PART III

AN EXPLORATORY APPLIED ENVIRONMENTAL HISTORY STUDY

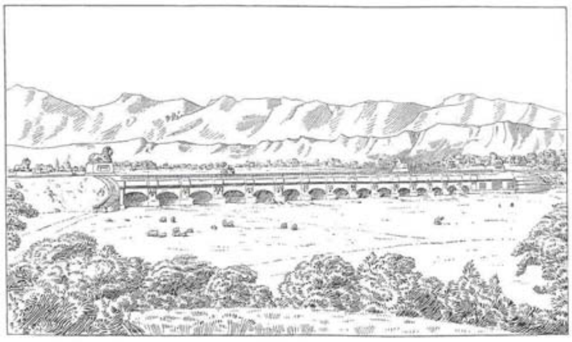
Preface

Part III (Chapters 8-10) comprises an historical study of irrigation development focused on the NRM problem of salinity. The AEH study is organised around a sequence of three specific questions. In addition, Chapters 8, 9 and 10 contain a breadth of material required for the discussion in Chapter 11. The discussion is centred on the inception in 1906 of the Murrumbidgee Irrigation Scheme, the first intensive irrigation project in Australia.

The first organising question, explored in Chapter 8, is: *Could* planners and policy makers in New South Wales in 1906 have learnt from the past about irrigation salinity? A search for answers to this question starts in India, because British India is known to have been an important source of information, on a great many issues, for the Australian colonies. By the late nineteenth century British engineers had some five decades of experience bringing irrigation to the vast *doabs* (land between the rivers) of the Indus and Ganges River systems. The British also had first-hand experience of salinity as a direct result of intensive irrigation. Their knowledge of designing, constructing and operating these irrigation systems provided a baseline from which irrigation planners in south-eastern Australia could have proceeded.

The second question, explored in Chapter 9, is: *Should* planners and policy makers in the Murrumbidgee Irrigation Scheme have learnt from the past, and been concerned, about salinity? Answers to this question can be found locally. In the last two decades of the nineteenth century, colonial governments in south-eastern Australia began to address issues of water conservation and irrigation. Several engineers who had worked in India played significant roles in Australian irrigation development. The experience from the western USA was also available. In Victoria the Mildura Irrigation Settlement suffered serious setbacks arising from the salt-affected mallee soils prevalent in the area. In New South Wales scientists began to understand local soils and groundwater as they investigated the potential uses and limitations of water from the Great Artesian Basin. In was evident at this time that the south-eastern landscapes were salt-affected to some degree. The planners should have been worried.

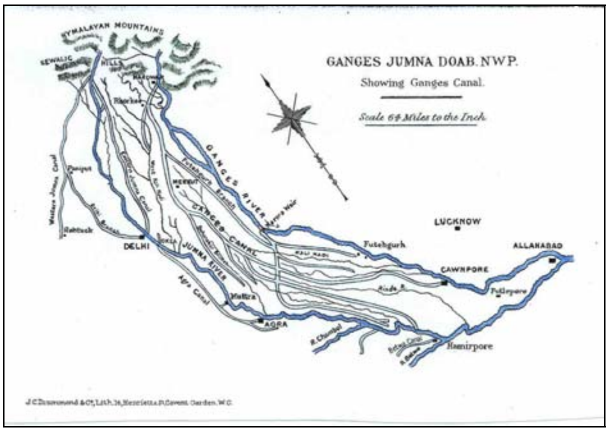
The third question is: *Did* planners and policy makers in the Murrumbidgee Irrigation Scheme learn from the past? The many public inquiries that foreshadowed the Murrumbidgee Irrigation Scheme gave great weight to engineering matters, but paid little attention to the bio-physical setting of the project. The evidence that the planners and policy makers did not learn from the past is presented in Chapter 10.

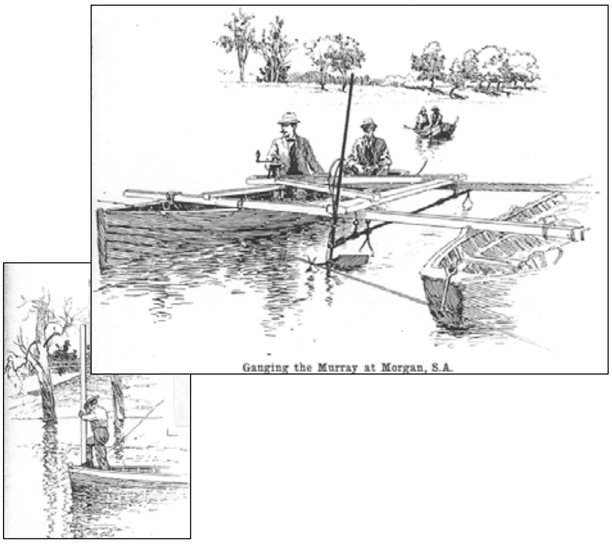


SOLANI AQUEDUCT.

The Solani Aqueduct is part of the Upper Ganges Canal system. It carries water over the Solani, a nearly dry river for the greater part of the year.
(MacGeorge 1894)

Ganges Canal system (MacGeorge 1894)





Ganging the Murray at Morgan, S.A.

Before intensive irrigation development could make progress in south-eastern Australia data to determine river flows were collected over several years.

(*Agricultural Gazette of NSW* 1903)

CHAPTER 8 BASELINE: PERSPECTIVES FROM INDIA

This chapter is organised around the first question: Could planners and policy makers in New South Wales in 1906 have learnt from the past about irrigation salinity? For a discussion of the source materials used in this chapter see Appendix B.

8.1 Introduction

From the first decade of British settlement at Sydney Cove in 1788, India was a vital supply depot for the colony. Not only essential goods and news from Britain, but practical information and professional experience flowed from India.[1] Through the nineteenth century army officers and civil servants came to Australia on furlough. Later, many retired here, and others found new careers in the Australian colonies after completing their tour of duty in India. The experience that India could provide the colonies of New South Wales and Victoria on matters of irrigation development was considerable. In this chapter I examine the nature of this experience, particularly with regard to understanding soils, groundwater and salinity in the semi-arid regions of northern India.

India has a very long history of irrigated agriculture which is mentioned in the earliest Sanskrit literature. In the fourth century BCE, Megasthenes, a Greek ambassador to the court of the Mauryan Empire (c.325-c.183 BCE) wrote an account of his visit to India. He described the bountiful effects of irrigation (quoted in Kalota 1978:37)

> India has many huge mountains which abound in fruit-trees of every kind, and many vast plains of great fertility . . . the greater part of the soil, moreover, is under irrigation, and consequently bears two crops in the course of the year.

Archaeological evidence from the Indus Valley shows that communities used irrigation from the time of the Harappan culture (c.2400-1750 BCE). During historic times the Rajput dynasties (1000-1200 CE) encouraged irrigation works. In the Mogul period (1500-1700 CE) canals were constructed from the Jumna River, and elsewhere, both to supply water to palaces and to extend irrigation into the dry lands of the north. By the colonial period many of the ancient canals had fallen into disrepair. Using contemporary developments in engineering, the British brought Indian irrigation into the technological age of the nineteenth century.

[1] The colonial networks of scientific learning were particularly important in the British colonial era. By the late 19th century they were relevant to the growing domain of policy for natural resource management throughout the British Empire. See, for example, Grove (1995) and Rajan (2002).

In this chapter *northern India* refers to the political units represented by the modern states of Uttar Pradesh, Uttaranchal, Haryana and Panjab[2] in India, and the states of Panjab and Sind in Pakistan. In the nineteenth century, as British administration evolved, Panjab, the North-Western Provinces and Oudh comprised this geographic area. They were also referred to as the *Upper Provinces* or *Upper India*. Later in the century, these areas came under the one description of the North-Western Provinces (NWP) for geographic and administrative purposes. Following partition in 1947, India held the irrigation works served from the Ganges-Jumna system, and those supplied from the Indus system were located in Pakistan.

8.2 The Landscape

The northern Indian plains comprise mainly the vast *doabs* (the land between the rivers) of the Indus and Ganges River systems. The rivers have been formed as a result of the natural drainage from the Himalayas, and are fed mainly from high mountain catchments. The great mountain chain of the Himalayas extends for 2400 km from the gorge of the Brahamaputra River in the east to the gorge of the Indus River in the west. The Indus system flows south through Panjab to the Arabian Sea. Panjab, meaning *the land of the five rivers*, is enclosed and watered by the Beas, Sutlej, Ravi, Chenab and Jhelum Rivers. Near Ferozepur, the Beas and Sutlej merge into one (Sutlej), and eventually join the Indus River. The Ganges flows out of the Siwalik Hills (at the foot of the Himalayas), and follows a south-easterly course across the plains to the Bay of Bengal (Figure 8.1).

The area of the *doabs* experiences irregular rainfall and high summer evaporation. From July to October all of the natural waterways depend on rains brought by the south-westerly monsoons. In the hot months of April to June, and in October and November, they receive melting snow from the Himalayas. Westerly disturbances bring modest rain in winter. The earliest canals along the principal rivers obtained water only when the parent streams were in flood. Before intensive canal irrigation was introduced, in the nineteenth century, many parts of northern India were subject to severe agricultural and meteorological drought.

The geological characteristics of the Indo-Gangetic Basin were understood in the nineteenth century. It showed that the greater part of the flat alluvial plains had been formed by enormous loads of sediment, carried down by the drainage of the Himalayas, and deposited in an immense depression (Roonwal 1968). The deposited material contained saline matter derived from the

[2] *Panjab* was the spelling used in the colonial period. Along with other recent changes to place names in India, *Panjab* is replacing *Punjab* that prevailed in the 20th century. This orthography more accurately reflects pronunciation.

decomposition of rocks. The rivers descending from the Himalayas carried down in solution proportions of salt which varied with the character of the strata they traversed. These salts were identified principally as calcium and magnesium carbonates, sodium sulphate and sodium chloride (Watt 1889:400).

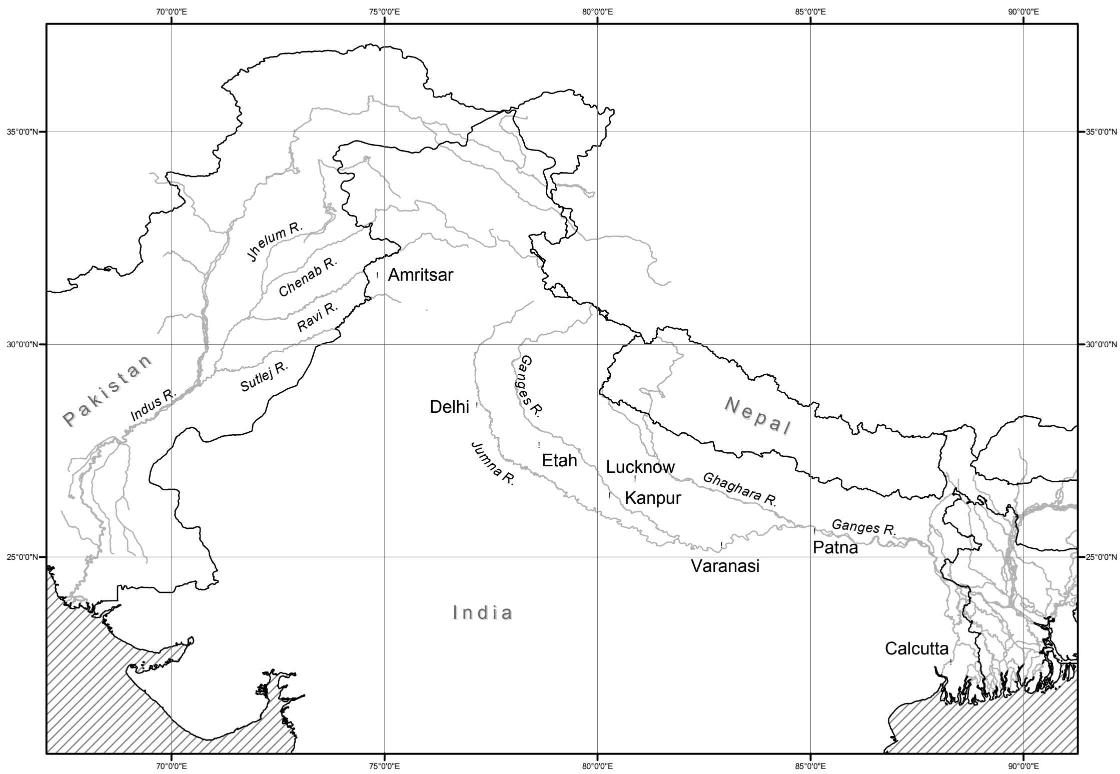


Figure 8.1: Map of northern India

Irrigation canals were established in a landscape with naturally saline soils and groundwater. The Jumna, which joins the Ganges at Allahabad, has been an important source of canal irrigation for centuries (IGI 1908). Consequently, from long before British occupation, large patches of salt-affected ground were evident throughout northern India (Medlicott 1880). The vernacular languages of northern India described these phenomena.[3] The white powdery efflorescent salts that accumulate on the surface of large tracts of land are called *reh*. The tracts affected by *reh* are called *usar* (barren) land.[4] Commonly *usar* lands have moderate to severe alkalinity, and the sun-dried-brick effect produced from over-watering the fields. *Usar* lands were sometimes seen as a result of deforestation.

The effect of canal irrigation on naturally saline land is illustrated in the case of the Western Jumna Canal. This canal was built originally in 1356 as a perennial source of water for the

[3] Baden-Powell (1868) discussed the regional variations in language, e.g., in Panjab *kallar, kalr, shora*.
[4] *Usar* also included other forms of land that were uncultivable.

Mogul royal gardens at Hissar and Hansi. The land served by the canal was known to have developed salt patches over the course of the next four centuries. In the sixteenth century, the Moguls restored it. By the middle of the eighteenth century, when it had fallen into disuse, the areas previously degraded by salt had regenerated (Islam 1997).

8.3 The British in India

The British connection with the Indian sub-continent dates from 1600 when a group of English merchants received exclusive rights to trade to the Indies. Their trading operations formed the basis of the British East India Company. By the late eighteenth century the Company had grown from a commercial body into a major territorial power in India with its headquarter in Calcutta. The political implications of this development caused the British Government in 1784 to exercise supervision over the Company's Indian policies through a Board of Control. Changes to the Company's commercial functions occurred, but it continued to exercise responsibility for the government of India until the Uprising in 1857 prompted major reforms. By the *India Act, 1858*, the British Government replaced the Company and the Board of Control with a single new department of state, the India Office. The India Office operated until India gained independence in 1947 (Wild 1999).

In time, British commercial interests led to large public works projects, particularly in development of irrigation and railways. Initially, they were designed to increase food production and to reduce the risk of drought-induced famine on the vast northern plains. Later, these projects formed the base of a strong trade in agricultural and industrial goods between India and Britain (Islam 1997).

In northern India the British found an agrarian system that had been created 'in the course of a stubborn struggle against Nature, which the Indian peasant had carried on for thousands of years' (Habib 1963:1). Techniques had evolved from hoe-cultivation, through migratory agriculture, to permanently settled cultivation. Crops commonly cultivated included grains (wheat, barley, rice, millet), pulses (*gram*, *mash* and *moth*), and cash crops (cotton, indigo and sugar cane). The area of land that could be cultivated was extended by clearing forests and by irrigation. Irrigation was based on wells and on perennial and inundation canals. The canals along the principal rivers of the Indus and Ganges basin were heavily dependent on seasonal conditions. Water was raised from wells and canals by various means, including the *noria* (Egyptian wheel) and the *saqiya* (Persian wheel).

From the beginning of the nineteenth century, the British began to develop irrigation in the Indus and Ganges basin. First, they restored and re-opened branches of some of the Mogul canals, for example the Eastern Jumna Canal (1823-1830). It served districts on the eastern bank of the Jumna in the North-Western Provinces. But as the old structures were found to have poor alignment, engineers soon recognised the need for new irrigation schemes. Prompted by commercial interests and by recurring famine, a massive program began in 1836. Several years of survey work were needed for each system of canals and its distributaries before construction could begin. Once water for irrigation was available for a district, construction continued in stages to provide regulating headworks, and to extend and upgrade canals.

Table 8.1:
Some principal developments in irrigation in northern India in the 19th century

System	Location	Technical details
Western Jumna Canal (1819-1886)	from the Jumna, at Faizabad, NWP	main canal and branches 550 km; distributaries 2900 km (IGI 1908)
Eastern Jumna Canal (1823-30)	from the Jumna, at Faizabad, NWP	main canal 200 km; distributaries 1170 km; 447 drains (IGI 1908)
Upper Ganges Canal (1842-54)	from the Ganges, at Haridwar, NWP	1500 km in length (Franklin 1892)
Upper Bari Doab Canal (1846-60)	between Beas and Ravi, with headworks at Mahhopur, Panjab	main canal and branches 590 km; distributaries 2560 km (Smith 1882)
Agra Canal (1868-74)	from the Jumna, at Okhla (18 km below Delhi), NWP	main canal and branches 175 km; distributaries and other 1418 km (IGI 1908)
Sirhind Canal (1869-82)	perennial from the Sutlej, at Rupar, Panjab	a large network of distributaries and feeders from 2 major branches (IGI 1908)
Lower Ganges Canal (1873-78)	from the Ganges, at Narora weir, NWP	Narora weir 1160 m long with 42 sluices; main canal 100 km; branches 220 km (IGI 1908)

Notes:
NWP = North-Western Provinces
IGI = *The Imperial Gazetteer of India*

By 1880 some 10,680 km of canals (main and distributaries) existed in the NWP, and 6215 km in Panjab (Indian Irrigation Revenue Reports, quoted in Whitcombe 1983:713).

At the end of the 20th century, the Indus irrigation system was the largest continuous system in the world, with a network of some 63,000 km of canals (Ghassemi *et al* 1995:378).

The first major British project was the Upper Bari Doab Canal (1846-1860) in Panjab. It originated in a plan to restore the Hasli Canal, built by the Mogul Shah Jehan (1633). After annexation of Panjab, irrigation was also prompted by the need to settle and give employment to the disbanded Sikh army. However, only parts of the Hasli channel were used as distributaries because of its poor alignment. The Bari Doab Canal waters the tract between the Beas and Ravi rivers. It also serves the cities of Lahore and Amritsar (IGI 1903, Smith 1882).

Other systems followed steadily throughout the nineteenth century (see Table 8.1). Two are particularly significant. The Ganges Canal (1842-54) (later called Upper Ganges Canal) was designed by the famous British Army engineer, Sir Proby Cautley. He produced a system that is impressive even by modern standards. The Lower Ganges Canal (1873-78) was conceived after the failure of rains in 1866. As a southward extension of the Upper Ganges Canal, it was designed to provide a better distribution of water between the upper and lower sections of the Ganges-Jumna Doab. It, too, was large, and employed diversion techniques. The Nadrai aqueduct is a remarkable example. It has 15 arches (18.3 m each span), and carries water from the Ganges over the Kali Nadi, which is subject to extreme variations in flow during floods (MacGeorge 1894). The scale of these systems and the techniques used to divert whole river flows contributed greatly to the prestige and influence of nineteenth century engineers.

8.4 Problems with Groundwater and Soils

The first phase of intensive irrigation development on the plains of northern India took place between 1836 and 1856. By the 1860s and 1870s the adverse effects of canal irrigation were appearing. Excessive and prolonged use of irrigation water was causing groundwater levels to rise and soil degradation. Although the salt-affected lands of northern India were of very ancient origin, land began to deteriorate rapidly within the new irrigation systems. By the 1860s high watertables, and waterlogged and saline soils associated with canal irrigation, were evident in many districts.

Before the British re-opened the western section of the Jumna Canal, it is said that the water wells in the surrounding district 'lay at a depth of 60 to 70 cubits'. After irrigation water had percolated through the subsoil and raised the watertable, the depth from the ground surface to the watertable was eight feet.[5] One scientist at the time observed the presence of *reh* 'on the banks of water-courses and canals about Lahore' (Center 1880:266). Fields were being turned into swamps where canals interfered with natural drainage, or where water percolated from the elevated canal banks. Waterlogging was an imminent problem, villagers were suffering ill health from malaria, and many villages were sustaining agricultural and financial losses.

The first known scientific account published in India on the effects of irrigation on groundwater and soils was by H.B. Medlicott, Professor of Geology at Thomason College, Roorkee. It appeared in the *Journal of the Royal Asiatic Society*.

Medlicott (1863) attributed the cause of the problem to a progressive concentration of soluble and partially soluble salts in the upper soil strata. Salts were brought to the surface by changes in the rate of movement of sub-soil water through percolation, capillarity and evaporation. He also believed the quality of the irrigation water itself had an effect. Water samples taken from two rivers supplying the Western and Eastern Jumna Canals were found to be high in sodium sulphate and sodium chloride. These were the predominant salts characterising *reh* and *usar* lands. Medlicott regarded canal water as an exacerbating agent, but not a prime cause. But inefficient drainage and insufficient application of water were responsible for the development of *usar* lands. Owing to low elevation and poor outlets for runoff in many areas, evaporation was the only means for the removal of surface water (Gupta and Pahwa 1978). Medlicott proposed intensive use of canal water to wash out the salts.

8.4.1 Watertables

At first, rising watertables were seen as having advantages for well irrigation by reducing the labour involved in manually drawing water. But the dangers of rendering wells inoperative and creating waterlogged soil were soon apparent. Rising groundwater could render useless many common temporary wells which irrigated large tracts. Unlike the stronger masonry wells, the earthen sides of the temporary wells would become unstable and required frequent repairs. One report on the temporary wells in villages irrigated from the Agra Canal addressed this problem. It conveyed the cautionary statement ‘that the canals were, very possibly, a failure as an insurance against famine owing to their indirect effect on indigenous methods of cultivation’. (Muttra Settlement Report 1879, quoted in Whitcombe 1972:81). In the Cawnpore (modern Kanpur) district, where many villages could depend on wells, the earthen wells 'fell in when the water level was raised through the introduction of the canal' (Voelcker 1893:69).

The price of water was calculated according to the area of land irrigated and the crop grown, rather than by volume. In 1864 rates were fixed at 5 rupees per acre for sugarcane, and 2-4 rupees per acre for other crops (Whitcombe 1972:88). This policy led obviously to waste. But more serious was the gradual destruction of natural soil fertility, for there was no incentive for farmers to let the land lie fallow from time to time.

[5] The cubit is an ancient measure of length, derived from the distance between the elbow and finger tip. Its length varied in different places over time, but equalled 18-22 inches. In this case the groundwater level changed from about 100 feet to 8 feet following the introduction of canal irrigation.

8.4.2 Salt

Ancient Sanskrit literature described the conditions for constructing effective water tanks. In it there are accounts of saline soil reducing a reservoir's usefulness and rendering water conservation difficult (National Institute of Hydrology 1990).

Soon after the large network of canals came into operation in the late 1850s, many villages were enjoying the benefits of intensive irrigation. In many areas, after initial bumper harvests, crop yields began to decline and salt efflorescence became widespread. In Panjab the plight of villages served by the Western Jumna Canal, and its branches about Delhi, Paniput, Rohtak and Karnal, first attracted serious attention to the problem. In 1857 the Joint Magistrate of the Aligarh district (between Delhi and Agra) examined the tracts of country affected by *reh*. He found that out of 580 villages nearly ten per cent had been injured in degrees ranging from severely to partially, and six per cent were severely affected. In the region of Paniput alone, 19 per cent of 242 villages were severely affected. The resulting loss of income to the villages was a serious problem for the Government of Panjab (Baden-Powell 1868).

In 1857 the Superintendent-General of Irrigation in the North-Western Provinces described the problem. He attributed the appearance of the salt efflorescence 'to the percolation under pressure of the canal water through the soil in various directions, the controlling factor being the volume of the canal and the surface of the surrounding country.' (Baird Smith to Sudder Board of Revenue, 13 April 1857, quoted in Whitcombe 1972:285).

Government revenue and canal officers made corroborating observations of *reh*-affected lands throughout Panjab. Scientists in India and Britain analysed soil and water samples, and by 1863 had reached shared conclusions: the cause of *reh*-affected land was due, in essence, to the presence in the soil of 'some minerals rich in alkaline, the decomposition of which is promoted by the irrigation water and . . . a large quantity of these substances are converted into soluble form, and gradually accumulate until they become so abundant as to become noxious to plants.' (Thomas Anderson, Professor of Chemistry, Glasgow, quoted in Whitcombe 1972:287). Effective drainage was seen as the cure.

Reports of occurrences of *usar* came also from the state of Oudh. A combination of highly soluble salts (*reh*) and a residual insoluble precipitate of carbonates found in a variety of conditions differing widely in the affected districts. While carbonates (rather than sulphates and chlorides) predominated, capillary action was seen as the prime cause of the condition. (*Memorandum on Reports by Commissioners on 'Reh'*, 1864, quoted in Whitcombe 1972: 287).

From 1864 discussions of the problem of *reh*-affected land were published in the Indian Public Works Department records, including the *Irrigation Proceedings* for the North-Western Province (NWP).

In 1869 Dr W.J. Ward, a metallurgist at the Royal School of Mines, in London, made analyses of soil and water from the Western Jumna Canal. He concurred with the general view 'that *reh* was a mixture of highly soluble salts, that water was the vehicle by which it was brought into prominence in the soil, and that the cure was the combination of sufficient irrigation, to wash down the salts, with adequate drainage.' (quoted in Whitcombe 1972:288).

As a result of Ward's report, the administration for the North-Western Provinces recommended immediate experiments in leaching and drainage on a portion of the Eastern Jumna Canal. However, the recommendation carried a qualification: 'all that is really wanted is that the Canal Officers should select one or two badly-drained plots of ground where *reh* is prevalent; that they should drain them in such a manner as to ensure the relief of the soil from over-saturation to a suitable depth—probably 2 feet should suffice; and then encourage their cultivation with irrigation. . . . The whole operation must necessarily be of an exceedingly simple character.' (NWP, *Irrigation Proceedings,* July 1869, quoted in Whitcombe 1972:288). Numerous reports on these drainage experiments appeared in the *Irrigation Proceedings*.

