APPENDICES

APPENDIX A CONCEPTUAL MODEL OF IRRIGATION DEVELOPMENT

To illustrate the dynamics of the process of irrigation salinisation a conceptual model of the development of an irrigated farming scheme was built using Stella® software. The technical details of the model are outlined in this appendix. A brief description of the graphical language used in Stella® is given in Chapter 3 (§3.3). The scenarios that the model is intended to capture, and its behaviour, are described in Chapter 6 (§6.4.1).

As shown in Figure A.1, CMID is a fifth order dynamical model. The five state variables of the system are average soil moisture in the crop root zone (represented by the symbol M and measured in units of the percentage weight of water in unit weight of soil), average watertable height in the district (H measured in metres above an impervious layer that lies 15 metres below the surface), average salt concentration in the root zone (S measured in deci-Siemens per metre), accumulated aggregate agricultural product (P measured in bushels), and accumulated aggregate wealth (W measured in pounds). Because this is a conceptual model that is designed to illustrate the general type of behaviour expected, all of the state variables are expressed in conveniently scaled units. As many of the scale factors as possible have been set to a nominal value of 1. All stocks and flows represent averages taken across the whole scheme.

In the description below the EQ numbers refer to the equations listed in Table A.1.

1 Average Soil Moisture

M represents the stock of moisture contained in the soil of the crop root-zone. This stock is influenced by two inflows *irrigation rate* and *rainfall rate*, and by three outflows *evapo-transpiration rate*, *recharge rate* and *surface runoff rate* (EQ 1). The evapo-transpiration rate is the combined rate of moisture loss into the atmosphere from the soil surface by evaporation and from plants by transpiration. It is the sum of the surface evaporation rate and the transpiration rate (EQ 6, 28, and 29). The recharge rate is the rate at which water in excess of the soil field capacity (see Figure 6.3 and the related discussion) percolates through the sub-soil and into the groundwater (EQ 8-11). M is initialised to 20% water w/w, the equilibrium value for the system when the only source of water is the rainfall (EQ 2). The rate at which irrigation water infiltrates the soil (EQ 3) is set to zero, because the farmer stops irrigating, if the water table comes within 1 metre of the surface (at which point the soil is taken to be saturated) and if the root-zone salt concentration reaches a high level (at which point the soil is assumed to be sterile). If neither of these conditions hold then the irrigation infiltration rate is set equal to half the average rate R at which water is applied to the area (compare EQ 3 and 25) to allow for channel and surface

