus emerged amongst engineers about the best treatment technologies. The paradigm gave firm control over the choice of technology to the engineering profession. Its formation depended on three major aspects which will all be discussed in this chapter. The first was the development of a notion of staged treatment, the second was the striving for minimum treatment and the third was the consensus on standards and criteria for measuring performance. The role of the British Royal Commission into Sewage Disposal in the latter was critical and so British Developments will be considered first.

Figure 5.1 The Development of a Sewerage Paradigm



BRITISH DEVELOPMENTS WHICH AFFECTED THE WORLD OF SEWAGE TREATMENT

In Britain the first Sewage Commission, appointed in 1857, reported that river pollution could only be avoided by applying sewage to the land and that this was the proper means of disposal. This was reinforced in 1875 by the Public Health Act which forbade local authorities from allowing sewage to pollute any watercourse.[4] Subsequently, chemical precipitation became a popular treatment method, pushed in large part by companies which had patented various chemicals for this purpose. However, the Royal Commission on Metropolitan Sewage Discharge, found in 1884 that although chemical precipitation removed suspended matter in solution, precipitation alone was insufficient treatment and recommended that the effluent should still be applied to the land, even after chemical precipitation.[5]

Artificial filters, using natural and patented materials, were experimented with in various parts of Britain during the 1880s, however the incentive to research along these lines was blunted when land treatment became a necessary condition imposed by the Local Government Board for any sewage disposal loan to local authorities.[6] The real breakthrough in artificial filters came in the United States where the first trickling filters were introduced. These enabled the sewage to trickle slowly through gravel filters, forming a thin film over the surfaces of the stones. The thin film, in contact with the air facilitated decomposition of the sewage by aerobic micro-organisms.[7]

The British were very interested in the U.S. experiments because these filters required much less land than conventional land treatment. As artificial filters were further developed the local authorities, keen to install them in place of land treatment, came into conflict with the Local Government Board which was still insisting on land treatment. In the face of mounting disputes, a Royal Commission was appointed in 1898 to "inquire and report what methods of treating and disposing of sewage may properly be adopted."[8]

The Royal Commission sat for seventeen years and took evidence from many engineers, scientists, doctors and other experts. It also conducted various experiments and site visits to treatment works. The Commission provided, firstly, a forum where the debates between rival processes could be played out but also enabled some of the more exaggerated and wild claims to be discredited. Not only the technical superiority of various methods was considered but also the rhetorical devices used to promote or discredit rival technologies. For example, the use of the term 'artificial' was objected to. Proponents of artificial filters preferred them to be called biological filters. It was claimed that the labelling

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[4] John Sidwick, 'A Brief History of Sewage Treatment-1', Effluent and Water Treatment Journal, February 1976, p68.

[5] H.H. Stanbridge, History of Sewage Treatment in Britain, Part 3, Institute of Water Pollution Control, Kent, 1976, p19.

[6] Sidwick, 'A Brief History of Sewage Treatment-1', p69.

[7] Stanbridge, History of Sewage Treatment in Britain, part 6, pp23-5.

[8] Sidwick, 'A Brief History of Sewage Treatment-1', p71.

'artificial' constituted an attempt to discredit them and to promote land treatment, which was considered to be a completely 'natural' process. [9]

In its Interim Report of 1901 the Royal Commission said that it was satisfied that artificial processes alone (meaning processes other than land treatment) could achieve a satisfactory standard of effluent for discharge into a stream and they found that the Local Government Board would be justified in modifying their conditions for loans.[10] This finding was confirmed in their Third report in which they stated that there was no essential difference between land treatment and artificial filters. (The essential difference, given no status by the Commission, was of course in terms of sewage utilisation.) The respectability of artificial methods grew from this time.[11]

The Royal Commission's importance was greater than the arbitration of a dispute between the British Local Government Board and local councils. It was a key event in the development of sewage treatment engineering all over the world and marked the transition between two distinctly different phases of that development. One engineering writer, commented,

> in a sense the Royal Commission marked the transition from folklore to a scientific approach to sewage treatment practices and requirements and heralded the opening of an era of rapidly developing and increasingly sophisticated technology.[12]

Although earlier sewage treatment methods were actually based in science and engineering rather than folklore, it is the perception of scientific maturity in the field that is significant here and this can be compared with Kuhn's description of the transition from a developing science to one that is governed by a paradigm. The incommensurable goals of sewerage experts were swept aside by the Royal Commission.

THE DEVELOPMENT OF STAGES AND STANDARDS - THE DEATH OF AN IDEAL

The origins of the modern concept of primary and secondary treatment arose from the division of treatment methods considered by the Commission into two stages. A number of the witnesses at the Commission hearings proposed two stage treatment for the sewage. The first stage would be to remove some of the sewage solids. The Commission reported on these methods in their fifth report under the heading of "Preliminary Processes" and they stated,

> The evidence which we have received and our own experience show that it is generally more economical to remove from the sewage, by a preliminary process, a considerable proportion of the grit and

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9 John Sidwick, 'A Brief History of Sewage Treatment-2', Effluent and Water Treatment Journal, April 1976, p194.

10 ibid., p197.

11 ibid., p198.

12 ibid., p199.

> suspended matter, before attempting to oxidize the organic matters on land or in filters.[13]

The Commissioners considered detritus tanks, plain sedimentation tanks, septic tanks and chemical precipitation as preliminary processes. The second stage of treatment consisted of biological filters, contact bed systems or land treatment and was the "real" treatment. The Commission did not consider these two stages as separable but rather as two stages, both necessary for the treatment of sewage. The very use of the term preliminary rather than primary (as came into usage later) makes clear the assumption that the first stage was only a preparatory stage.

The consideration of first stage treatment methods was therefore in terms of their use in conjunction with either filters or land treatment. The Commissioners found that chemical precipitation, sedimentation and septic tanks were all suitable forms of preliminary treatment. They dismissed many of the claims which had been made on behalf of septic tank treatment but nevertheless maintained that in certain circumstances it would be an efficient and economical preliminary process. Likewise they did not dismiss chemical precipitation although they noted that there had been a tendency for some authorities to regard it as an obsolete form of treatment. Again they felt that certain circumstances warranted the use of chemical precipitation, especially when the sewage contained trade wastes.[14]

In comparing the cost of each preliminary process the Commission found that chemical precipitation was twice as expensive as septic tanks and plain sedimentation tanks but that this difference disappeared when the cost of filtering the resulting effluent was also considered. This was because chemical precipitation tanks were more effective at removing suspended and colloidal matter and the effluent from such tanks could be treated on a filter of finer material and therefore smaller size and so the filtering operation was less expensive.[15]

Since each process, when considered in conjunction with filtering costs, had very similar annual operating costs, the Commission recommended that the choice between them be made on the basis of the means at hand for disposal of sludge, on the class of filter to be used and on the strength and character of the sewage. For example strong sewage would give less nuisance if treated by chemical precipitation and weak sewage might be more economically treated by septic tanks.[16]

The relative merits of the second stage treatments were also considered. The rivalry was not only between artificial or biological filters and land treatment but also between various types of biological filters and contact beds. The Commission found it extremely difficult to adjudicate.

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13 Royal Commission on Sewage Disposal, Methods of Treating and Disposing of Sewage, Fifth Report, London, 1908, p18.

14 Royal Commission, Methods of Treating and Disposing of Sewage, p21-30.

15 ibid., pp41-3.

16 ibid., pp43-6.

> The information obtainable from the evidence as to the cost of works on various systems was extremely scanty and altogether inadequate for purposes of comparison. This was inevitable in view of the inveterate tendency of a large section of the sanitary public to indulge in sweeping generalities on the slightest provocation [17]

The Commissioners did not pretend to fully understand the scientific workings of the various processes. For example they said of the Contact Bed process,

> The purifying agents seem to be not only bacteria, but also worms, larvae, insects, etc., and we can offer no opinion as to the respective amount of work done by each set of agents... Little is known of the kind of bacteria essential for purification, or as to their mode of action... [18]

Nevertheless they could still monitor the performance of each process. In the end, rather than recommending one method over another in absolute terms, they recognised that each had its place depending on circumstances: a biological filter could treat nearly twice as much sewage as a contact bed made from the same amount of material; that biological filters were better suited to variable flows and their effluents more aerated; but biological filters were more likely to create a nuisance from flies and from smells.[19]

Although the Commission declared no winners, they presented the rules of the game by recommending minimum quality standards for discharge of sewage into rivers and streams. In order, to work out these standards the Commission attempted to correlate the actual effects of sewage discharge with various measures of purity. These standards, commonly referred to as the 20:30 standard (Biological Oxygen Demand not more than 20mg/l and suspended solids not more than 30 mg/l), were not only accepted in Britain at the time but they are still used all over the world and refer to concentrations of suspended solids and biological oxygen demand. It was known that sewage used up oxygen dissolved in waterways when it decomposed and so it was decided that the amount of dissolved oxygen absorbed by a particular effluent in 5 days at 65 degrees Fahrenheit gave the best single test index of the polluting potential of that effluent.[20] This BOD^5 test is still used as an indicator today. In setting standards for effluents to be discharged into streams, the Commission assumed that the stream was neither very clean nor very polluted and that the sewage would be diluted by 8 times.[21]

The Commission's real achievement was in paving the way for some form of consensus amongst the engineering community. They did not do this by imposing their judgement on the engineering community. What they did was to recommend standards of effluent that should be achieved by whatever process was chosen. In so doing they made the competition between processes on the basis of technical superiority irrelevant. What use was it to achieve a higher degree of purity than was necessary?

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17 Sidwick, 'A Brief History of Sewage Treatment-2', p197.

18 Royal Commission, Methods of Treating and Disposing of Sewage, p51.

19 ibid., p119.

20 Sidwick, 'A Brief History of Sewage Treatment-2', p198

21 ibid., p199

The philosophy behind this consensus was that treatment should not be optimal but rather 'good enough'. This attitude was typified by an American text which argued that the purpose of treatment was to ensure the body of water into which the sewage would be discharged could cope with it. Any treatment beyond that which was only for the sake of making the sewage less offensive or dangerous, the text argued, would be a big waste of money.[22]

The usage of the term 'sewage purification' was gradually replaced partly because it was said to be misleading to "laymen" who supposed that once purified the sewage became pure "whereas the sanitary engineer may mean only that it is purer than it was before."[23] The skill of the engineer now lay, not in achieving a high quality effluent but rather in achieving an adequate quality of effluent for as little money as possible and letting nature do as much of the work as possible.[24]

The incorporation of economic criteria into engineering design is a crucial facet of the philosophy of engineering. Engineers repeat with pride the saying that an engineer is someone who can build for $1 what any fool can build for $2. Complex mathematical formulae replace rule of thumb methods in an effort to reduce costs. The art and science of engineering is focussed on minimising use of materials and maximising efficiency.

The experimental nature of engineering noted by Petroski[25], Blockley[26], Martin & Schinzinger[27] and Gravander[28] manifests itself in different ways in different branches of engineering. In structural engineering, innovative structures are overdesigned to begin with and as engineers gain more confidence the margin of safety is lowered.[29] In sewerage engineering, there is also a desire to reduce costs, and whilst the actual structures in the sewage plant may be overdesigned there is no analogous concern to overdesign for the environment. Rather sewerage treatment plants are underdesigned in terms of both capacity and efficacy, the experiment being to see whether they will meet the standards required. If not treatment can be upgraded.

Of the three main processes considered by the Royal Commission as a preliminary treatment, it was plain sedimentation that came to be the standard treatment used. Sedimentation tanks were simply tanks in which the sewage was left for a period of time during which some of the solids settled out. Plain sedimentation had been used with the early sewers in the nineteenth century to reduce the nuisance caused from sewage going into streams, but because the sludge was sometimes not removed allowing it to build up and occupy most of the space in the tanks, it was not considered a satisfactory method and was seldom

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22 Metcalf & Eddy, quoted in H.H.Dare & A.J. Gibson, Sewer Outfall Investigation, 1936, p13.

23 Leonard Metcalf & Harrison Eddy, American Sewerage Practice, vol III, 1st ed, McGraw-Hill, New York, 1915, p197.

24 ibid., p197.

25 Henry Petroski, To Engineer Is Human: The Role of Failure in Successful Design, St Martins Press, New York, 1985

26 D.I.Blockley, The Nature of Structural Design and Safety, Ellis Horwood, Chichester, 1980.

27 Mike Martin & Roland Schnzinger, Ethics in Engineering, McGraw-HIll, 1983.

28 Jerry Gravander, 'The Origin and Implications of Engineers' Obligations to the Public Welfare', *PSA 1980*, vol 2, pp443-55.

29 Petroski, To Engineer Is Human, p163.

seriously considered before the Royal Commission.[30] It was considered to be "a process midway between chemical precipitation and septic tank treatment, but having the advantages of neither"[31]

The claimed advantages of chemical precipitation and septic tank treatment had been exaggerated and although they were as efficient, and in the case of chemical precipitation, more efficient than plain sedimentation at removing solids (see Table 5.1) the game had changed and efficacy was no longer the primary concern.