Many people feared that *reh* would spread like a disease across the landscape and convert it into a 'howling wilderness'. In 1874 the first outspoken technical criticism of the Government's zeal in promoting canal irrigation appeared. A.F. Corbett, in his *Climate and Resources of Upper India*, had drawn attention to the excessive application of water by farmers. He noted that the practice caused hardening of the upper soil under a cycle of repeated watering and drying out, and the natural salts accumulated near the soil surface as *reh*. As canal irrigation replaced well irrigation, villages needed fewer cattle to work the wells. As the number of working beats declined, so did the ready supply of manure for adjacent land. Corbett saw the canal system, in effect, as destroying the harmony between man, beast and land (Whitcombe 1972:76).

Intensive irrigation was designed primarily to reduce the risk of drought-induced famine by providing conditions to increase basic food production. Villages were expected to plant staple grains to provide food for the population and fodder for working animals. These *rabi* crops, (grown in the cold season and harvested in the spring) were traditionally grown on the middle- and poorer quality soils. The better soils were reserved for crops of higher commercial value, such as cotton, indigo, sugarcane and wheat. These *kharif* crops (grown in the rainy season and harvested in the autumn) needed a lot of water. As canal irrigation spread, villages increased production of these high-value crops, and overcropping occurred (Voelcker 1893:76, Whitcombe 1972:71).

Canal irrigation also brought unwanted social effects. As the ambitious program of public works continued, reports followed on the effects of irrigation on human health. In parts of India irrigation created 'a safeguard against dearth only at the cost of desolating the villages by malaria' (Randhawa 1983:171). Voelcker (1893) noted that many villages in Panjab and the North-Western Provinces had become unhealthy on account of the faulty construction of canals. Whitcombe (1996) has found that 'fever-tracts', as they were called, existed along the Western Jumna Canal from 1846, where the incidence of malaria remained high through much of the nineteenth century. Similar conditions were found along the Ganges Canal, particularly in the low-lying areas of Aligarh and the central and lower reaches where the gradient was very small. Malaria in the irrigated districts of the Bari Doab Canal followed the same pattern (Whitcombe 1996).

8.4.3 Experiments in Land Reclamation

In 1874 the newly created Department of Agriculture began a program of experiments in reclaiming *usar* tracts. These experiments demonstrated that *usar* land could be brought back into cultivation by careful watering accompanied by intensive manuring. Yet no attempt on a significant scale was made to increase the local supply of manure near *usar* land to balance the effects of irrigation.

Near the Western Jumna Canal the Irrigation Department experimented with salt-tolerant plants. The results were 'most conclusive', but had other unexpected results. Center (1880:271), the Chemical Examiner to the Panjab, later described this case.

> A piece of utterly useless *reh* land, for which revenue was remitted, was taken up by the Department and planted with kikar trees [*Acacia arabica*]. These flourished and a very fine crop of doab grass, 2 feet high, came annually up under the trees, and the efflorescence disappeared. The villagers, seeing that the land was improved and fearing it would be alienated by the new settlement, applied for the restoration of both trees and land, and carried their point in the courts of law. A few days after the restoration the wood was sold to a wood merchant and every tree cut down. At present the doab grass is all gone, and the soil is encrusted with salt. Such an experiment made among American farmers would have excited the keenest interest and given rise to numerous trials of the same.

8.5 The Reh Committee (1877-1878)

By the 1870s an enormous body of information on the subject of *reh* existed in government reports from northern India. It had been gathered over many years by revenue officers, engineers and scientists. Correspondence on the subject of *reh*, its causes and effects was said to be large enough to form an official *Blue Book* (NWP, 1877, p.26).[6]

In May 1877 the Government of North-Western Provinces and Oudh convened a committee of inquiry, called the Reh Committee. The inquiry began as a result of action taken by a European planter, David Robarts, at Sikandra Rao in the Aligarh District, served by the Ganges Canal. In 1876 he sought compensation from the Board of Revenue for land degradation based on the ill effects of canal irrigation and from *reh*. The terms of reference for the committee were to examine two issues: (1) the claim by Robarts, and (2) the impoverishment of soil under canal irrigation and *reh*. It is the Committee's detailed consideration of the second point on which I draw in this section.

The Reh Committee comprised:

- Mr H.S. Reid, Senior Member of the Board of Revenue, North-Western Provinces and Oudh (Committee President)
- Mr E.C. Buck, Director of Agriculture and Commerce, North-Western Provinces and Oudh (Committee Secretary)
- Mr H.B. Medlicott, Superintendent, Geological Survey of India[7]
- Mr D. Ibbetson, Settlement Officer of Karnal, Panjab
- Mr R.E. Forrest, Superintending Engineer, 1st Circle Irrigation Works (in which Sikandra Rao is located) North-Western Provinces
- Captain T. Howard, Executive Engineer, Aligarh Division, Ganges Canal

Other people consulted by the Committee about *reh*:

- Mr J. Michel, an indigo planter in the Meerut District, who had conducted experiments for the treatment of *reh*-affected land
- Mr F.N. Wright, Settlement Officer, Cawnpore
- Mr H.B. Webster, Commissioner, Agra Division
- Mr W.C. Plowden, Commissioner, Meerut Division
- Mr A. Sells, Collector of Muzaffarnagar
- Mr J. Sladen, Collector of Saharanpur
- Mr A. Cadell, former Settlement Officer of Muzaffarnagar
- Mr C.C. Anderson, Officiating Chief Engineer, Irrigation Works, North-Western Provinces

[6] The *Blue Books* are the large tomes containing official government records, and were common to all areas of administration throughout the British Empire.

[7] H.B. Medlicott, F.R.S, was Professor of Geology and Experimental Science (1854-62) at Thomason College, Rourkee. He was an outstanding geologist who did pioneering work on the geology of India.

Although the Committee was formally convened in May 1877, it could not meet because of 'duties connected with the impending famine' until February 1878. It then inspected villages most affected by *reh* around Akrabad (Aligarh District), and submitted a preliminary report in March 1878. The President provided a review of the Committee's work in September 1878, and a final report followed on 26 December 1878. The full 81-page report was published in the North-Western Provinces and Oudh Revenue Proceedings for June 1879. A 26-page summary of the findings is also found in the more accessible *Dictionary of the Economic Products of India* (Watt 1889).

The Committee drew largely on written material, and conducted much of its work by correspondence. It examined the voluminous evidence of the conditions for *reh*-affected lands to develop, with particular reference to canal irrigation in the Aligarh District (NWP). The final *Reh Report* was essentially a summary of existing papers on the subject.

8.5.1 The Issues

The Reh Committee addressed two main issues: (a) the conditions under which *reh* developed in the North-Western Provinces, and (b) how these conditions were affected by the introduction of canal irrigation (NWP 1879, Index No. 112). Members of the Committee inspected four areas where destruction had taken place on a large scale. These were in the Districts of Karnal, Aligarh and Meerut, and in the Kali Nadi valley.

The Committee framed the inquiry around the following questions,
- first, with regard to the spread of the problem:

(a) Is the introduction of canal irrigation believed to be a principal cause of *reh* extension?
(b) How far is the extension supposed to be due to sub-soil percolation of the water?
(c) How far is the extension of *reh* due to irrigating with canal water?
(d) How far is the extension of *reh* supposed to be due to the interruption of drainage by canals or distribution channels?
(e) What relation (if any) does the extension of *reh* bear to the proximity of a canal or a canal watercourse?
(f) Is there any relation between the extension of *reh* and the surface level of land affected?

- second, with regard to preventing the spread of *reh*:

(g) Is any improvement of drainage desirable?
(h) Is any alteration of the canal system desirable?
(j) Is the substitution of lift for flush irrigation, or any other measure of controlling the surface supply of canal water, recommended?

8.5.2 Findings of the Reh Committee

The Reh Committee gave its findings, first, with regard to the spread of the problem and, second, with regard to preventing the spread of *reh*. Generally, it endorsed the existing technical understanding of the cause of the problem. This was that saline material, derived from the decomposition of rocks, was formed of highly soluble sodium salts. Over millennia salts were concentrated in the soil. As rainwater drained through the soil profile, salts entered the groundwater. In regions of intense evaporation the saline water rose by capillary attraction and evaporated, and a salt efflorescence remained in the upper soil layers. In time, the soil became degraded and unfit for healthy plant growth. (NWP 1879, Index No 112)

With regard to the spread of the problem, the Committee addressed the six questions in §8.5.1:

(a) It found that the damage to soils was directly attributable to excessive irrigation in each case that it examined. Buck warned that these cases illustrated ‘the first and earliest outcome of the introduction of a canal system’. He feared similar ‘disturbing influences which may perhaps be working in a slower but not less sure action in many areas, where symptoms are still obscure or unobserved by educated eyes’ (NWP 1879, Index No 117, para 15).

(b) The Committee was less sure about the effects of water percolating from the channels laterally through the subsoil, and opinions were mixed.

(c) In the absence of better data on canal water quality, the Committee was unclear whether the canal water itself brought salt to irrigated fields. Some members believed it was the supersaturation of the land, and absence of effective drainage, that caused the problem.

(d) There was abundant evidence that waterlogging and *reh* occurred where there was interference with natural drainage channels. According to Ibbetson, 'In Karnal every drainage line in the country is crossed at intervals by high banks' (NWP 1879, Index No 112, para 11).

(e) Generally, in the absence of data on the conditions of more tracts, the Committee was unsure about the proximity of *reh*-affected land to the canals. Members could not identify instances of serious extension of *reh* at a distance from a canal system. When Reid investigated parts of the Ganges Canal he found far greater developments of *reh* close to canals. But, there were also some areas close to canals little affected.

(f) Medlicott found that shallow watertables provided a particular hazard in irrigation areas. Variation in the height of the watertable accounted for the patchy appearance of *reh* in many areas. He noted that the surface level could be affected by a secondary influence in the form of local obstructions of surface drainage.

With regard to preventing the spread of *reh*, the Committee addressed the three questions in §8.5.1:

(g) The Committee was in no doubt about the need for effective drainage. It noted that during the planning of the Ganges Canal, 'It was the wish and intention of Colonel Cautley, . . . that measures for drainage and for irrigation by canal should proceed *pari passu*.' (NWP 1879, Index No 112, para 14).

(h) Any proposal to redesign the whole canal system was deemed out of the question because of the enormous cost. This was particularly so for the main canal. However, the Committee believed that there was scope for improving the alignment of distributaries.

(j) *Lift* irrigation referred to ancient techniques of raising water manually by scoop, bucket or wheel, either directly onto the field or into a holding tank. This is a labour-intensive operation, and requires labour-intensive preparation of the fields. *Flush* irrigation, on the other hand, refers to the technique of supplying water by causing a stream to flow over the ground via a network of artificial channels. The adoption of this technique under conditions of intensive irrigation resulted in waste from an uneconomic application of water. Farmers simply inundated the fields unnecessarily. Buck considered it 'absolutely necessary to do anything possible to put an end to the vicious system of swamping field for irrigation, which is the result of accessibility of flush water.' (NWP 1879, Index No 112, para 16). The Committee saw the best remedy was to raise the price of flush water, but recognised that it was not in the interests of the Canal Department to do so. The charges for flush water were much higher than for lift water, because the absolute amount of water was greater and its price was higher. Raising the price would deter farmers altogether. The Committee was in no doubt that flush water encouraged excessive saturation of the soil, 'which is one of the commonest and most powerful causes of *reh* extension'. The problem would persist until canal water was dispensed and charged by volume, rather than according to land area and crop type.

In the course of its inquiry the Committee commented on other matters relevant to irrigation. It was evident that all those who presented reports to the Committee were aware of the importance of deep drainage. In experiments on his salt-affected land in the Meerut District, Michel found that surface drainage had been no help to the problem. In his view, there was only one alternative to remodelling the entire system: deep drainage 'to tap and keep down the water to some fixed level'. (NWP 1879, Index No 114, para 18)

There was general discussion and some criticism of farming practices. Webster held the view that irrigators around Agra were responsible for their impoverished soils because they cropped the lands year after year, without manuring it. Plowden believed that canal irrigation induced irrigators to keep fewer cattle, compared with when they used them to draw water from wells. Thus, less manure was available. At the same time, canal irrigation resulted in smaller amounts of fallow land. With canal irrigation Cadell saw that the land would no longer have an opportunity to lie fallow during drought. Therefore, a greater need for soil improvement existed under canal irrigation. Yet the supply of manure was not keeping up with the rapidly extended irrigated areas.

The Committee made several recommendations. In an attempt to reduce the problem of over-watering, it proposed lift irrigation be used, as far as possible, in place of flush irrigation. Yet it recognised that this was 'an inferior remedy' to the problem. The inquiry resulted in measures to improve drainage in the affected areas. The Committee also recommended the following work in the North-Western Provinces: data gathering and monitoring of *reh* by the Agricultural Department; mapping the surface drainage system by the Survey Department; data gathering of the watertable level by the Agricultural and Canal Departments to understand the relationship between groundwater and *reh*; experiments to understand the physics of capillary attraction; and experiments on land reclamation by the Agricultural Department. Medlicott drew particular attention to the absence of trained scientists in India who could conduct the necessary experiments. He recommended the appointment of 'a well-qualified agricultural chemist for five years' who would devote himself to the experiments in the Agriculture Department. (NWP 1879, Index No 123-124)

In May 1879, as a measure to reduce waterlogging in the worst affected areas, the government of the North-Western Provinces took steps to stop canal irrigation to selected villages. (NWP 1879, Index No 149)

8.6 Responses to the Problem

Although the Reh Committee examined a large body of evidence on the occurrence of *reh* and *usar* lands, it did not have the benefit of expert advice from an agricultural chemist, either directly as a Committee member or by consultation during the course of the inquiry. The Committee, however, did recommend the appointment of a permanent agricultural chemist to the Agricultural Department, but the government was unable to meet the costs of this appointment. It was not until Dr W.J. Leather was appointed in 1888 that the North-Western

Provinces had a permanent agricultural chemist to undertake a program of systematic work recommended in 1879 (Whitcombe 1972:79, 289).

As the Reh Committee was concluding its work, the Indian Government convened a Famine Commission (1879) to assess the value of irrigation throughout India. This Commission investigated the general effects of irrigation on the character of cultivation in the irrigation provinces, including waterlogging and salinity. The administrations of the northern Indian irrigation districts submitted reports. Panjab and the Northern-Western Provinces agreed that irrigation had resulted in increased cultivation. They found some recent evidence that salinity was declining around the Western Jumna Canal. While it was true that the faulty alignment of the original canal had given rise to waterlogging, the best way of treating salt-effected land was to leave it fallow. Along certain canal-irrigated tracts of the North-Western Provinces there were serious problems of waterlogging and village health. There the government acknowledged that drainage and irrigation development had to proceed together. According to Whitcombe (1983), the Famine Commission seems to have made little use of the Reh Report, although it shared its broad conclusions.

From her analysis of the findings of the Famine Commission, Whitcombe concluded that 'the general increase in production and in productivity more than compensated for diminished out-turns from salt-infected fields'. Furthermore, 'the conspicuous success of canal-irrigation outclassed its drawbacks and its benefits disguised all but its financial costs'. (Whitcombe 1983:708)

As measures to contain salinity were investigated, there were proposals for the government to buy large tracts of *usar* land and regenerate them as productive land, but these were rejected at both the local level and by the Revenue and Agricultural Department of the Government of India. Likewise, the cost of creating fuel and fodder reserves from *usar* land was deemed beyond the means of the Government (Whitcombe 1972:83-84).

The price charged for canal water was an on-going problem for the environment. However, there were various reasons for not changing the policy to allow for a price based on volumetric use of water. Gilmartin (1996:225) has explained that a different administrative structure would have been required to assess the volumetric use. Technical issues also contributed to the problem. For decades engineers were concerned with developing tamper-proof canal gauges capable of measuring the amounts of water delivered to outlets. Devices needed to be reliable under variable levels of the canals. Administratively, it was difficult to mark off the precise areas attached to each outlet so that the measure of water to fields could be calculated.

The Indian Irrigation Commission (1903) examined the difficult issue of water pricing. It agreed that the existing policy encouraged irrigators to use water to excess. It agreed that a change to volumetric pricing was needed but recognised a set of new problems which this change in turn would create. In particular, a volumetric pricing system denied irrigators certainty of cost at the start of a season. New infrastructure would be needed in the form of water meters. Seasonal variations in rainfall would result in variations to the price of water, and consequently to the income of irrigators. The latter uncertainty applied equally to the revenue of the Irrigation Department (Islam 1997:119-20).

8.6.1 Report on Improvement of Indian Agriculture (1893)

In December 1889 Dr J.A. Voelcker[8] began his extensive tour of India in order to report on the country's agricultural conditions. In many of his conclusions, he endorsed findings of the Famine Commission (1879). Voelcker addressed a wide range of subjects in his report, including the effects of intensive canal irrigation in northern India. He estimated that *reh*-affected land in the North-Western Provinces amounted to 4000-5000 square miles, and described patches of valuable crops standing out 'like oases in the salt-covered desert around them' (Voelcker 1893:55).

Voelcker frequently expressed concern over the absence of expert scientific advice across many agricultural domains. He made a particular plea for an agricultural chemist. Since 'chemistry is the science that comes most in contact with agriculture', he considered there was urgent need for an agricultural chemist to act as an agricultural expert (Voelcker 1893:315). He believed that projects for reclaiming *usar* lands had suffered as a result of an almost total absence of scientific study of soils. Enquiries into the *reh* problem, he noted, were carried out without any advice from an agricultural or even a general chemist. For soil improvement he recommended that the government would have to devise measures to increase India's manure supply. For the greater part of India, he noted, 'the necessity for using manure is enormous, and the supply of it is notoriously inadequate' (Voelcker 1893:131). He recognised that increased agricultural production led to 'export of both crops and manures', and must result in soil degradation.

The use of cow dung for fuel was an issue connected with the both the supply of wood for fuel and the availability of manure for the land. In considering a widening of the Forest Department's functions to serve agricultural interests, he proposed a fundamental shift in forest policy. He

[8] John A. Voelcker was the son of Dr Augustus Voelcker, an agricultural scientist. He succeeded his father as consulting chemist to the Royal Agricultural Society in 1885, and directed the Society's experimental farm. Later he was President of the Society of Public Analysts, a member of the Council of the Chemical Society of London, and the Institute of Chemistry of Great Britain. In 1889 the Government of India appointed him to report on the scientific improvement of Indian agriculture (Henry 1995).

believed that 'There are other ends which the Forest Department should serve besides that of growing timber and making a large revenue out of the forests' (Voelcker 1893:147). The recommendation to create *Fuel and Fodder Reserves* to provide wood for agricultural purposes would release cow dung for essential manure.

Voelcker also encouraged arboriculture, and saw tree-planting as a means of arresting soil erosion, and assisting land reclamation. He recommended increasing the water supply to the dry tracts of the north by means of irrigation, but was aware of the need for subsoil drainage. Nevertheless, drainage was a very difficult and costly matter in India. It was hardly to be thought of 'for the purpose of merely *reclaiming salty land (usar)*' [emphasis original]. Yet where farmers were abandoning waterlogged districts the question of subsoil drainage needed serious consideration (Voelcker 1893:71).

8.7 Growth of Scientific Knowledge

After the Reh Inquiry the *Records of the Geological Survey of India* published two papers that discussed in detail the problem of *reh* in the soils and groundwater of northern India. One was by Center, the Chemical Examiner to the Panjab, the other by Medlicott.

Center (1880) provided a detailed review of understanding of the chemistry of soil salinity. He addressed the origin of the alkali efflorescence. He described the accumulation of the resulting salts in upper soil layers or in subsoil waters, and how this depended on various chemical properties and permeability of soils, and on drainage. He recognised *reh* as a very variable compound, rather than a specific salt or mixture of salts, with its ingredients and their relative proportions varying in different places. He also recognised the importance of the relationship between action taking place on the surface and in the strata permeated by groundwater.

Medlicott (1880) addressed the seriousness of the problem of saline efflorescence 'which has been, and will continue indefinitely to be, a subject of the gravest concern to those interested in the welfare of North-Western India.' In a tone of frustration, he dealt a blow to government policy makers, and their lack of understanding. '[These] men who have to deal with the matter practically are very much the reverse of experts, scarcely even believers.' (Medlicott 1880: 273) Compared with policy makers, the chemists clearly understood the dynamics at the heart of the problem of *reh* and *usar* lands. In the words of Medlicott (1880:273):

> The question is truly a geological one, as embracing all the conditions of a complex operation now at work in producing a change in the whole region affected. This has been the difficulty throughout— to induce an apprehension of the situation: that the evil to be encountered is not a fixed obstruction of assignable dimensions and position, but the present active array of natural causes bent upon fulfilling the effects due to conditions that have supervened. In such a case our best efforts may be no more than palliative, unless indirectly, by modifying those conditions, we can mitigate the action of the prime cause.

From 1890 more scientific papers started to appear, as described by Gupta and Pahwa (1978). Several papers reported the results of land-reclamation experiments. Warth (1891) investigated the salts of the Sambhar Lake, a natural salt lake in the northern state of Rajputana (modern Rajasthan). Duthie (1896) conducted experiments with different grasses on reserves in the Aligarh district in 1893-94. He observed a grass (*Diplachne fusca*) to be useful on low-lying areas where water was most liable to accumulate. He recommended tree planting, particularly *Tamarix articulata* and *T. gallica* which thrive in saline soil. Leather (1897a) described experiments on the *usar* plains with soils containing sodium carbonate, sodium sulphate and sodium chloride. He attributed the accumulation of *reh* to imperfect drainage, surface washing, wind drift and canal irrigation. His preliminary experiments showed that surface drainage, sub-surface drainage and scraping *reh* off the surface were ineffective. But the results of planting *Babulor sisoo* were very encouraging, and an application of canal silt proved profitable. Leather (1897b) presented the results of analyses of *usar* soils from different parts of India, showing regional variations in the type of salts present. His pot-culture experiments showed the salt-level effects on different crops. Results from other experiments followed: on the use of artificial fertilisers and gypsum (Moreland 1901), and on salt levels in well water for irrigation (Leather 1902). Watt (1902) examined the critical limits on the presence of certain salts for cereals, and included some American results on the use of alkali wastes.

8.8 Could they have learnt from the past?

The account of irrigation development presented in this chapter shows how policy makers in northern India approached the problem of irrigation salinity in the nineteenth century.

The *Reh Report* (1879) has provided evidence of the focus of policies for irrigation development in the North-western Provinces up to 1878. That development was not guided by the needs of the agricultural enterprise, but driven by economic policies. It is well known that strong commercial interests drove many British activities in India (Whitcombe 1972, Islam 1997, Wild 1999). Irrigation was no exception. The British regarded irrigation as a matter of *water delivery* and primarily a revenue-generating activity like other Government enterprises, such as railways and forestry.

As the networks of canals expanded across the northern plains there was no clear agricultural policy to guide the development of irrigated agriculture. At this time Robert Knight, in his paper *Indian Agriculturalist*, often criticised the Government of India for the neglect of agriculture. On 1 July 1876 he wrote (quoted in Whitcombe 1983: 98):

> There is great truth in [Corbett's] assertion that an irrigation cry and a drainage cry have induced the Government to embark in projects purely engineering and not agricultural, to trust the agricultural education of India solely to engineers and to district officers; the former of whom look upon agricultural projects from a purely engineering point of view . . . [In India] the science of agriculture should doubtless be made of the first importance and should have been called in to aid all projects of agricultural improvement.

Whitcombe has described the lack of co-ordination between those concerned with the design of irrigation expansion and those struggling with the growing problems of waterlogged and salt-affected land. In spite of the latter problems, 'the construction of the Lower Ganges Canal proceeded, from 1873 to 1878, much of it to cover areas actually or potentially threatened by *usar* and *reh*, with no provision for preventive measures.' (Whitcombe 1972:288)

The remark has been made elsewhere (Hobhouse 1985) that throughout the nineteenth century the government administration in India lacked a co-ordinated policy for the management of large-scale works. The skills necessary to manage such projects were slow to develop. The management of irrigation schemes is just one example of the problem. Hobhouse has analysed a similar lack of co-ordination in the Indian Government's commercial production of quinine. The cinchona, or quinine, industry was mature by 1880. Nevertheless, there was a lack of co-operation among British authorities in England, Calcutta, south India, Singapore and Ceylon. Hobhouse found there was no co-ordination between government departments, let alone between government and commercial growers, chemists, processors and merchants.

Imperial resource managers could have learnt much from the experiences that India could provide. But as long as India was regarded as a testing ground for European ideologies concerning the purpose, use and control of nature, British social and revenue policies ignored the social ecology of the country (Guha 1989, Hill 1997). Officials needed to understand the nature and extent of environmental change across many regions. In the highly flood-prone areas of Bihar the dynamics of the riverine environment 'mocked the concept of a permanent revenue settlement' (Hill 1997:6). The interaction of social, political and ecological variables was ignored throughout colonial history.

The water-pricing policy that operated in northern India in the 1870s produced two important patterns of behaviour:

The first pattern relates to over-watering (Figure 8.2). As more Indian villages had access to water from the expanding canal network, they progressively replaced the labour-intensive lift irrigation with flush irrigation. At the same time, the Canal Department adopted a water-pricing policy based only on the size of the field irrigated and on the type of crop grown. This method provided a rough surrogate for the volume of water used. However, because it did not restrict actual volumes used, it led to over-watering. In the absence of efficient irrigation practices, the groundwater rose. In time, rising salty groundwater caused waterlogging and salinised soils, and a subsequent reduction in harvests. As was the case in the Paniput villages in 1857, salinity created a serious decline in village income.