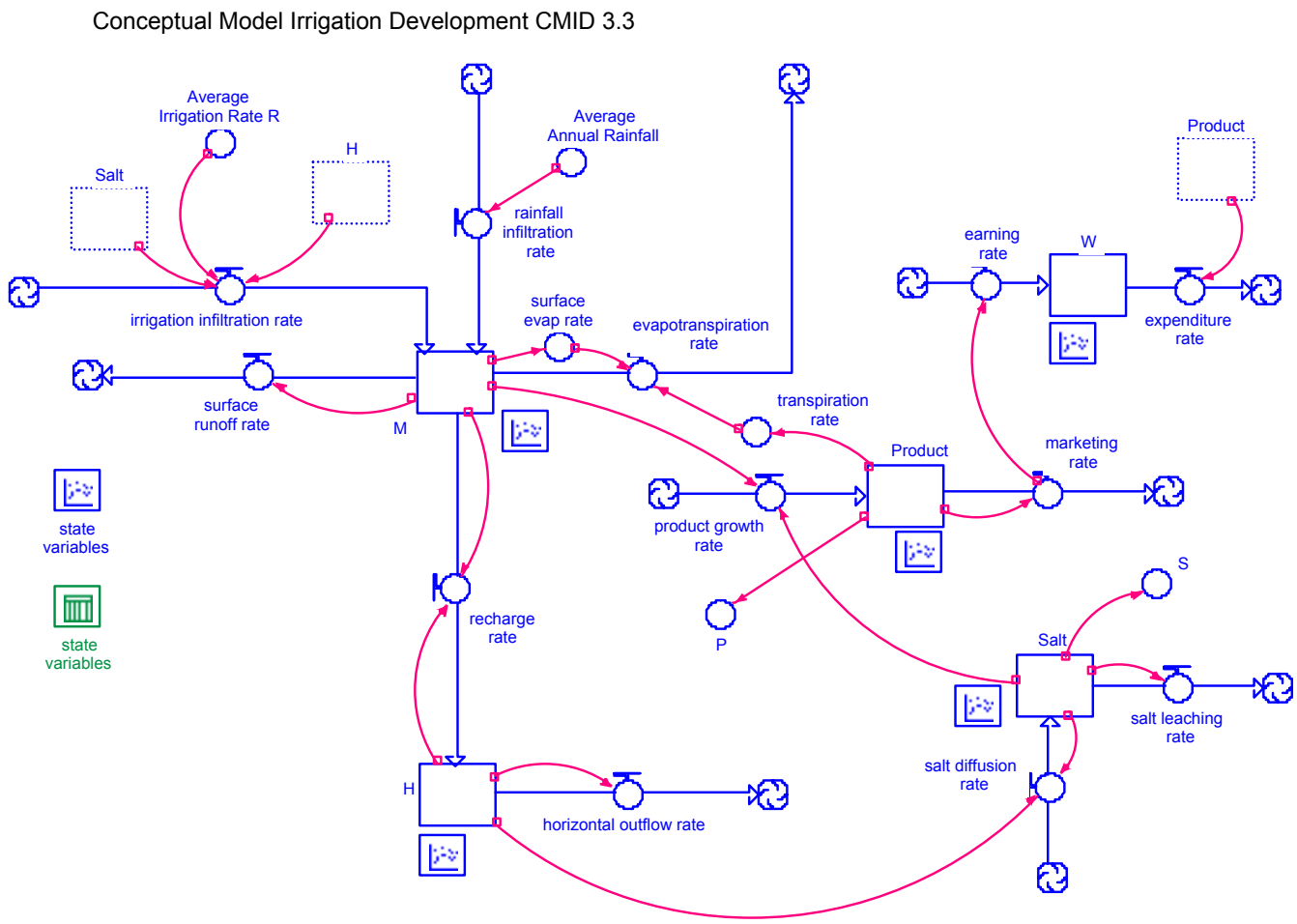

Figure A.1. The conceptual model of irrigation development (CMID). See text for description.

Table A.1:

CMID Equations

Average Soil Moisture in the Root-Zone

1. M(t) = M(t - dt) + (irrigation_infiltration_rate + rainfall_infiltration_rate - recharge_rate – evapotranspiration_rate - surface_runoff_rate) * dt
2. INIT M = 20
3. irrigation_infiltration_rate = IF (H >= 14.0 OR Salt >20) then 0 else Average_Irrigation_Rate_R/2
4. rainfall_infiltration_rate = Average_Annual_Rainfall/30
5. recharge_rate = 1*(M-30)*(1 - exp(4*(H - 14)))
6. evapotranspiration_rate = surface_evap_rate + transpiration_rate
7. surface_runoff_rate = 1000*(M-40)

Average Watertable Height

8. H(t) = H(t - dt) + (recharge_rate - horizontal_outflow_rate) * dt
9. INIT H = 0
10. recharge_rate = 1*(M-30)*(1 - exp(4*(H - 14)))
11. horizontal_outflow_rate = 0.05*H

Average Salt in the Root-Zone

12. Salt(t) = Salt(t - dt) + (salt_diffusion_rate - salt_leaching_rate) * dt
13. INIT Salt = 0
14. salt_diffusion_rate = 1*(50 - Salt)*exp(4*(H - 14))
15. salt_leaching_rate = 0.01*Salt

Aggregate Agricultural Product

16. Product(t) = Product(t - dt) + (product_growth_rate - marketing_rate) * dt
17. INIT Product = 0
18. product_growth_rate = 1*(1 - 0.1*(Salt-2))*(IF (M > 13 AND M < 37)
    THEN 1*(0.041666*(M - 13))
    ELSE IF (M >= 37 AND M <40)
    THEN 1*(1.0 - 0.3333333*(M-37))
    ELSE 0)
19. marketing_rate = 1*Product

Accumulated Aggregate Wealth

20. W(t) = W(t - dt) + (earning_rate - expenditure_rate) * dt
21. INIT W = 0
22. earning_rate = 20000*marketing_rate
23. expenditure_rate = 2000 + 200*Product

Auxiliary Variables

24. Average_Annual_Rainfall = 300
25. Average_Irrigation_Rate_R = 60
26. P = 20000*Product
27. S = Salt/10
28. surface_evap_rate = 0.5*M + 20*exp(10*(M - 40))
29. transpiration_rate = 20*Product

runoff losses. For similar reasons, the rainfall infiltration rate (EQ 4) is assumed to be 1/30th of the annual average rainfall (EQ 24). The surface runoff rate (EQ 7) is the rate at which excess water is removed from the area by means of artificial drainage or via natural streams. Since saturated soils cannot accept more moisture, the surface runoff rate is set to a large value if M exceeds the soil saturation level (40% w/w, see Figure 6.3) to represent the condition where the soil cannot accept further moisture.