Chemical treatment had promised large profits from the manufacture of fertiliser out of the precipitated sludge and it had been thought that this treatment would be sufficient on its own to produce an effluent free from nuisance that could be put into a stream. Instead it was found that the sludge was a nuisance, the chemicals costly and the fertiliser could not compete with artificial fertilisers. Even though the Commission gave chemical treatment a good write up, it fell into disfavour except in temporary or exceptional circumstances, for example when there was a high proportion of industrial waste in the sewage (for example an acidic trade waste might cause an acidic sewage which needed to be neutralised).[32]

Likewise septic tanks had promised to eliminate the sludge problem but failed to do this. Additionally they tended to be smelly. When separate sludge digestion was developed and biological filters took over from contact beds septic tanks ceased to be installed for sewage-treatment works. They are still, however, used for individual and small groups of houses that are too isolated to be connected to a public sewerage system.[33]

Plain sedimentation won out for municipal sewerage works, not because it was technically superior, achieved a better effluent or even because it was considered a satisfactory treatment on its own. The Royal Commission had set standards that could be met using sedimentation in conjunction with a second stage of treatment. Sedimentation therefore experienced a revival. Sedimentation was simpler, more easily controlled and cheaper if you didn't count the costs of the second stage treatment. In many places, particularly at ocean outfalls, one stage processes were installed and sedimentation was definitely cheapest if that was all you were installing. Moreover, even where two stages were planned, the first stage was often built some time in advance and the tendency was to go for the cheapest solution with respect to short-term costs.

THE PARADIGM - CONSENSUS & NARROWED OPTIONS

The narrowing of sewerage treatment research to ways of improving existing methods rather than innovative new treatments is characteristic of practice within a technological paradigm. Writers have variously referred to technological regimes, paradigms, traditions, frames and trajectories to describe the narrowed spheres of practice which are adopted by technologists.

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[30] Metcalf & Eddy, American Sewerage Practice, p5.

[31] Sidwick, 'A Brief History of Sewage Treatment-2', p195.

[32] Stanbridge, History of Sewage Treatment in Britain, Part 3, p20.

[33] Stanbridge, History of Sewage Treatment in Britain, Part 4, p44.

Constant[34], Laudan[35], Nelson and Winter[36] all describe 'normal' technology, as involving the "extension, articulation or incremental development" of existing technologies in certain directions.

Progress in sewerage treatment research since the Royal Commission has been largely of this type. Rather than radical innovations, improvements have been incremental. Screens have been mechanised, the grit removal process improved and mechanical scraping devices developed for removing the sludge from sedimentation tanks and methods for removing the scum from those tanks. A large part of the effort has concentrated on automating the process which is not only unpleasant for workers but also expensive because of the labour intensity.[37]

A comparison of engineering texts at the turn of the century and today shows that little new has been developed in the way of new treatment methods. In fact the options have considerably narrowed for primary treatment. Table 5.2 shows the major methods covered by the 1915 Metcalf and Eddy text used in Australia earlier this century and those covered by a modern Australian text for engineering students at the University of NSW.[38] The new developments which appear in Table 5.2 include comminutors, which are cutting screens that macerate the large sewage solids, oxidation and tertiary ponds which are methods of storing the sewage whilst the oxidation process goes on, and the rotating filters which use the same principle as trickling filters but have rotating discs upon which the film is formed.

Engineers today are sometimes quite defensive about the lack of original ideas that have emerged since 1915. John Sidwick, a sewerage engineer, in an article on the history of sewage treatment wrote that he was surprised how much "the earlier impetus of development" was reduced;

> improvements have largely been refinements of existing practices rather than the creation of new practices. It may, of course, be that there are no new techniques to be discovered, but this seems unlikely. A more probable explanation is that until recently effluent standards are capable of consistent achievement by conventional processes and that since research investment is always limited, those directing research preferred, quite rightly, to devote effort to improving processes of known worth rather than to investigating the unknown.[39]

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[34] Edward Constant, 'Communities and Hierarchies: Structure in the Practice of Science and Technology' in Rachel Laudan (ed), The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?, D.Reidel, 1984.

[35] Rachel Laudan, 'Cognitive change in technology and science' in Rachel Laudan (ed), The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?, D.Reidel, 1984, p95.

[36] Richard Nelson & Sidney Winter, 'In search of useful theory of innovation', Research Policy 6, 1977, pp36-76.

[37] John Sidwick, 'A Brief History of Sewage Treatment-5', October 1976, pp515-6.

[38] Metcalf & Eddy, American Sewerage Practice; D. Barnes et al, Water and Wastewater Engineering Systems, Pitman, 1981.

[39] Sidwick, 'A Brief History of Sewage Treatment-5', p520.

It must, however, be to the credit of earlier workers that a great deal of time and money has been devoted merely to proving the validity of their empirical judgement and that essentially little has yet been developed through central research that has significantly altered the principles of sewage treatment.[40]

TABLE 5.1 PURIFICATION EFFICIENCIES OF TREATMENTS

TREATMENT PROCESS	measured by suspended solids tests	measured by bacteriol-ogical tests	measured by B.O.D. tests
fine screening	5-20%	10-20%	5-10%
sedimentation	40-70%	35-75%	25-40%
chemical precipitation	70-90%	40-80%	50-85%
sedimentation + trickling filters	65-92%	70-95%	65-95%
sedimentation + activated sludge	65-95%	70-95%	50-90%

source: D.K.B.Thistlethwayte, 'Water Pollution and Pollution Control Methods for Reducing Pollution Levels', The Australian Health Surveyor, November 1970, p23.

TABLE 5.2 SEWAGE TREATMENT PROCESSES

METCALF & EDDY, 1915		BARNES ET AL, 1981	
Preliminary Treatment	Grit Chambers Screens	Grit Chambers Screens Comminutors	**Preliminary Treatment**
Primary Treatment	sedimentation septic tanks chemical precip travis tanks	sedimentation	**Primary Treatment**
Secondary Treatment	activated sludge trickling filters contact beds	activated sludge trickling filters rotating filters oxidation ponds	**Secondary Treatment**
	broad irrigation sand filters disinfection	grass filtration land filtration disinfection tertiary ponds	**Tertiary Treatment**

INFO FROM: Leonard Metcalf & Harrison Eddy, American Sewerage Practice, vol III, 1st ed, McGraw-Hill, New York, 1915; D Barnes et al, Water and Wastewater Engineering Systems, Pitman, 1981.

40 ibid., p520.

David Wojick concentrates more on engineering practice than research and development in his description of technological paradigms and he says that 'normal' technology involves the "artful application of well-understood and well-recognised decision-making procedures". In this way there is no ambiguity or doubt about what counts as a good solution within the engineering community.[41] The skill of the modern sewerage engineer lies in the ability to choose, from within the paradigm, the cheapest treatment process for a given situation that will perform the minimum treatment necessary to conform with local regulations and standards.

However, even engineering practice allows for technological improvement through experimentation and experience. 'Normal' engineering allows for cumulative improvement but the paradigm embodies strong prescriptions on which technological directions to go in and ensures that engineers and the organisations for which they work are "blind" to certain technological possibilities. Giovanni Dosi identifies various dimensions for a technological paradigm including the generic tasks to which it is applied, the material technology and the physical/chemical properties it exploits.[42] This latter point is emphasised by an engineer writing for an American engineering journal.

> it is indeed distressing to find "instant experts", many in the public arena, who believe the field is static because modern methods resemble those of past years. This belief demonstrates their ignorance, for the current methods of treatment are based on sound physical, chemical, and biological principles which do not change with time... The fact that the application of these basic principles has changed so little is a monumental tribute to our forebears in the field.[43]

In particular, the sewerage paradigm relies on the principles of gravity, dilution and oxidation. Gravity is utilised both in the sewers to transport the sewage and in sedimentation tanks to settle out heavier particles. The desire to utilize gravity for sewage carriage has placed constraints on the range of solutions seriously considered for any particular location which slopes in one direction. This has meant that sewage has been taken to locations that are not necessarily the most ideal for disposal but which have been chosen because the sewage can be taken there by gravity rather than by pumping. This may have been a false economy in the long run.

Water-carriage technology automatically implies some dilution of wastes. The idea that dilution of sewage should be considered as a treatment method was an American idea which was not picked up in Australia at first, because of the Australian dependence on British expertise and methods. Engineers in nineteenth Century U.S. towns resisted treating their wastes before putting them into rivers and streams because of a belief that "running water purifies itself."

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41 David Wojick, 'The Structure of Technological Revolutions' in George Bugliorello & Dean Boner (eds) The History and Philosophy of Technology, University of Illinois Press, 1979, p241.

42 ibid.

43 Ralph Fuhrman, 'History of water pollution control', Journal WPCF 56(4),`April 1984, p312.

> This hypothesis depended on chemical and physical methods of analysing water quality, which demonstrated that after sewage had been in a stream for a certain distance its physical elements dissipated.[44]

Although this practice brought many complaints from downstream users of water, sanitary engineers insisted that downstream users filter and treat their drinking water rather than forcing upstream dischargers to install wastewater treatment. Even in 1909, 88 percent of the wastewater of sewered areas in the United States was discharged into waterways untreated.[45] In 1917 an American engineer declared that the engineers' view "that the dilution power of streams should be utilized to its fullest for sewage disposal" had triumphed over the views of the "sentimentalists and medical authorities" who thought otherwise.[46]

The American engineering text by Metcalf & Eddy observes of the second British Royal Commission on River Pollution appointed in 1868, "the complete failure to recognize the dilution of sewage as a method of treatment".[47] The text complains that for many years after that the British neglected dilution as a subject of study even though the changes in sewage which took place on the land were similar to the changes which took place in the water with both the land and the water suffering if it was burdened with more sewage than either could handle.

> While the distribution of sewage over land was then a well-recognized method of sewage treatment, its dilution in water was regarded exclusively as a method of disposal, As a matter of fact, dilution is a valuable method of treatment, and a city which has a neighbouring body of water where it can be practised safely possesses an important natural resource.[48]

By 1930, the majority of American urban populations were disposing of their untreated sewage by dilution in waterways and the trend was that more towns were adopting this method than were treating their sewage before discharge.[49]

In Australia, dilution was not considered to be treatment until about 1936. A paper in The Commonwealth Engineer in 1919 stated categorically that sewage disposal into a river or sea was not sewage purification.[50] In 1936 the experts called in to investigate a Sydney sewerage scheme referred to a later edition of the Metcalf & Eddy text to put forward the case for dilution in the ocean as a treatment process that was as scientific as any of the most complex "artificial" treatment methods.[51]

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44 Joel Tarr et al, `Water and Wastes: A Retrospective Assessment of Wastewater Technology in the United States, 18001932', Technology and Culture 25(2), April 1984, p236.

45 ibid., p239.

46 ibid., p245.

47 Metcalf & Eddy, American Sewerage Practice, p3.

48 ibid., p3.

49 Tarr et al, `Water and Wastes', p246.

50 A.C.Hewitt, `The Design of Sewage Purification Works', The Commonwealth Engineer, May 1, 1919, p308.

51 Dare & Gibson, Sewer Outfall Investigation, p13.

Oxidation is another mechanism upon which the sewerage treatment paradigm depends, either in the treatment works (in secondary treatment) or in the natural environment. Waterway disposal relies on this mechanism and engineers have often overloaded waterways by overestimating their ability to continually provide the right environment for oxidation to take place. Moreover the use of oxidation in secondary treatment has led engineers in recent times to refer rhetorically to ocean disposal as secondary treatment because oxidation takes place in the ocean.

Although the sewerage engineering paradigm rests heavily on the aforementioned principles, it is not a supertheory, nor merely a set of shared beliefs, values and techniques. Nor is it easy to see what the exemplar is exactly which serves as the basis of the paradigm. Rather the paradigm is based on a set of methods and processes which the engineering community have agreed are both appropriate and sufficiently effective. These methods and processes are not superior technically but are superior in terms of the various objectives of the engineers.

PROFESSIONAL CONTROL & AUTONOMY

The importance of British engineering developments to Australian engineering arose not only from Australia's situation as a British colony. In fact, it has been argued that from the 1880s there was "little evidence of an especially 'colonial' technological dependency relationship" between Australia and Britain.[52] Rather, nations all over the world were looking to British developments in sewerage because the British were on the forefront of endeavour in this field. Moreover, British engineers travelled all over the world, particularly in the second half of the nineteenth century spreading British technology in their wake. The railway boom in the early part of the century in Britain encouraged an unprecedented expansion of the engineering profession which left it with a surplus by mid-century because of the downturn in railway work. This situation encouraged a flow of engineers to other parts of the world in search of work and to fill the gaps in expertise in other countries.[53]

In Australia, when the colony of New South Wales was first being established, engineers were recruited from the ranks of military officers and convicts and any engineers who could be persuaded to come out to the colony.[54] As the indigenous engineering profession developed, there were still plenty of opportunities for British engineers, and before any sanitary engineering profession was established, engineers of all types found themselves giving advice on, and designing, water and sewerage systems, although they had no background in the area.