The second pattern relates to crop production for domestic and export markets (Figure 8.3). As the canal system expanded, more districts were freed from the constraints imposed by a dependence on rainfall. An important aim of intensive irrigation was to increase the annual yield of staple grains, and produce reserves for use in poor seasons. This would give a degree of security to drought-affected districts by reducing the probability of famine. However, a reliable source of water also gave villages the opportunity to invest in high-value crops (such as cotton, indigo and sugarcane) for the export markets. These crops needed large amounts of water, but brought a higher price than the staple grains. Whitcombe (1972:73) has argued that by the 1890s in some districts the attraction of growing these high-value crops had reduced the supply of staple grains that could be drawn on during times of famine. Consequently, an economic focus on producing high-value crops undermined the social policy designed to provide for famine relief.

In both situations the opportunity to grow crops independent of rainfall meant that villages were no longer forced to let fields lie fallow. This resulted in overcropping, and also hastened the rise in groundwater.

The problem of *reh* and *usar* lands continued to concern governments in northern India throughout the twentieth century. The concerns were essentially the same as those identified in the period to 1880. Insufficient natural drainage and hindrance to natural surface and sub-surface drainage by the canals were on-going problems. Other civil engineering works, such as railways, which were carried on embankments, also interfered with drainage. Seepage losses occurred from unlined or poorly lined canals. Inappropriate irrigation practices, especially excessive water use, caused land degradation. Moreover, all these factors were made worse in many cases when large-scale drainage works were postponed or abandoned (Ghassemi et al 1995).

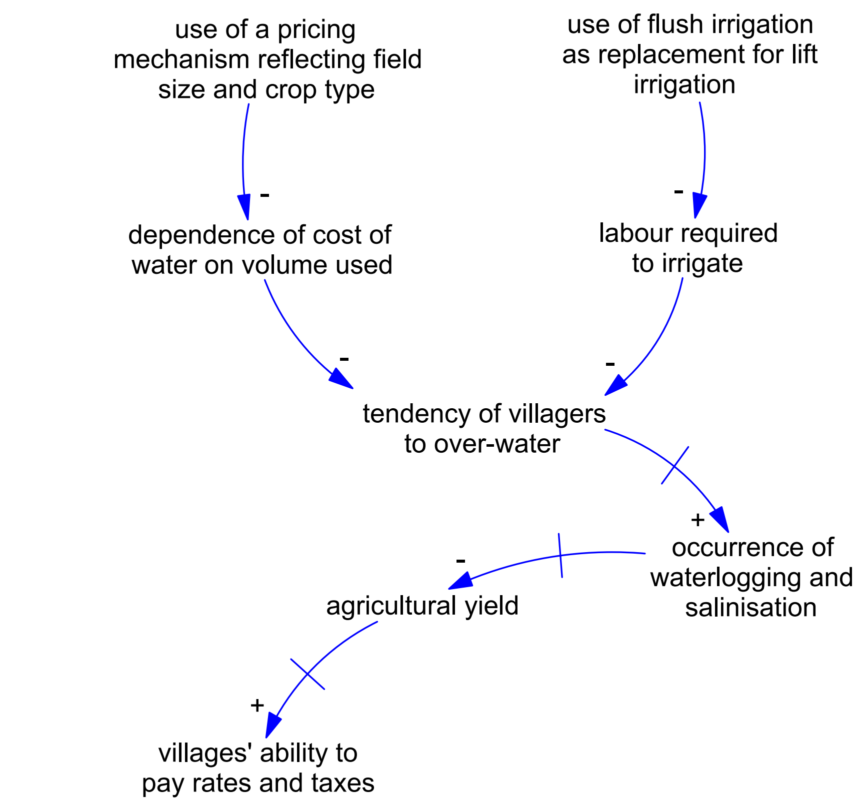


Figure 8.2: Effects of water-pricing policy. This policy encouraged over-watering, undesirable in sustainable agriculture. Note the delays marked on the causal links. See text for discussion.

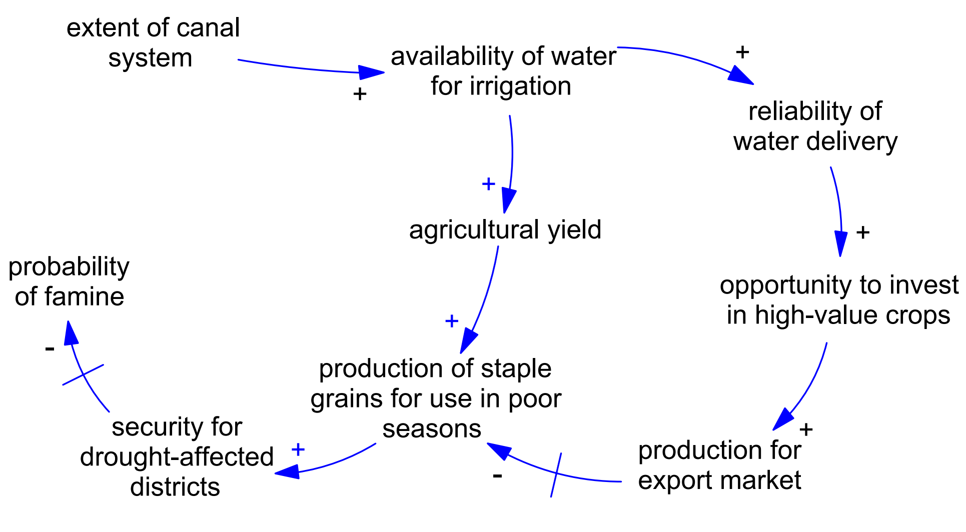


Figure 8.3: Effects of irrigation on the type of crop cultivated. In some localities high-value crops replaced staple grains. Note the delays marked on the causal links. See text for discussion.

A clear summary of the problem of irrigation salinity came from King (1900) (quoted in Trevaskis 1931:299):

> It is a noteworthy fact that the excessive development of alkalies in India, as well as in Egypt and California, is the result of irrigation practices, modern in their origin and modes, and instituted by people lacking in the traditions of the ancient irrigators, who had worked these same lands thousands of years before. The alkali lands of to-day, in their intense form, are of modern origin, due to practices which are evidently inadmissible, and which, in all probability, were known to be so by the people whom our modern civilization has supplanted.

Intensive canal irrigation in northern India mobilised naturally occurring salt and caused serious economic, environmental and social problems. Solutions were difficult to find since they required better scientific understanding, better political and economic decisions, and a need to co-ordinate the often-competing interests of government. Such was the nature of the problem in India at the end of the nineteenth century. The accumulated Indian experience represented a baseline from which the colonies in south-eastern Australia could have proceeded in developing irrigation. The response of those colonies to similar problems is investigated in the following chapters.

CHAPTER 9 OBSERVING GROUNDWATER AND SOILS IN SOUTH-EASTERN AUSTRALIA

This chapter is organised around the second question: Should the planners and policy makers for the Murrumbidgee Irrigation Scheme have been concerned about salinity? It traces the growth of knowledge of the soils and groundwater in south-eastern Australia in the late nineteenth century. For a discussion of the source materials used in this chapter see Appendix B.

9.1 The Landscape

The waterless character of a large part of Australia has been a subject much dwelt upon by those who first explored the continent. Knowledge of the naturally poor quality of the soils beyond the Great Dividing Range was readily available from observation. Yet the presence of salt in many of these soils and in the groundwater was not immediately apparent. Settlers had to acquire this knowledge by hard-won experience along with an understanding of the Australian landscape and its unique environment. Some of their early observations are recorded below.

9.1.1 Rivers

During his journey through southern New South Wales in 1829, Charles Sturt described the Darling as a 'noble' river. After tasting the water, he wrote: 'I found it extremely nauseous, and strongly impregnated with salt, being apparently a mixture of sea and fresh water'. Unfamiliar with the environmental history of the country, he could not explain whether it arose 'from local causes, or from a communication with some inland sea' — but, he wrote, 'the discovery was certainly a blow for which I was not prepared' (Sturt 1833, 1:86).

A sheep grazier and amateur scientist, W.E. Abbott, made observations of the natural environment. On his Hunter Valley property, New South Wales, he studied the effect of ringbarking on the stream flow. He concluded that 'when the timber is dead the large proportion of the rainfall which was formerly taken up by the roots of the growing trees and evaporated from their leaves is allowed to find its way to creeks and rivers. The fact that the Eucalyptus is perhaps the most vigorous growing tree known, and that it has been used successfully to dry up swampy land in other parts of the world, would seem to support this explanation.' (W.E. Abbott 1880:101)

9.1.2 Vegetation

After exploring the Murrumbidgee Squatting District in 1848-50, Surveyor Thomas Townsend reported that extensive saltbush plains spread out from one to three miles back from the Murrumbidgee River. He found the watercourses known as Billabong and Yanco Creeks were entirely destitute of water in the summer months (Townsend 1850). Some years later the

Riverina district of New South Wales was described as comprising 'vast pastoral plains, with occasional ranges, belts of myall scrub, and swampy flats, sometimes covered with reeds, and at other times under water. The cultivation is limited, there being little grown beyond Cape barley for horse feed, as both climate and soil are unfavourable' (Bailliere 1866:478).

The native saltbush (*Atriplex* spp.) attracted the attention of other travellers. The visiting English novelist Anthony Trollope (1815-1882) described the effect of sheep grazing on the saltbush plains of the Riverina. 'It was told that the salt-bush was disappearing on runs which had carried sheep for many years, and that it certainly receded as the squatters advanced. But, though the salt-bush may go, the salt remains' (Trollope 1874:214).

The sheep grazier, Abbott, observed the effect of the local water on vegetation in the central west of New South Wales. 'In 1880 I examined an orchard on the Lower Macquarie which had been planted about five years on a piece of salt-bush country. The trees grew with great luxuriance for some time, and then died. It seemed to me they died as soon as their roots reached the salt subsoil after passing through the surface soil, out of which the salts had in a great measure been washed by rain' (Abbott 1884:86).

Reports from the first explorers of Victoria described the Tragowel Plains on the Loddon River as having a salty watertable which rose to within centimetres of the soil's surface in wet seasons. Here a squatter, Edward Curr, found that the salt-tolerant pigface (*Dysphyma* spp.) covered the land. He described travelling in the area, where he found the plain 'from the Campaspe to Mount Hope, was one bed of ripe fruit' (Curr 1883: 423).

At Mildura a settler, James Henshilwood, had serious problems with salt on his property near the River Murray: 'My opinion is that wherever there is mallee growing there is salt' (Victoria 1896:10). Numerous varieties of Victorian mallee (e.g., *Eucalyptus oleosa*) are salt-tolerant.

9.1.3 Soils

Knowledge held by Aboriginal Australians on the nature of their environment was rarely recorded in the nineteenth century. Sometimes we find that European settlers have referred to indigenous knowledge. One such example is that of a farmer in the Goodooga district referring to pre-European saline land, who wrote: 'The People about this part call it scalded ground, as it will grow nothing' (Pollock 1903:110).

Charles Sturt had noticed the relationship between soils and plants during his 1829 exploration of the colony (Sturt 1833). The early land surveyors commonly learned to identify particular vegetation cover with local soil type.

A calcareous and gypsiferous rocky outcrop, known as copai (or copi), covered large areas along the Murray River on the *Tapio Run*. An agricultural officer described it: 'Wherever there is an abundance of it the land is barren, and in some places the soil is so much impregnated with it that after light showers, and when evaporation is great, it is brought up to the surface by the action of capillarity, and forms an efflorescence which has the appearance of hoar-frost or newly-fallen snow.' (NSW Dept Agriculture 1892)

9.1.4 Groundwater

Landowners made an important contribution to understanding groundwater. In 1880 T.K. Abbott was collecting data from wells on the Liverpool Plains, including measurements of the depth at which salt water appeared (T.K. Abbott 1880). At that time the chemical properties of groundwater and its suitability for agriculture were poorly understood. Abbott used a windmill to raise water from a shallow aquifer to water a small garden on his property in the Gunnedah district. He told a public inquiry how he allowed 'the water to spread over the surface but it did no good; it left a white sedimentary deposit on the surface, and caused a growth of vegetation which I had never seen before — a growth quite foreign to the district.' He believed that the groundwater was not suitable for irrigation because 'in most cases it contains chemicals — salt, or soda.' (NSW, 1885, Q.1806-8)

At the Lyne Royal Commission many witnesses described striking salt water while testing for freshwater bores. The Inspector of Public Tanks and Wells, H.A. Gilliat, explained how he collected from 20 to 30 pounds of clear salt crystals which had formed around the service tank and troughing at Holybox Well in 1879. So severe was the salinity that he recommended that this well be condemned. He understood that the water got its saline properties from the strata in which the wells were sunk; for the strata were heavily charged with salt. (NSW, 1885, Q.3600)

The Superintendent of Diamond Drills with the Department of Mines, W.B. Henderson, gave evidence regarding the presence of salt water in the bore near Bourke. 'It arises from the saline properties of the deposits which were made when the land was under the sea. There have been deposits at different times, and in some of the beds, which are almost horizontal, we get salt water and in others fresh water.' (NSW, 1885, Q.1933)

At the Royal Commission into the Construction of Public Wells and Tanks, the Commission heard that water in the Old Gunbar well in the Riverina was so saline it was unfit for stock (NSW, 1888-89, 3: 24).

9.2 Government Science

Scientific knowledge of groundwater and soils developed with government-led geological exploration of New South Wales from about the 1870s. It began with the need to understand the water quality in shallow aquifers, first in the Sydney region (Dixon 1878). It grew with the discovery of artesian water from the large natural feature known as the Great Artesian Basin. The pressure to find suitable water supplies for pastoral and agricultural expansion hastened the growth of this knowledge.

In 1878 the first artesian bore was sunk at *Kallara Station*, south-west of Bourke, at 144 feet. The NSW Government Astronomer, H.C. Russell, further roused interest in subterranean supplies of water. He had observed and demonstrated mathematically that the water flowing down the Darling River did not account for all the water falling in its catchment. He suggested that the missing volume of water seeped into underground storages (Russell 1879). These events encouraged exploration at greater depths, and within a few years many bores were supplying good flows in New South Wales and other colonies. The discovery of underground water made possible the greater use of remote stock routes in the far west of the colony. Under the *Public Watering Places Act, 1884,* the Government began to establish permanent tanks and wells for watering stock on these formerly waterless, precarious and little-used routes.

A period of severe drought from about 1877 drew attention, in a major way, to the problem of water conservation and irrigation in New South Wales. As one engineer said in 1883, ‘There are few questions of such importance, few questions with which the future prosperity of this Colony is so intimately inter-woven as that of irrigation.’ (Wood 1883)

This situation prompted the government to set up a Royal Commission into Water Conservation (1884) under William Lyne.[1] The Commission's terms of reference were: ‘to make a diligent and full inquiry into the best method of conserving the rainfall, and of searching for and developing the underground reservoirs supposed to exist in the interior of the colony, and also into the practicability, by a general system of water conservation and distribution, of averting the disastrous consequences of the potential droughts to which the colony is from time to time subject’. The Lyne Royal Commission operated from 14 May 1884 to Nov 1887. It heard lengthy evidence from 137 witnesses over a wide area of the colony, and published three reports over the period 1885-1887.

[1] A Royal Commission is a process authorised under State legislation which empowers the Governor to appoint a person as Commissioner to hold an inquiry. The Commissioner may summon any person to give evidence and produce documentary evidence, and be examined under oath. A Royal Commission is a costly and time-consuming investigative process generally reserved for matters of serious public concern.

One of the outcomes of the Lyne Royal Commission was the hydrological work in the colony. H.G. McKinney, engineer and Secretary to the Commission, completed surveys of the Murray and Darling Rivers, and measured accurate cross-sections and discharges of the Murray, Murrumbidgee, Macquarie and Darling Rivers. He instituted a system of gauging of discharge on all major rivers in the colony with stations at Albury, Gundagai, Dubbo, Bourke, Brewarrina, Walgett, Dora Dora and Warren. Starting with the survey data gathered by the Railways Department, he compiled the first map to connect all known levels with the river systems of New South Wales. This information was fundamental for engineers to design future irrigation systems. It would indicate where future canals and distributaries might be laid. McKinney's work during 1884-87 marked the beginning of a scientific approach to hydrology in the colony.

By 1889 the chemist W.A. Dixon had collected a number of water samples from wells and rivers in the eastern part of the colony (mainly on the Cumberland Plain). Although he had no samples from the interior, he stressed the importance of water quality in irrigating the dry inland regions. He presented the results of his chemical analyses at a meeting of the Royal Society of New South Wales (Dixon 1889b:465-6).

> It is evident that to apply water containing any considerable quantities of salts in solution to soils already containing large quantities of them will, unless there is efficient drainage, cause a gradual increase of salts until the soil becomes unfit for the growth of useful plants. So far as I know, there has been no systematic chemical examination of the various waters obtained by boring in this country and it seems a pity that this has not been done, as it is possible that in some of our arid country the use of such water, either directly for irrigation or indirectly and much more slowly through its use for watering stock, may for the time be advantageous, whilst the ultimate effect may be quite the reverse.

In 1891 the Superintendent of Public Watering Places and Artesian Boring, in the Department Mines and Agriculture, J.W. Boultbee, published his *Report on Artesian Boring*. Although artesian water was already used in America for irrigation, he believed that the idea had not yet attracted public attention in New South Wales. He identified the need for a program of water sampling as part of a proposal to consider artesian water for irrigation (NSW Dept Mines, 1891-92: 241). As the colony's geological history unfolded, scientists began to understand the chemical nature of artesian water. 'It is a well known fact that rain water which has percolated into the Tertiary formations, which overlie large areas of the Cretaceous formations forming our western plains, rapidly become salt in those areas where it remains stagnant.' (David, quoted in NSW Dept Mines, 1891-92)

Knowledge of soils grew more slowly. It was encouraged by an interest in identifying suitable native fodder plants. As a lecturer in chemistry at Sydney's School of Arts, Dixon made chemical analysis of various saltbush plants to provide advice to farmers on the best crop to feed stock. He wrote (Dixon 1880:133):

> It seems reasonable to suppose that in our peculiar climate, subject to periods of continued drought, and having in many cases soils peculiarly saline, that the plants which have withstood these influences for ages past would be more reliable than others developed under different conditions of soil and climate.

An engineer's account of healthy and unhealthy soils in the Sydney region provided discussion of their origin, parent material and formation (Henson 1887). In the same year T.W.E. David published a geologist's view on the origins of laterite soils in north-eastern New South Wales (David 1887). Later, Maiden presented a botanist's approach to soils from his concern with soil drift, ecology and landscape conservation, both on the coast and on the western plains (Maiden 1903). At this time, no particular attention was paid to saline soils.

9.2.1 The Government Chemists

By the 1890s there was enthusiasm for applying artesian water to irrigated agriculture in the western division, drawn from the immense water supply of the Great Artesian Basin.[2] But the analytical chemists were cautious. The task of careful chemical analysis was left to a very small group of men over the next two decades. W.A. Dixon (Sydney Technical College) and J.C.H. Mingaye (Department of Mines) were general analytical chemists. F.B. Guthrie, R. Helms and R.S. Symmonds worked specifically as agricultural chemists for the Department of Agriculture. The work of Dixon, Mingaye and Guthrie up to 1900 is described below, then the research of Guthrie, Helms and Symmonds, after 1900, is described in Appendix D.

In 1890 New South Wales established a Department of Agriculture as a separate government agency with a broad range of activities and responsibilities. Immediately the Chemist's Branch (first under Richard Helms, as consulting chemist, and then with Frederick Guthrie as permanent chemist) began a soil analysis program. The Department promoted this program through its journal, *The Agricultural Gazette of New South Wales*. It explained the value of such a program, and invited farmers, orchardists and others interested in soils to apply for free advice from the Branch (Helms 1980a and 1890b). Farmers were asked to supply information about the location and history of their samples to assist the soil analyst. They received a full analysis with advice on what would best grow in the soil, or how to improve soil quality. In the first decade over 500 samples were analysed from across New South Wales.

According to Dixon (1889a) soil analysis as a branch of a chemist's work was regarded as having little value in the 1880s. The techniques necessary to produce useful results were under-developed. Methods for collecting soil samples were poor; analysis was conducted with insufficient refinement to secure the necessary information; and there were few good

[2] The Great Artesian Basin is a groundwater resource that underlies 22% of Australia. It is used extensively in rural Queensland and South Australia. Parts of Northern Territory and New South Wales also have access to it.

technicians with the necessary experience at laboratory work. Dixon believed that at that time the measurement of soil constituents to only two decimal places failed to provide sufficient scientific accuracy.

In the early years, some farmers resented being asked to supply information about the source of the soil sample, as they appeared not to appreciate the collaborative relationship between farmer and scientist. On one occasion, when 'one or two [farmers] have pointed out that they do not wish to impart, but to obtain information', Guthrie (1897) was prompted to explain at length why the analyst needed information on location and how each sample was acquired.

By 1897 Guthrie recognised the desirability of a broad-scale analysis of soils across New South Wales. He signalled the need for analyses with which to characterise districts, but the distribution of samples received from farmers at that time was rather haphazard, and prevented the Chemist's Branch from drawing useful conclusions on districts. As a first step, Guthrie was looking to prepare a general description of the soils around Sydney in the Counties of Cumberland and Camden (Guthrie 1898, Guthrie and Barker 1900).

Dixon drew attention to the critical relationship between water and soils in irrigation. He was aware of the adverse effects of canal irrigation in India where the water-salt-soil relationship over a long period had produced soil degradation in large tracts of Upper India. He wrote (Dixon 1889b:473):

> The fresh water may contain a proportion of salt, and still be fresh water to the taste. It has been found in India, where irrigation is carried on in places where no drainage takes place, that particular patches of ground have been rendered perfectly barren through the continued application of water. This fact should be taken into account in any irrigation scheme brought forward in a country so dry as a good deal of ours is, and where there is a good deal of soil without drainage. Nothing at all will grow on the surface of these soils, and therefore I think a chemical examination of the deep waters should be obtained, even of the river waters used for these purposes, so that we might be able to judge with some degree of certainty of their effect for purposes of irrigation and cultivation.

The pastoral industry also showed interest in artesian water (NSW Dept Mines, 1894). Mingaye analysed water from 19 bores for their suitability for wool scouring, as well as other samples from the western division for suitability for stock and irrigation purposes (Mingaye 1892 and 1895). Many of the samples were chosen because they were suspected to contain injurious matter. His findings showed a development of understanding about artesian water (Minagye 1892:107):

> The value of a water for irrigation purposes depends not simply on the nutrient matters in solution, but the sediment in suspension must also be taken into account. The ingredients contained in water and valuable for this purpose are mainly nitrogen, potash and

phosphoric acid. Large quantities of alkaline salts excite a serious influence on the soil, and injure all useful vegetation, their action being a corrosive one; chiefly upon the root crowns and upper roots of plants. The alkaline carbonates (carbonates of soda and potash) damage the soil if present in excessive quantities, by the dissolution of the humus, which is often shown by the dark colour of the water and the black rings left where such waters have evaporated. This can to some extent be remedied when the salts consist chiefly of carbonate of soda, by the addition of a small quantities of gypsum (plaster of Paris) to the soil prior to leaching, which renders the humus soluble again, and thus prevents waste. The neutral salts i.e., chloride of sodium (common salt), sulphate of soda (Glauber's salts) and sulphate of potash, etc., are only injurious when present in large quantities, and relief can only be obtained by washing then out of the soil by under drainage, etc.

While studying the mineral content of artesian water for irrigation, Mingaye also recognised the importance of soil analysis. This view was shared by the Victorian Government Agricultural Chemist, A.N. Pearson; he noted that an excess of common salt and other chlorides would diminish soil productivity. Both chemists were aware of an experiment in India, where one tenth of one per cent of salt in a soil was shown to make the soil absolutely barren. Mingaye consequently proposed analysing some of the typical soils in the irrigable districts to measure the presence of alkali (Minagye 1892: 108, 112). It was at this time that Guthrie began a soil-analysis program in the Department of Agriculture.[3] Farmers in all parts of New South Wales sent soil samples and sought advice on the plantings best suited to their soils.

Mingaye presented results of analyses of artesian water to the Australian Association for the Advancement of Science (Mingaye 1895). Again, he emphasised that water fit for irrigation must be free from large quantities of injurious salts, both alkaline and neutral salts. It is evident from his paper that he was familiar with current scientific knowledge in this field. He referred to the great problem caused by alkaline salts in irrigated soils in India and America. He noted the large amount of valuable work that had been undertaken in those countries with regard to the use of groundwater for irrigation. He referred to research into saline soils under E.W. Hilgard at the University of California. Hilgard had found sodium carbonate (Na_2CO_3) to be the worst form of salt for irrigation. Experiments in California had shown that the application of gypsum (lime sulphate $CaSO_4$) had produced good root crops, such as beets and carrots. These crops are known to absorb a large amount of soluble salts. The research showed that keeping the soil loose during summer by regular tillage was important.

Mingaye was familiar with research in India on the effect of salts on different soil types. He had read the *Report on Reh, Swamp, and Drainage of the Western Jumna Canal Districts* (1881, Lahore Public Works Dept Press). He noted that *reh* rarely developed in sandy soils, was seldom apparent in stiff clayey soils, but it had a large effect on loams. An antidote for *reh*-affected land in the Panjab was lime nitrate ($Ca(NO_3)_2$). When the nitrate was mixed with the

[3] The Department of Agriculture continued the program until 1922.

injurious salts ‘decomposition occurs, and nitrate of soda with the sulphates and carbonates of lime are produced; these salts being directly beneficial to vegetation, the nitrate of soda supplying the plants with the nitrogen they so much need, and the sulphate of lime absorbing ammonia from the air.' (Mingaye 1895:267)

9.2.2 The Experimental Farms

As more bores were sunk in the western division of the colony, a satisfactory supply of water became available for travelling stock and human consumption. Once that need was met the Department of Agriculture considered extending artesian water from the most successful bores to irrigate small farms and orchards. The Superintendent of Public Watering Places and Artesian Boring, James Boultbee, suggested that experimental farms should be started to study the suitability of artesian water for irrigated agriculture. The experts who considered this proposal thought such a scheme was impracticable. They feared ‘that the soil and water were of such a nature as to render problematical the prolonged production of profitable crops’. Some also had concerns about the economic viability of the scheme. But the Minister for Agriculture was eager to explore possibilities of developing the western lands under irrigation, and supported the idea. He believed that 'if any scheme of water conservation could touch on the development of the arid western lands, artesian boring alone could afford the large and inexhaustible supply of the commodity most needed — water.’ In 1892 the Minister gave approval for work to begin at Native Dog Bore, 45 miles from Bourke (NSW Dept Agriculture 1898:273).