2 Watertable Height

H represents the height of the groundwater surface above an impermeable layer that is assumed to lie 15 metres below the soil surface. It is influenced by one inflow *recharge rate* and one outflow *horizontal outflow rate* (EQ 8). H is initialised to zero (EQ 9). The recharge rate is proportional to the amount by which the soil moisture M exceeds the assumed field capacity (30% water w/w) and makes an exponential transition to zero as the water table approached the bottom of the root zone, which is assumed to be 1 metre thick (EQ 10). The exponential transition is designed to capture the effect of the watertable capillary fringe. The horizontal outflow rate increases with watertable height (EQ 11).

3 Root Zone Salt

S represents the amount of salt in the crop root zone. It is influenced by one inflow *salt diffusion rate*, and has one outflow *salt leaching rate* (EQ 12) and is initialised to zero in the model (EQ 13). The salt diffusion rate is the rate at which salts, dissolved in the groundwater, move into the upper soil profile. This rate is assumed to reduce to zero as the root-zone salt concentration increases towards 5.0 deci-Siemens per metre and to show the same capillary fringe effect as the groundwater recharge rate (EQ 14). Note that S is a scaled version of the variable Salt used in the computations (EQ 27). The salt leaching rate represents the concentration-dependent flow of salt out of the root zone (EQ 15).

4 Agricultural Product

P represents the aggregate agricultural product, stored for marketing, derived from all farming operations across the irrigation area. It is controlled directly by one inflow *product growth rate*, and has one outflow *marketing rate* (EQ 16). CMID is intended to represent the start-up phases of the irrigation development, therefore P is initialised to zero (EQ 17). The product growth rate is reduced as the root-zone salt increases in concentration and reflects the moisture-dependence of crop yield (EQ 18). The IF-THEN-ELSE structures in EQ 18 represent, as linear equations, the growth rate behaviour specified in Figure 6.3. The marketing rate (EQ 19) represents the rate at which agricultural products are harvested or otherwise converted into commodities for sale in

the market place. It is assumed to be directly proportional to the amount of agricultural product available.

5 Accumulated Wealth

W represents the accumulated profits from the irrigation scheme, aggregated across all farms. It is influenced by one inflow *earning rate* and one outflow *expenditure rate* (EQ 20). Again, because CMID models the start-up phases of the scheme, the initial value of W is set to zero (EQ 21). The earning rate is taken to be proportional to the marketing rate (EQ 22), scaled to produce a reasonable level of income in pounds. The expenditure rate is assumed to be the sum of a constant overhead component and a stream of production-dependent operating costs (EQ 23).

APPENDIX B SOURCE MATERIALS USED IN PART III

In the AEH study in Part III I have used primary and secondary historical sources. As in many environmental history studies undertaken by other scholars, in my study I have used well-known, and some lesser known, primary materials to answer new questions not previously asked of the documents. As in most historiographic work, the AEH study reflects the limitations of the sources.

India

The material for Chapter 8 comprises nineteenth century primary records, secondary sources from the nineteenth and early twentieth century, and contemporary sources from c.1950s. Primary records exist in both India and Britain. The National Archives of India is an enormous official repository in New Delhi. It was set up in 1891 in Calcutta as the Imperial Record Department. Later, it was moved from Calcutta when the national capital was relocated to New Delhi in 1911. An equally rich source of primary material is found in the India Office Library (British Library), London. This is the repository for government records from the British colonial period of India. The archive represents all official correspondence between India and London from the days of the East India Company until 1947. Many items in the India Office Library are also found in the National Archives of India.

The government reports most relevant to irrigation are found in the various *Proceedings* of the Departments of Public Works, of Agriculture and of Revenue in the North-Western Provinces. As irrigation was expanded, and new settlements and formalisation of tenure boundaries followed, *Settlement Reports* tracked their progress and problems. The Indian central administration conducted inquiries, for example, Famine Commission (1879) and Irrigation Commission (1903), and these provide useful insights into the effects of irrigation and associated issues.

An important archival collection comes from Thomason College of Engineering (founded in 1847), now the Indian Institute of Technology (Roorkee). It contains a huge collection of primary records and other material concerning irrigation development in northern India, particularly the design and construction of the Ganges Canal. Documents relating to canal engineering are also found in libraries in London (e.g., the Engineering Department of Imperial College of Science and Technology, and the Institution of Civil Engineers).