An example is Robert Rowan Purdon Hickson, an engineer with railway and harbour experience in Britain, who first came to South Australia to work on the various harbour and port works. He became NSW Chief Engineer for Roads and

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52 Ian Inkster, "Intellectual Dependency and the Sources of Invention: Britain and the Australian Colonies in the 19th Century", a paper delivered at the Anglo-Australian Meeting, Royal Institution, London, 7th January 1988, p41.

53 R.A. Buchanan, 'The Diaspora of British Engineering', Technology & Culture, 27(2), 1986, pp507-509.

54 ibid.

Bridges, a member of the Water Board in 1889, and two years later Engineer-in-Chief for Roads, Bridges and Sewers. He presented papers on sewage treatment and disposal and even wrote a book on it.[55] His biographer remarked; "First harbours, then roads and bridges, and now sewage-he was certainly proving himself a man of catholic professional tastes!" [56]

Such hopping between specialisations became more difficult as Australia's engineering profession grew and became more specialised. Growth was marked by the establishment of an engineering school in Sydney but the profession drew on British engineers for lecturers.[57] Also, for many years British engineers were called upon to advise on and endorse major water and sewerage engineering works because they had the experience and the expert status that local engineers lacked. Clark, who was brought out to Australia to advice on a water supply project, also endorsed the proposed sewerage diversion from the harbour to Bondi and the Botany sewage farm and helped in getting it accepted by the electorate.(see previous chapters)

After about 1914 the "diaspora" of British engineers subsided.[58] Moreover, the sanitary engineering profession was consolidating and the growth of an indigenous sanitary engineering profession in Australia fostered local expertise in sewerage treatment methods. The formation of a paradigm overseas permitted the development of educational courses devoted to this field and united sanitary engineers in Australia against outsiders and other members of the engineering profession.

The circular argument inherent in Kuhn's scheme; that a paradigm is something that results from the consensus of a community of scientists and a community of scientists is defined by the paradigm they adhere to, also causes problems for technological paradigms. Does the paradigm define the engineering community or does the engineering community form the paradigm? Henk Van den Belt and Arie Rip argue that the development of a technology along a trajectory requires a 'cultural matrix', that is, a subculture of technical practitioners.[59] Whilst a cultural matrix may be necessary for a paradigm to exist, it may also be that a technological community cannot exist in any coherent form without some form of paradigm. Michael Callon has argued that social group formation is simultaneous with the definition of research problems and he links the struggle between social protagonists to define what is problematic and what is not with the formation of the groups which will take charge of those research problems which are defined in the struggle.[60]

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55 James Antil, 'Robert Rowan Purdon Hickson: Civil Engineer (1842-1923)', J.Royal Australian Historical Society 55(3), September 1969, pp228-244.

56 ibid., p234.

57 Buchanan, 'The Diaspora of British Engineering', p521.

58 ibid.

59 Henk Van den Belt & Arie Rip, 'The Nelson-Winter-Dosi Model and Synthetic Dye Chemistry' in Wiebe Bijker, Thomas Hughes and Trevor Pinch (eds), The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology, MIT Press, 1987, pp135-158.

60 Michel Callon, 'The state and technical innovation: a case study of the electrical vehicle in france', Research Policy 9, 1980, pp358-76.

Whilst sewage disposal methods were a matter of debate amongst engineers last century, the general public were able to take part in the debate and be taken seriously by decision-makers. Doctors, lawyers and non-professionals felt competent to comment on the theory of treatment methods and criticise proposed schemes. The formation of a paradigm has enabled sewerage engineers to consolidate their position as the 'experts' and to restrict the role of outsiders to that of an 'uninformed public' which can acquiesce with a particular proposal or protest against it but which is in no position to question the range of treatment methods available. Other professionals are particularly likely to respect the boundaries of expertise set up by the paradigm.

And although various treatments for sewage were debated in the meetings and proceedings of engineering and scientific societies in the nineteenth century, today's engineering magazines deal with the details of particular applications of an acceptable technology or improvements and refinements to existing technologies. Such discussions contain assumptions and jargon which make them uninteresting to the uninitiated and they are seldom read by those outside the field.

The sewerage engineering community perpetuates its paradigm through education and practice, which are largely determined by the engineering community. The acceptable treatment methods, classified into stages, have been taught for several decades to students training to be sewerage or public health engineers and as a result it is taken for granted by most engineers that such methods are satisfactory and appropriate to most situations.

Although earlier engineers could design and build effective sedimentation tanks, the engineering science of sedimentation has progressed to a stage where students are taught how to calculate the submerged weight of a particle of sewage, the velocity it will settle at, what drag forces it will be subject to as it settles and so on so that sedimentation tank shape and size can be optimised and detention times fine-tuned. Modern sewerage engineering students are taught exactly why and how a sedimentation tank works.

The advantage of such sophisticated knowledge is debatable, especially given that sewerage treatment works are seldom operated at optimum conditions, and flows are extremely variable. (The situation in Sydney is discussed later in this chapter.) The acquisition of this knowledge does however serve another purpose. The increased scientisation and mathematisation of these sewage treatment methods has given them an aura of precision, efficiency and certainty and conveys the impression that only engineers can understand the field of sewage treatment.

A specialised knowledge base was sought keenly by engineers as a basis for the claim for professional status during the nineteenth century. Although most engineers were employees, they believed in a social hierarchy which awarded power and influence to those with knowledge and skill and they sought to be recognised as professionals rather than workers. In particular, civil and mechanical engineers required science as part of their specialised knowledge base so that they would be differentiated from the technicians, mechanics and skilled craftsmen in the occupational hierarchy.

Demarcation disputes over the teaching of the theoretical principles of technology and jealousies on the part of science faculties forced the engineering faculties to develop an engineering science. Engineering educators, such as the Scottish engineer W.J.M. Rankine, sought to create an engineering science that would "transcend the traditional categories of theory and practice" so as not to threaten scientists or compete with on-the-job engineering training. For Rankine, a leading figure in the development of thermodynamics and applied mechanics, the answer lay in reducing the laws of actions and the properties of materials to a science. This amalgamation of theory and practice allowed a new science to be developed which could be claimed to belong to engineering.[61]

Chemical engineers also faced a demarcation problem in the early part of the twentieth century in the United States. To avoid being confused with chemists and to gain control of their field in the face of competition from other engineers they sought a scientific knowledge base that amalgamated theory and practice.[62] Similarly, for sewerage or sanitary engineers to mark out territory from within the civil engineering field it was necessary for them to develop an engineering science, a field of specialised knowledge, which they could lay claim to and which would support their bid to control the field of practice.

Although engineers could mark out their professional territory their autonomy was still limited. Gary Gutting has criticised the concept of a technological paradigm because of the difficulty of defining a technological community and attributing to it the autonomy necessary to make the term of paradigm significant. If evaluation is up to outsiders then engineers cannot be autonomous.[63] This view neglects the ability of engineers to influence the evaluation that outsiders make or impose.(This will be explored in greater depth in chapters 8 & 9) Moreover the ability of engineers to set their own objectives and constraints may be less than that of scientists but it is difficult to argue that scientists have a free choice about their goals and constraints either.

The formation of the sewerage paradigm did rely to a large extent on the official sanction of the British Royal Commission on Sewage Disposal which met at the turn of the century but the Commission based its conclusions on evidence given by the engineering community and results of experiments and projects undertaken by engineers. Moreover the Commission did not determine the paradigm but only set the standards that it should meet. The formation of the paradigm resulted from choices made by engineers working for local government authorities. Such choices were made on the basis of their search for the cheapest 'good enough' solutions.

The autonomy of the engineering community lay in its ability to dictate the range of technologies which would be taken seriously. Outside authorities might set standards and regulate the available money but the engineers decided how to meet the standards and if they could be met with the finances available. A community might demand a higher level of treatment but would not be able to ensure that alternative treatments from outside the paradigm were taken seriously.

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61 David F Channell, 'The Harmony of Theory and Practice: The Engineering Science of W.J.M.Rankine', Technology & Culture 23(1), Jan. 1982, p45.

62 Terry Reynolds, 'Defining Professional Boundaries: Chemical Engineering in the Early 20th Century', Technology & Culture, 1986, pp694-716.

63 Gary Gutting, 'Paradigms, revolutions, and technology' in Laudan, The Nature of Technological Knowledge, p57.

The infringement on engineering autonomy by employers is a different question. The difference between engineers and scientists is that career success and promotion, for engineers, is almost completely defined and controlled by employers rather than peers or professional organisations. Employers set the goals and evaluate engineers on their ability to help the organisation reach those goals.[64] Moreover engineering work takes place very obviously and directly in a context of economic and social interests and ideologies.[65] However, the identification of engineers with business interests and the existing status quo of Western industrialised countries,[66] means that these outside constraints are not so much an interference as a collaboration. The setting of goals from outside does not necessarily distort "normal" practice.

A 1971 study of American engineers found that although engineers placed great importance on having freedom to manage their own work they placed relatively little importance on being the originators of the projects they worked on.[67] The infringement on engineering autonomy posed by employers is also limited by the shared interest in the same technological system and the correlation between the engineers paradigm and the interests of the firm or authority for whom they work. Constant observed that practitioners are usually located within a few organisations that are readily identifiable with a particular technology.[68]

The paradigm was necessary for the profession of sanitary engineering to maintain a certain degree of autonomy and to help guard the boundaries of their profession against outsiders. In 1923 Colonel Longley gave a paper before the Sydney division of the newly formed Institution of Engineers, Australia, entitled "The Sanitary Engineer and His Place in Relation to Public Health in Australia" which exemplified the struggles for professional status and autonomy of the sanitary engineeer in Australia.

> Few people in Australia are qualified to bear the title. Not only is a comprehensive training in civil engineering necessary, but more vital still is a solid grounding in the special subjects of biology, bacteriology and chemistry, with considerable experience in the laboratory processes associated with the analysis of water for all purposes, sewage and garbage, and in their treatment and disposal.[69]

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64 Robert Zussman, Mechanics of the Middle Class: Work and Politics Among American Engineers, University of California Press, 1985;Peter Whalley, The Social Production of Technical Work: The Case of British Engineers, MacMillan, 1986; Edwin Layton Jr, The Revolt of the Engineers: Social Responsibility and the American Engineering Profession, Cape Western Reserve University, Cleveland and London, 1971; Robert Perrucci & Joel Gerstl, Profession Without Community: Engineers in American Society, Random House, New York, 1969.

65 Stewart Russell & Robin Williams, 'Opening the Black Box and Closing it Behind You: On Microsociology in the Social Analysis of Technology', revised version of paper to the British Sociological Association Conference Science , Technology and Society, Leeds 1987, p5.

66 for example, Layton, The Revolt of the Engineers.

67 Richard Ritti, The Engineer in the Industrial Corporation, Columbia University Press, 1971, p52.

68 Edward, Constant, 'Communities and hierarchies: structure in the practice of science and technology' in Laudan , The Nature of Technological Knowledge, p29.

69 Colonel F.F. Longley, 'The Sanitary Engineer and His Place in Relation to Public Health in Australia', I E Aust Transactions 4, 1923, pp194-5.

THE PARADIGM IN PRACTICE - PROPOSALS FOR SYDNEY

When treatment was first considered at the ocean outfalls, in the late 1930s, the philosophies of staged treatment and minimum standards ensured that there was no attempt to adopt the best, most effective treatment process. Rather the aim was to find the minimum, cheapest treatment that would suffice, with provision for more treatment if it was found necessary. Thus, Dare & Gibson recommended that treatment at the ocean outfalls be limited to removal of offensive solids and the grease. If experience showed that was not good enough, "then provision for such disinfection and sedimentation, and later, if necessary, sludge removal and treatment" could be added.[70]

In a letter to the Board of Health seeking approval for the first treatment works at Bondi the Secretary of the Water Board explained that,

> after lengthy and exhaustive deliberations the opinion has been reached that it is both unnecessary and uneconomical to submit the sewage discharged from Sydney's ocean outfalls to more than partial treatment designed to protect the beaches from floating and suspended matter.[71]

The engineers looked to the paradigm for their choice of technologies. The only two options for treatment of the effluent considered by Farnsworth, the Engineer-in-Chief of the Sydney Water Board in his 1938 report were a screening plant or a primary sedimentation plant. Septic tanks were not mentioned and chemical precipitation was only mentioned as a possible advanced treatment which would be "unnecessarily extravagant".[72] Similarly, secondary treatment was considered to be totally unnecessary. Farnsworth reported the common view "that the most efficient method of removing solid matter is to subject the sewage to a period of sedimentation". [73] Floating matter and grease would be skimmed off the surface of the sedimentation tanks with mechanical scrapers.