The Department of Agriculture laid out the first farm on 20 acres at Native Dog Bore in October 1892. Experiments were conducted with lucerne, millet, maize, sorghum, and a small sample of wheat. This farm was enlarged nine months later to include 456 fruit trees, 70 olives, 480 vines, a few bananas, 2000 forest trees, 23 sugarcane plants as well as pumpkins and melons. The soil was watered on average once every three weeks, and weekly in warm weather. The Department established other farms in the Bourke district. Similar crops were planted at Barringun Bore, and 100 acres were under irrigation to produce fodder for working horses. Forest and fruit trees and vines did better at Belalie Bore where the caretaker gave each plant one pint of water daily during September and October. At Enngonia Bore over 500 forest trees, 100 fruit trees and 80 vines were watered once every two or three weeks (NSW Dept Agriculture 1898).

Following the success of experiments at the Native Dog Bore, and guided by economic considerations, the Minister directed that an irrigation settlement be established closer to Bourke. In 1894 a 50-acre farm for ‘illustrative cultivation’ was completed at Pera Bore, seven miles from the town (Figure 9.1). It formed part of a settlement containing 640 acres that surrounded the bore. The site was divided into 20-acre allotments, which were available for lease in August 1895. A year later the government farm and local farmers exhibited some notable results at the Bourke Show. The crops included sorghum, amber cane, Kaffir corn, lucerne, broom millet, Japanese buckwheat, a range of vegetables, and melons of all varieties.

The Department of Agriculture carried out a series of experiments to determine the suitability of artesian water for growing fodder crops. Crops such as sorghum, corn, lucerne, millet and wheat, plus 11 different grasses were grown continuously on the same land under irrigation. Nevertheless, results from Pera over the first five years were contradictory (Allen 1908:17).

Generally, results from the government farms were sufficiently encouraging that the government passed the *Artesian Wells Act, 1897*, to further assist development in the western division of the colony. This act encouraged individuals, or groups of settlers, to share the costs of sinking a bore for their joint use. The Department of Mines provided the technical expertise and labour to find the artesian water, to sink the bore and to construct the canals to each holding. In 1899 a second experimental farm was established, this time at Moree, to investigate the use of artesian irrigation on the black soils of the north-west.

9.2.3 The Proto-Irrigation Schemes

The Department of Agriculture had taken the lead in investigating the possibilities of applying artesian water for irrigation in 1892. At the same time, the Department of Public Works was investigating the use of river water for irrigation. It established what I call three 'proto-irrigation' works (small schemes) at Wentworth in 1890 on the Murray River, and at Hay in 1892 and Balranald in 1893 on the Murrumbidgee River. They were seen as still in an experimental stage at the beginning of the twentieth century. Ultimately they were unsuccessful, partly because of the indifferent quality of the soil, but mainly because of the lack of practical experience of the first irrigators.

Around this time individual landholders were also conducting their own experiments with irrigation. In the western division they were using groundwater. Very few had river frontages to experiment with river water. In the Riverina William McGaw pumped water from the Murrumbidgee River and used irrigation on a small scale at *Kooba Station*. But the efforts of Samuel McCaughey were better known. He brought water to his property *North Yanco* to irrigate lucerne paddocks and other crops using some 60 miles of channels. Further north, N.A. Gatenby at *Jemalong* had impressive results with irrigated crops using water from the Lachlan River (Dunnicliffe 1903). Progress towards intensive irrigation moved slowly. None of these experiments was on a scale or at a stage where it could contribute to knowledge of groundwater and soils under irrigation.

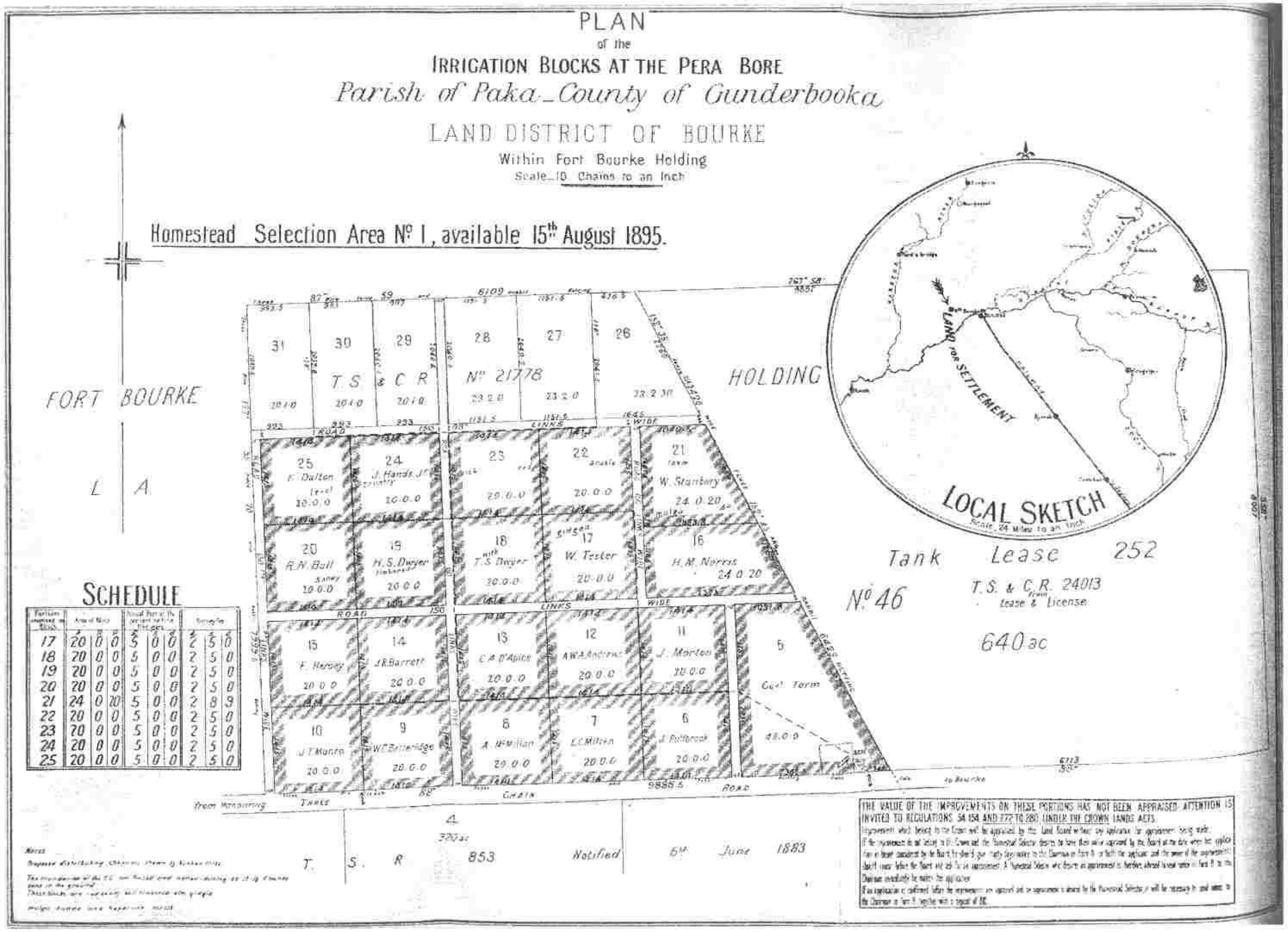


Figure 9.1: Plan of the irrigation blocks at the Pera Bore 1895 (as reproduced in *Agricultural Gazette of New South Wales,* 1898, 9:277)

9.3 Learning from Experience beyond the Colony

New South Wales was not alone in its desire to bring irrigation into the semi-arid regions of the colony. Nor was it alone in its need for good scientific knowledge. During the second half of the nineteenth century issues concerning groundwater and soils were challenging those involved in irrigation development in India, the western United States and Victoria. Scientists and policy makers in New South Wales were in a position to learn from experience in these places.

9.3.1 India

Scientists in New South Wales had a reasonable knowledge of the work that was taking place in Indian irrigation. Mingaye, as mentioned earlier, made several references to scientific papers from India. Voelcker's detailed study of Indian agriculture in 1893 was presumably also known. Guthrie (1892) cited a paper by Voelcker [1865] in which Voelcker had shown that 'the presence of more than 0.1 per cent of NaCl in a soil renders it sterile'. Dixon demonstrated an unusually good understanding of the problems with groundwater and soil in India, even though he never visited the country. His knowledge is most evident during discussions at the Royal Society of New South Wales (Dixon 1889, David 1893). He trained as an analytical chemist at the University of Glasgow under Professor Thomas Anderson. In the 1860s he worked as one of Anderson's principal assistants, when the University was making some of the first independent analyses of *reh* samples for the Indian Government (*JPRI* 1917-18). However, expert knowledge of this kind was of interest and available mainly to scientists.

Information with more popular appeal came from Alfred Deakin (1856-1919). Deakin was a member of the Victorian Parliament, Chairman of the Victorian Royal Commission on Water Supply (1885), and Prime Minister of Australia three times between 1903 and 1910. In the absence of published literature on water conservation and irrigation, he made tours of irrigation works in USA (1885), Egypt and Italy (1887) and India (1890-91) to gain an understanding of the issues. At the time, his detailed reports made significant contributions to the subject internationally. He toured the irrigated lands of the Indian sub-continent extensively, and published accounts of irrigation in a series of newspaper articles for the Melbourne *Age*, the Adelaide *Advertiser*, and the Sydney *Daily Telegraph*.

Deakin looked at India from the point of view of a promoter of irrigation development. A technical view of Indian irrigation came from the engineer Hugh McKinney (1846-1930). McKinney joined the NSW Public Works Department after ten years service in India.[4] He had worked on major irrigation development on the Bari Doab system and Lower Ganges Canal (1869-1879), and was well acquainted with the problems of irrigation salinity. In 1877-1878 he

[4] For an account of his career in India and NSW see Appendix E (Proust 2004).

was in charge of irrigation development from the first portion of the newly opened Fatehgarh Branch of the Lower Ganges Canal (McKinney 1893:398). In the Etah District, where McKinney worked, the *Reh* Committee had examined some of the worst salt-affected areas along the path of the Canal. This district suffered from poor drainage, as Deakin (1893:189) has described:

> . . . the Fategarh district, lying nearest to the Ganges, and drained by means of old river channels which intersected it in every direction. It may be taken as illustrating the conditions to be coped with in parts of the Doab. In wet years it lies soaked and sodden, while its people cry for drainage, which can only be partially given them, because of natural difficulties, and of the objection of those below to receive more water in such seasons . . .

McKinney was a strong and able advocate for irrigation in New South Wales, and communicated effectively with both government officers and farmers. His ideas have been recorded in scientific journals, government reports, newspaper articles and delivered in talks to meetings of farmers.

9.3.2 United States of America

Irrigation development in the western United States and the Australian colonies was closely related in time and context. Communities in the two countries shared the popular ideology concerning the creation of a 'garden environment'. They both benefited from the social arrangements that resulted from intensive agriculture and horticultural expansion (Tyrrell 1999).

Scientists in south-eastern Australia also learnt from scientific research conducted in America. Research in California was already well advanced when the Australian colonies began to contemplate irrigation. The problem of soil salinity confronted immigrant farmers new to the American south-west from the 1850s. After successes or disappointments on the Californian gold fields, prospectors were turning to a more secure life in agriculture. But in the semi-arid regions the presence of salt in the soils challenged their traditional ideas of agriculture. Canal irrigation was introduced in the south-west from the 1880s, and the existence of an agricultural college in California allowed scientific investigations to progress along with irrigation development. By the 1890s the presence of large concentrations of alkaline salts in irrigation water and soils was recognised as a problem.

From the 1890s, Australian scientists regarded the American E.W. Hilgard (1833-1916) as the principal authority on the subject of alkaline soils. Eugene Hilgard was a geologist, chemist and botanist who became Professor of Agriculture and Botany at the University of California, Berkeley, from 1875, and later Director of the Experiment Stations. With already a broad experience of American soils, he undertook research into a range of problems concerning irrigated soils. His work arose initially from the need to reclaim saline soils in the south-west and to understand the chemical and physical changes to the land as a result of intensive irrigation (Yaalon et al 1997). Hilgard's approach to the study of soil salinity, as described by his biographer, explains the reason for the wide respect he received. 'His constructive, over-all assessment, his blending of land forms, water tables, rock weathering, alkali processes, plant responses and cultural practices — including irrigation and drainage — offered a unified approach that is now seldom matched.' (Jenny 1961:123)

By 1877 Hilgard had clarified the composition of alkali in soils, and recognised three alkali conditions. First, neutral alkaline salts, such as common salt (NaCl), Glauber's salt (Na_2SO_4) and potassium sulphate (K_2SO_4), are injurious only when present in large quantities. They can be washed out of the soil by flooding and removed by underground draining. The second group comprises soluble earthy and metallic sulphates and chlorides, such as Epsom salts ($MgSO_4$), calcium chloride ($CaCl_2$), alum ($KAl(SO_4)_2$) and copperas ($FeSO_4$). These substances in the soil can be treated with the cheap and efficient antidote of lime. The third group comprises the alkaline carbonates and borates. These, especially the former, are injurious in the smallest amounts, rendering the soil-water caustic and corrosive. Gypsum is the antidote to these, so called, 'true alkali salts'. Hilgard found that as little as 0.08 per cent of sodium carbonate (Na_2CO_3) was sufficient to render the soil practically untillable. He identified the first two groups as the 'white alkali soils', and the third as 'black alkali soils' (Jenny 1961:43-44).

In the 1880s the alkali content of irrigated lands in the upper San Joaquin Valley was rising with the watertable. Hilgard recognised that the alkali salts were drawn up from below 'through the agency of the water evaporating upon the surface'. He found that as water leaked from the unlined irrigation ditches, the soil became waterlogged. This water had taken up 'the alkali salts developed by the weathering of forty feet of soil material for thousands of years, and had brought it to the surface by an easily intelligible process of upward leaching. As this water evaporated from the surface, its hoard of alkali salts was left behind and . . . wide stretches of land, where alkali had never been seen before, became spotted with alkali areas.' (Jenny 1961:47)

With the co-operation of local farmers Hilgard carried out field experiments to demonstrate the effectiveness of applying gypsum to soils affected by black alkali. It was an immediate success, and by 1890 gypsum was a widely used treatment for these soils in California. He recommended ways of counteracting the evaporation of soil moisture. He advocated measures to remove salts from the soil, by planting salt-tolerant crops, and leaching down salts by flooding and under-drainage. The work of the Experiment Stations addressed a wide range of problems common in arid-zone agriculture.

Hilgard's reputation in soil chemistry and paedology was firmly established in the 1890s, and his reputation grew internationally. Already in 1884 his work was known in India, and the government of the North-Western Provinces sent an engineer, W.J. Wilson, to California to learn about the research taking place at Berkeley. Hilgard was interested in the alkali problems in Upper India and read the *Reh Report* (1879) which, he said, presented an 'exact analogy' between the situation in northern India and the American south-west (Jenny 1961:59-60).[5]

On his visit to the United States in 1885, Deakin visited irrigation colonies in southern California, Colorado, Arizona, Kansas and Nevada, and irrigation works of Mexico. He learnt from local irrigators about their experience with salinity. In the *First Progress Report* of the Royal Commission on Water Supply (Victoria 1885) Deakin published results of soil and water analyses from California for comparison with Victorian conditions.

Later, the NSW Government sent James Boultbee to America to observe progress in irrigated agriculture in the south-west. Boultbee visited irrigation colonies in California, Arizona, New Mexico, Louisiana and Texas. At Berkeley he met Hilgard. Boultbee's report to parliament was a comprehensive account of many issues affecting irrigation and artesian boring in the United States (Boultbee 1902). An account of his visit which focused on scientific aspects of alkali in soils and water was delivered to the Royal Society of New South Wales (Boultbee 1903).

Boultbee's reports acknowledged research findings from Berkeley's Experiment Stations. In particular, he was alert to the dangers of using alkaline waters to irrigate lands already containing salt. He noted that once the agricultural chemists in California had identified the kinds of salts in soil and water, it was a simple arithmetic step for them to estimate how much alkali would be added to the soil each year. Accordingly, scientists could calculate the number of years within which the soil would become incapable of bearing ordinary crops. It was important, where possible, to flush the soils of excess alkali salts through into the sub-drainage at least once a year (Boultbee 1903).

Access to the Californian research probably became easier for scientists in New South Wales from the mid-1890s. It appears that the Royal Society of New South Wales received annual reports from the University of California, Berkeley, on a regular exchange basis from 1895 (Royal Society NSW 1895). By then, the chemists Mingaye and Guthrie were reading and referring to the research results from Berkeley. In his papers on artesian water for irrigation Mingaye made several references to Hilgard's *Reports of Examinations of Water and Water Supply* (Mingaye 1892 and 1895).

[5] This flow of knowledge was not one way. Irrigation engineering in India provided an example for American engineers who visited the Lower Ganges Canal project (Worster 2001).

In an article in the *Agricultural Gazette* (1898) an anonymous author (most likely Boultbee) summarised progress at the Pera Bore experimental farm. The Department of Agriculture, he said, followed the model of the American irrigation colonies, and he quoted from 'the reports available' to illustrate the success in California. The author distinguished correctly between the saline content of the soils, on the one hand, and of the water, on the other. He noted, 'It is one thing to drive the alkali from the soil to the surface by evaporation and another to deposit it from the water by filtration. In America they have the former contingency to deal with; in these colonies the latter.' He also found authority for local practices at Pera Bore in the findings from the research at Berkeley and in the Indian *Reh Report*.

9.3.3 Victoria

Victoria led the way with irrigation development in the Australian colonies, prompted by the need for storing water for use in the semi-arid areas of the colony.[6] In 1884 the Victorian Government asked the Deakin Royal Commission 'to make full and diligent inquiry into the operation and effect of the various schemes of water supply, and into the extent to which the present sources of water are utilized, with a view to ascertaining whether further and better provisions can be made for the conservation and distribution of water for the use of the people'. (Victoria 1885) Murdoch (1923) noted that at the time practically no literature in English or any other language existed on the subject of irrigation. Hence, Deakin undertook fact-finding tours of irrigation colonies overseas (see §9.3.1).

In the United States Deakin met George Chaffey, a Canadian pioneer of irrigation. He was impressed with the progress achieved by George and his brother in California. In 1886 under an agreement with the Victorian Government, George and W.B. Chaffey were granted 100,000 hectares and set up an irrigation colony on the abandoned *Mildura Station* by the Murray River (Figure 9.2). They also set up a colony on the South Australian side of the Murray at Renmark. These colonies were located on mallee soils which proved to be strongly alkaline. Owing to the low rainfall of the lower Murray area the salts in the soils were only slightly leached (Wadham et al 1964:38). The first drainage and salinity problems appeared at Mildura in 1891-92. Coupled with other factors, particularly economic, the Mildura settlement experienced a serious setback in the early 1890s. Powell (1989) has pointed out that the Chaffeys were land developers, more than irrigators, and that their Australian ventures followed the pattern typical of other land development sagas.

[6] J.M. Powell has written widely on the development of water resources in Victoria and elsewhere in Australia (e.g., Powell 1989, 1991, 1993 and 1998).

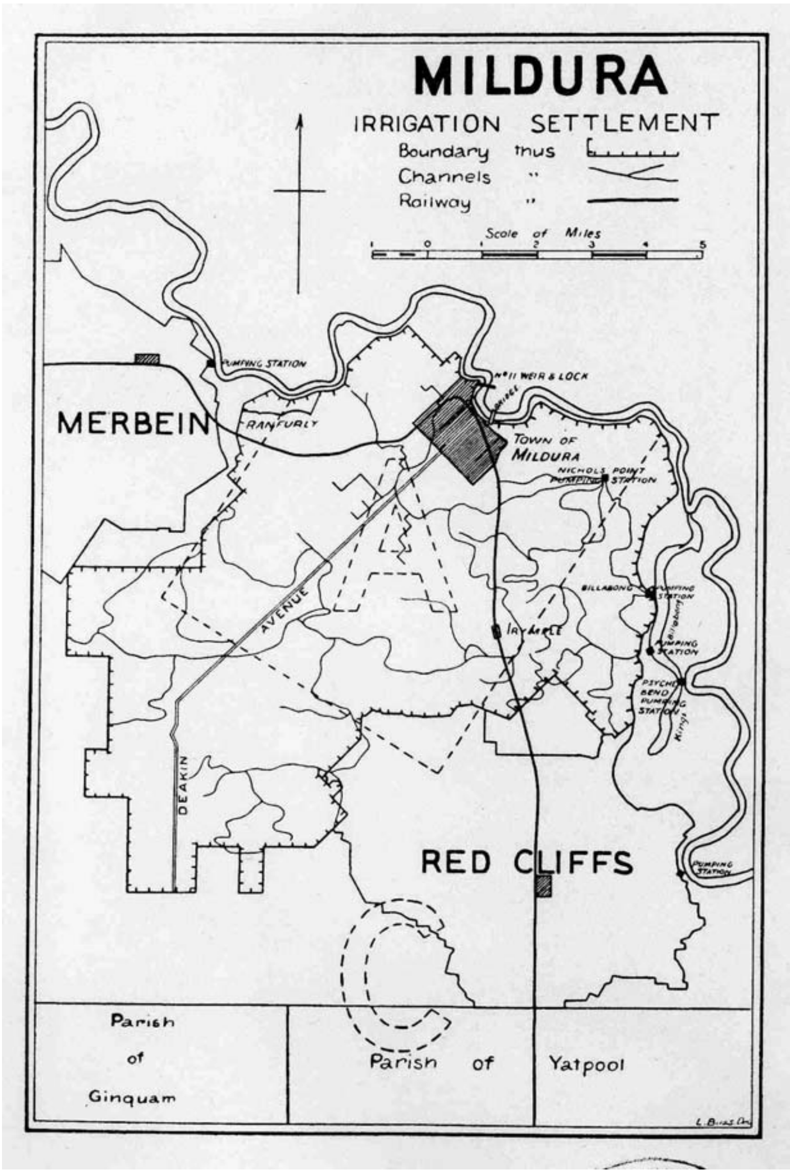


Figure 9.2: Plan of the Mildura Irrigation Settlement (Alexander 1928)

A Royal Commission on the Mildura Settlement examined the causes behind its failure (Victoria 1896). It heard evidence relating to groundwater and soils: over a comparatively small area seepage from along the channels had damaged vegetation by bringing salt, contained deep in the soils, to the surface. Although losses due to evaporation and percolation were as high as 50 per cent, experts believed that an improved drainage system would improve the operation.

Witnesses gave evidence on salt in the soils, and water seeping from unlined canals. The horticultural journalist, William Taylor, was familiar with Hilgard's work in California, and recognised that saline lands could be used for salt-tolerant crops. The land valuer, William Salmon, knew that saline matter came up in depressions in parts of the mallee country: 'You will see a white material on the surface'. George Chaffey gave this description of the problem (Victoria 1896:191):

> . . . the trouble was that alkaline soils were not suitable for the trees that were planted. The Company did not know that the land was unduly salty. There is a large proportion of land in Mildura which has to be well drained, but if there is any salt in it we do not know it; it percolates downwards, but in this class of the mallee soil the salt is brought to the surface by what I should term "water-logging". Too much water has been put into the soil to begin with, and this has been drawn to the surface and with it the alkali, the water has evaporated and left the alkali.

One settler, James Henshilwood, cultivated 40 acres with fruit trees, much of which became seriously salt-affected within six years. He told the Commission how he had sent soil samples to the Department of Agriculture in Victoria and to Hilgard at Berkeley for analysis. Some soils on Henshilwood's land contained as much as 40 per cent calcium carbonate ($CaCO_3$). Hilgard described this as 'a pretty precarious soil for citrus trees', and recommended under-drainage and washing out of the salts. Henshilwood's approach was judicious watering which he described to the Commission (Victoria 1896, appendix A2):

> We should water often, but not much at one time; not to let the irrigating water penetrate more that about 4 feet deep. I am speaking of mallee soils, where salt is present. So far we have been compelled to give heavy waterings, as we never knew when we would get it again.

The Royal Commission presented its report in September 1896. The result of the inquiry was an amendment to the *Mildura Trust Loan Act,* the original legislation that established the colony.[7] This initiative was concerned exclusively with economic measures affecting settlers and mortgagees. The Act authorised new arrangements for the survival of the settlement. It was debated in both houses of parliament during 1897, without any discussion of the salt problem on which so many witnesses gave evidence, or of the poor irrigation practices.

George Chaffey's biographer claimed that the members of the Royal Commission were politicians hostile to the Chaffey Brothers. 'All were laymen, without the slightest pretensions to expert knowledge of the irrigation, engineering and social problems they were called upon to investigate.' (Alexander 1928:228) He wrote that their report was biased, and 'cannot be too strongly condemned for its contemptuous indifference to the evidence tendered by such men as Deakin and Stuart Murray. . .' Alexander is referring to complaints about the unlined condition of the Mildura channels, and that the Royal Commission heard much evidence on this. Yet Deakin gave evidence that he had seen unlined channels at Riverside, California, running through sandy soil comparable with the Mildura conditions (Victoria 1896, Q.5216). Stuart

[7] The *Mildura Trust Loan Amendment Act, 1896,* was passed in 1897 (Victoria Parliamentary Debates 1897).