Thousands of secondary sources exist on irrigation development in India. Publications from the nineteenth century begin with general descriptions of the introduction and development of the canal systems (e.g., Smith 1882; Deakin 1893; MacGeorge 1894; Buckley 1880 and 1905; Clibborn 1909;

Trevaskis 1931). Some of the earliest accounts of the problem of rising watertables and salt come from government reports that have been republished in more publicly accessible forms (e.g., Baden-Powell 1868, Watt 1889). Gupta and Pahwa (1978) have provided a useful bibliographic tool with which to identify the earliest known scientific accounts published in India on soil salinity. Papers in this field appeared particularly in the *Journal of the Royal Asiatic Society* (from 1834), *Records of the Geological Survey of India* (from 1868), and *The Agricultural Ledger* (from 1894). Discussions on salt-affected lands are found in these journals, and in treatises written by engineers, (e.g., Clibborn 1909).

An important perspective on the problem has come from Voelcker (1893). In 1889 the Government of India appointed the first agricultural chemist to report on the country's agricultural conditions. Dr J.A. Voelcker published the findings from his 13-month tour of India in *Report on the Improvement of Indian Agriculture*.

Contemporary evidence moves beyond reporting and describing. It examines in more detail the economic and social effects of intensive irrigation in northern India (e.g., Whitcombe 1972, 1983, 1996, Stone 1984, Banerji 1995, Henry 1995, Gilmartin 1996, Islam 1997). Among the recent sources here, Whitcombe (1972) stands out. Her excellent studies of the social and economic effects of irrigation in the nineteenth century make exhaustive use of primary records. For this reason, I have drawn on them where I could not consult the original records. As interest has grown in environmental studies, a new area of research is emerging which studies the effects of irrigation on the environment (e.g., Ghassemi et al 1995, Arnold and Guha 1996, Mann 1998, Postel 1999). The effect of irrigation on human health is also of particular interest to Whitcombe (1996).

I spent ten days in London, when I visited the India Office Library, Imperial College of Science and Technology and the Institution of Civil Engineers, and undertook part of the research for Chapter 8. While the visit was immensely valuable, it did not equip me to review the field on the wide range of issues concerning irrigation salinity in India. Therefore, Chapter 8 does no more than present an overview of the understanding of key issues to irrigation salinity, as reported in the nineteenth and early twentieth centuries.

South-eastern Australia

The material for Chapter 9 comes from both primary and secondary sources. It includes the recorded observations of explorers, men on the land and scientists in the last two decades of the nineteenth century. Much of this has survived via the *Journal of the Royal Society of New South Wales*. In fewer cases, scientists published findings of their work in the *Report of the Australian Association for the*

Advancement of Science. Evidence given before royal commissions and has also preserved the observations of these groups. The NSW Department of Agriculture, established in 1890, published the *Agricultural Gazette of New South Wales* from that year. This journal is an important source because its illustrates the kind of current information that agricultural scientists were able to provide the farming community.

In Victoria the Royal Commission on the Mildura Settlement (1896) and subsequent parliamentary debates are the principal sources for the official report on Mildura. The Victorian Department of Agriculture, established in 1872, published occasional research bulletins, but there was no regular series of publications until the *Journal of Agriculture of Victoria* appeared in 1903.

Various reports arising from investigations into water conservation and irrigation matters were published as official government reports, and can be found in the parliamentary records of the day.

The Murrumbidgee Irrigation Scheme

An enormous body of literature exists on the history of the Murrumbidgee Irrigation Scheme in all its dimensions (e.g., King 1957; Rutherford 1960; Wilson 1963; Langford-Smith 1966; Davidson 1969; Cowper 1968, 1987; Lloyd 1988). The *Annual Reports* of the Water Conservation and Irrigation Commission (WCIC)[1] from 1914 contain official reports on all aspects of land acquisition, subdivision and settlement, capital works, business enterprises (e.g., fruit cannery, cheese and bacon processing factories) within the MIA, management and the financial operations of the Scheme. From the formative years the Department of Agriculture provided reports on progress in crop development at the Yanco Experimental Farm (*Agricultural Gazette of NSW*), and these reports evolved to form part of the later scientific literature on irrigated agriculture. Government *Year Books* continue to provide statistical data on irrigated agriculture in New South Wales, including the MIA.

In 1913 the WCIC published an official version of the MIA development in the Commission's own publication *Irrigation Record* (15 March 1913), primarily to promote the Scheme to potential settlers. This publication omitted any recognition of the part played by McKinney and Gibson in the development. It carefully avoided references to the behaviour of the political parties around 1906-1910, when all parties subordinated long-term State interests in favour of their respective political interests. Later writers have repeated the 1913 official version of the MIA, without attempting to reconstruct events from reliable sources. From the 1980s, as concern was growing over the

[1] The Water Conservation and Irrigation Commission (1913-1975) evolved into the Water Resources Commission (1976-1986), the Department of Water Resources (1987-1992), the Department of Conservation and Land Management (1992-1994), the Department of Land and Water Conservation (1994-2003), then the Department of Infrastructure, Planning and Natural Resources (2003). See also Table 11.2.

management of Australia's water resources, many writers included the MIA in broad studies on water and the environment (Crabb 1982, Pigram 1986). Consequently, an important part of the early MIA history was ignored and almost forgotten.