Farnsworth claimed that sedimentation tanks would remove 50-60% of the suspended solid matter in the form of sludge which settled out or scum which floated on the top of the tank. A screening plant would only remove less than 10% of the solids and yet would cost almost as much because the major cost was in the excavation of the headland to house the treatment plant. The screening plant would have higher operating costs than a primary sedimentation plant as well because of the requirement for cleaning the screens regularly whereas a sedimentation tank could be roofed over and would have no possibility of nuisance arising from its operation.[74]

Farnsworth's framing of the relative costs of the two treatments was deceptive. The choice between a screening plant and a sedimentation plant was really the choice between two forms of treatment that were normally installed together. Screening was a preparation process before sedimentation. The choice of

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70 Dare & Gibson, Sewer Outfall Investigation, p22.

71 S.T.Farnsworth, Elimination of Nuisance From Ocean Outfall Discharges, 1938, appendix 7.

72 ibid., p10.

73 ibid., p4.

74 ibid., pp4-5.

sedimentation over screening really represented a cost cutting exercise because Farnsworth thought he could get away with omitting preparatory treatment. His real choice was between screens and sedimentation and sedimentation on its own. Yet he was able to make his decision sound as if he was favouring the best option although it cost slightly more. In reality here was an example of the ever present desire of engineers to minimise treatment and to even cut corners on conventional treatments.

The objective of putting treatment in at Bondi was seen by the engineers as being to prevent a nuisance on the nearby beach by removing the floating matter. It was considered that it was only this floating matter which caused any problems. Although the perceived problem at the sea was therefore different from that of river disposal, the choice of treatment technologies came from the paradigm developed for waterways other than the ocean and never specifically designed to remove floatable matter. After all, sedimentation aims primarily to remove settleable solid material. The addition of scrapers to skim the surface of sedimentation tanks was an afterthought and only removed material that floated in fresh water. The fact that sewage floats in sea water because fresh water is lighter than seawater was conveniently forgotten. Nevertheless Farnsworth claimed that primary sedimentation would remove all floating sewage matter. At the same time he hedged his bets and pointed out that if the demand arose in the future for more complete treatment, then filters (i.e. secondary treatment) could be added to the treatment process so that the effluent would be of the standard required for inland waters.[75]

Farnsworth's attempts to avoid screening were not successful perhaps because it was realised that screening was necessary for the sedimentation process to work properly. Nevertheless, without the benefit of a report and supporting arguments a minimum of treatment was installed and by 1959 only the screens has been installed at Bondi and no treatment was in place at Malabar or North Head.

In May 1959 the Water Board acknowledged the growing problems of beach pollution, increased sea bathing and the accompanying complaints about pollution. It adopted a plan proposed by the Engineer-in-Chief for sewage treatment at Bondi and Malabar. The 1959 plan provided for construction in four stages at each plant:[76]

1. Provision of Screens (done at Bondi already) and Grease Removal Units (to be discussed later);
2. Provision of Sedimentation Tanks and Submarine Sludge Outfall Line;
3. Provision of Further Treatment for Sludge;
4. Provision of Submarine Effluent Outfall Line or Activated Sludge Treatment Units (secondary treatment).

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75 ibid., p9.

76 Brown and Caldwell, Design Report: Malabar Sewage Treatment Works, M.W.S.&D.B., July 1965, pp2-3.

The reasons for staged development were stated by a Board representative as follows. The level of treatment necessary could be assessed at each stage in the light of what had been achieved by the treatment already installed. Staged development also provided an opportunity to take advantage of research locally and overseas into sewage disposal. Thus pollution control could be improved as improvement was required rather than all at once. Nonetheless staged development was necessary because the Board had a policy of funding new works from current revenues and this limited the funds available at any one time for treatment works.[77] The philosophy of minimum treatment no doubt played a major part in this strategy as well.

The Board proceeded to install screens at Malabar and modified stage 1 to include a sludge treatment that could also be used to deal with screenings.[78] (Sludge treatment will be dealt with in more detail later in this chapter) However in November 1964 work was stopped on the Malabar treatment works whilst the entire program was reevaluated by a firm of American consultants, Brown & Caldwell. Brown & Caldwell say this was done because of doubts as to whether nuisance would be eliminated on the beaches and bacterial contamination controlled in bathing waters under the old plan.[79]

Brown & Caldwell, did not depart from the paradigm nor from the original plan very much. They too recommended primary sedimentation treatment with the following three stages[80];

1. Construct six of the ultimate twelve sedimentation tanks and two sludge digesters.

2. Construct a deepwater submarine outfall

3. Install additional sludge digesters and some grease removal equipment.

Other methods of treatment were not considered in the report by Brown and Caldwell and the existence of the paradigm meant that no comparisons or justifications were necessary, only predictions of performance for their proposed plant. Primary treatment, they claimed, removed 50-70% of the suspended matter, 50-70% of the grease and 25-40% of the biochemical oxygen demand. Also chlorination facilities could be provided in the long term to disinfect the effluent in case bacterial contamination levels were too high.[81]

The submarine outfalls, which were planned for a later stage would have deepwater diffusers which would meet two objectives. Firstly they would increase dispersion of effluent so that objectionable amounts of grease and debris would

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77 Conference of Professional Officers Representing the Authorities Controlling Water Supply and Sewerage Undertakings Serving the Cities and Towns of Australia, Report of the Proceedings of the Ninth Conference, 1959, paper 4; Brown & Caldwell, Design Report, p2.

78 Brown & Caldwell, Design Report, p3.

79 ibid., p1.

80 ibid., p29.

81 ibid., p10.

not accumulate. Secondly they would increase the dilution which might be necessary to keep bacterial concentrations down.[82]

Brown and Caldwell later did a similar study for the outfall at North Head. In it they reported that although screening alone would remove the nuisance caused by large solid material in the sewage, "significant improvement" could only be obtained with primary sedimentation to remove the floating and suspended solids in the sewage. Primary treatment would remove any visible evidence of sewage contamination, they claimed, but could not reduce bacteriological contamination appreciably. This would have to be done by disinfection of the sewage or by discharging the sewage through a properly designed submarine outfall.[83]

Brown and Caldwell therefore proposed the following stages for treatment of sewage at North Head;

1. Provision of Screens

2. Provision of five sedimentation tanks, screens, grit removal and sludge treatment tanks.

3. Construction of a deep water submarine outfall.

4. Additional primary sedimentation tanks.

5. Doubling the capacity of the works.

Facilities would also be constructed for intermittent chlorination (disinfection) when required.[84]

SUBMARINE OCEAN OUTFALLS - INNOVATION OR AD HOC ADJUSTMENT

Submarine ocean outfalls were not a radical departure from the paradigm but rather an augmentation of the paradigm. The concept dated back to the nineteenth century and it was not until the mid-twentieth century that submarine outfalls were referred to as a treatment method rather than just a means of disposal.

As far back as 1876 the Sydney and Suburban Sewage and Health Board recommended that some of the harbour outfalls be extended into deeper water. They argued,

> When the sewage is discharged into deeper water, and at a lower level, it will be at once mixed with a larger quantity of salt water, and be thus to a greater extent diluted and disseminated, being more exposed to the action of the tide, instead of being discharged upon the

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82 ibid., p21.

83 Brown & Caldwell, Northern Suburbs Sewerage Survey 1966-1967, M.W.S.&D.B., 1967, p86.

84 ibid., p184.

foreshore, where it festers in the sun and air, and becomes offensive; or spread over the surface of the water with almost equally bad effect.[85]

Submarine ocean outfalls were recommended in nineteenth-century texts for situations where "the influence of prevailing winds and currents" were not directly on-shore and likely to carry the sewage back to shore.[86] Other writers were more dubious about the advantages of extending the outfalls out to sea.

In some cases, by means of long outfall sewers, the sewage is carried away from the place producing it to the sea, but they are frequently simply transferring the refuse to others, the tide carrying it so as to cause mischief and nuisance elsewhere.[87]

An early submarine outfall was built at Santa Barbara in California in 1886. It was 1,500 feet long and 12 inches in diameter and laid on the floor of the ocean. It was reported to be working well by the engineer who suggested it.[88]

The Sydney Water Board had considered constructing a submarine outfall at Coogee in 1923 when the existing outfall there had been subject to constant complaints. They informed the local Randwick Council that soundings were being taken to find out whether it would be feasible to construct a submarine pipe to take the sewage further out to sea.[89] The proposal was later dropped in favour of diverting the sewage from Coogee to the Long Bay outfall and the Sun reported rumours that experiments made with corks had proved that "even at this distance [half a mile] the northeasters carried the corks back to Coogee Bay."[90]

One of the first researchers into submarine outfalls was an American, A.M.Rawn, who investigated a number of outfalls on the Californian coast. Rawn was particularly excited at the prospect of utilising the ocean as a free means of treatment.

To be able to relegate the entire job of secondary treatment to a few holes in the end of a submarine pipe and the final disposal of the effluent to the mass of water into which the fluid is jetted, and to accomplish this without material cost of maintenance and none for operation, presents a picture of such great allure as to capture the imagination of the dullest and justify extensive exploration into the ways and means of satisfactory accomplishment.[91]

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85 Sydney City and Suburban Sewage and Health Board, Sixth Progress Report, 1875, p5.

86 George Waring, Sewerage and Land Drainage, D.Van Nostrand, 1889, p76.

87 Henry Robinson, Sewerage and Sewage Disposal, E & F Spon, London, 1896, p45.

88 Waring, Sewerage and Land Drainage, p76.

89 Evening News, 18th April 1923.

90 Sun, 4th October 1926.

91 A.M.Rawn, `Fixed and Changing Valves in Ocean Disposal of Sewage and Wastes', in E.A.Pearson, ed, Proceedings of the First International Conference on Waste Disposal in the Marine Environment, Pergamon Press, 1959, pp6-7. (note that the title of the paper was obviously about Fixed and Changing Values rather than valves but that 'values' are such a foreign concept to engineering papers, 'valves' must have seemed more appropriate to whoever did the headlines for the papers.)

Rawn conducted many experiments, starting from the 1920s, aimed at finding out how to effect the most dispersion and dilution using diffusers at the end of submarine ocean outfalls. He considered such factors as depth, direction, quantity and velocity of discharge for the outfall. Using the results of his investigations an outfall was built in 1937 at Whites Point in Southern California. The outfall pipe was 60 inches diameter, extended a mile out to sea and its outlets were 100 feet under the sea surface. The effluent was discharged through three nozzles in a horizontal direction.[92]

A second parallel outfall was built in 1947 to cater for the extra flow caused by population growth and it was extended in 1953 from 5000 feet to 6100 feet out to sea so that it discharged at a depth of 155-165 feet. Submarine outfalls were also built at Hyperion, Los Angeles in 1959, San Diego in 1963 and Seattle in 1967. Each new outfall took advantage of the advancing investigations of researchers such as Rawn, Palmer and Brooks and their multi-port diffusers were refined and improved with the main aim of keeping the sewage field below the surface of the sea and preventing pollution of the shoreline and beaches.[93]

Rawn himself notes that the principle concern during all these years was to prevent the nearby shores being contaminated and that apart from trying to prevent the contamination of shell fish, the effects of sewage discharge on the marine environment were ignored.[94] The rational behind submarine outfalls was that the dilution would be enhanced if discharge was at greater depths, the greater distance out to sea would mean that the time for sewage to reach shore would be greater and hence time for bacterial die off would be increased, and finally attempts were made to make use of the density stratification of the sea to keep the sewage field below the surface.[95]

The idea that the sewage might be kept below the surface of the sea if density differential between top and bottom layers of sea water (the thermoclyne) was sufficient did not become accepted until 1956 after the construction of an outfall at Los Angeles when it was found that the sewage field did indeed remain submerged most of the time.[96]

When Brown and Caldwell proposed submarine outfalls as future stages of treatment at Malabar, Bondi and North Head, several groups who were concerned about beach pollution seized upon the concept as the answer to the problem of beach pollution. For example the Bondi Advancement Society was worried that "multi-million dollar plans for a glittering new Bondi could be ruined by an 80-year-old sewage problem". They pointed out the "incredible backwardness in a modern city" where the treatment works at Bondi had been commenced thirty years before and the treated effluent made its way back to the beach. The Society called for a submarine outfall or a plant to turn the sewage into fertilisers.[97]

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92 ibid., p10.

93 Paul Ryan, Submarine Ocean Outfalls, typed report for SPCC, undated.

94 Rawn, `Fixed and Changing Valves in Ocean Disposal of Sewage and Wastes', p9.

95 Ryan, Submarine Ocean Outfalls, p13.

96 Brown & Caldwell, Northern Suburbs Sewerage Survey, p146.

97 Sun-Herald, 1st September 1968.

A Water Board spokesman was reported in the media as saying that the primary treatment works would remove pollution from the beaches and all that would remain of the pollution would be a harmless stain. The only way to remove this brown stain, the Board spokesman said, in anticipation of the future plans, would be to install outfalls to carry the discharge several miles out to sea.[98]

The problem of the "huge brown stains" was taken up by the Anti-Beach Pollution Campaign Association which called for the immediate construction of the submarine outfalls which would get rid of the stains.[99] The Anti-Beach Pollution Association, according to its secretary, Bob Wurth, was concerned about the loss of business to shopkeepers and related businesses caused by pollution.[100]

In March 1971 the Water Board instructed the consultant engineering firm, Caldwell Connell Engineers P/L, to do a feasibility study into the construction of submarine outfalls for the North Head, Malabar and Bondi. Caldwell Connell Engineers were an amalgamation of engineers from the US firm of Brown and Caldwell, who had already recommended the submarine outfalls, and the Australian firm of John Connell, Mott Hay & Anderson.