Murray, Chief Engineer of Water Supply in Victoria, said that 'no man in his senses would attempt to line all the channels, because many would do without any lining at all if properly maintained' (Q.3433). Furthermore, the cost of lining all channels was prohibitive.

Although the Chaffey Brothers had already established an irrigation colony in 1882 at Ontario, California, they appear to have been ignorant of the local research on irrigated soils. The influence of the Californian studies is not evident in the planning of Mildura.

Despite the occurrence of salinity at Mildura, the Victorian Government later ignored warning from its own irrigation engineers. Alfred Kenyon (1867-1943) was involved from 1887 in opening up the northern and western Mallee by extending irrigation from the Murray River. He was familiar with the causes and effects of salinity as experienced in India in the nineteenth century, and was one of very few Australians to make specific reference to findings of the Reh Committee (1879). Later, he wrote (Kenyon 1907:208) that:

> . . . introduction of irrigation increased the alkali areas but by seepage from the canals, and by excessive use of water in irrigating, and that where the removal of such excess waters was mainly due to evaporation, the result was a destructive accumulation of alkali. The remedy proposed by the [Reh] Commission was subsoil drainage.

Another engineer, G.H. Tolley, was Secretary of the Chaffeys' Mildura Irrigation Trust before 1896. Later, as Manager of the Wyuna Irrigation Farm, he emphasised the dual necessity of efficient drainage and careful watering. It was essential, he wrote, 'to avoid the grievous mistakes which had been made in applying water to areas utterly unsuitable for irrigation [at Mildura]'. (Tolley 1911:223)

Victoria established a Department of Agriculture in 1872. The Department's Chemical Branch was under Alfred Pearson (1856-1933), an agricultural chemist who joined the Victorian Government in 1886 from India. It seems that the Branch was always under-funded, and the agricultural community did not appreciate the importance of its work. Trained staff frequently moved to better positions outside the Department. Pearson himself left in 1902 and went to South Africa. The Branch analysed soils samples for farmers, as well as water samples from the Victorian water supply. Research bulletins appeared occasionally to publicise particular work in the Department, but there was no regular series of publications with information for farmers until 1903, through the *Journal of Agriculture of Victoria*. In the absence of a regular and earlier series of articles it is difficult to trace the growth of interest in soils in general or, indeed, saline soils. Nor did the Royal Society of Victoria publish papers relevant to saline soils and groundwater in its journal during the period up to 1900. Nevertheless, the problems of saline soils at Mildura and the hardships they produced were well known to settlers across the Murray in New South Wales.

9.4 Debate on the Danger of Salt

By the 1890s scientists were keenly discussing the suitability of artesian water for irrigated agriculture in New South Wales. The chemists, Dixon, Mingaye and Guthrie, advocated a precautionary approach. Those with a strong belief in the undoubted benefits of irrigation, led by McKinney, were enthusiastic. Nevertheless, the problem remained: scientists and landowners needed to understand the chemical nature of groundwater and soils in particular districts. Yet the mineral content of artesian water showed wide variation across the colony.

At a meeting of the Royal Society in 1889 Dixon first commented on the dangers of a gradual accumulation of salt in the soil (quoted in §9.2). A squatter from the Cobar district, P.R. Pedley, told the same meeting that the wells from Hillstone and Cobar contained large proportions of sulphate of magnesium. He understood that the soil was impregnated with these salts, and that the rain had to a certain extent washed the salt out of the surface soil (Pedley, reported in Dixon 1889b:474):

> If you are going to start a garden there you will find that plants will grow, but trees will not. If you put in fruit trees you find that as soon as the roots go down beyond a certain depth the trees fail entirely. . . the larger roots get down into the salt and the vegetation suffers. It strikes me that if they are going to use for irrigation waters the so-called salt water wells, the result will be the impregnation of the surface soil and prejudice to the vegetation.

Although there had been no systematic chemical examination of artesian water, Dixon was well aware of the long-term effects of salt. Later, he said (Dixon, reported in David 1893:437):

> All the salts held in solution in water . . . would gradually accumulate in the soil and render it absolutely sterile as has been the case in some places in India. This effect might not be noticed or act injuriously for ten, twenty, or fifty years, but under the conditions stated it is sure to come sooner or later according to the quantity of matter held in solution.

McKinney (1892:15) held a different view:

> The statement that artesian water is fatal to vegetation is generally baseless. Even if the cumulative effect of the water should in some instances prove temporarily injurious, new land could be cultivated while the old recovered. So far, this cumulative effect is only a fear. Artesian water is extensively used in American irrigation.

A year later, however, he modified this view, conceding that some artesian waters contained such proportions of salts that the water should be used with caution in irrigation (McKinney 1893:400). The geologist, Edgeworth David, also believed that 'the danger had been much exaggerated' (David 1893:441).

Speaking at a Farmers' Conference in Sydney in 1895, McKinney spoke strongly in favour of irrigation. He claimed that many statements publicly made on the subject had exaggerated the danger of spreading salty efflorescence by irrigation water. He acknowledged that a danger could exist if careless irrigation practices were allowed. But he claimed that every precaution had been taken in India with satisfactory results. 'It is necessary to add that land which is not fit for irrigation, so far as regards a high proportion of salts is so uncommon in this Colony that little need have been said on the subject if it had not been for the reason . . . that an exaggerated importance has been given to it by various writers' (McKinney 1895:548).

In 1896 the New South Wales Government asked an irrigation engineer from India, Colonel Fredrick Home, to review proposals for irrigation development. In his *Report on Prospects of Irrigation and Water Conservation in New South Wales*, Home commented on the artesian water supply in the western division of the colony. He wrote: 'As usual in the case of those new to irrigation, water was being used far too lavishly, and too little attention was being paid to cultivation; but these errors will doubtless be discontinued in time under the guidance of the Superintendent, and with the example set in the Government farm.' Home noted that 'as the soil cakes on the surface after irrigation, and the water from [Pera] and other bores contains alkali, the necessity for keeping the surface broken up and for using the water sparingly is obvious.' With respect to new bores, Home advocated a careful preliminary investigation of the soils. Aware of the serious problem of drainage in India, he stressed that on no account should the question of drainage be neglected. (NSW 1897:21-22)

When planning the experimental irrigation works near Bourke, the Department of Agriculture had been aware of the potential problems inherent in artesian water. Mingaye had summarised the prospects before the Public Works Committee: 'water containing from 30 to 60 grains of total solids can be used without any fear of their proving corrosive to plant life or to the soil provided they are carefully used. There must be a proper system of drainage, and the soil must be properly tilled.' The Department had consulted the findings of Hilgard in California and the Reh Committee in India. Guthrie, the Department's agricultural chemist, had given advice. He had analysed seven soil samples from Native Dog Bore after two years of irrigation. He found only two with a slight alkaline reaction, and the remainder neutral (NSW Dept Agriculture 1898:276).

Many saw the problem of salinity as defined by one of two situations. In the America case, irrigation was providing the moisture to draw the alkali from deep in the soil to the surface by evaporation. In New South Wales the problem was that irrigation water was depositing alkali on the surface and affecting the soil by filtration. According to Boultbee, the Department of Agriculture was largely guided by the success of irrigation with artesian water in California. He described 'the wonderful development at Fresno in the San Joacquin Valley', the prosperous fruit-growing settlement at Riverside, wholly dependent on artesian water, and 'the revolution in the condition of land' in the arid regions of the western United States (Boultbee 1898:89-97).

9.5 Should they have learnt from the past?

The account of scientific development presented in this chapter shows how scientists and men working on the land were starting to understand the problem of salinity in south-eastern Australia. Because the 1880s and 1890s was a period of intense learning about the natural environment from observations and practical experience, when irrigation was in an experimental stage, it was not a period in which significant policy learning took place in Australian.

By the end of the century south-eastern Australia was experiencing severe drought. As stock were dying by the millions, many in New South Wales believed it was imperative to develop the colony's underground water resources. Following the Lyne Royal Commission (1884-87) important engineering data had been assembled on river discharges and from land surveys. The government chemists had made progress in understanding the soils and groundwater of the colony. Knowledge from both domains was vital for the development of irrigation. Nevertheless, the engineers and scientists were concerned with different fundamentals of irrigation: the former with water delivery, and the latter with the more complex issue of crop production. The knowledge and experience of the engineers were well established. As the knowledge of the scientists depended on the slow accumulation of local experience they always lagged behind the engineers, and often had difficulty in influencing policy. This pattern of behaviour was also evident in India.

Artesian water had proved to be fit for stock watering, but there was not yet unanimous opinion on its suitability for irrigated agriculture. On the one hand, Boultbee was optimistic for the future of agriculture in the western lands, 'where we have a soil of unbounded fertility, free from the alkali so prevalent in American soils, only requiring the beneficent aid of the water now lying hidden beneath the surface.' He interpreted the initial results from the Pera Bore settlement as evidence that 'the prejudice or fear as to the unsuitability of artesian water for irrigation is passing away' (Boultbee 1898). On the other hand, Gorman, the manager of Pera Bore, witnessed the detrimental effects of artesian water on fruit trees, vines and various crops in the Bourke district. In less than 12 months the ground on which they grew was barren. He attributed the failures to poor farming practices. Soils irrigated with artesian water demanded that the irrigator work them thoroughly. Therefore, Gorman was cautious of how long soil quality would last under artesian irrigation (Gorman 1898).

Time would prove that the chemists were correct in concluding that water from the Great Artesian Basin was unsuitable for sustainable agriculture. In addition, as chemists continued to improve their understanding of the soils in the colony from experiments at the government farms, there was growing evidence that any attempt to develop river-based irrigation would need to be approached with caution. There was clearly a danger that irrigation salinity could impact large-scale schemes. The MIA planners and policy makers should have been concerned.

CHAPTER 10 INTENSIVE IRRIGATION IN NEW SOUTH WALES

This chapter is organised around the third question: Did planners and policy makers for the Murrumbidgee Irrigation Scheme learn from the past? It also contains background material on the development of the scheme intended as a basis for the analysis in the next chapter. For a discussion of the source materials used in this chapter see Appendix B.

10.1 The Setting

Steps towards intensive irrigation in Australia were taken in the first years of the twentieth century, and in 1906 the NSW Government passed enabling legislation for the Murrumbidgee Irrigation Scheme. The scheme began operation in 1912. This chapter principally describes the planning and development phase, and the first two decades of its operation. During this time, policy makers, farmers and scientists faced the full complexity of a human-environment system, as they attempted to learn about intensive irrigation from their own experiences. Their early efforts were made all the more difficult as they proceeded in the context of World War I and another drought, both of which began in 1914.

The prospect of intensive irrigation in New South Wales had been debated widely since the Lyne Royal Commission (1884-87). McKinney had been an enthusiastic promoter of irrigation across the state (see Appendix E). Yet he was unable to accelerate the pace of development as the community responded to good seasons with complacency. When the cycle of bad seasons inevitably returned in the mid-1890s, a serious economic depression accompanied a prolonged drought. The worst year of this drought was 1902 when stock were dying by the millions, and residents were walking off properties. By 1903 some 620,000 acres (251,100 ha) had been abandoned in the Hillston District on the Lachlan River (NSW PSCI 1903:3).

McKinney left the Department of Public Works in 1900 to promote his plan for a large irrigation scheme in the Riverina. He envisioned this as a private enterprise, based on plans he had drawn up originally in 1891. McKinney was joined in this enterprise by Robert Gibson, an original selector in the Hay district in 1874, a grazier and prominent member of the Hay community. Among other things, Gibson had been a founding member and, later, President of the Hay Irrigation Trust. Together, in 1903, the two men put forward a proposal to government for irrigating the northern bank of the Murrumbidgee River in the region north-west from Narrandera.

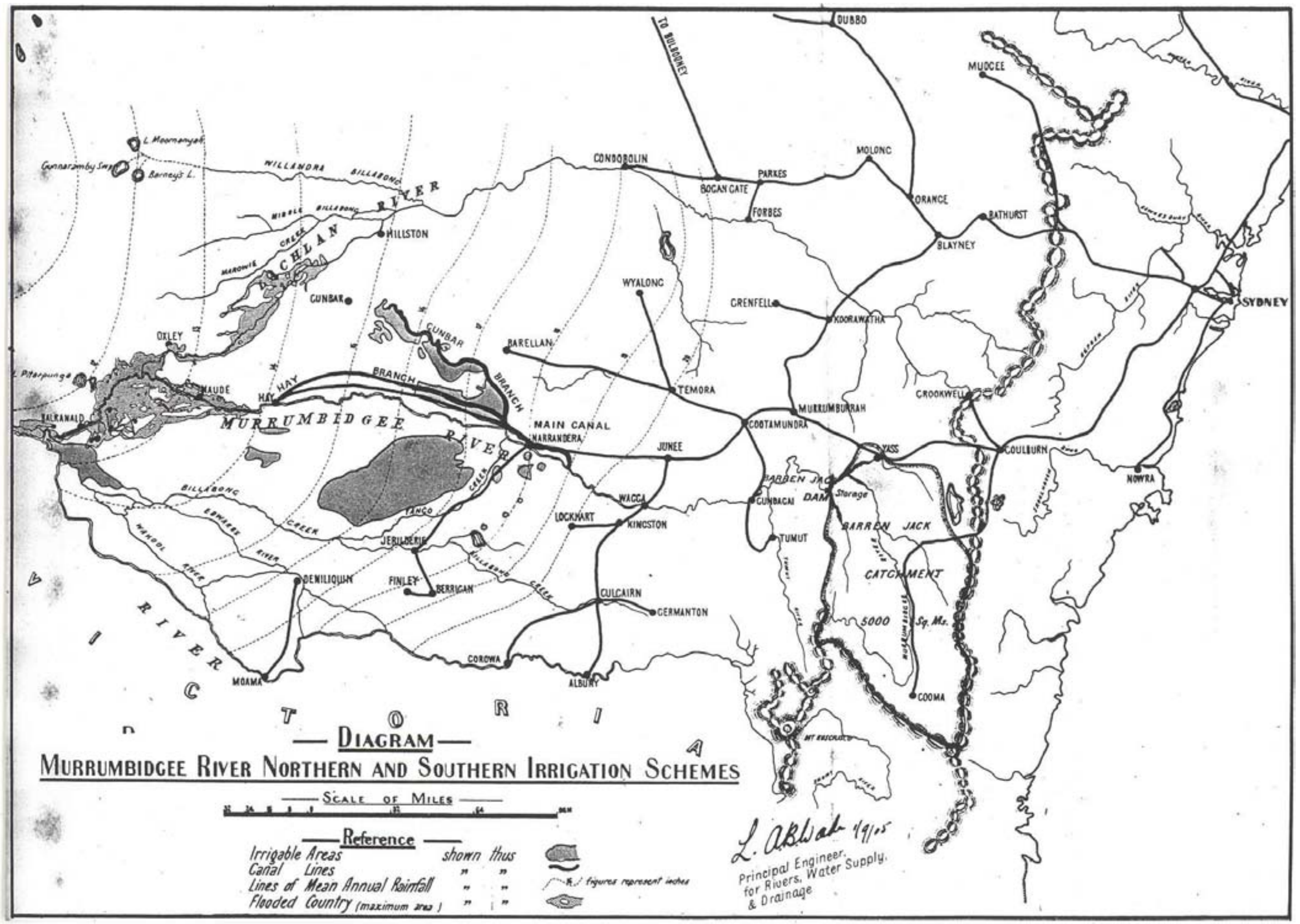


Figure 10.1: Proposed irrigation schemes from the Murrumbidgee River. (Plan drawn by NSW Public Works Department 1905; as reproduced in the *Agricultural Gazette of NSW* 1907)

10.1.1 The McKinney-Gibson proposal

McKinney and Gibson proposed establishing a system of irrigation and water supply in the district lying between the Murrumbidgee and the Lachlan Rivers by constructing a storage dam at Barren Jack Mountain in the New South Wales Southern Highlands. From the western boundary of the town of Narrandera an off-take canal would serve the area between Whitton and Gunbar, and a branch canal would serve the district of Hay and Booligal. The scheme was estimated to cost about £300,000 to be supplied by private financiers from Victoria.[1]

The proposal to government took the form of a private member's bill, known as the *Murrumbidgee Northern Water Supply and Irrigation Bill*, and was tabled in the New South Wales Parliament on 1 September 1903.[2] It then went before a Parliamentary Select Committee of Inquiry in that year (NSW PSCI 1903), and again two years later (NSW PSCI 1905) where details of the proposal were examined and certain amendments made.

The State authorities were reluctant leaders in water conservation and irrigation development, but the initiative of McKinney and Gibson forced the NSW Government's hand. The Department of Public Works held a conference on water conservation and irrigation in Sydney in January 1905 (NSW PWD 1905a), and in September presented its own proposal for irrigation north of the Murrumbidgee (NSW PWD 1905b) along very similar lines to the McKinney-Gibson proposal (Figure 10.1). In January 1906 both proposals were referred to the Parliamentary Standing Committee on Public Works (NSW PSCPW 1906). This Committee conducted a thorough inquiry over nine months. Finally, the NSW Government adopted a modified version of the two proposals. The *Barren Jack Dam and Murrumbidgee Canals Construction Act 1906* marked the formal beginning of a scheme that was fully funded, owned and operated by the State Government. Table 10.1 lists these steps in the process.

Accounts tracing the early years of discussions leading to the Murrumbidgee Irrigation Scheme are few, but the public inquiries during the period under review provide useful historical summaries of events. The public inquires held between 1903 and 1906 predominantly addressed the economic viability of the scheme, site selection, land acquisition, engineering design and water delivery — all primary issues for any irrigation scheme. The environmental implications of intensive irrigation received little consideration. It was only when downstream pastoralists became concerned about the potential loss of natural flooding of their perennial pastures that discussions touched on environmental issues. From the activities that took place at this time it is possible to find evidence bearing on the community's level of understanding of soils and groundwater, and in the following sections I examine this evidence.

[1] For a detailed account of the political background see Cowper (1968 and 1987).
[2] G.S. Briner, the Member for Raleigh, introduced the Bill.

Table 10.1: Preliminary steps towards the Murrumbidgee Irrigation Scheme	
1903, Sep 1	McKinney-Gibson proposal, *Murrumbidgee Northern Water Supply and Irrigation Bill,* tabled in parliament for the first time
1903, Sept 24 - Nov 12	McKinney-Gibson Bill went before a Parliamentary Select Committee of Inquiry
1905, Jan 16-20	Public Works Department Conference on Water Conservation and Irrigation
1905, July 11	McKinney-Gibson Bill tabled in parliament for the second time
1905, Aug 9-24	McKinney-Gibson Bill went before a Parliamentary Select Committee of Inquiry for second time
1905, Sept 1	Public Works Department proposal to Minister *Proposed Barren Jack Storage Reservoir and Northern Murrumbidgee Irrigation Scheme*
1906, Jan - Oct	Both proposals went before the Parliamentary Standing Committee on Public Works
1906, Dec	*Barren Jack Dam and Murrumbidgee Canals Construction Act, 1906*

10.1.2 Field studies in the Riverina

In the period from 1903 to 1906 the NSW Government undertook various field studies of the Riverina to gather information on the soils in the areas proposed for irrigation. The reports from these field studies and the evidence of witnesses at the public inquiries, connected with the events listed in Table 10.1 (see §10.1.3), reveal the existing attitudes towards of soils and groundwater.

Land survey by Department of Public Works, 1903: The Chief Surveyor, A.L. Lloyd, completed a land classification survey over seven months. It covered 2.635 million acres (1,067,175 ha) and embraced a stretch of country north of the Murrumbidgee River west and north-west of Narrandera to the Lachlan River, about 20 miles (32 km) from Hillston. Lloyd examined soil quality and subsoil depth by means of trial holes dug with a spade where a change of soil was observable. To achieve this he travelled over 1450 miles (2334 km) in vehicles. He took 15 soil samples (a surprisingly small number), and the lands were classified into four groups according to soil quality (Table 10.2). In his report, Lloyd commented on the importance of good drainage, and how irrigation water must be drained off the lands as soon as it has fulfilled its purpose. He showed knowledge of the dangers of waterlogged soils and their association with fevers (i.e., malaria, well known in India). However, he did not mention the danger of excess water mobilising the salts in the soils — a phenomenon equally well known in India at this time.

Table 10.2:
Summary of land and soil classifications for the Murrumbidgee Irrigation Areas developed by Lloyd in 1903

Soil group	Soil type	Area	Surveyor's notes
No. 1	Rich chocolate or sandy loam; good depth, with fairly retentive subsoil	106,300 acres (43,052 ha)	Best land for irrigation, unlikely to cause failure from over-watering
No. 2	Chocolate or sandy loam, 6 to 10 inches deep, with fairly retentive subsoil	473,820 acres (191,897 ha)	Best land for irrigation, unlikely to cause failure from over-watering. But as this soil type approaches the saltbush plains it becomes very shallow. It is doubtful if more than 4-5 years' crops could be grown without resorting to manuring.
No. 3	Black, red, and grey clay soil; fair depth, heavy clay subsoil	390,680 acres (158,225 ha)	Fear that on this land over-watering could cause crop failure in the hands of inexperienced irrigators.
No. 4	Soil suitable for growing grass under irrigation	558,300 acres (226,112 ha)	Opinion that it will never pay to irrigate land for growing grass. This area need not be considered.

NSW Standing Committee on Public Works, 1906:158-160

Soil survey by Department of Mines and Agriculture, 1905: The Fruit Expert in the Department of Agriculture, W.J. Allen, extended the land classification work of Lloyd with a soil survey. Allen collected 15 soil samples from which he produced a classification system for first- and second-class lands (i.e., first- and second-class lands for irrigation, and generally for irrigated fruit trees). The first-class lands, north of the river, were situated close to the hills to the north of Mirrool and the Wah Wah Creeks. They comprised rich red loams of considerable depth, with a rubbly limestone subsoil and good natural drainage. The second-class lands were located on both sides of the river, and included *North Yanco, Gogeldrie, Kooba* and *Beneremhah Pastoral Holdings*. Generally, they comprised a shallower soil of a heavier nature, which was not well suited to irrigation (Figure 10.2). This division represented what would become known as the irrigation areas at Mirrool (with first-class land) and at Yanco (with second-class land). Allen regarded the soils best suited for the growth of crops under irrigation as 'those of a light loamy and porous character, notwithstanding the fact that they are sure to absorb more water than the heavier soils. Having the advantage of good natural drainage, those light soils will not become waterlogged, as the heavier soils are likely to do.' (NSW PSCPW 1906:146)

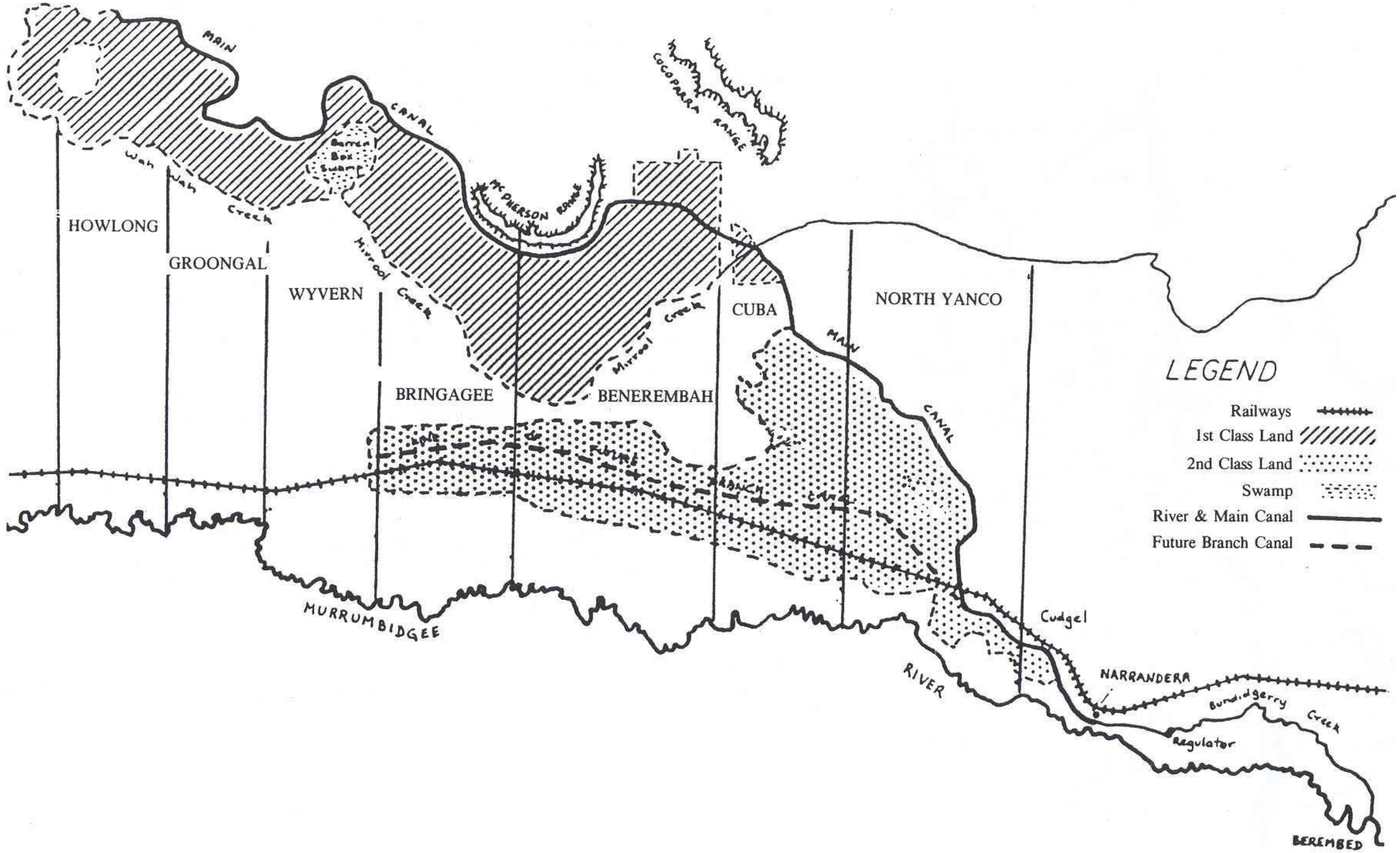


Figure 10.2: Murrumbidgee Irrigation Areas. Plan showing the first-class land in the Mirrool area and second-class land in the Yanco area (Cowper 1967).