Histories of irrigation in New South Wales are few. Walker (1941) included the MIA in his broad view of irrigation in New South Wales from 1884 to 1940. King (1957) discussed the MIA from the point of view of land tenure as a result of closer settlement and soldier settlement policies. Rutherford (1960) treated the MIA in his studies of integrating wet and dryland farming in the southern Murray-Darling Basin. Wilson (1963) gave a critique of Murrumbidgee irrigation as a form of investment and national development. Davis (1974) in his three-volume juridical science thesis gave an excellent account of irrigation history in Australia, but it remains an unpublished work from an American university. It was not until Lloyd (1988) produced his history of the development of water policy and administration in New South Wales that the MIA history received specific treatment. Nevertheless, Lloyd described the 'political machinations' around the MIA in 1906-1910 and their later significance as 'too labyrinthine to disentangle'. Cowper, on the other hand, took up this challenge, first in his MA thesis (Cowper 1968), which was later published (Cowper 1987). These two authors make extensive use of primary sources to produce the best critical analyses of the MIA and its multiple historical, social and political dimensions.

Given the quantity of source materials that cover the development of the MIA, it was neither my intention nor possible to cover the field. As Chapter 10 was guided by the three dynamical questions, it draws on the sources that I believed were most relevant to my purpose.

APPENDIX C BIOGRAPHICAL SKETCHES

In this appendix I present brief biographical sketches of scientists and engineers who were significant players in the period described in Part III.

	**Hugh Giffen McKinney** (1836-1930) received his engineering training at the Queen's University in Ireland. He gained his experience in irrigation with the Indian Public Works Department (1869-79) where he worked on major irrigation schemes for the Indus and Ganges systems. In 1880 he joined the NSW Public Works Department. During the next twenty years he carried out fundamental studies of the state of the rivers in New South Wales, collecting data essential for future development of the colony's water resources. As head of the Irrigation Branch, he designed water conservation infrastructure on the inland rivers, and was an enthusiastic promoter of irrigation development. He was responsible for the initial design, and later with Robert Gibson, the direct promotion of the Murrumbidgee Irrigation Scheme. He delivered nine papers to the Royal Society of NSW, wrote technical reports and papers, gave evidence at public inquiries, and public talks on irrigation. (Sources: see Bibliography.)
	William Adam Dixon (1841-1917) was trained as a chemist at the University of Glasgow under Professor Thomas Anderson. He was Anderson's principal assistant during 1862-1865 when Anderson was making some of the first independent analyses of *reh* samples for the Indian Government. He spent two and a half years (1866-69) on Malden Island in the Pacific Ocean studying natural history. He left the island rather hurriedly owing to a severe illness in March 1869, and probably arrived in Sydney. He appears to have set up his own school teaching chemistry in Sydney from the early 1870s, and was also an examiner in chemistry at the University of Sydney. In 1878 he was appointed instructor in chemistry when the Sydney School of Arts was opened. At the same time he continued to accept work in chemical analyses for the newly created government Department of Mines. Between 1891 and 1898 he was a

	lecturer in chemistry at Sydney Technical College. When he resigned he may have returned to private teaching. Later, in 1912, he appeared as a foundation director of North Sydney Gas Company. His 12 publications in the *Journal of the Royal Society of NSW* cover a range of topics on natural history, and organic and inorganic chemistry. (Sources: Obituaries in *Journal and Proceedings of the Royal Institution* (1917-18) and in *Journal of Royal Society of NSW* (1917), and see Bibliography.)
	**Frederick Bickell Guthrie** (1861-1927), an agricultural chemist, was educated at University College London, and gained his doctoral degree from the University of Marburg, Germany. He came to Australia in 1890 to take up a position in chemistry at the University of Sydney, but after two years joined the new NSW Department of Agriculture. He is best known for collaborative work with William Farrer on wheat breeding. Guthrie was involved in many areas of activity of the Department of Agriculture, particularly soil and fertiliser analyses. His Australian career extended from 1892 to 1924 during which time he was author or co-author of 180 scientific papers. He was a regular contributor to the *Agricultural Gazette of NSW*, providing practical advice to farmers, and often appeared as an expert witness before public inquiries. (Sources: *Records of the Australian Academy of Science* 1978, 4:7; *Australian Dictionary of Biography*; and see Bibliography.)
	James Boultbee (1851-1909) gained his farming experience on the family farm in the Vale of Eversham, Warwickshire, England. In 1874 he arrived in New South Wales and went to work on the pastoral property, *Gnalta*. Over the next 12 years his colonial experience grew as he worked as an overseer on other large pastoral properties, *Packsaddle* and *Cobham Lake,* and as manager of *Tarella* in the NSW Western District. He joined the Department of Mines and Agriculture in 1886 as Superintendent of Public Watering Places and Artesian Boring. This office later moved to the Department of Lands, then to