Caldwell Connell presented their 288 page report in 1976 following investigations costing around one million dollars. They dismissed the alternatives to submarine outfalls in one paragraph at the beginning of their report.

> Because Sydney's major sewerage systems are already established, it would not be economically or physically feasible to consider significant changes to the basic system layouts.[101]

Given the system layout the choice, they claimed, was between providing a high degree of treatment with minimum ocean outfall facilities or a low degree of treatment with submarine outfalls. Since the "site constraints and the acquisition of the necessary land would prove very difficult" they only considered the latter alternative in their study.[102] This gives an indication of how past decisions, prior capital investment and an existing physical infrastructure all act to reinforce the paradigm.

This brushing off of alternatives may also be understood in terms of the objectives of the feasibility study, which were to study the offshore environment so as to be able to develop design parameters, prepare conceptual and preliminary designs and collect data about existing marine conditions to enable later monitoring of changes due to the submarine outfalls. The Board did not want them to consider the alternatives and Caldwell, at least had already recommended the submarine outfalls. Caldwell Connell's study concluded that not only was it feasible to construct submarine outfalls at Bondi, Malabar and North Head, but also such outfalls would "result in a marked improvement in

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98 Sydney Morning Herald, 5th March 1970.

99 Sun, 23rd March 1970.

100 Mirror, 7th September 1970.

101 Caldwell Connell, Sydney Submarine Outfall Studies, M.W.S.&D.B., 1976, p1.

102 ibid., p2.

aesthetic and bacteriological conditions at many beaches now affected by shoreline discharges."[103]

Similarly, and not surprisingly after a five year, million dollar feasibility study, the Environmental Impact Statements (EIS's) for the submarine outfalls gave scant regard to alternatives. EIS's are required to cover alternatives but the discussion of alternatives was prefaced with the statement that the existing sewerage systems represented fixed investments of many hundreds of millions of dollars and serviced areas that were so highly populated that major sewer reconstruction would be very expensive because of the difficulty and the unavoidable disturbance which would be caused to normal activity.[104]

The alternatives considered in the EIS's were reduced discharge, which would involve some sort of recycling or utilisation of the sewage, shoreline discharge, nearshore discharge or deepwater discharge and each alternative was considered with regard to a range of levels of treatment from preliminary treatment through to tertiary treatment. The EIS's concluded that reuse of the effluent within the Sydney area was not feasible because of low demand and high costs. The idea of pumping the effluent over the Dividing Range to western NSW was also dismissed as being too expensive considering the demand for water there in the foreseeable future.[105]

Shoreline discharge would have required secondary treatment to meet the SPCC requirements and the long term expense in terms of energy and chemical resources were claimed to make this option impractical. One of the main objections was the difficulty of siting secondary treatment plants at existing sites. Figures 5.2 and 5.3 show a possible layout of conventional secondary treatment facilities at North Head and Bondi. At North Head the military reserve would have to be used and at Bondi the golf course. At Malabar (figure 5.4) the Rifle Range would have to be used.

Nearshore discharge was considered in conjunction with some sort of chemical primary treatment but this was also dismissed on the grounds of costs and also because the effluent field would still be visible.[106] Table 5.3 shows the alternatives considered and comparative costs for the Malabar outfall as given in the EIS. The submarine ocean outfalls are shown to be cheapest in terms of both capital costs and annual operating costs.

Nonetheless there were calls for secondary and even tertiary treatment at the outfalls. In 1975 the State Labor MP for Maroubra, Mr Haigh, argued that secondary treatment was necessary at all the ocean outfalls.[107] Whilst these demands were for more treatment within the parameters of the sewerage treatment paradigm, there were some non-engineers who suggested unconventional treatment methods.

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103 ibid., pxv.

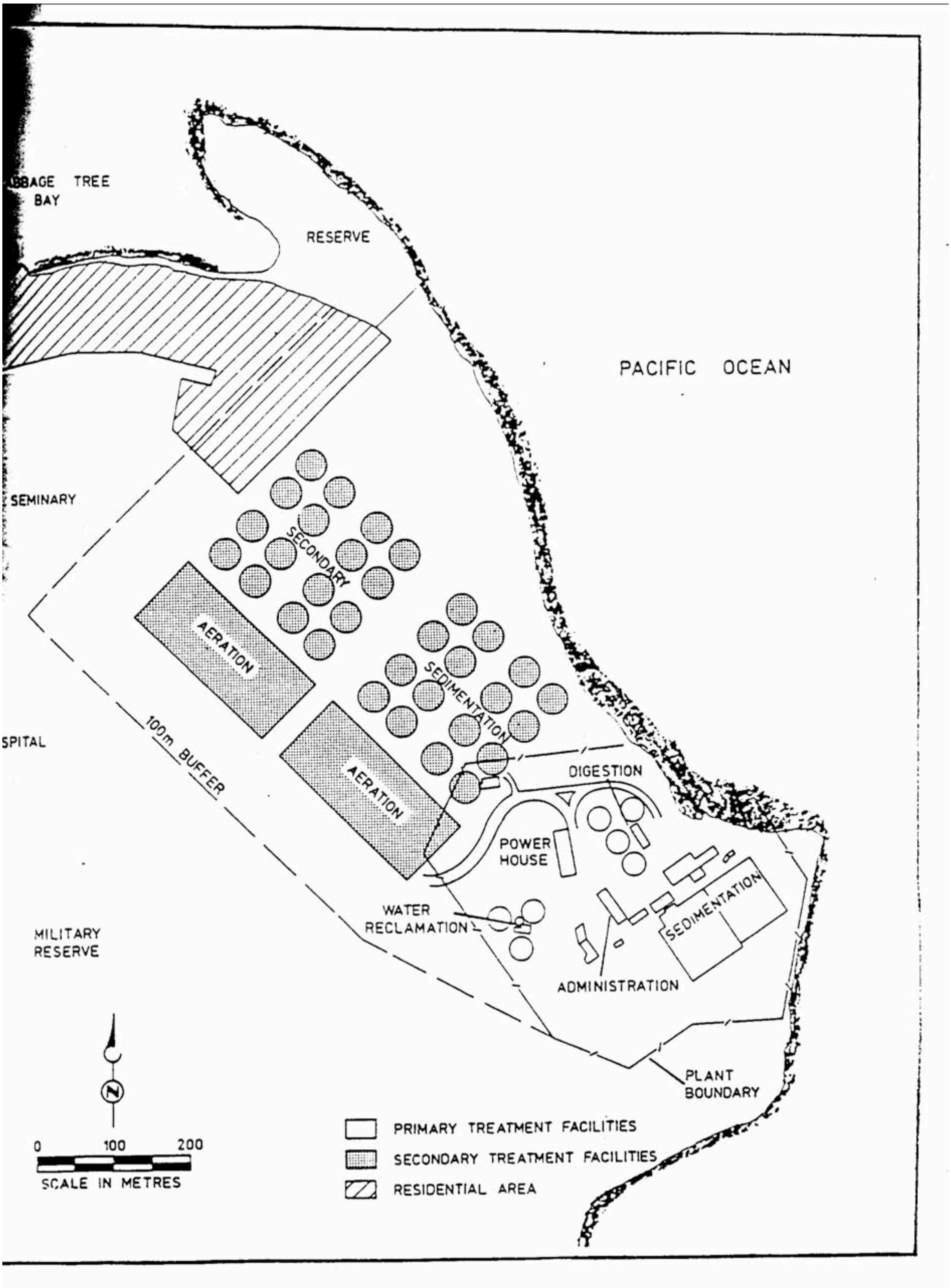
104 For example, Caldwell Connell, Environmental Impact Statements, North Head Water Pollution Control Plant, M.W.S.&D.B, 1979, p34.

105 For example Caldwell Connell, Environmental Impact Statements, Malabar Water Pollution Control Plant, M.W.S.&D.B., 1979, p46.

106 ibid., pp49-52.

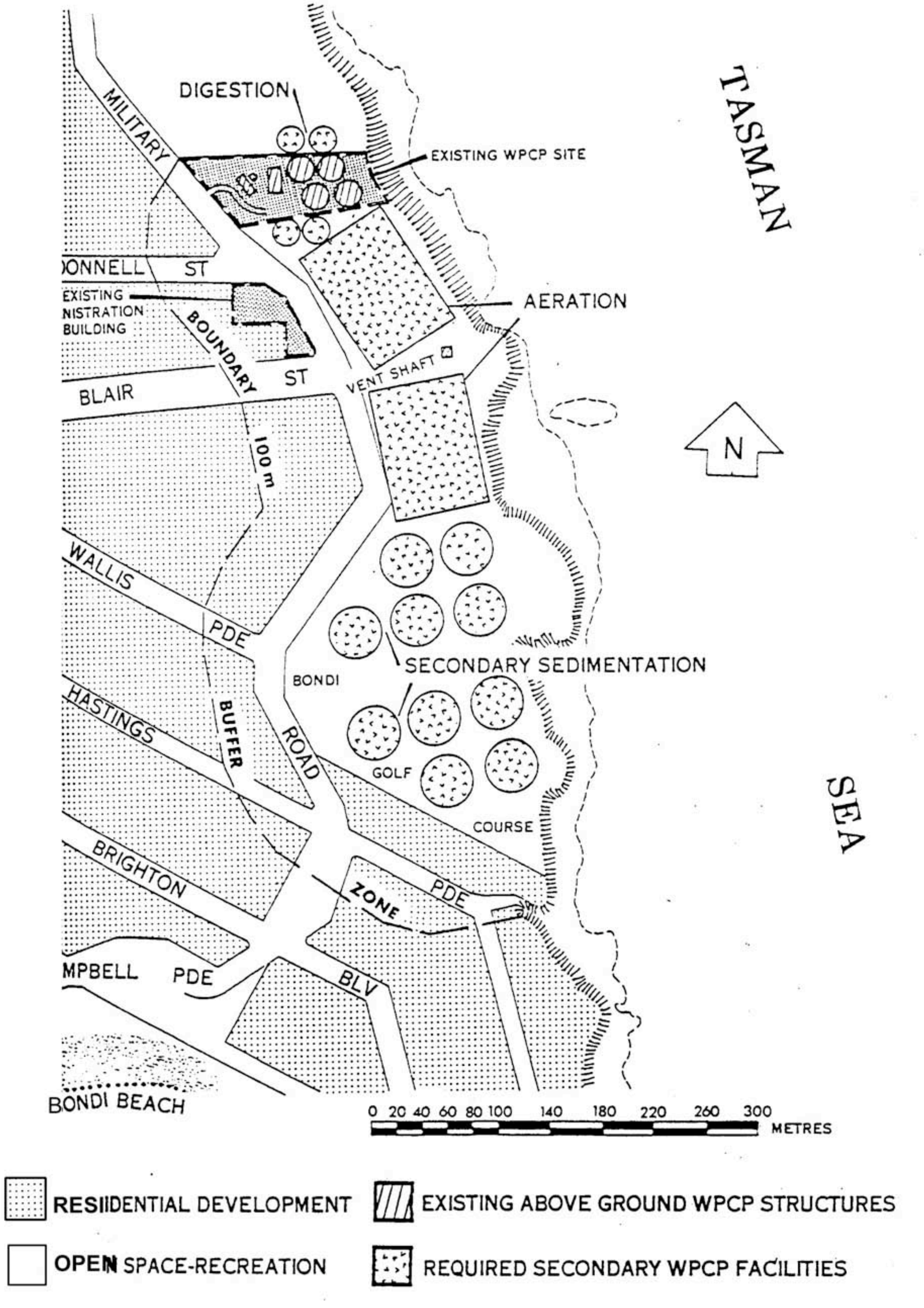
107 Mirror, 25th November 1975.