Soil analyses by Department of Mines and Agriculture, 1905 and 1906: The agricultural chemist, F.B. Guthrie, analysed the 15 soil samples collected by Allen. This was a very small sample considering that it was called on to represent over 600,000 acres (243,000 ha) between Narrandera and Gunbar. Later, in 1906, Guthrie himself visited the area and collected 13 more samples. His analyses addressed the mechanical properties of the soils and adaptability for irrigation, capillary power, the presence of particular chemical elements and humus, bacterial activity and nitrifying ability, leading to a statement of the general fertility of the soils for particular crops. Apart from reference to an alkaline reaction of some samples, Guthrie did not investigate the salt-content of the soils. He presented his findings in evidence to the Standing Committee on Public Works in October 1906, and a general summary of his work was published later (Guthrie 1910a). The soil classification derived from this work is presented in Table 10.3.

Table 10.3:
Summary of Guthrie's soil analyses from the Riverina

Soil group	Soil class	Notes on mechanical properties	Land
No. 1	Light sandy soils, with a clay subsoil at a depth of about 2 feet, mixed with particles of disintegrated limestone, which have the effect of rendering the clay friable and the subsoil porous.	Sand 67 % Fine sand & silt 8% Clay 24 % best type of irrigation country	1st class
No. 2	Sandy soils somewhat heavier that the above, with a clay subsoil unmixed with limestone, and which are consequently not quite so open and porous. Well supplied with lime.	Sand 53 % Fine sand and silt 12 % Clay 34 % well suited to irrigation	1st class
No. 3	A stiffer type of soil containing a large proportion of clay	Sand 17% Fine sand, silt and clay 82%	2nd class
No. 4	A shallow soil with a sandy surface, changing at 6 inches to 1 foot to a stiffer clay.	Surface soil (to 6 inches) Sand 85% Fine sand & silt 4½% Clay 9½% Subsoil (at 2 feet) Sand 44% Fine sand & silt 7% Clay 48%	2nd class

Agricultural Gazette of NSW, 1910, 21: 663-666

By 1906 four technical and scientific reports relevant to soils were available:

- *Report upon Investigation and Classification of Lands suitable of Irrigation Purposes north of the Murrumbidgee River, in connection with the North Murrumbidgee Canal and Branches*, by A.L. Lloyd, Chief Surveyor, Department of Public Works, 24 Nov 1903 (published in the Report of the 1906 Inquiry, see below)

- Report by W.J. Allen, Fruit Expert, Department of Mines and Agriculture, on the soils suitable for irrigation in connection with the Murrumbidgee scheme, 17 March 1905.

- Report by W.S. Campbell and W.J. Allen, on the soils suitable for irrigation in connection with the Murrumbidgee scheme, to the Minister for Mines and Agriculture, 23 July 1905

- Reports by F.B. Guthrie, agricultural chemist, Department of Mines and Agriculture, on soils analyses, to the Parliamentary Standing Committee on Public Works, 28 Aug 1906 and 11 Oct 1906. (Later published as 'Notes on the Soils in the Area served by the Barren Jack Irrigation Scheme' in the *Agricultural Gazette of NSW,* 1910)

More general information on irrigation development was obtained from witnesses at the public inquiries and meetings during 1903-1906.

10.1.3 The public inquiries

The **Parliamentary Select Committee of Inquiry (1903)** was conducted over seven weeks, and heard evidence from 17 witnesses. It examined witnesses who were concerned about regular irrigation of their natural pastures below Hay, and the effect of the scheme on downstream users of the Murrumbidgee. It questioned witnesses on various technical matters with respect to dam construction at Barren Jack. It looked at the prospects for closer settlement, and the appropriate size of farms to support a family engaged in horticulture. With regard to soils and groundwater, there was little evidence to present, as no studies had yet been undertaken of the district under consideration.

The Inquiry found that the Public Works Department (PWD) had not collected a single soil sample to judge what land was best suited to irrigation. L.A.B. Wade, PWD Chief Engineer for rivers, water supply and drainage,[3] told the Inquiry that the survey line of the distributary canal from the river depended entirely on the land classification. 'I think it is very necessary to know the quality of the land you are going to irrigate', he said. Yet it became clear that he had organised soil surveys only as recently as February in that year, when one man began collecting

[3] Engineer L.A.B. Wade (1864-1915) was brother of C.G. Wade, NSW Liberal Premier 1907-1910.

data for the Murray valley. A second had joined him only a few weeks before this Inquiry. Wade presented no explanation for the delay in dealing with so fundamental a matter, but when pressed regarding the Murrumbidgee, in particular, he said: ‘It is well known that there is good soil there.’ Under further and more rigorous examination it became evident that Wade's presentations to the Interstate Royal Commission on the River Murray in 1902, with regard to irrigation development, were made without the support of any soil data (NSW PSCI 1903:60).

The purpose of the **Parliamentary Select Committee of Inquiry (1905)** was to examine the engineering aspects of the McKinney-Gibson Proposal (chiefly regarding the construction of the reservoir and weirs), and to make amendments to the 1903 Bill. It did not address issues of soils and groundwater.

The Minister, Charles Lee, called the **Public Works Department Conference (1905)** which some 130 delegates attended (NSW PWD 1905a). It was designed to hear opinions from a range of parties with respect to water conservation and irrigation across the State. The Minister put thirteen questions to delegates. Eight related to interstate issues of water use, and were clearly prompted by the Royal Commission on the River Murray (1902). The other five questions concerned irrigation for the pastoral industry; irrigation for horticulture; the McKinney-Gibson scheme; the effect of irrigation on land values; and trusts as a desirable administrative form for any scheme. While the conference preferred a government scheme, it approved of a private enterprise if government could not deliver it, provided there were mechanisms to protect the public interest, and to allow government to exercise a right of resumption of the scheme. There was clearly broad community support for the introduction of irrigation. Pastoralists recognised that they needed to raise fodder crops; and they heard reports of Gatenby's successful trials with fodder crops using irrigation from the Lachlan River. Because this conference addressed broad issues of irrigation, there was no discussion of soils and groundwater.

A direct result of this conference was a new proposal from the Public Works Department, entitled *Proposed Barren Jack Storage Reservoir and Northern Murrumbidgee Irrigation Scheme*. When Minister Lee introduced the proposal to parliament, he described it as ‘the first decisive step that had been taken towards bringing a scheme of any magnitude within the region of practical attainment’ (NSW PWD 1905b). The proposal made use of the land-cover data collected by Lloyd in 1903 and the land-classification system devised by Allen in 1905. Consequently, the Department’s preferred location for the scheme was the northern side of the river, with the large area of first-class land suitable for intense cultivation.

At the beginning of 1906 the **Standing Committee on Public Works** examined both the McKinney-Gibson proposal and the PWD proposal. The two were similar in many respects. The PWD proposal extended over the plains between the Lachlan River and Billabong Creek, to the junction of the Murrumbidgee and Murray. It commanded some 6.5 million acres (2.6 million ha), an area greatly in excess of what the water from the Murrumbidgee could service. Therefore, it was noted that it would be necessary to irrigate only those areas with the most suitable soils.

Over nine months the Committee took evidence from 172 witnesses at hearings in more than 16 locations, and visited sites in both New South Wales and Victoria. It examined the expediency of constructing a dam across the Murrumbidgee at Barren Jack, and a moveable diversion weir 19 miles above Narrandera, the construction of a main canal from the weir to a point ten miles north-east from the village of Gunbar, distributary channels and associated works. It also considered the necessary infrastructure, the effects of the scheme on downstream users, and the different means of marketing the water. Although Wade had produced financial estimates for the whole development, based on the classification of first-class lands at Mirrool and second-class lands at Yanco, little attention was given to the economic viability of the scheme, the suitability of lands for irrigated crops, and the markets for horticultural produce.

Various issues were not resolved, particularly whether either scheme should be for drought relief for the pastoral industry alone, for intense horticulture and agriculture under closer settlement, or a mix of both. The Committee failed to address the vital interconnections between soil quality, farm size, land use, crop type and economic viability for horticultural holdings.

Several witnesses at the 1906 Inquiry spoke about soils and groundwater. Their evidence is presented below and cited by the question (Q) number in the Minutes of Evidence (NSW PSCPW 1906).

The principal witnesses concerning land-soil classification were Lloyd, Allen and Guthrie. Lloyd and Allen were examined on their written reports. Guthrie appeared before the Inquiry on three occasions. The Committee asked him for ‘very minute information as regards the capabilities of the land’ (Q.230). Later, he admitted he had no experience with irrigation (Q.13229). Although he did not discuss saline soils in his report to the Committee, the words ‘capillary attraction’ prompted the Chairman to ask about salinity. As so little evidence on this subject was presented to the inquiry, it is worth reproducing the questions and answers that passed between the Chairman and Guthrie.

Q.15128. *Chairman*.] What do the words capillary attraction imply?

A. . . attraction of the soil for moisture. That is, of course, an important point with regard to land proposed to be subjected to irrigation. If the capillary power is low, the water runs away.

Q.15129. Suppose it were very high, would it not follow that, the attraction being so great, it would be destructive to the soil if the water were of a saline nature?
A. That would materially alter conditions.

Q.15130. The capillary power would be so great that it would probably lead to a reduction in the value of the land?
A. It would probably lead to the accumulation of alkali on the surface, caused by too rapid an evaporation of the water.

Guthrie explained how there was not much variation in the soils of the country he traversed in the Riverina, and any variation was due to the proportions of clay or sand in different parts of the landscape (Q.15144). He did not draw comparisons with Mildura soils, but believed that soil examination was in a 'much better position now than was the case when Mildura was first established [in 1887]' (Q.15150).

The Committee visited Mildura and saw the saline efflorescence on the ground. Commenting on the cause of the salt, Guthrie said, 'either the soil below is too clayey, and they have put too much water upon it, or the water has not run away. It may have collected upon the surface and waterlogged the soil, then evaporated and left the salt behind; or it may have been caused through too rapid evaporation from the surface' (Q.15168). He did not think the New South Wales land examined in his report would be affected in the same way: 'The surface is too sandy in nature and too friable. Even if it should happen on the stiffer class of soil, it might be easily remedied by a slight mulching of the surface soil, or by harrowing it to prevent rapid evaporation (Q.15169). On the question of injury from salt, he said 'if it is ordinary saline matter found in fairly pure water, it would not be injurious, but if the water contained alkali, or common salt, then it would be injurious' (Q.15170).

It is surprising that the Committee heard so little evidence regarding salt, given the experience of Mildura irrigators, the failure of the first Mildura settlement, and the Royal Commission in 1896. However, saline soils did concern one engineer, C.J. Grant, from the Mildura Irrigation Trust. He said: 'In soil which is salty the concrete is eaten out in three or four years.' (Q.975)

Some witnesses questioned the usefulness of soil analyses, as Robert Gibson told the Inquiry (Q.528-529):

I do not attach much importance to analyses after the analysis we had in connection with the Hay irrigation area by the Works Department. They analysed the soil, but I know that we ought not to have put the irrigation settlement where it is. [The analysis] showed that

> the land was suitable for irrigation, but the bulk of it is not. We are trying to get more land added to it, which we think does comprise a fairly large area of suitable soil.

Another witness, J.J.T. Lever, Chairman of the Mildura Irrigation Trust, told the Inquiry (Q.816):

> Analyses have been made at different times by the Government chemist, but the result of analyses of the soil is not satisfactory in practice. You get to know more by studying the nature of the land, and comparing it with other land, than you do from any analysis a chemist can make, because our blocks vary very much.

Lever also commented on the appearance of 'the crystallised-looking substance on the surface of the Mildura soils'(Q.912):

> There is not nearly the same amount of salt visible now as there was before the improvement of the irrigation works. [Salt] was the cause of a great many blocks being abandoned. Many of those blocks are now found to be workable. Whilst they will not grow trees, they will grow sultanas. The sultana vine will grow with a certain quality of salt which will kill other things, and many of the blocks which were abandoned because of being unsuitable are found suitable for sultanas.

Witnesses spoke of the wasteful use of water at Mildura, and the need for settlers to learn how to run an irrigated farm. The NSW Director of Agriculture, Walter Campbell, told the Inquiry of the lack of experience in irrigation farming when Mildura was set up, and thus wanted an experimental farm to train settlers in irrigated agriculture in the Riverina. By 1906 experience was still minimal; only McCaughey and Gatenby had demonstrated the possibilities for irrigation from New South Wales rivers (NSW PSCPW 1906:34-35). Arthur Ritchie, an engineer with experience in India, criticised McCaughey's approach to irrigation at *North Yanco* (Q.12012):

> It has been carried out in a most wasteful manner. Sir Samuel McCaughey has used far more water, from what I saw, than he had any necessity to use, and his channels are very shallow and very wide. This gives the maximum evaporation and the least amount of water, and, of course, the least amount of useful effect.

Ritchie commented favourably on the Mirrool soils of the first-class lands (Q.12005-7):

> It seems if you put water on it, all the soil will grow something, particularly when you get beyond the creek. Beyond that you get onto a red sort of loamy soil, neither clay nor sand, and little particles of limestone gravel. . . . The soil has a good slope, and it is not likely to clog or make a "glue pot" or anything of that sort. It appears to be a very good district indeed.

A great part of the 1906 Inquiry was given to engineering matters, which prompted *The Sydney Morning Herald* agriculture writer to criticise the emphasis on the engineering aspect of the development (i.e., water delivery) at the expense of water use (*SMH* 28 May 1906).

As the Committee's investigations progressed, it was clear that the majority of witnesses saw an irrigation scheme on the Murrumbidgee to be of 'enormous benefit to the state, by rescuing from the disastrous effects of drought large areas of excellent land, and peopling them with a thriving population.' One of the most valuable results of the proposed schemes for the Riverina was seen as 'bringing into profitable occupation dryland worked in conjunction with irrigated land' (NSW PSCPW 1906:54). However, there was scant concern expressed regarding the presence or possible injurious effects of salt. The extracts quoted above are the only mentions of the topic that were found in the dense 640-page Minutes of Evidence (NSW PSCPW 1906).

10.2 The Murrumbidgee Irrigation Scheme

Before the close of parliament in 1906 the NSW Government passed the *Barren Jack Dam and Murrumbidgee Canals Construction Act, 1906*. This legislation set in motion the legal and policy processes, and the initial program of construction works, for the Murrumbidgee Irrigation Scheme.[4]

The first stage of major engineering works included construction of Burrinjuck Dam in the Southern Tablelands (1907-1927), the Main Canal (1907-1912), Berembed Weir (1909-1910), Bundidgerry Regulator (1907-1910), along with hundreds of kilometres of distributary channels and associated works. Following the recommendations of the Standing Committee on Public Works in 1906, the Department of Agriculture established the Yanco Experimental Farm in 1909 to provide the foundations of agricultural instruction and development.

The *Murrumbidgee Irrigation Act, 1910,* established the Murrumbidgee Irrigation Trust as the interim operating agency. The Trust dealt with land acquisition, on-going construction works, levying of rates, and general administration of the areas. The Trust comprised the Minister for Lands, Minister for Public Works and Minister for Agriculture. Under this arrangement the Trust co-ordinated the functions of land acquisition, public works and agricultural development. Management was placed on a more permanent basis when parliament passed the *Irrigation Act, 1912*, thereby creating the Water Conservation and Irrigation Commission (WCIC). In 1913 engineer Wade was appointed its first Commissioner. The Act gave the Commissioner extraordinarily wide powers, which Langford-Smith (1966:28) likened to those of 'an eighteenth century enlightened despot'.

[4] The name *Barren Jack*, a representation of the Aboriginal words for 'precipitous mountain', was later changed to Burrinjuck (McKay 1907).

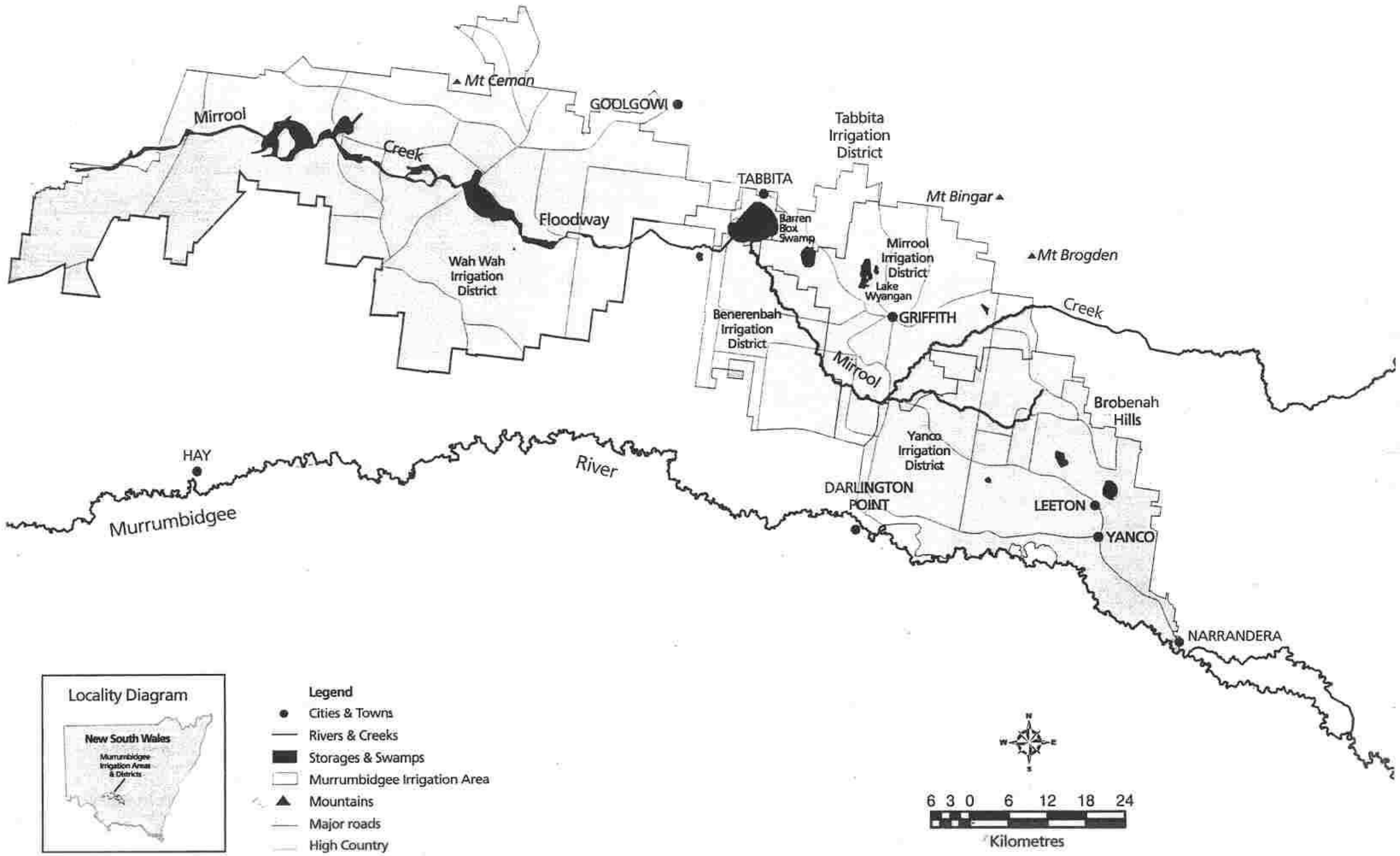


Figure 10.3: Murrumbidgee Irrigation Areas and Districts (Murrumbidgee Irrigation Limited 2004)

The *Murrumbidgee Irrigation Area Resumption Act, 1910*, authorised the government land-acquisition program. It covered 1.7 million acres (675,540 ha) and authorised the acquisition of land for head works, distributary channels, new towns, and individual allotments for lease to irrigation farmers. Allotments of land were originally developed for use in three categories: the smallest blocks (0.8 ha) were intended as working men's blocks, the medium sized blocks (4 ha) for horticulture only, and the largest blocks (20.25 ha) for mixed farming. Land would be acquired for two new towns: Leeton to service the Yanco Irrigation Area, and Griffith for the Mirrool Irrigation Area (Figure 10.3). The layout of these towns was under way in 1911. The Yanco No 1 Irrigation Area was proclaimed in May 1912, and by June there were 748 farms of 25,201 acres (10,206 ha) laid out in the area, and another 448 of 23,362 acres (9461 ha) around Mirrool. The survey of Leeton was completed by July 1912, with 251 acres (100 ha) subdivided into 925 town allotments. The scheme was officially opened on 13 July 1912 when water was made available from Burrinjuck Dam to the Yanco Irrigation Area.

10.2.1 Land development

The Standing Committee on Public Works had failed to make any clear recommendations on the fundamental point of whether the Murrumbidgee Irrigation Area (MIA) was designed as drought relief for the pastoral industry, as intense horticulture and agriculture for closer settlement, or some combination of the two. In the absence of a clear policy, uncertainty produced delay. The move towards closer settlement had already began in the Australia colonies in the 1890s, but the *Closer Settlement Act, 1904*, opened the way for the resumption of the large pastoral estates in New South Wales. This policy had strong popular support among small farmers because the estates had the advantage of water from good river frontages to the exclusion of small holders. Further closer settlement legislation followed in 1911.

In 1911 the Murrumbidgee Irrigation Trust asked the American irrigation engineer, Elwood Mead (1858-1936), to advise on the best means of dealing with the settlement of the irrigable lands. Mead had pioneered the idea of closer settlement and intense horticulture as the basis of irrigation development in the western United States. He became head of the Victorian State Rivers and Water Conservation Commission from 1907-1915, during which time he shaped irrigation policy development in Victoria. He proposed applying all the Murrumbidgee water to the first-class lands of Mirrool Creek on 400 farms of 50 acres each, and deferring the development of the second-class lands. This proposal appealed to Wade, as intense culture would reduce the waste of water that inevitably accompanied scattered or partial irrigation. The Trust decided to adopt a policy of concentrated irrigation, and proposed developing the Yanco lands for mixed farming (on account of their being intersected with pastoral land unsuitable for irrigation) and the Mirrool lands for intense horticulture and lucerne. In fact, it proceeded quite differently.

Despite Mead's recommendations, the Trust launched a development of horticultural blocks at Yanco, after purchasing a large part of *North Yanco*, and made the farms much smaller than originally planned for the first-class lands (mainly two and ten acres) (NSW MIT 1912:3-5).

The mode of financing of the scheme demanded that land acquisition be followed quickly by subdivision and settlement to provide revenue for development elsewhere in the MIA. Wade had said in 1905 'quick settlement is an essential for financial success' (NSW 1905b, Appendix 4:13-22). Thus, the government chose to begin development on the second-class lands. This reversal of policy, prompted by the purchase of *North Yanco*, represented a departure from a fundamental principle for sound irrigation development. It had serious long-term effects for the whole scheme.

Wade had told the Standing Committee on Public Works in 1906 that 'The best land in the whole of the Murrumbidgee basin which can be irrigated is that lying to the north of Mirrool and Wah Wah Creeks, and a portion of the most northern end of North Yanco' (NSW PSCPW 1906:153). Given this clear statement about the most suitable land, an explanation is necessary for the reversal in the sequence of the development recommended by the Standing Committee on Public Works. What prompted the government to develop the Yanco lands first?

From a detailed study of the parliamentary debates and newspaper accounts at the time, Cowper (1967 and 1987) exposed land deals involving Samuel McCaughey that led to the inverted sequence of land development. The problem began when the Carruthers Government failed to introduce the necessary land-resumption legislation in 1907. When the legislation finally came before parliament in 1910, it proposed to compensate small landowners for the resumption of their properties. The government did not intend to resume the large pastoral holdings. Nevertheless, newspaper reports in 1910 disclosed that McCaughey, a large and influential landowner, was already selling parts of his property *North Yanco*, along the path of the main canal, at elevated prices. Small settlers and the government opposition party made much of the fact that McCaughey stood to benefit from the increase in land values since the irrigation scheme was announced. *The Sydney Morning Herald* wrote that 'the greatest experiment in irrigation yet made in Australia will be subject to land speculation' (*SMH* 9 Aug 1910). And small settlers hated land speculation.

Corrupt land dealings had long been part of political and government life in the Australian colonies. They had been rife in the late nineteenth century. As recently as 1905 a Royal Commission into the Administration of the Lands Department (NSW 1906) had revealed that the Minister for Lands, W.P. Crick, was at the centre of illegal land dealings. Therefore, in an attempt to avoid talk of another land scandal in 1910, particularly as an election was imminent, the Liberal (Wade) Government purchased McCaughey's second-class *North Yanco* lands at their 1906 valuation 'to forestall criticism of the Government during the election campaign' (Cowper 1968:140). This step greatly increased the complexity of later development.

In October 1910 James McGowan's party won the election by a close margin. New South Wales' first Labor Government became responsible for the largest government-funded public works project ever undertaken in Australia at the time. The Murrumbidgee Irrigation Scheme progressed under the direction of an inexperienced Labor Government, poorly guided by policies of the previous two governments that were rushed, superficially considered, and deficient. The new government carried the extra burden of the purchase of *North Yanco*.

At the end of 1912 *The Sydney Morning Herald* reported: 'The Government admits that the preliminaries of establishing the settlement were in a chronic state of unpreparedness' (*SMH* 14 Nov 1912). Cowper (1987:32) also has described the situation:

> The Government of New South Wales became responsible for carrying out a vast programme of development, involving water conservation, irrigation, agriculture and land settlement — the largest work of its kind ever undertaken in the State, or in any other democratic state in the world, at a time when it was lacking the resources and the people with the knowledge to conduct an Experiment Farm.