	Public Works. Boultbee was responsible for selecting sites for bores on many *Improvements Leases* in the Western Division. In 1902 the NSW Government sent him to the USA for three months to study the position of irrigation and artesian boring in the south-western states. After this visit he produced a lengthy official report and a scientific paper. He was a regular expert witness at royal commissions wherever water conservation and irrigation in New South Wales was under examination. He retired from the Department of Public Works in 1903, worked as a metropolitan bail magistrate, and acted as advisor on artesian bores. (Sources: Royal Commission on the Condition of the Crown Tenants 1901; Owen Royal Commission 1906, and see Bibliography.)
	John Mingaye (1859-1958) had a long career with the NSW Department of Mines. He began as Assistant Government Analyst, and in 1887 was appointed to run the Department's new chemical laboratory. Although he was concerned mainly with assay work for the mining sector (rather than analyses for agriculture), he published two important papers on analysis of artesian water for agriculture (Mingaye 1892 and 1895). At this time there were very few men with his skills in New South Wales. His other papers appeared mainly in the *Geological Survey Records*. He joined the Royal Society of NSW in 1889 and was still a member in 1925. (Sources: see Bibliography).
	Harold Ingeman Jensen (1879-1964) was born in Jutland, Denmark. He was awarded a Doctorate of Science by the University of Sydney in 1908, and worked in the Chemist's Branch of NSW Department of Agriculture. He conducted a systematic soil survey of selected parts of New South Wales in 1909-11, and produced a textbook on soils for the farming community (Jensen 1914). He became Director of Mines and Chief Geologist of the Northern Territory (1912-16), then Geologist for the Queensland Government (1917-22). He was a member of the Aerial Geological and Geographical Survey of Northern Australia. (Sources: *Historical Records of Australian Science*; and see Bibliography).

	William John Allen was raised on a farm in Canada where he had training in agriculture. From there he went to California and spent ten years in irrigation in the Riverside district. Next he spent six years in Victoria on the Mildura irrigation settlement, and thereafter was a fruit expert in the NSW Department of Agriculture. He inspected irrigation schemes throughout America, Continental Europe, Sicily and Egypt for the Department of Agriculture. His interest in agriculture and irrigation led him to study soils in order to ascertain what would give the best results under irrigation. At Mildura he advised fruit-growers, many of whom in the early years helped him to find out which crops would be best suited to irrigated soils. From 1898 he contributed over 100 articles to the *Agricultural Gazette of NSW* on fruit growing and irrigation at the Department's experimental station at Pera Bore. He also wrote a regular piece, *Orchard Notes*, and answered farmers' questions on fruit growing in the *Gazette*. (Sources: Carmichael Royal Commission, 1915; *Agricultural Gazette of NSW*, and see Bibliography.)
	Leslie Augustus Burton Wade (1864-1915) began his career in 1880 with the NSW Public Works Department where he received training as a cadet surveyor. In 1890 he joined the newly formed water conservation branch of the Department Mines and Agriculture as assistant engineer under Hugh McKinney. He remained with the agency responsible for water conservation and irrigation for the rest of his life. In March 1901 he took over the position of principal engineer in Public Works Dept previously held my McKinney. The mature part of his career was occupied with the Murrumbidgee Irrigation Scheme, and he was closely associated with construction of Burrinjuck Dam and MIA infrastructure. Later he became Commissioner of the WCIC in 1913. His sudden death in 1915 was attributed to the cumulative strain of overwork as WCIC Commissioner. (Sources: Obituary, WCIC *Annual Report 1915*, *Australian Dictionary of Biography*, Lloyd 1988.)

APPENDIX D ARTESIAN IRRIGATION RESEARCH 1900-1912

The Great Artesian Basin provided a laboratory for chemists in New South Wales to study problems associated with the use of artesian water for irrigated agriculture. The Department of Agriculture operated experimental irrigation farms at Pera, Moree and Coonamble where scientists were occupied in understanding how different crops performed under artesian water, and particularly their tolerance to soluble salts in artesian water. The Department provided practical advice to farmers via the *Agricultural Gazette*, and published findings from farmers' own experiments. The *Agricultural Gazette* also kept farmers in touch with current research overseas. Quoting from the work of one American hydraulic engineer it reported: 'There is great need of long-continued systematic study and acquisition of knowledge concerning the actual effect which the water has upon the soil and upon the plants. We can see the ultimate result, but have only a vague conception of the steps by which the results are produced.' (NSW Dept Agriculture 1903:105). Artesian irrigators were encouraged to work closely with the agricultural chemist to understand the quantity of soluble salts in irrigation water (Fry 1906).