Figure 5.2 Layout of Possible Secondary Treatment Plant at North Head



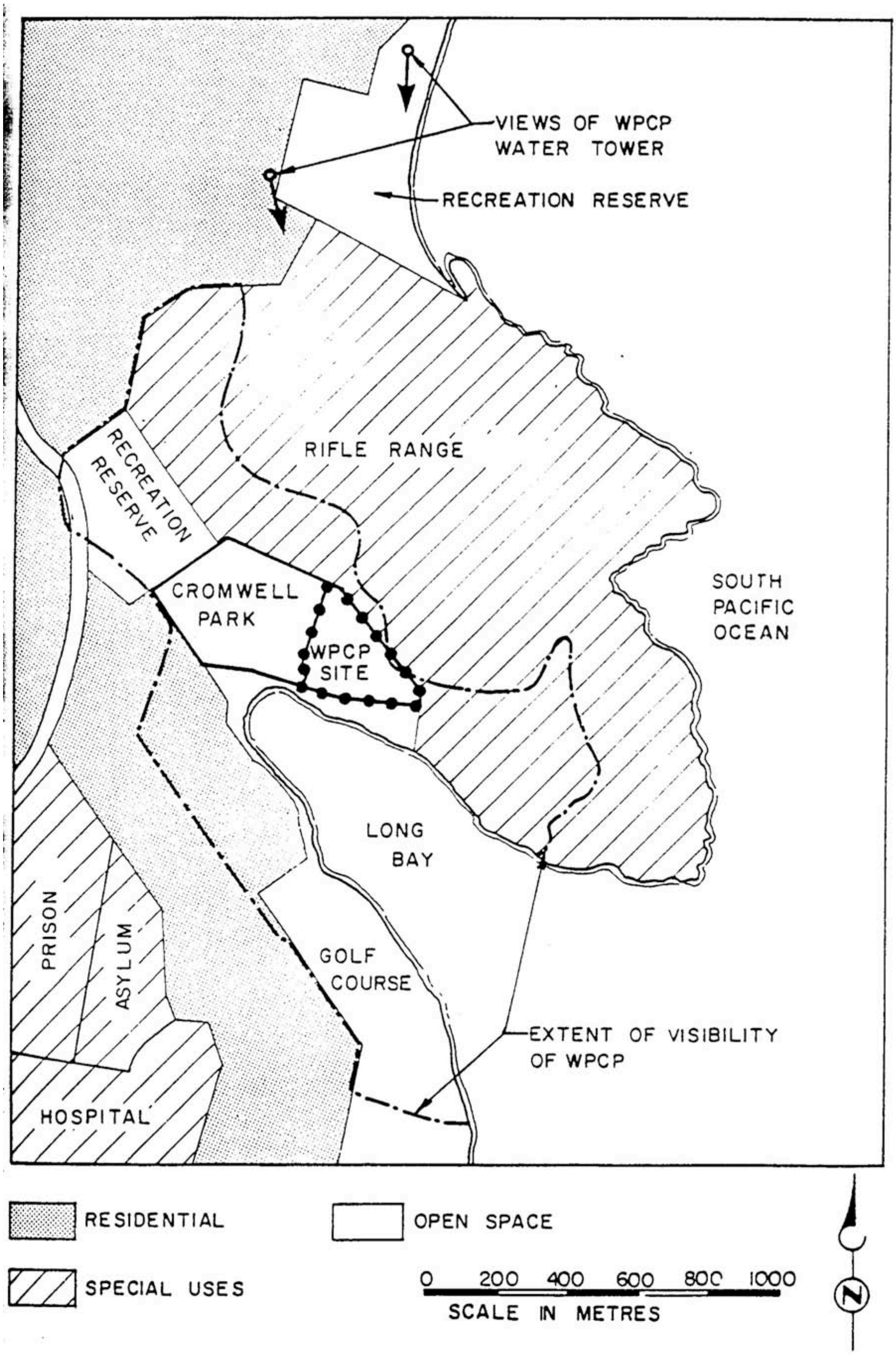
Source: Caldwell Connell, Environmental Impact Statements, North Head Water Pollution Control Plant, M.W.S.&D.B, 1979, p40.

Figure 5.3 Layout of Possible Secondary Treatment Plant at Bondi



Source: MWS&DB, Environmental Impact Statements, Bondi Water Pollution Control Plant, M.W.S.&D.B, 1979, p360.

Figure 5.4 Land Available at Malabar for Secondary Treatment Plant



Source: Caldwell Connell, Environmental Impact Statements, Malabar Water Pollution Control Plant, M.W.S.&D.B, 1979, p21.

Table 5.3 Comparison of Sewage Treatment and Disposal Options

Effluent option	Summary of major characteristics of options	Indicative 1978 costs ($ million) Capital cost	Annual operating cost	Total capitalised cost
REDUCED DISCHARGE				
Reuse within catchment	Low level of demand for effluent; possible lack of public acceptance; supplementary treatment required; conveyance of effluent through heavily populated areas.	300	8.8	410
Reuse outside catchment	Formidable physical and economic obstacles; supplementary treatment required prior to reuse. Power requirements for pumping equivalent to demand from a population of 300 000.	500	18	720
SHORELINE DISCHARGE				
Secondary treatment of primary effluent	Costs and space requirements create serious constraints; separate discharge of digested sludge will be required; may meet receiving water quality criteria but the effluent discharge would probably be noticeable.	152	5.0	215
Secondary treatment of screened sewage	Secondary treatment would have to accept screened and degritted sewage; extensive and costly modifications to main piping and open channel flow systems would be necessary; bypassing required during modifications, may meet receiving water quality criteria but the effluent discharge would probably be noticeable.	82	5.0	145
NEARSHORE DISCHARGE				
Chemical treatment with lime	Major impacts on solids handling, processing and disposal systems; lime recovery would probably be practised, and would require extensive investment in centrifuging and incineration facilities; chlorination for disinfection required.	45	5.2	110
Chemical treatment with polyelectrolyte	Discharge to approximate depth of 40 m would appoach about 35:1 average dilution; chlorination for disinfection required; needs further experimental work to determine feasibility.	45	2.4	75
DEEPWATER SUBMARINE DISCHARGE				
Primary treatment	Viable option. Will meet water quality objectives and SPCC requirements. Cost assumes construction of 2 additional sedimentation tanks after amplification of SWSOOS.	38	0.5	45

NOTES:
Total capitalised cost determined over 50 year period at 8% per annum.
Costs do not include capital or operting cost attributable to the existing Malabar WPCP or to sludge treatment facilities.
Costs for each option include provision of facilities to cater for ultimate population.
Estimates are based on December 1978 cost levels.

Source: Caldwell Connell, Environmental Impact Statements, Malabar Water Pollution Control Plant, M.W.S.&D.B, 1979, p54.

Tom Mullins, a marine chemist at the NSW Institute of Technology and an opponent of the submarine outfalls, criticised primary treatment as an "old fashioned" process which removed only 30% of pollution. He suggested two other methods of treatment in use in the United States - wet oxidisation process, which mixed heated sewage with air or a more advanced process combining primary treatment with reverse osmosis which could treat trade wastes as well as sewage.[108] The Board responded that wet oxidation was a process for treating sludge which had been removed by secondary treatment and that reverse osmosis was an experimental process which was extremely costly.[109]

The Sun quoted a Californian Professor who they claimed was a world authority on sewage treatment who stated that properly designed aerobic ponds could be half the cost of conventional sewage treatment methods. The article said that in the US it was mandatory to consider land disposal for sewage waste. It concluded

> However the Government has allowed conventional thinking engineers in government departments to commission consultant engineers with conventional views on the issue to give an "independent" view.
> The result was sadly predictable.[110]

Commonwealth Industrial Gases (CIG) made a major submission in response to the environmental impact statements for the submarine outfalls[111] which argued that In-Sewer Treatment, a process marketed by CIG, which involved aerating the sewers to allow oxidation to occur there, could improve Sydney's beach and in-shore conditions immediately and would be more environmentally acceptable in the long run.[112] They pointed out that the alternative of secondary treatment had been dismissed in the EIS's on the basis of cost and yet this was based on the costs of "conservative and costly secondary treatment techniques" whereas a number of new processes existed which were cheaper than conventional secondary treatment methods. In-Sewer Treatment, in particular, had not been evaluated by either the Board or their consultants.[113]

This process, they claimed, could remove 70-90% of bacteria and micro-organisms and achieve the precipitation of "dissolved and colloidal pollutants" in the sewers before reaching the treatment plant by the oxygenation of the sewage at various points along the main sewers, thus allowing the aerobic decomposition of the sewage. There would be the added advantage that Hydrogen Sulphide, which resulted from the anaerobic decomposition of the sewage, would not be formed and this would reduce odour complaints, corrosion of the sewers and the health risk to Board employees.[114]

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108 Sydney Morning Herald, 22nd February 1970.

109 Sydney Morning Herald, 26th May 1970.

110 Sun, 31st January 1977.

111 Commonwealth Industrial Gases Ltd, Oxygen Technology for Sewage Treatment and Disposal: Fast, economic alternatives to the proposed Deepwater Submarine Outfalls for Sydney, March 1980.

112 ibid., p1.

113 ibid., pp7-8.

114 ibid., pp35-6.

A trial of In-sewer treatment had been conducted at Bath in the UK and it had been found that aerobic conditions in the main were maintained giving an improved settleability of suspended solids and a reduction of about 40% of the organic load. Oxygen had also been used elsewhere in Australia to 'sweeten' sewers and aid in activated sludge treatment. CIG argued that the Water Board should take the opportunity to "follow this pioneering work to its logical conclusion. The result would be a system unique in the world." [115]

The Water Board did not quite see it that way. They criticised the process for being unproven and not used anywhere else in the world. Moreover they questioned the technical feasibility of the CIG proposal and the economics.

> The ability to achieve an effective activated sludge system in a gravity sewer is extremely doubtful,... It is clear that the system proposed by CIG is so far from a workable system that a worthwhile estimate of capital cost cannot be prepared.[116]

The initial capital outlay, they argued would not be small, as suggested by CIG, as extensive feasibility investigations would have to be carried out. Moreover the existing sedimentation tanks at Malabar would be inadequate for removing the activated sludge solids. Therefore the CIG proposal would probably be more expensive than submarine outfalls and would still not meet the SPCC criteria for ocean outfalls.[117]

The SPCC agreed that In-sewer treatment would probably not achieve the aesthetic objectives set by the Water Board (sic). Moreover one of their officers said that even if 90% faecal coliform removal was achieved, a shoreline discharge would not ensure satisfactory bacteriological quality of beaches. But the SPCC were sufficiently impressed to consider the process as an interim strategy to improve beach pollution until the extended ocean outfalls were built. The more efficient removal of grease seemed particularly attractive. However, they concluded that if the Board's estimate of the cost, which was fifteen times the CIG estimate, was correct then this would preclude its use as an interim strategy.[118]

Several other submissions made in response to the environmental impact statements suggested alternatives to the paradigm, which revolved around the utilisation of the sewage and these were also rejected by the Board. (see chapter 8) The Board was unprepared to go outside the paradigm because it involved risk, because they had already invested capital and built infrastructure that committed them to the paradigm, because its own engineers and consultants recommended a conventional solution and because they were committed to submarine ocean outfalls once they had undertaken an expensive and time intensive feasibility study.

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115 ibid., p9.

116 Chief Engineer (Investigation)'s Minute, M.W.S.&D.B., 29th April 1980.

117 Chief Engineer (Investigation)'s Minute, M.W.S.&D.B., 29th April 1980.

118 Ralph Kaye, S.P.C.C. internal report on C.I.G. submission.

HIGH-RATE TREATMENT FOR LOW QUALITY EFFLUENT

Although primary treatment facilities had been constructed at Bondi and Malabar by the mid 1970s, the North Head works were only equipped with screens although it had been intended to install sedimentation tanks and sludge digesters as recommended by Brown and Caldwell in 1967.[119] Following the Caldwell Connell study and during the preparation of the Environmental Impact Statement for the North Head submarine outfall, the Board decided that full primary treatment might not be necessary given that the sewage going to North Head was mainly domestic. A report was prepared to reevaluate the treatment options for North Head.

The idea of building the submarine outfall before the primary treatment works had been considered at least twice before. A representative of Brown & Caldwell had told the Board in 1967 that the provision of primary treatment would not remove the sewage field nor the occasional deposition of fine solids and fats on the beaches and that if the submarine outfall was built before the sedimentation tanks then all evidence of pollution would be removed, there would be less pollution and it would be cheaper. The Board decided, on the basis of this advice, to ensure that construction of the primary treatment works proceeded in such a manner that this could happen if it was so decided.[120]

Later Caldwell had "apparently changed his mind" and said that primary treatment should precede the submarine outfall but the seeds of the idea had been planted. The Board again discussed this option at the beginning of 1969. It was recognised even then that primary treatment alone would not be sufficient to prevent pollution on the beaches despite Water Board public claims to the contrary.

Whilst `in committee' the president of the Board had pointed out to other Board members that by the time the primary treatment had been built and funds had became available for a submarine outfall it could be 10 to 15 years "before worthwhile relief would be afforded" and he was worried that those who were pressing for action would not be prepared to wait that long.[121] The president thought it might be a good idea to build the submarine outfall first because

> Those people who were unhappy about sewage matter being dumped off the headland and washed onto the beaches might not be disturbed about material finding its way to these from about two miles out to sea.[122]

The president said that he was concerned that mounting pressure from Manly residents could cause the State Government, which was about to face State Elections, to make a special allocation of funds for North Head and then if the

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119 Brown & Caldwell, Northern Suburbs Sewerage Survey, p184.