Indeed, the Government's *unpreparedness* would create many serious problems for the development of the scheme, hardship for individual settlers, and havoc for the environment.

10.2.2 Irrigation farming

The first settlers began farming at Yanco in 1912, while settlement moved ahead slowly at Mirrool. Water was not available at Mirrool until October 1913, and progress with infrastructure and services came even later. Table 10.4 gives an indication of the rate of development.

Table 10.4:
Number of farms held by settlers at Yanco and Mirrool and approximate area irrigated in 1912-1919

as at 30 June	*1912*	*1913*	*1914*	*1915*	*1916*	*1917*	*1918*	*1919*
Number of farms held	196	503	677	888	893	882	811	804
Acres watered	?	6412	54,531	24,112	24,947	21,547	?	30,426

WCIC *Annual Reports 1913-1920*

Serious errors in matters of policy and planning occurred before the scheme was opened in 1912. These errors related to the inadequacy of the soil surveys of the MIA. In the absence of this vital body of scientific data, mistakes followed with respect to the appropriate size of farms, land use, crops and plantings, and choice of settlers. Agricultural and irrigation policies received little attention. In 1910 Arthur Griffith, Minister for Public Works, had recognised that his Department knew little about agriculture, but he (and others) thought it was enough for settlers to obtain all the necessary knowledge from the Yanco Experiment Farm. Opposition member and former Premier, C.G. Wade, believed that the important factor was a regular supply of water to farmers 'in quantities necessary to make the soil productive in the highest degree' (NSW Parlt Debates 1910, 39:1180).

As almost none of the settlers had experience in irrigation farming, instructors at Yanco Experiment Farm were expected to advise them. From 1913 the WCIC published practical information in its fortnightly *Irrigation Record*. The publication covered a wide range of topics that new farmers needed to know: preparing a block; set-up costs; crops and their water requirements; raising animals, especially dairy cows, under irrigation; soil fertility; the results from Yanco Experiment Farm; the dangers of over-watering; and overseas experiences, particularly from America. There was a regular column on progress and problems at Mildura, and many articles encouraged good irrigation practices.

Settlers did not readily heed advice about the dangers of over-watering, rising watertables and waterlogged fields. In the winter of 1913 the *Irrigation Record* published an article on the over-watering in Egypt. This prompted a reply from a private settler, calling himself *Verax*, who was concerned about the general tendency to over-water across the MIA. Only one year after water was delivered to Yanco he was encouraging farmers to irrigate as sparingly as possible (*Irrigation Record* 15 July 1913). By 1914 rising watertables producing waterlogged soils were already evident. This condition was explained as a result of water seeping from unlined irrigation channels. The WCIC addressed the concerns raised by *Verax* in an editorial over one year later (*Irrigation Record* 16 Nov 1914). Langford-Smith (1966:44) believed it was singularly unfortunate that the editorial used the headline ‘The Seepage Danger’. Settlers associated seepage with a problem on the part of the WCIC (its unlined channels), and not with their own practice of over-watering.

Nevertheless, the editorial illustrated that the WCIC was aware of rising watertables. It is worth quoting at length from the *Irrigation Record* (16 Nov 1914):

> In most matters no one has any time for the man who refuses to be guided by the lessons of experience, but on irrigation schemes all the world over this general rule does not seem to apply in every case. The Murrumbidgee Irrigation Scheme is no exception to the rule,

> and by nothing is this fact better exemplified than by the manner in which water is still being applied to farms that are crying out for cultivation rather than moisture. Practically they are “asking for bread and being given stone”. Innumerable articles have been written on the troubles that follow in the train of irrigation. It has been pointed out that smaller crop yields are the natural result; that plant food is dissolved, taken out of reach of the plant root systems and lost; that the area which the available water will serve is reduced, and consequently the rates which individual settlers have to pay to meet the requirements of the scheme are unduly increased; and that there is grave danger of the water-plane being permanently raised and the land water-logged and ruined.

The editorial referred to experience at Mildura and overseas:

> It is well known that many of the early Mildura settlers were practically ruined by the water-logging of their soil, and the bringing to the surface of injurious alkaline salts. Their trouble has only been overcome by the construction of expensive drainage schemes for the individual farms. The water is carried by earthenware pipe lines to the lower portions of the farms, and from there it is taken to shafts which have been sunk down to the sand drift many feet below the surface. This drift carried the water away at a depth so low that its alkalinity does not interfere with the proper growth of crops. The cost of these expensive works, however, is born by the individual farmers concerned – that is the important factor – and the same thing applies directly or indirectly to any reclamation or drainage schemes wherever they may be carried out – the settler has to bear the expense of remedying the injury which the improper use of water invariably does to the land. Hundreds, if not thousands, of similar cases could be quoted from American experience, and they are still meeting with the same trouble over there despite all the warnings given.

The editorial concluded by quoting from an American irrigation expert, M.B. Hartt:

> It is confidently predicted that before the Yanco scheme gets fairly on its legs it will go bankrupt, like every other Australian project in its infancy. Settlers never know at first how to farm irrigated land. They fancy slopping water on the soil is all there is to it. And the water comes back. Sooner or later they find it creating unauthorised swamps. Then they begin to think about drainage.

There seems to have been little response to this editorial. Commissioner Wade was unable to attend to the rising watertable problem himself for he died suddenly two months later, on 12 January 1915. His death was a serious blow to the scheme as it followed the day after the death of L.J. Trefle, the Chairman of the WCIC and Minister for Lands and Agriculture. The MIA lost both the ministerial and executive heads at the same time.

10.2.3 Settlers' grievances

Throughout the first two decades of the MIA's operation administrative, economic, political, social and scientific problems confronted the community. Settlers were dissatisfied with the capacity of the land to produce the promised lucerne crops. They objected to the high land valuations, the subsequent rates they were charged, and to the high cost of transport and housing. They disliked the leasehold tenure, because it limited their ability to raise bank finance. Consequently, new settlers were reluctant to take up irrigation blocks. By 1915 the distress of settlers and complaints against the Labor Government were serious enough to prompt a Royal Commission.

The Royal Commission in June 1915, under Commissioner A.C. Carmichael, was prompted by specific allegations of irregular land dealings on the part of WCIC officers. Carmichael had terms of reference to investigate a range of concerns: permissive occupancies, land values, the policy of allotting farms, management of the business undertakings, organisation of marketing, misleading literature, and conduct of WCIC officers (NSW 1915). As he was a Government Minister (rather than impartial appointee) his wholly inadequate and ineffective report came as no surprise to the settlers. His report failed to address the systemic problems in the WCIC administration, and the Government essentially ignored his recommendations.

Nevertheless, the evidence of witnesses provides valuable clues to the underlying problems in the MIA, and the scant attention given to soils and groundwater. Carmichael found that the Yanco Experiment Farm failed in the very purpose for which it was established: to help settlers (NSW 1915:liv). Although many settlers had tried unsuccessfully to grow lucerne, he found that the land classification for this crop was generally correct. Yet he conceded that the soil and its working were not well understood by either experts or MIA settlers (NSW 1915:xxv). Lucerne was keenly promoted as a 'drought-insurance' crop based on McCaughey's outstanding results. The Chairman of the Closer Settlement Advisory Board, W.N. Sendall, gave evidence that he had a poor opinion of McCaughey's *North Yanco* lands: '. . .from being badly graded and watered in an indiscriminate sort of way, he had spoilt them as lucerne paddocks. But whether it was a permanent deterioration of the land I do not know.' (NSW 1915: Q.17352)

The decision to adopt some intense culture (as recommended by Mead) seriously disadvantaged Yanco settlers on the second-class lands. W.C. Wilson, engineer in charge of the Yanco works, gave evidence that he had argued with Wade and Minister Griffith about development of the second-class lands. He was against breaking up *Yanco* into small blocks, because of the poor soil quality. He believed that only part should be under irrigation, and that bigger areas be designed for mixed farming. He said that only a small part of *Yanco* was suitable for intense culture (NSW 1915: Q.17272), and noted that Mead 'paid more attention to Mirrool' for the development of intense culture. He regarded the decision to develop *Yanco* as a clear, yet unwise, change of policy (NSW 1915: 511).

On the complaint of misleading literature, Carmichael found there were several offending items. One pamphlet entitled *Murrumbidgee Irrigation Areas: Public Opinion*, compiled by Wade, contained statements attributed to settlers and professionals. It quoted Guthrie as saying, 'Soil Analysis – Lands in no way exhausted'. This was a highly abbreviated version of Guthrie's report from ten years earlier, and its generality rendered it completely useless and misleading. Other articles in the *Irrigation Record* and the *Agricultural Gazette* provided particularly misleading information concerning the capacity of the areas to support lucerne production.

Although Carmichael recognised that the understanding of soils was limited, he dismissed the proposal from E.J. Polkinghorne, Murrumbidgee Irrigation Settlers' Association, that a soil-testing laboratory be established in the MIA. Carmichael saw no need for this facility because a general soil analysis had already been made (NSW 1915:lviii). Considering that he was referring to the analyses made by Allen and Guthrie in 1905 and 1906, this conclusion provides strong evidence for his failure to appreciate the severe limitations of this earlier work. Nevertheless, he did find that some settlers who had tried unsuccessfully to grow lucerne on unsuitable land, should have their cases referred to the government for assessment.

A second Royal Commission into the Water Conservation and Irrigation Commission (known as *The Lucerne Commission*) took place under Judge Bevan in 1916. Beven was instructed to submit recommendations in the case of settlers who could prove that they came to the areas to grow lucerne, but were not granted suitable lands, and who were seeking compensation. He concluded that every settler in question had failed to grow lucerne because the second-class lands at Yanco were unsuitable. Some 130 settlers established a case that they came to the MIA to grow lucerne for dairying, pig or lamb raising, or for marketing. But they were located on farms 'which have proved to be quite unsuitable for the purpose, and they will have now to surrender their farms and start afresh.' (NSW 1916:131) Bevan found that Wade had been aware of the unsuitability of some farms, and if he had not died in 1915, believed Wade would have provided a remedy. Bevan noted that the Yanco soils varied greatly across the area, and even within individual blocks. He heard evidence that the clay soils were differently constituted compared with those in America and other irrigated areas. He read of their colloidal quality, whereby repeated watering and drying produced extreme hardness (NSW 1916:136). Beven concluded that the State had made a mistake in its soil and land classifications (NSW 1916:136). He noted that it would have been desirable to carry out exhaustive soil surveys and land subdivisions according to proposed uses, but this had not been done because of the resources required to cover so large an area as the MIA.

10.2.4 The effects of war

By the middle of the decade World War I (1914-1918) overshadowed all aspects of Australian life. As money and labour were scarce for new development in the MIA, the WCIC focused simply on maintaining the Yanco Irrigation Area. The Commonwealth and State Governments were drawing up policies to resettle troops as they returned, and central to these policies was the Soldier Settlement Scheme. Irrigation farming, with intensive cultivation on relatively small blocks, was regarded as highly desirable for discharged soldiers (Lloyd 1988). In New South Wales the MIA was seen as a solution to the problem of scarcity of Crown Lands and the insufficient fund for land acquisition voted to the Scheme. The Government began plans to enlarge the Main Canal so water could supply farms for soldier settlers in the Mirrool area. It also started laying out plans of the new township of Griffith to service the Mirrool Irrigation Area. Returned soldiers began settling in the MIA in 1920, and further works were undertaken to support the settlement. By June 1922 there were 802 settlers on 24,638 hectares.

Under wartime conditions there was little progress in developing basic infrastructure. Settlers continued to bear the consequences of the poor design of the whole Yanco area — problems of soil quality, size of allotments, farm productivity and rising watertables. They complained of the unfair evaluation methods used to assess rent, and the difficulty of securing bank finance to improve their blocks. The MIA had no formal local government structure, which denied settlers a mechanism for exercising their rights on important local government issues. Moreover, the deficient handling of their grievances by the WCIC and Government Ministers was a source of bitter complaint (Cowper 1987, Lloyd 1988). The post-war period showed little improvement. The Farmers' and Settlers' Association continued to press the grievances of members on a government that was still poorly resourced. They wanted the lands re-classified and re-valued, the farms re-designed, and their debts re-structured; and they wanted an independent authority to do it.

The activities of the MIA were the subject of numerous reviews during the 1920s, which went some way to helping settlers. In 1921 a Select Committee of Inquiry looked into the conditions and prospects of the agricultural industry in New South Wales. Here, Guthrie had the opportunity to criticise the original soil survey of the MIA. He said that he had long agitated for an effective survey, one that used 'trained observers who have some botanical, geological, chemical and agricultural knowledge' (NSW 1921:685). Other inquiries focused on the financial plight of settlers. New South Wales conducted two inquiries in 1925: the first, into soldier settlement on the irrigated areas (NSW 1925a), and the second in connection with proposed shires in the irrigation areas (NSW 1925b). In 1929, because of the Commonwealth's interests in soldier settlement, it convened the Pike Royal Commission into Losses due to Soldier Settlement (Australia 1929). In the same year the Commonwealth Development and Migration Commission held an inquiry into the canned fruits industry (Australia DMC 1929).

Nevertheless, it was not until 1933 that real changes were possible. In 1933 the NSW Government set up the Water Conservation and Irrigation Advisory (WCIA) Committee to investigate the construction, control and management of the works for irrigation and water supply, and the administration and management of the MIA. In parliament the Member for

Cobar pointed to the 'political blundering and meddling by politicians with affairs about which they knew nothing' in the crucial years 1906-10, as the source of unending problems for the MIA (NSW Parlt Debates 1932, 136:2480). The WCIA Committee provided the first thorough investigation into the structure and activities of the MIA. It marked a turning point in the fortunes of the scheme (Cowper 1968:273).

Many settlers suffered badly as a result of flawed government planning and a deficient administration during the first two decades of the MIA. One settler at Mirrool, D.G. Stark, described in *Murrumbidgee Irrigator* (30 July 1926) the settlers' depth of feeling:

> [T]he draughtboard method of designing irrigation farms is a criminal blunder, and the men responsible deserve to hang for it, and [for] the cause of the loss, not merely of State money, but of settlers' hard earned savings and patient toil.

Despite the problems that settlers experienced there was still little evidence of interest in irrigation salinity. During the war years a series of seven articles appeared in the *Agricultural Gazette* entitled 'Practical irrigation farming in Australia' (NSW Dept Agriculture 1915 and 1916). The articles contained essential information for those intending to take up irrigation farming, and complemented advice already published in the *Irrigation Record*. On 15 March 1916 the *Irrigation Record* published an article, entitled 'The Alkali Danger', on experiences in Western America. The writer made the point that the excessive water-user brings 'alkali injury' to his responsible neighbours. Nevertheless, it was followed by another article on 1 September 1916, which stated that 'luckily alkali has no terror for irrigationists in sunny New South Wales'.

10.3 Government Science

During the decades of the MIA development described above, government scientists continued their research into soils, groundwater and crops suited to irrigated agriculture. The following brief description outlines the scientific activity that was carried out in parallel to the MIA development.

10.3.1 Soil science

The soil-analysis program, begun in 1890 by the Chemist's Branch of the Department of Agriculture, continued to play a useful role in helping farmers across New South Wales. Although the service was reduced during World War I, it operated until 1921. Figure 10.4 indicates the growth of the Branch's work in this area over the period 1890-1921.

From 1907 Guthrie emphasised the need for a soil survey of the whole of Australia. He repeatedly reminded the government of this need in each annual report of the Department from 1908. He was particularly concerned that soil surveys should precede subdivision of new areas, so that subdivision was 'carried out on more equitable lines than is possible at present, and the size and value of the holdings could be apportioned in accordance with their agricultural value' (Guthrie 1907). Later again, he pressed for soil surveys before subdivision under the Soldier Settlement Scheme (NSW Dept Agriculture 1919).

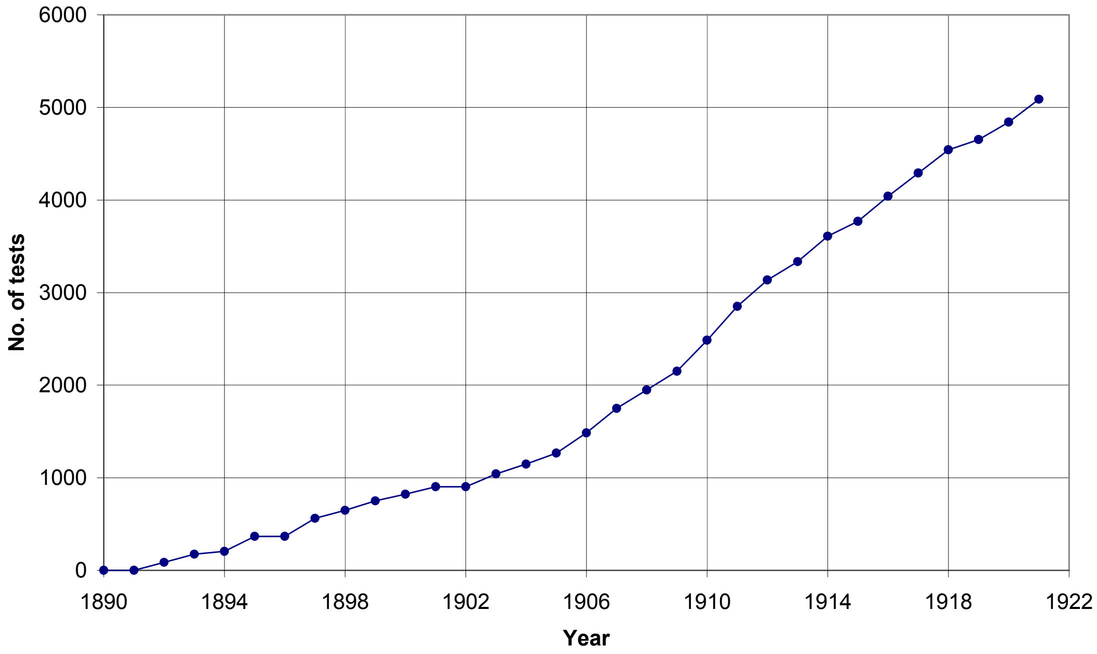


Figure 10.4: Growing knowledge of NSW soils. The graph shows the cumulative distribution of the number of soil analyses made by the Chemist's Branch, NSW Department of Agriculture, 1890-1921. (Data from annual returns published in the Department's *Annual Reports*.)

The Department went some way towards achieving a broad-based soil survey when it appointed the geologist, H.I. Jensen, to the Chemist's Branch in 1909. Over three years Jensen began a systematic soil survey of selected parts of the State, visiting a considerable area and collecting samples. He collated the results from farmers' analyses taken over the previous 20 years, and combined them with analyses of his own recent samples to produce a text book on soils for the farming community in New South Wales (Jensen 1914). He published several review papers on granite soils, North Coast and South Coast soils, orchard soils around Sydney, and the Armidale district soils (Jensen 1909, 1910a, b, c, 1911a, b) and the black soil plains (Guthrie and Jensen 1910). He began to correlate the botanical survey work of Maiden and Cambage with the geological and chemical soil surveys, and to establish the relationship between the nature of native vegetation and that of the soils of New South Wales.

Saline soils received attention in Jensen's work. He noted that salts existed in large measure in the soils of inland Australia, and New South Wales had large areas of alkali-affected land. The greatest salt concentration was at the depth to which summer rains penetrate, washing them down to 6-18 inches from the surface. In dry seasons Jensen had seen saline matter effloresce on the surface in parts of the northern NSW Pilliga Scrub. He summarised current understanding of the factors affecting saline soils (Chapter 5). He regarded the condition of the colloidal constituents of clay of utmost importance to agriculture. A clay in the swollen, saturated, jelly-like conditions is very impervious to water and air, and very sticky and incapable of tillage. But in a shrunken coagulated (crumbly) condition the same clay may be a fertile soil. Saline matter was known to be effective in coagulating clay, but the alkaline carbonates produced the dangerous colloids. Salt movement was known to be controlled by the diffusibility of salts and the water movement in soils. Soils varied greatly in their power to retain salts, with potassium and aluminium diffusing before sodium and calcium, and chlorides before sulphates. In Chapter 13 Jensen paid particular attention to alkali land:

> Where alkali exists in the subsoil, irrigation is apt to bring it to the surface, since irrigation raises the level of the ground water, and the salts accumulate in the layer where the ground water is evaporating and concentrating. Irrigation may, therefore, completely ruin dry areas unless great precautions are taken to subdrain, so as to keep down the water table. In our western districts the subsoils of intended irrigation areas should be carefully examined, and the percentages of water-soluble salts should be estimated. The quantity present in the whole of the subsoil can thus be readily computed, and it will be easy to see how much alkali can, by careless irrigation, be brought to the topsoil, and to what extent sub-drainage is required. . . . The portions of New South Wales which have less than 24 inches annual rainfall may be regarded as potentially alkali land.

Although very little experimental work had been carried out on alkali land in Australia (to identify the salt-tolerances of different crops), Jensen was familiar with research overseas. He noted how well adapted Australian saltbush (*Atriplex* spp. and *Rhagodia* spp.) was to alkali conditions. It 'not only flourishes on alkaline lands, but abstracts salt from the land in great amount.' (Jensen 1914:75)

After studying artesian water in irrigated agriculture, over three decades, the chemists had considerable knowledge of salt-affected soils and groundwater in northern New South Wales. Guthrie (1910) summarised the results of these efforts. He attributed alkalinity to the presence of sodium carbonate (Na_2CO_3) in the soil, and associated it almost exclusively with bore water. He explained that the continued use of bore water without adequate drainage produced a white encrustation of sodium carbonate on the surface as the water evaporated. The alkali corroded the stem or crown of the plant where it contacted it at the surface. It dissolved out the soil humus, and combined with clay to form a substance that was slimy and sticky when wet, and dried to a hard mass. Further damage occurred to the roots of crops as the surface dried and cracked. He believed that although common salt (NaCl) was hardly ever found in the New South Wales soils, experiments had demonstrated that most farm crops would tolerate as much as 0.2 per cent salt in the soil. Salt did affect nitrate production and soil texture, and caused clay particles to flocculate, making the soil temporarily more friable. The formation of colloidal silicates, thus rendering the clay slimy, was a very damaging longer-term effect.

By the time intensive irrigation in the Riverina was a serious proposition artesian irrigation was in decline, and the experimental farms in the Great Artesian Basin had fulfilled their role. By 1910 it was evident that artesian water was unsuitable for intensive agriculture. The farm at Moree closed in 1910. The Pera farm went into a long, slow decline, and the orchard continued at a much scaled-down operation into the 1920s. Attention was shifting to irrigation using the water from snow-fed rivers, which avoided the problems of artesian water.

Although artesian water often contained injurious alkaline carbonates, Jensen found that water taken from a deep source had a better quality for irrigation. Nevertheless, injurious results were 'just as likely to occur from the rise of subsoil alkali, as from the salinity of the bore water'. Compared with the red loam soils at Pera Bore, the humus-rich black soils of the State reacted less to artesian water. But Jensen believed that, in time, these too would become salt-affected unless remedial measures were in place (Jensen 1914:84).

Much of the scientific progress in understanding soils was summarised in Jensen's *The Soils of New South Wales*. It has been described as 'quite the most outstanding Australian contribution to soil classification based on geological and chemical features' (Stephens 1953). He spent three years on soil-survey work, and emphasised the need for a complete soil survey of the State. The Department of Agriculture lacked the resources for such an ambitious project. Instead, by 1914 the Department had begun to concentrate on areas containing representative series of soils, and from existing results began to make deductions and generalisations of wider application for the State.

Pressure for a soil-survey program also came from the botanical community. Botanists were aware that native vegetation was an excellent index to the nature of soils. They saw the need for an accurate record of the distribution of native plants and for information on the factors regulating their distribution. In his Presidential address to the Linnean Society of New South Wales, R.H. Cambage addressed the need for a botanical and soil survey (Cambage 1925).

10.3.2 Irrigation from the Murrumbidgee and Murray

In 1906 the Standing Committee on Public Works, in reference to the MIA, recommended that an experimental farm 'be established without delay in the midst of the 10,000 acres set apart for cultivation, for the instruction and guidance of persons desirous of taking up land, in the use of water and the capabilities of the land for cultivation' (NSW PSCPW 1906, rec 7). The

Department of Agriculture began preparations for Yanco Experiment Farm in 1908, and the Riverina became the focus of scientific research for irrigated agriculture. Although the farm was located on the second-class lands, it had the advantage that settlers could see it from the railway and visit from Narrandera. The *Agricultural Gazette* reported progressively on the clearing, levelling, laying out and planting of the farm. Vines covered 30 acres, assorted fruit trees 16 acres, and nut trees 6 acres. Native trees (sugar gums, kurrajongs and blue gums) and oriental planes were planted as windbreaks and for firewood. By 1911 it supported vineyards and orchards for citrus and stone fruits. There were 28 acres under lucerne, and experiments were conducted with different strains of lucerne, barley, oats, sorghum and cowpeas for fodder crops. Once the first trees and crops were planted, the Department of Agriculture conducted trials to determine the appropriate water usage required for different species, and the ability of the Yanco soils to support new crops (*Agricultural Gazette* 1908, 1911, 1913). No studies were made of the propensity of the area to become salinised.

Irrigation farming was already operating on a very small scale at the sites established in the 1890s: Hay and Balranald on the Murrumbidgee, and Wentworth on the Murray River. These schemes had been slow to get started, and contributed little to the science of irrigation by the time the MIA was under way. Vegetables and fruit (vines and citrus) were grown under irrigation, but the impact was insufficient to produce watertable problems and thereby contribute to knowledge of the interaction between groundwater and salts. Later, when promoting land again in the Wentworth Irrigation Area, the Department of Agriculture focused on soil quality in terms of mechanical conditions and chemical constituents, while describing the potential fertility of arid lands under irrigation (Harris 1909).