Before the Murrumbidgee Irrigation Scheme chemists were well aware that the quantity of soluble salts was the harmful factor in artesian irrigation. They were also concerned with human factors — excessive use of water and the practice of allowing water to stand too long on the ground (Allen 1901). Yet they were encouraged, for a while, when conditions in New South Wales were compared with those in the western United States. The Royal Commission on Western Lands heard evidence on the problems of *reh* in India and alkali in the USA. The Superintendent of Public Watering Places and Artesian Boring, Boultbee, told the Commission (NSW 1901:718):

> It is clear from the American and Indian reports that the alkaline carbonates are a constituent of the soil, and that the application of water, whether artesian or from the rain, in excessive quantity, and an absence of porous subsoil, or any system of drainage, are the predisposing causes of the efflorescence so fatal in those countries to plant life. . . . In New South Wales our soils are to an enormous extent quite free from these obnoxious carbonates; consequently, provided care in the selection of the land to be treated is exercised, there is little or no liability of any extensive or damaging deposit by means of evaporation.

For many years Guthrie studied the chemical nature of the soils under irrigation in New South Wales. He saw the systemic connection between water and soil: 'No scheme for the utilisation or conservation of water for the purposes of irrigation can afford to overlook the nature of the water itself or of the land to which it is to be applied' (Guthrie 1903:LII). He emphasised the need to consider more than just the amount of chemical plant food in determining the fertility of soils. He drew attention to important soil features, such as the power to absorb and retain water and salts, and its capillary and hygroscopic powers. He urged irrigators to be aware of the

injurious effects of common salt (NaCl) and sodium carbonate (Na_2CO_3) on both plants and soil. He supported the use of some waters containing alkali for irrigated agriculture. But he warned that water with a high alkali-content must be used only on salt-tolerant crops, under conditions of good drainage, good tillage and in some cases the application of gypsum to neutralise the alkali. 'If the water is applied without some appreciation of the problems of soil chemistry and soil physics, I am convinced that much disappointment and much actual failure will be experienced' (Guthrie 1903:LXV).

The Department of Agriculture conducted laboratory experiments to establish alkali-endurance limits of different crops. Guthrie and fellow chemist, Richard Helms, led this work. They found that the growth of wheat was affected by quantities as low as 0.05 to 0.15 per cent of common salt, and an amount of 0.2 per cent prevented germination (Guthrie and Helms 1902).

Despite the research by the Department of Agriculture, opinions remained divided on the effects of water containing alkali. The *Agricultural Gazette* reported: 'some people say that bore water is apt to render the soil unproductive through impregnation by alkali, but the water is sometimes not so much responsible for the sterility of the soil as the conditions of forced draught that the combination of great heat and artificially applied water set up' (*Agricultural Gazette* 1904:807). Engineers stressed the remedial effects of good drainage. One wrote that the presence of alkaline carbonates in artesian water caused encrustation on the soil, which could be completely obviated by efficient drainage (Gibbons Cox 1904).

Mingaye, the chemist, told the Owen Royal Commission in 1905 that knowledge of artesian water was in its infancy in New South Wales, but he acknowledged the large research effort in America and India. He emphasised the importance of understanding both the chemical constituents of the water and the soils on which the water operates (NSW 1906, Q.21475-6). Boultbee told the Commission that the alkaline carbonate content of artesian water varied greatly from different bores. He was concerned that inexperienced irrigators tended to use water to excess. Little research had been done to ascertain the appropriate amount of water necessary for different crops. 'In a great many instances irrigation has been started, but I do not think people have given the slightest consideration to the quality of the soil—that is, the chemical constituents of it, and the effect of a combination with a given soil or a water that may or may not be alkaline. This is when the trouble has arisen.' Boultbee saw that 'people have not been alive to the scientific aspect of the question. . . You may even use river water and destroy a crop'. He explained that the problem for vegetation was whether the alkali had been deposited in sufficient quantity. Healthy plant growth was also affected by bad irrigation practices, such as using water to excess, failure to aerate the water which in some cases had a temperature as high as 139 degrees Fahrenheit, and a want of proper drainage (NSW 1906, Q.20148-61).