120 `Draft Report on Investigation of NSOOSystem and North Head Sewage Treatment Works by Messres Brown & Caldwell', report of meeting of NSOOS Committee with Mr Reinsch of Brown & Caldwell, 26/6/67, appended to M.W.S.&D.B., North Head and Ocean Outfall Re-evaluation of Treatment and Disposal Options, Sept 1977.

121 M.W.S.&D.B., minutes, 19th February 1969, p468.

122 M.W.S.&D.B., minutes, 19th February 1969, p468.

Board admitted that nothing could be done for several years "the general reaction to this could be well imagined".[123]

The Board brought Caldwell out from the United States to discuss the matter. At a special meeting of the Board Caldwell explained to members the principles of sewage treatment. He told them that the effluent from primary treatment, although not having any solids in it which would rise to the surface, contained organic matter, fine particles of fats, etc. Secondary treatment was a biological process that effected the breakdown of the organic matter through the agency of naturally occurring bacteria. This could be achieved in the sea and in the case of North Head, if primary treatment preceded discharge, the ocean provided "the world's best secondary treatment process".[124]

Caldwell had studied and discussed the matter and "the absolute definite conclusion reached was that the primary treatment plant should be constructed prior to the submarine outfall". If it was not then floating matter, such as grease balls, pieces of rubber goods, etc, would not be removed and these would rise to the surface and blow onto the beaches if the winds were unfavourable. Primary treated effluent released at the cliff face would be merely coloured water with some dissolved salts in it and enough grease to allow the slick to be seen, but no grease balls would go to shore and the bacteria could be controlled by disinfection.[125]

Without primary treatment even fine screens would fail to remove the grease balls which would coalesce in the water after screening. With primary treatment the liquid grease might still make its way to the beach and the sewage field would be seen and even smelt. But he thought that the discolouration of the sewage field would not be noticed by the public as much as the floatables and solid materials which might result without primary treatment.[126] Another problem with not providing primary treatment but only submarine outfalls was that if bacteria needed to be controlled then disinfection, usually done with chlorine, might be necessary. This was not effective if the solids had not been removed since the chlorine would not be able to penetrate them and get to bacteria inside.[127]

The Board discussions about which form of pollution would be most acceptable to the public gives a different perspective on the promises that were being made publicly about primary treatment in the late 1960s, early 1970s and about reduced onshore treatment with submarine ocean outfalls from the late 1970s until the present. The Board clearly knew, even before construction, that primary treatment would not prevent pollution and that anything less than full primary treatment with the submarine outfalls would also cause pollution.

Caldwell argued that the cost of providing the submarine outfalls and the time taken to do so were both equivalent to the cost and time for a primary treatment plant since the pumping station would still be required. Moreover he gave a "firm

123 M.W.S.&D.B., minutes, 5th March 1969, p504.
124 M.W.S.&D.B., Minutes, 26th March 1969, p559.
125 M.W.S.&D.B., Minutes, 26th March 1969, p560.
126 M.W.S.&D.B., Minutes, 26th March 1969, p560-61.
127 M.W.S.&D.B., Minutes, 26th March 1969, p559.

assurance" that primary treatment together with the submarine outfall would ensure that there would be no evidence of sewage on the surface of the sea "if the correct procedures were followed."[128]

The Board formally endorsed Caldwell's recommendation that a primary treatment plant should be constructed first, followed by a submarine outfall, after his visit in 1969.[129] Nonetheless this decision was reconsidered in 1977 in an internal report on treatment options for North Head.[130] Three options were considered in the report; full primary treatment with submarine outfalls and the digested sludge discharged with the effluent; reduced onshore treatment consisting of screening, grit and floating grease removal and submarine outfalls; and full primary treatment with discharge of effluent and digested sludge at the existing outfall.

In the report it was claimed that the Board was only committed to building primary treatment at the North Head outfall. The deepwater outfall was to have been considered in the light of the performance of primary treatment. Extensive excavation work was undertaken in preparation for the construction of primary treatment facilities but it was then realised, that primary treatment alone would not meet the water quality criteria set by the SPCC. The report argued that because primary treatment would not meet these criteria there was a need to go ahead with the construction of submarine outfalls immediately. This would have meant constructing submarine outfalls at the same time as primary treatment facilities and it was decided to reconsider the priority of the primary treatment facilities.[131]

The water quality criteria had been set by the SPCC at the request of the Water Board so that the submarine outfalls could be designed (see chapter 6). It is unlikely that a realisation that primary treatment would not meet these criteria was the real reason for abandoning construction of the primary treatment facilities. It is more likely that the desire to try a reduced form of onshore treatment in the hopes that it would be sufficient with the submarine outfalls prevailed here.

The 1977 report reevaluating the treatment options argued that both primary treatment with submarine outfalls, and reduced treatment with submarine outfalls would meet the criteria set by the SPCC for water quality and that both options would still produce a better quality effluent than that produced by the primary treatment at Malabar.[132] This was because, the Malabar sewage was worse to start with containing as it did a higher proportion of industrial wastes and because the primary treatment plant at Malabar was already overloaded and therefore not treating the sewage properly.

Moreover, the report claimed that the advantages of subjecting sewage to primary treatment over merely screening it and removing the grit and some of

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128 M.W.S.&D.B., Minutes, 26th March 1969, p563.

129 M.W.S.&D.B., Minutes, 9th April 1969, p586.

130 M.W.S.&D.B., North Head and Ocean Outfall Re-evaluation of Treatment and Disposal Options, Sept 1977.

131 ibid., pS-7.

132 ibid.

the grease, disappeared to a large extent when the digested sludge extracted by primary treatment was returned to the effluent before discharge. This was what happened at the existing primary treatment plants at Bondi and Malabar and what was planned for the future with the submarine outfalls. The report even went so far as to say that the effect of digesting the sludge, as at Malabar, was to stabilise the organic fraction and render the sludge more settleable, which would be a disadvantage in the sea because it would be more likely to settle out and accumulate on the ocean bottom where ocean currents were low.[133] This says a lot for the treatment that the Board had installed at great cost at Malabar and Bondi.

It is not surprising, then, that the report concluded that the extra cost of full primary treatment ($30 million in capital outlay and $5 million per year) could not be justified and that the reduced treatment option in conjunction with submarine outfalls was recommended.[134] Should additional facilities be required, the report went on, "it is likely that they may take a much simpler and more economical form than sedimentation and digestion tanks" such as enhanced capture of grease or "rotostraining" (fine screening).[135]

The Board had hesitated to take this step for several reasons. Firstly they were worried about appearances given that they had spent so much money and effort excavating for the primary treatment plant and had then changed their mind. They were also concerned that the diffusers might not work so well with less treated sewage but decided, on advice from overseas submarine outfall operators, that if they removed the floatable grease the diffuser ports would not be clogged and other precautions could be taken to prevent this.[136] They were also concerned that the SPCC approve the change in plans. The report stated

> Close liaison with senior officers of the SPCC has clearly established that the Commission favours the early provision of deepwater outfalls, at the expense of deferring or reducing onshore treatment facilities.[137]

The report referred to some of Caldwell's 1969 arguments for the necessity of primary treatment. With regard to the problems he predicted with floating material such as grease balls and rubber goods they argued that this advice had been based on the assumption that screenings would be macerated and returned to the flow and that since screenings were now to be incinerated his advice no longer stood.[138] They did not consider that the grease balls would be a problem. With regard to the problem of disinfecting solid particles of sewage, they argued that this too was outdated advice since

> the proposition that chlorination of primary effluent can effectively control bacterial pollution is not supportable. The fact is recognised in the Board's policy of not chlorinating primary effluent.[139]

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133 ibid., p2-7.
134 ibid., pS-6.
135 ibid., p5-2.
136 ibid., p5-2.
137 ibid., p5-4.
138 ibid., pp5-2,5-3.
139 ibid., p5-3.

Clearly they did not share Caldwell's concern that beaches might be polluted with high bacterial levels.

To alleviate the grease removal problem, a minimal form of primary treatment was developed in Australia whereby tanks were used, in which the sewage sat for fifteen minutes or so, giving time for some of the floating grease to rise to the surface and be skimmed off. This detention time was much shorter than for sedimentation tanks and so the treatment was named "high-rate" primary treatment. The name was ambiguous enough to confuse some members of the public into thinking that it might be a superior type of primary treatment. The cost advantage of high rate primary treatment was that only one third to one quarter of the tank capacity was required and, since the suspended solids wouldn't have time to settle out, there would very little sludge to worry about.[140] Figures 5.5 & 5.6 show schematically how a High Rate Primary Treatment Plant works and the primary treatment as installed at Bondi.

Since high-rate primary treatment was an idea developed in Australia and not tried elsewhere, experiments were carried out between 1977 and 1979 at Geelong under the direction of Caldwell Connell and at Malabar under the Board's direction. Although less suspended solids and total grease were removed and the biological oxygen demand was not lowered as much it was concluded that high-rate primary treatment was just as good as conventional primary treatment at removing the floating grease and this was what mattered to the Board as far as submarine outfalls were concerned since it was the floating grease which made the sewage fields visible and the beach sands sticky.[141]

TABLE 5.4 COMPARISON OF REMOVAL EFFICIENCIES

REMOVAL EFFICIENCIES %	CONVENTIONAL PRIMARY TREATMENT		HIGH RATE PRIMARY TREAT-MENT	BONDI PRIMARY TREATMENT PLANT		
	excluding digested sludge	including digested sludge		excluding digested sludge	including digested sludge	
					1979	predicted year 2025
BOD_5	27	20	13	12	9	12
Suspended Solids	63	20	18	36	11	18
Grease	55	45	30	40	25	30
Faecal Coliforms	17	17	NIL	NIL	NIL	NIL

INFORMATION FROM: Caldwell Connell, Environmental Impact Statement, North Head Water Pollution Control Plant, MWS&DB, 1979, p44; MWS&DB, Environmental Impact Statement, Bondi Water Pollution Control Plant, MWS&DB, 1979, p7.

Although high rate primary treatment at North Head required official approval before it was constructed, Malabar and Bondi have in recent years been operated as high rate primary treatment plants. For example, the Malabar primary treatment plant was designed to treat an average dry weather flow of 250 ML/day with a peak dry weather flow of 380 ML/day yet by 1980 the average dry weather flow was up to 400 ML/day and the peak dry weather flow up to 565 ML/day with no additional sedimentation tanks. A 1985 Water Board technical report stated that no additional sedimentation tanks were to be installed.

140 Caldwell Connell, Environmental Impact Statement North Head, p43.
141 ibid., pp43-5.

figure 5.5 FLOW DIAGRAM OF HIGH RATE PRIMARY TREATMENT

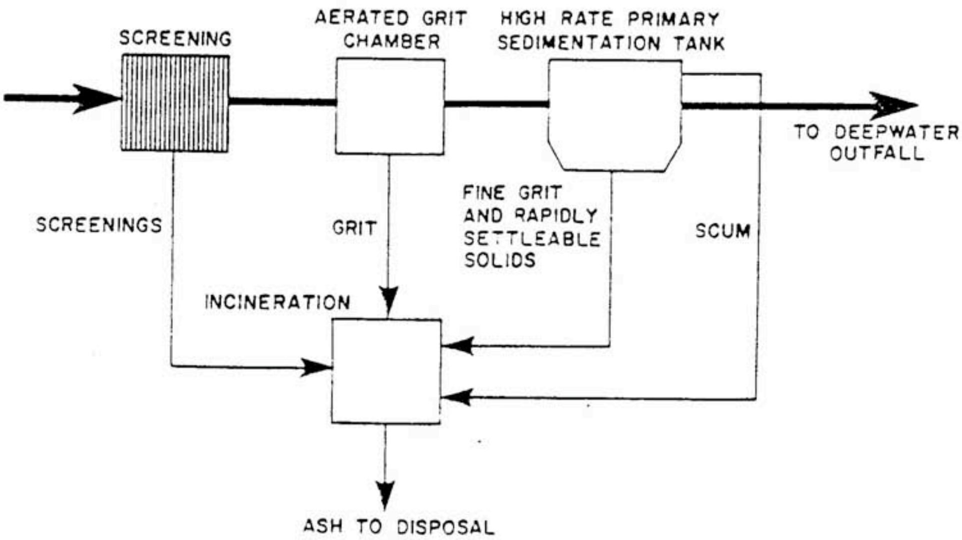
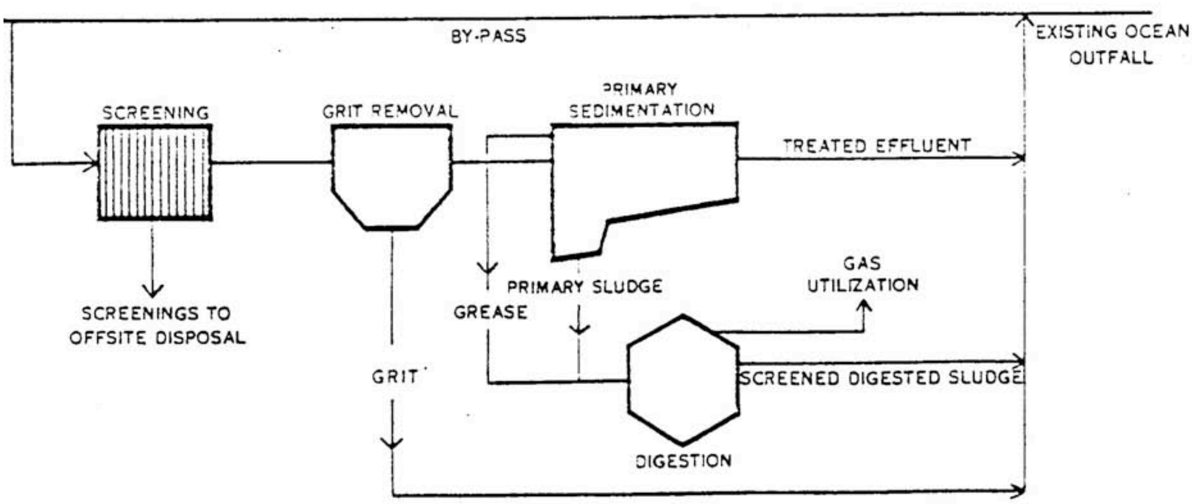


figure 5.6 FLOW DIAGRAM OF PRIMARY TREATMENT AT BONDI



Source: Caldwell Connell, Environmental Impact Statement, North Head Water Pollution Control Plant, MWS&DB, 1979, p43; MWS&DB, Environmental Impact Statement, Bondi Water Pollution Control Plant, MWS&DB, 1979, p8.