During the 1920s the WCIC began to investigate the prospects of growing rice on the poorer quality soils of the MIA. Trials were successful, and from 1928 rice planting spread on the MIA. Good returns from rice offered hope to farmers and new opportunities during economically difficult times. But rice growing used large amounts of water, and within a few years contributed to serious groundwater recharge across the MIA.

10.3.3 Soil degradation

By the 1920s both Federal and State authorities were concerned about soil degradation. In the irrigation areas of the Murray and Murrumbidgee River valleys rising watertables, waterlogging and salinity had become steadily increasing problems. Research into these problems made progress under the scientific leadership of soil scientist, J.A. Prescott (1890-1987).[5] Following

[5] Prescott was Professor of Agricultural Chemistry, Waite Agricultural Research Institute, University of Adelaide (1924-1955), Director of the Institute (1938-1955), and part-time Chief, CSIR Division of Soils (1929-1947). Before coming to South Australia he had been Chief Chemist and Superintendent of Field Experiments, Bahtim Experimental Station, Sultanic Agricultural Society Egypt 1916-24.

discussions in 1926 with the newly created Commonwealth Council for Scientific and Industrial Research (CSIR),[6] Prescott inspected affected irrigation areas in the three irrigation states. He proposed to establish a Soil Investigation Section at the University of Adelaide, and this new research body was set up in 1927. A long program of soil surveying began in all irrigation areas of the riverine region. At the same time the Geological Surveys of New South Wales, Victoria and South Australia began the complementary stratigraphic and groundwater studies of the region. By 1929 the Soil Investigation Section was renamed the Division of Soils of CSIR, with Prescott as its first (part-time) Chief (Stephens et al 1988).

In 1924 a CSIR research facility was established at Griffith, funded jointly by the Commonwealth and NSW Water Conservation and Irrigation Commission, called the Commonwealth Citrus Research Station (1924-1927). It worked closely with the CSIR Soils Division, and later was concerned with every aspect of production under irrigation (CSIR 1936). It evolved into the fully Commonwealth Research Station, Murrumbidgee Irrigation Area (1927-1939) and Irrigation Research Station (1939-1961).[7]

10.4 Learning from Experience beyond the MIA

MIA planners and policy makers were able to draw on experience generated beyond the MIA. Farmers engaged in irrigated agriculture in south-eastern Australia shared common problems which were largely the result of government-sponsored irrigation developments on land unfit for the purpose. Inadequate investigations into the nature of soils and their potential for irrigation produced long-term unwanted consequences. Farms failed to yield their expected production, and families sank further into debt.

10.4.1 The Murray Valley

By 1914 new settlers on the MIA were experiencing the effects of over-watering. In Victoria the problem had evolved into the next phase, salinity. At a Royal Commission on Closer Settlement in the irrigated districts, the Victorian Government examined salinity in the Cohuna Settlement on the Murray River (Victoria 1916). The Commission emphasised that the suitability of land for irrigation was absolutely vital in closer settlement: ‘Unsuitable land actually means failure from the outset in respect to intense culture’ (Victoria 1916:22). Cohuna, one of the earliest irrigated districts, was already salt-affected in the 1890s. By 1910 one area had 1200 out of 11,000 acres unfit for any production because of salt. The Victorian Water Commission dealt

[6] In 1949 CSIR became the Commonwealth Scientific and Industrial Research Organization (CSIRO).

[7] Later again the Station evolved into the following CSIRO agencies: Irrigation Research Laboratory (1961-1967); Division of Irrigation Research (1967-1982); Centre for Irrigation Research (1982-1987); Centre for Irrigation and Freshwater Research (1987-1988); Division of Water Resources (1988-1997); Division of Land and Water (1997-). See Australian Science and Technology Heritage Centre at http://www.austehc.unimelb.edu.au/asaw/biogs/A000774b.htm

with the problem by means of remedial drainage works. However, because drainage was costly, the measure was often introduced too late, when the problem was already serious. This was the case at Cohuna.

Many settlers on irrigated blocks in Victoria criticised the quality of the instruction available. The Commission found 'the clearest evidence' that the closer settlement program had been greatly lacking supervision 'by officers thoroughly conversant with the practices of intensive culture' (Victoria 1916).

Soldier settlement added a new element to the issues and problems of irrigated agriculture. By 1925 the Murray-Darling Basin states were again investing public resources to investigate the problems. From the proceedings of the Victorian Royal Commission on Soldier Settlement it is evident that the community believed no experience was needed to have a life on the land, whether in irrigated or dryland farming. After World War I the Government had tried to implement a system of accreditation, whereby war veterans had to prove they had satisfactory farming experience. These attempts were thwarted by the ‘public excitement’ that every soldier should get a chance if he desired to go on the land. Hence, many ill-equipped men slipped through the selection process, only to fail. In a short time, this dearth of experience threatened the economical viability of the Victorian Soldier Settlement Scheme (Victoria 1925).

The minority report of the Victorian Commission drew attention to the risks of irrigating salt-affected land. It was stated that the risk of salinity arising in almost all the dried-fruit areas was fairly well established. The worst affected areas were Tresco where many flourishing citrus groves had died; Mildura (where salinity was discussed in 1893); Woorinen, Nyah and Merbein; and Cohuna (mentioned in the 1916 Inquiry). Since 1916 the salt-affected area at Cohuna had grown to 5000 out of 34,000 acres (an increase from 11% to 14.7%). The minority report continued. ‘It seems inevitable that all soils with an alkaline substrata must finally reach the stage where no vegetable growth can survive’ (Victoria 1925:50). Salt and seepage were seen as a serious menace to the success of the Soldier Settlement Scheme, and the report recommended that drainage be installed at the inception of any irrigation scheme (Victoria 1925:58). There was also concern over the large settlement at Red Cliffs, where salinity was appearing.

The seriousness of the salinity problem in the Victorian Mallee is illustrated in the case of the Tresco Irrigation Area. Subdivided in 1913, and planted with citrus orchards in 1915, Tresco already had problems by the end of the war. Trees deteriorated rapidly from 1921, and watertables rose to within 30 and 60 cm of the surface. By 1925 half the citrus trees across the settlement were dead (Barr and Cary 1992).

Between 1916 and 1918 the South Australian Government investigated the problems of water supply in ten areas of the state, including areas along the Murray River. While these studies focused more on water for stock and domestic needs, they reported on the need for irrigation water to produce stock fodder on small plots on the Murray Flats. Salinity was not yet an issue for this State Government (SA 1916, 1918).

In 1925 the financial liabilities of returned soldiers on irrigation areas along the Murray was a matter of concern in South Australia. The Government convened a Royal Commission to examine the conditions underlying their financial and social distress. Like every inquiry on the subject of irrigation so far, the Commission criticised the practice of opening up areas for irrigation in the absence of proper soil surveys. For irrigated farming to succeed it was essential that the Department of Agriculture and the Irrigation Commission had a co-ordinated approach to development. The Commission saw that settlers needed more training in the scientific aspects of irrigation (SA 1925). Salt was not mentioned.

10.4.2 Western Australia

By the 1910s there was evidence that salinity was a serious problem in Western Australia. There, the problem was associated with land clearing, not irrigation, but the consequences were the same. So were the lessons for the rest of the country. In the 1890s the engineer W.E. Wood observed, first in South Australia and later in Western Australia, that where the destruction of native vegetation occurred rapidly, an increase in local stream salinity quickly followed. By 1905 railway and water-supply engineers were concerned about the high salt content of the water supplied for steam engines (Wood 1924:35).[8] In 1909 N.C. Reynolds, an engineer with the Country Water Supply that operated the Kalgoorlie water pipeline and supplied water to the railway, noted that the most saline water came from the most heavily cleared catchments (Beresford et al 2001).

The Royal Commission into the Mallee Belt and Esperance Lands (WA 1917) investigated the development of mallee lands for wheat. This Commission not only ignored the established links between salinity and land clearing, but also set out to discredit the expert evidence and to manipulate the findings. John Patterson, Professor of Agriculture at the University of Western Australia, produced a disturbing report in which he concluded that a large part of the district in question was unfit for agriculture because of the high salt concentrations. The Commission sidelined the evidence and concluded (WA 1917:xiv):

[8] Wood's paper is a landmark in understanding the dryland salinity problem of Western Australia.

> In other parts of Australia adverse professional opinion respecting mallee lands has been disregarded with advantages to the State, and the Commission having given the question close consideration strongly urges that scientific prejudice against our mallee lands be not permitted to stand in the way of their being opened up.

10.5 Did they learn from the past?

The account of irrigation development presented in this chapter provides insights into how policy makers in New South Wales approached intensive irrigation development in the early decades of the twentieth century. By this time, as irrigation practice moved from the experimental phase into the large-scale operational phase, government planning and policy needed to address a much wider set of issues than in those considered in the 1890s. Although there was still much to learn about soils and groundwater in New South Wales, useful lessons from the past could have been found. I argue that the MIA planners did not learn from the past on matters that were crucial for a successful irrigation enterprise.

Despite the large body of evidence on irrigation salinity in India, relatively few references were found to India as a source of important understandings for irrigation development in the MIA. Engineer McKinney had worked in some of the worst salt-affected areas along the Lower Ganges Canal, but he did not alert people to the dangers of salinisation. In fact, he regarded it as a subject that had been given 'exaggerated importance' (McKinney 1895: 548).

By 1900 a growing body of evidence existed from south-eastern Australia that salt could have serious effects on the soils and groundwater. The area of the MIA was not excluded. A royal commission in 1888 heard that water in the Old Gunbar well in the Riverina was so saline it was unfit for stock (NSW 1888). Settlers at Mildura in the 1890s suffered serious setbacks as a result of irrigating the highly saline mallee soils. Scientists studying the possibilities of artesian irrigation were aware of the high salt content of groundwater in the Great Artesian Basin. Nevertheless, the field surveys conducted in 1903-1906 for the proposed MIA produced a remarkably small number of soil samples from which to classify an area of over one million hectares.

During the public inquiries between 1903 and 1906 relatively little attention was paid to soils and groundwater. The Parliamentary Standing Committee on Public Works visited Mildura in 1906, and heard from witnesses about saline conditions there. But the potential for this evidence to shape planning and policy for the MIA was diminished by evidence that badly salt-affected land had since been found suitable for growing sultanas. The information derived from soil analyses at this time was generally seen as having little practical value. Nowhere was evidence found that planners were proceeding from an assumption that salt *might* become a problem in the MIA.

From 1909 the Department of Agriculture conducted trials with different crops at the Yanco Experiment Farm to identify the most appropriate species for the MIA. Scientists continued the soil-testing service for farmers across New South Wales. Jensen's soil survey (1909-1911) enhanced understanding of the State's soils, and Guthrie's studies of alkali-affected soils under artesian irrigation progressed. Nevertheless, these advances seem to have had little influence on day-to-day operations in the MIA. In 1915 settlers were unsuccessful in having a soil-testing laboratory established in the MIA.

Experiments at Pera Bore had demonstrated the importance of good water-usage practices. Over-watering was known to be a problem in India, Mildura and the western USA. Warnings about over-watering in the MIA seem to come via American experience, rather than as a result of any organised program to monitor local effects of irrigation on the watertable. As rising watertables became evident at Yanco in 1914, one MIA irrigator voiced his concern about poor irrigation practices. But waterlogging increased across the areas.

At this time Victorian farmers in the Murray Valley were already encountering salinity. The problem became more widespread as irrigation areas were opened up to soldier settlements after 1918. No evidence was found that the NSW community in the MIA was actively seeking to learn from the experiences of the Victorians.

PART III

EPILOGUE

The planners of the Murrumbidgee Irrigation Scheme failed to learn from the past, and consequently they ignored the possibility that salt would be a problem. As the following brief survey shows, this tendency has persisted well into the modern era.

Irrigation Development in New South Wales 1930s to 1970

In the 1920s the NSW Government established small irrigation schemes in the Murray and Murrumbidgee valleys. Others were planned in the 1930s, but progress was held back by the effects of the Great Depression and World War II. These developments had to be delayed until after 1945. (See Table E.1.)

Table E.1:
Major irrigation development in New South Wales 1920-1960

Year constituted	Scheme	Notes
1920	Tullakool I.A. Wakool Region of Murray	Began as 5 small irrigation trusts for ex-servicemen, watered from Edwards River. 1943 rice growing introduced on Tulla Estate as wartime measure, which continued after war. 1950s significant rise in watertables and evidence of salinity.
1921	Yanco-Colombo-Billabong Creek W.T.D. Murrumbidgee	First Water Trust District on Murrumbidgee, set up to water pastures with high sheep-grazing value.
1924	Curlwaa I.A. and Coomealla I.A. Murray	Formerly Wentworth Water Trust, first scheme in NSW (1890). By 1931 waterlogged soils, followed later by salinity. 1937 CSIRO soil survey (No 107)
1932	Wakool I.D. Wakool Region of Murray	First of major developments along Murray, it covered 209,000 ha between Edwards and Wakool Rivers. 1943 CSIRO soil survey (No 162). 1950s waterlogging and salinity as a result of rice growing.
1934	Berriquin I.D. Deniliquin Region of Murray	300,000 ha for soldier and closer settlement. Development interrupted during war. 1945 CSIRO soil survey (No 189)
1934	Jemalong I.D. Lachlan	Originally 70,000 ha served by water from Wyangala Dam (1936) and Jemalong Weir (1940) for stock and domestic purposes and irrigation.
1934	Wylde's Plains I.D. Lachlan	Originally 21,000 ha served by water from Wyangala Dam (1936) and Jemalong Weir (1940) for stock and domestic purposes and limited irrigation.

Table E.1 (continued)		
Year constituted	Scheme	Notes
1935	Tabbita I.D. Murrumbidgee	First of the Districts adjacent to MIA to be developed. Land initially acquired for readjustment of MIA holdings. Constituted with only 4 holdings, which later increased.
1936	Benerembah I.D. Murrumbidgee	Located west of Mirrool I.A., served by North Kooba Branch channel. Works began in 1933. Set up initial with 30 large holdings for mixed farming on 49,000 ha. Rice growing introduced as wartime measure in 1942. It continued to expand and produce rice. Shallow watertables and salinity appeared in 1984 over large areas.
1938	Wah Wah I.D. Murrumbidgee	Formerly Gunbar W.T.D. (1930) established to use drainage waters from MIA for stock and domestic purposes.
1938	Deniboota I.D. Wakool Region of Murray	Development interrupted by the war, and water not supplied until 1955 to 172 holdings.
1945	Lowbidgee F.C. & I.D. Murrumbidgee	Purpose was to take advantage of sporadic high flows for irrigation and pasture between Lachlan and Murrumbidgee. Constituted with 50 holdings covering 140,000 ha. Included the Nimming-Pollen Creeks W.T.D. (1931).
1946	Denimein I.D. Deniliquin Region of Murray	Considered at the end of the war, it was set up over 42,000 ha for sheep and wheat farming. Since 1956 increasing shift to rice growing.
1948	Gumley Stock and Domestic Water Supply and I.D. Murrumbidgee	A small operation near Wagga Wagga, using spray irrigation, set up with 46 holdings over 140 ha.
1956	Coleambally I.A. Murrumbidgee	Last of major government schemes. Began in 1960 with 54 mixed and 8 horticultural farms. Opening of Blowering Dam (1967) prompted a second stage of development. Rice growing introduced in 1960s as a temporary measure to provide a cash crop, then replaced horticulture. 1981-91 significant rise of watertable. 1984 salinity evident as watertable approached < 2m from surface.

Langford-Smith 1966; Lloyd 1988; Hallows and Thompson 1995.

W.T.D. Water Trust District
I.D. Irrigation District
I.A. Irrigation Area
F.C. & I.D. Flood Control and Irrigation District

From the 1930s the problems associated with rising watertables increased. Langford-Smith (1966) have described the natural conditions that accompanied irrigation development at this time. Periods of exceedingly wet weather drew attention to the problems of rising watertables in the Riverina. In May 1931 there were devastating floods in many areas of the Murrumbidgee, and widespread waterlogging throughout the MIA. The worst was at Yenda (Mirrool IA). Here its peculiar topographic characteristics produced high concentrations of salt in the upper soil horizons. From 1931 watertables were high, and in some cases close to the surface. Serious flooding from the Murrumbidgee occurred again in spring 1934. A wet winter in 1939 produced another significant rise in the watertable in the MIA. There was widespread flooding in New South Wales during much of 1950. Flooding from three major rivers (Murrumbidgee, Lachlan and Macquarie) caused devastation in the winter of 1952. A wet season in 1956, with flooding from the Murrumbidgee, drew attention to salinity in the MIA. It produced losses greater than in any previous wet periods, with serious damage to fruit trees (Langford-Smith 1966).

With irrigation expansion and a succession of wet seasons watertables were steadily rising. From 1935 waterlogging and drainage became a constant problem for the MIA. Once watertables were within two metres of the surface the land was also at risk of salinity. Although deep drainage had long been known as a necessary part of intensive irrigation, drains had not been included in the original construction of the MIA. The installation of tile drains, as a means of lowering the watertable, was slow at first but progressed after World War II.

From 1930 scientific research progressed on the problems associated with intensive irrigation. In 1929 the NSW Water Conservation and Irrigation Commission had set up its own Research Branch, under F.K. Watson, to study hydrological problems that were causing losses in the MIA.[1] In 1930-31 the Council for Scientific and Industrial Research (CSIR) began a program of watertable surveys and soil surveys of irrigation districts. Results of the soil surveys were published in CSIR *Bulletins* (Table E.2). Later, CSIRO undertook another program of surveys to identify soils with horticultural potential. Results of 62 surveys were published in the CSIRO *Soils and Land Use Series* from 1949.

[1] In 1938 the NSW Soil Conservation Service was established to deal with other forms of land degradation.

Table E.2: **CSIR soil surveys of irrigation districts in the southern Murray-Darling Basin**	
1929	Block E (Renmark) and Ral Ral (Chaffey) Irrigation Areas (SA), No 42
1930	Woorinen settlement, Swan Hill Irrigation District (Vic), No 45
1932	Cadell Irrigation Area and New Era (SA), No 62
1932	Blocks A, B, C, D and F, Renmark Irrigation District (SA), No 56
1932	Murrabit (Vic) and Bungunyah (NSW)
1933	Nyah, Tresco, Tresco West, Kangaroo Lake (Vic), and Goodnight (NSW) Settlements, No 73
1935	Berri, Cobdogla, Kingston and Moorook Irrigation Areas and the Lyrup Village District (SA), No 86
1937	Coomealla, Wentworth (Curlwaa) and Pomona Irrigation Settlements, No 107
1938	Murrumbidgee Irrigation Areas (NSW), No 118
1939	Merbein Irrigation District (Vic), No 123
1939	Part of the Kerang Irrigation District (Vic), No 125
1940	Mildura Irrigation Settlement (Vic), No 133
1941	Red Cliffs Irrigation District (Vic), No 137
1941	Waikerie Irrigation Area (SA), No 141
1943	Wakool Irrigation District (NSW), No 162
1945	Berriquin Irrigation District (NSW), No 189
CSIRO *Soils and Land Use Series*	

At an Interstate Conference on Water Conservation and Irrigation held in Sydney in 1939 the States and Commonwealth were turning their collective attention to irrigation development (NSW 1939). The parties were concerned with water resource planning as part of national development. Nevertheless, the problems of waterlogging and salinity were not addressed.

After World War II the Commonwealth Government promoted development of a different kind when it provided financial assistance for expansion of water storage capacity to serve both irrigation and hydro-electricity generation. The Snowy Mountain Scheme (1947-1974) was the flagship of this phase of development, located in New South Wales. Irrigation from the Murray and Murrumbidgee benefited from the Snowy Scheme which provided additional water for irrigation in times of drought. Table E.3 lists smaller State-funded water storage facilities that were constructed up to 1970. No new large government-sponsored irrigation schemes, like the MIA, were established in New South Wales after the Coleambally Irrigation Area in 1956. Irrigated agriculture in the State was confined generally to its 1956-land cover.

Table E.3: **Development of water storages in New South Wales 1928-1970**		
Year of completion		Effective capacity (megalitres)
1928	Lake Victoria, Darling River	680,000
1929	Burrinjuck Dam extension, Murrumbidgee River	800,000
1936/71	Wyangala Dam, Lachlan River	1,220,000
1952	Lake Brewster Storages, Darling River	153,000
1954	Hume Dam, Murray River	3,080,000
1956	Burrinjuck Dam extension, Murrumbidgee River	1,030,000
1958	Glenbawn, Hunter River	360,000
1960	Keepit Dam, Namoi River	423,000
1966	Menindee Lakes, Darling River	1,800,000
1967	Burrendong Dam, Macquarie River	1,677,000
1968	Blowering Dam, Tumut River	1,630,000
1969	Pindari Dam, Severn River	37,000
1970	Carcoar Dam, Belubula River	36,000
Hallows and Thompson 1995		

In 1945 the Commonwealth set up the Rural Reconstruction Commission (RRC) to consider many aspect of resettling men after World War II. In its *Eighth Report* the RRC addressed several problems already experienced in irrigation development (RRC 1945). The report showed that by 1945 certain facts about soils and groundwater with respect to irrigation were clearly known. For example, it was stated that groundwater in rock heavily charged with carbonates was useless for irrigation (para 1704). Numerous studies had demonstrated that groundwater with a high salt content was disastrous for irrigated agriculture (para 1732). It was recognised that high watertables were a serious problem. Clearly, advances in the scientific understanding of soils and groundwater had taken place since the inception of the MIA. Scientists were well aware of the tightly coupled nature of the problems of waterlogging and the accumulation of surface salts. Thorpe (1942:86) summarised the mandate for science:

> . . . research should aim to correlate the factors affecting irrigation and define the relationship of water and soil, topography, climate and crop requirements, and so determine the most suitable practices of irrigation and land use according to these factors.

Nevertheless, progress in practical understanding on the part of irrigators lagged seriously behind scientific understanding. Despite experience from earlier settlements on the Murray and

Murrumbidgee, the RRC found that in some recent settlements lessons had not been learned about over-watering. Further troubles would likely occur on some farms in future (para 1746). The RRC expressed 'surprise at this state of affairs' and was 'at pains' to understand it. It attributed this failure to learn from experience to 'the time-worn belief that Australian soils are highly fertile', and that only the shortage of rain inhibited plant growth (para 1747).

The 'common fallacy' about soil fertility led the RRC to comment on developments in understanding of native plants. The RRC noted that increased moisture in the dry season would not prolong growth beyond the natural growing season. Crops raised under dryland farming were quite unsuited to irrigation. It expressed surprised that 'wild flooding' was still practised in various parts of Australia, whereby water was distributed unevenly and excessively over the land. Such examples of poor irrigation practices prompted the RRC to recommend intensive education extension programs that were carefully devised for all new irrigation schemes (para 1750).

To address the poor irrigation practices in the farming community the education extension program, which had already begun in the late 1920s, grew stronger after the war, particularly through the work of the Irrigation Research Extension Committee (Langford-Smith 1966).

Over the post-war decades the work of the Irrigation Research Branch of the Water Conservation and Irrigation Commission continued across a range of problems affecting irrigation in the Murrumbidgee and Coleambally Irrigation Areas. As existing areas were expanded and new ones came under irrigation, the Branch was busy with geological and hydrological investigations, and research into soil chemistry, horticulture and plant physiology. After the abnormally wet conditions in the winter of 1956, when watertables rose dramatically, the need for developing programs using deep subsoil drainage and tile drains became even more important. By 1960 some 302 farms in the MIA had been tile-drained since that program began in 1953 (WCIC AR 1960). Other programs continued for monitoring watertable levels and for investigating deep drainage, and soil and groundwater salinity. A summary of the work of the Irrigation Research Branch appeared in the *Annual Reports of the Water Conservation and Irrigation Commission*.

The hydrogeological studies of the Riverine Plain in New South Wales were an important step towards understanding the waterlogging and salting problems in irrigated areas. The earliest work to understand the natural features of this landscape resulted in mapping all sediments of the plain simply as floodplain sediments of the present rivers. But a significant contribution came from Butler (1950) who put forward the theory of prior streams (see Chapter 7). He showed that the pattern of deposition of the bulk of the plain sediments was related to prior streams radiating out from gaps in the eastern ranges, and that three vast alluvial fans coalesced to form the plain.

By the 1960s scientific understanding of rising watertables and salinity in the southern Murray-Darling Basin made further advances. It was enough to prompt a local conference in 1966,[2] and for scientists to be in a position to review the progress that had been made. Among the significant papers that appeared during this time were those on the sources of salt in catchments in Victoria (Cope 1958); reviews on the broad problem of salinity (England 1963, Forster 1963); and on the soil physics background to salinisation (Talsma 1963). The research of Pels and Stannard made further contributions to understanding of the geology and geomorphology of the Riverine Plain (e.g., Pels 1960, Stannard 1962). Other scientific papers followed, as a result of the Commonwealth initiating the first national survey of Australia's water resources (AWRC 1965). Developments in hydrogeology are also evident, for example, from papers delivered at a symposium on the hydrogeology of the riverine plain in South-East Australia (Storrier and Kelly 1978).

Similar progress in scientific research took place on the part of Victorian Government agencies in the irrigation areas south of the Murray River. Here the geological history and irrigation practices had been creating serious salinity problems earlier than in the MIA. By the mid-1960s highly salinised runoff from the irrigation areas of the Murray and its tributaries was having a serious impact on the water quality of the Murray, particularly in the lower reaches. These events prompted the River Murray Commission in 1967 to call for the first major study of salinity in the Murray Valley. This study by Gutteridge, Haskins and Davey (1970) marked the first real phase of attempts to understand the whole system (see Chapter 7).

The effect of establishing irrigation schemes without concern for soils and groundwater and the problem of poor irrigation practices characterised irrigation development in south-eastern Australia during much of the twentieth century. In the next chapter I will consider some of the possible causes for such persistent failure to learn from the past.

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[2] Notably a symposium on the geomorphology and palaeohydrology of the Riverine Plain, held at the CSIRO Irrigation Research Station, Griffith, in August 1966 (CSIRO 1966).