> The six (6) sedimentation tanks shall be operated at pseudo-high-rate loadings as flow to the WPCP [Water Pollution Control Plant] increases. The need for any additional tanks shall be reviewed following operational experience under the pseudo-high-rate loading mode.[142]

A comparison between the removal efficiencies expected with the High-Rate Primary Treatment plant and at the primary treatment plants also shows that the primary treatment plants are actually operating as high rate primary treatment plants and are expected to do so for many years to come. See table 5.4.

PARADIGM INADEQUACIES - GREASE, SLUDGE AND VIRUSES

High-rate primary treatment represented in essence the philosophy of staged treatment and, although disguised as an innovation, it was also a manifestation of the ever-present push towards minimising costs by minimising treatment rather than by technological innovation. In some ways high rate primary treatment was a late recognition by the Board that primary treatment was inadequate. Since primary treatment was inefficient at removing grease and bacteria, why bother with it? Primary treatment merely removed some of the solids in the sewage (and this was what is was designed to do) and therefore it ameliorated the visual and aesthetic impact on the beaches but it was thought that this same degree of amelioration could equally well be achieved by submarine ocean outfalls.

The paradigm was nevertheless retained. The grease problem was put off for later solution and provision made for the later addition of grease removal units. Air flotation was one technique suggested for this task and would involve blowing air into the sedimentation tanks to cause more grease to rise to the surface of the tank where it could be skimmed off. Air flotation constituted an adjustment to a process not primarily designed for grease removal but it allowed for the retention of the paradigm. Grease has in fact turned out to be a major problem on Sydney beaches and this will be discussed further in chapters 7 and 8. Moreover the grease and scum scraped off the sedimentation and high-rate treatment tanks has posed a problem for disposal because of the chlorinated hydrocarbons that it contains.[143]

The problem of bacterial and viral contamination was also put off to a later stage when it was hoped that either disinfection or extended ocean outfalls, further adjustments to the paradigm, might be able to solve it. The problem of bacterial contamination was not dealt with by the British Royal Commission. The standards recommended by the Royal Commission were aimed at the preventing the rivers from becoming foul and protection of downstream water supplies and so dealt with suspended solids and oxygen demand. It was considered that oxidation and dilution in the rivers would deal with the organic matter. The problem of disease-causing bacteria and viruses in the sewage will be further addressed in chapter 8.

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142 MSW&DB, "Malabar Water Pollution Control Plant, WPCP 2, Description of Existing Facilities and Upgrading Requirements, Technical Data", 14th February 1985, p14.

143 MWS&DB, "Malabar Water Pollution Control Plant No 2", internal report, March 1983.

The other major problem was with sludge disposal. By the end of the last century sludge disposal was already causing engineers headaches. Sludge is the part of the sewage which settles or precipitates out during treatment and it usually has a high water content. Little research had been done into methods of dealing with sludge because it had been hoped that the septic tank system or something like it would be able to eliminate the sludge altogether. Sludge pressing went out of fashion, partly because it was thought that it would be redundant and partly because of the expense and disappointed expectations for sale of the sludge cake as fertiliser.[144]

The idea of digesting the sludge separately from the effluent was put forward in 1899. Using the same principle as septic tanks, that is anaerobic bacteria to break down the sludge, various two-storey tanks were developed, such as the Imhoff tank in 1904 which digested the sludge in the lower chamber. The gas produced during this digestion process was mainly methane and the Parramatta treatment works was one of the first in the world to utilise this gas (from the septic tanks there) to generate power to pump the sewage.[145]

Sludge disposal problems increased in the ensuing years because of improvements in sedimentation techniques and also because there were pressures to release valuable land for uses other than sewage and sludge disposal. Moreover there was an increasing realisation of the consequences of having heavy metals and toxic chemicals in the sewage sludge.[146] Where possible the sludge was taken out to sea for dumping or disposed of on land, but engineers were forced to develop sludge digestion and dewatering techniques. At first sludge was dewatered on drying beds but the scarcity of land led to mechanical dewatering and filter presses made a come back.[147]

The alternatives for dealing with sludge discussed by Farnsworth in his 1938 report covered disposal of sludge by

1) barging raw sludge to sea.

2) chemical conditioning, vacuum filtration and incineration.

3) sludge digestion and spreading of digested sludge on land.

4) sludge digestion and discharge via the ocean outfall.

5) sludge digestion, chemical conditioning, vacuum filtration and incineration.[148]

The fourth option, disposal by sludge digestion (for 80 days) and discharge to sea via the outfall was the chosen option because it was the cheapest, it was "in

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144 John Sidwick, 'A Brief History of Sewage Treatment-3', Effluent and Water Treatment Journal, June 1976, op.cit., p301.

145 F.E.Bruce, 'Sewerage and Sewage Disposal', in Trevor Williams (ed), A History of Technology, vol VII, Part II, Clarendon Press, Oxford, 1978, p1394; Fuhrman, `History of water pollution control', p312.

146 Sidwick, 'A Brief History of Sewage Treatment-5', pp518-9.

147 ibid., pp518-9.

148 Farnsworth, Elimination of Nuisance From Ocean Outfall Discharges, p10.

accordance with most modern practice", no odour nuisance would be created, and the principles of digestion were "well understood" and "sound and safe."[149] This was also the method recommended later by Brown and Caldwell and eventually adopted at both Bondi and Malabar. The choices were again canvassed in the EIS's for the submarine ocean outfalls. The preferred option was disposal through the deepwater outfalls and this was also the cheapest in terms of operating and capital costs. For North Head the sludge problem was solved by not treating the sewage enough to obtain a significant amount of sludge. Sludge problems will be discussed further in chapters 7 & 8.

CONCLUSIONS - THE BEGINNINGS OF TUNNEL VISION

The nature of the development of sewage treatment processes has quite clearly changed since the first world war in most industrialised countries. Until that time, new ideas were rapidly forthcoming, concepts vied with each other for prominence and ascendency and various methods had ardent advocates who were willing to stake their reputations on their preferred methods. The main development impetus in the nineteenth century came from Britain where the river system, long abused as a waste disposal system, had become so obviously violated that there were public pressures to clean up the waterways. In the United States where population was sparser, rivers larger and the history of river pollution shorter there was much more willingness to rely on dilution as a form of treatment.

The debates between engineers required a different form of closure from that which operated in the public arena. The debate between water carriage and dry conservancy methods of collecting sewage were closed in Sydney because the alliance of engineers and bureaucrats was stronger and more powerful than those supporting dry conservancy methods. The debate between engineers was more of a debate amongst equals and closure required consensus. The attainment of that consensus was aided by the British Royal Commission into Sewage Disposal. There had been previous commissions and inquiries in various countries but none had the same prestige and influence. This Commission was a sufficient embodiment of expert authority to carry the day.

Although the Commission did not pronounce any method superior, it not only put an end to the factionalised fights and pushes for various methods but also to the search for new and novel approaches to the problem of dealing with sewage. It enabled engineers to reach a consensus on the range of methods which they could concentrate on, refine and use. It paved the way for the formation of a paradigm. This paradigm was written into engineering texts and education curricula. Whereas proposals for early sewage treatment works had to at least give a token mention and rebuttal of other alternative methods, modern sewage treatment proposals did not. A primary treatment plant had sedimentation tanks and that was that.

Moreover the nineteenth century search, in Britain, for the perfect method which gave a high standard of purity had yielded a number of treatment processes which were "good enough" and pronounced so by the British Royal Commission. It was considered uneconomical and extravagant to construct a treatment works

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149 ibid., pp6-7.

that did more than the minimum required for the particular situation at that time, as judged by the authorities and the engineers.

This attitude gave rise to the idea of staged development whereby the degree of treatment given was upgraded as more was demanded by the public and more money became available, given that demand. In its own way the philosophy of staged treatment was a recognition by engineers that the "efficacy" of treatment methods was socially constructed and therefore variable and they were making provision for changing public perceptions of what was "good enough". But it was also a recognition that such perceptions were to some extent manipulable and that implementing sewage treatment incrementally would enable them to delay the agony of public spending and higher rates by convincing the public that what they planned to build would provide a perfect solution and insisting once it was built that it was in fact "working" as promised.

The idea of primary and secondary treatment had originally signified the order of two processes which were both considered necessary. The British Royal Commission had not evaluated the processes separately or in isolation. However, the idea of staged development and "good enough" treatment led to primary and secondary treatment being regarded as two different levels of treatment with primary treatment being sufficient on its own in many cases.

The development of high rate Primary Treatment arose from the continual quest by engineers to minimise treatment costs by reducing conventional treatment methods. The Board clearly knew, even before construction, that primary treatment would not prevent pollution and that high rate primary treatment with the submarine outfalls would also cause pollution. This is in stark contrast to the impression the public were given. The technology in this case was not chosen because it could remove sewage pollution. Rather the choice was between different technologies producing different types of pollution and the decision was based on the question of which type of pollution was least likely to cause protest and alarm and most likely to meet the rudimentary standards set by the government.

The pressure to reduce costs cannot be directly attributed to the public in this case. The continual push by the community, particularly beach users, for more treatment had been counteracted by the push by engineers for less treatment and it is as if engineers get a certain degree of pride in achieving their minimum designs. In other areas of public sector engineering there is a tendency to overdesign and oversupply commodities such as electricity because this ensures more work for the relevant bureaucratic organisations and their employees. This has not been the case with the Sydney Water Board. It is tempting to suppose that they have always been so far behind in supplying the proper facilities that the prospect of running out of work does not bother them.

The lack of impetus for new research provided by the "good enough" philosophy and the existence of an infrastructure of sewage works built on old ideas has meant that research funds are channelled into improving existing methods, and solving the problems associated with those methods. The processes are understood much more in scientific terms and the design of equipment is far more precise, standardised and reduced to formulae. There is less room for public discussion in such a climate. Whilst early sewage treatment and disposal decisions were reviewed by a parliamentary committee at a public hearing, the decisions with regard to the treatment at the main Sydney ocean outfalls in the

1950's and 60's had no public input at all and the reports involved remained internal to the Water Board.

Yet the paradigm had some inadequacies right from the beginning in terms of grease removal, removal of bacteria and viruses, and sludge disposal. As time went by more inadequacies became apparent and the conditions under which the paradigm was formed changed. These problems and the resolute adherence by engineers to the paradigm despite them will be covered in chapter 8.

The persistence of the paradigm can be partially understood when it is seen as being embedded within a technological system. Thomas Hughes defines a technological system as being a socio-technical system which includes not only physical artifacts, but also organisations, scientific components (including publications, research programs and university courses), legislative artifacts and natural resources. Technological systems attain a certain momentum as they grow.[150] In the case of sewerage technology, the system not only has momentum because of the vested interests of the engineers and authorities whose skills and practices are tied up with the paradigm but the momentum is added to by the existence of the physical structure of sewage plants. By the end of the first world war many of the larger towns and cities in Britain had established their treatment works and as time went on the same was true in many other industrialised countries. Change was therefore in terms of augmenting and improving those plants which often did a partial job. Such plants incorporated a certain amount of capital and people's reputations and it was not easy to tear them down and replace them with new plants using new processes which were not as "tried and true".

Other components of this technological system will be considered in the remaining chapters. In particular the role of legislation, regulation and government control will be considered in the next chapter and the influence of industrial interests will be considered in the following chapter.

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150 Thomas Hughes, Networks of Power: Electrification in Western Society, 1880-1930, John Hopkins University Press, 1983, chapter 6.