For some time scientists had known of the high fertility of soils in arid regions of the world where water had not leached out the valuable nutrients. The soils of America's western arid region were known to contain higher proportions of potash, magnesia and lime than existed in the soils of the eastern states (Harris 1909). In New South Wales experiments showed that crops grew taller with the addition of nitric acid (Symmonds 1910a). Such was the enthusiasm of one scientist that he studied the possibility of producing cheap nitric acid by an electrical process from the atmosphere, using the natural pressure of the bores as a power source. He proposed that alkali could be converted into the high-cost fertiliser, sodium nitrate. Nevertheless, when bore pressure was found to be insufficient for the purpose, this research ended (Symmonds 1908, NSW Dept Agriculture 1910: 444).

By 1910 it was evident that artesian water was unsuitable for intensive culture. Under conditions of artesian irrigation the brown loam soils and gravelly sands become very hard and impervious to air and water. Symmonds (1910c: 946) explained this condition as the production and coagulation of diffusible colloids:

> . . . defoliation of fruit trees at Pera Orchard is due to insufficient aeration and denitrification of the soil, which condition has been brought about by the action of the alkali contained in the water used for irrigation. The alkali (carbonate of soda) neutralised the natural acidity, dissolved out the humus (organic matter), broke down the crumb-like structure, and reduced the soil to a condition of ultimate particles in jelly which on drying becomes a hard compact mass, impervious to air and water.

The same process was identified as creating water-tight compartments in the geological strata. The salt content could vary in different strata, and the alkali in the water acted on the colloidal constituents of the clay and converted it into a diffusible state (Symmonds 1910b). When existing bores were deepened in the Coonamble area they were found to have less sodium carbonate with a corresponding increase in lime and potash.

At the first Interstate Conference on Artesian Water in 1912 the NSW Under-Secretary for Agriculture, H.C. Anderson, summarised the current level of understanding about the problems in artesian irrigation. He said that very little was known about '[t]he extremely intricate nature of the chemical operations which go on in the different qualities of soil, watered with artesian water, containing varying quantities of substances injurious to the physical composition of the soils'. (NSW 1913:72)

Nevertheless, by 1912, the State had shifted its attention to development of irrigation from the Murrumbidgee River.

APPENDIX E HUGH MCKINNEY: A COLONIAL ENGINEER

Introduction

Hugh Giffen McKinney (1846-1930) was an engineer who played a major role in the development of water conservation and irrigation in New South Wales. After his engineering training in Northern Ireland, he gained experience in the irrigation branch of the Indian Public Works Department. In 1880 he joined the New South Wales Public Works Department. During the next twenty years he carried out fundamental studies of the state of the rivers in New South Wales, collecting data essential for the future development of the colony's water resources. Later, with Robert Gibson, McKinney was directly responsible for promoting what became the Murrumbidgee Irrigation Scheme. Formally initiated in 1906, it was the first large water conservation and irrigation project undertaken by the Government of New South Wales. McKinney was an enthusiast. In 1903 he was described as 'a kind of personal embodiment of everything in connection with irrigation in this State'. But, like other engineers of his time, his enthusiasm led him to down play the dangers of irrigation salinity which were well known in arid and semi-arid lands.

Northern Ireland

Hugh McKinney was born at *Sentry Hill*, Carnmoney, in County Antrim, Northern Ireland. He was the eighth of ten children in a family which had owned and farmed land in the county for several generations. Subsequently, the families of four of these ten children were to have strong connections with pastoralism in New South Wales.

McKinney attended school at Ballycraigy and the Royal Belfast Academical Institution. From October 1864 he began three years of study for an engineering degree at the Queen's University in Ireland. In the first year he obtained a scholarship, valued at £24, held in the science division at the Queen's College Belfast. His second and third years were spent at Queen's College Galway. During the final year he was articled to Samuel Roberts, civil engineer and County Surveyor in Galway, with whom he gained practical experience in canal works. This experience included preparing plans and estimates for work in progress, and preparing maps and sections for railway works. He saw in progress the construction of the waterworks for the town of Galway.[1]

McKinney graduated in 1867 with a Diploma in Civil Engineering (Honours) from Queen's College Galway. In December 1868 he and his life-long friend and fellow-engineer, David McMordie (1846-1902), were successful in the annual examinations for appointments to the Indian

Civil Service. McKinney obtained third place out of some fifty candidates. In March of the following year the two young engineers set off for India where they began work as Assistant Engineers, 3rd Grade, in the Bengal Public Works Department.[2]

The Articles of Agreement between McKinney and the Council of India described his appointment as 'a civil engineer for general services in the East Indies'.[3] He was given free passage from Southampton to Calcutta with ten pounds to cover his other travelling expenses. The contract was for ten years. His initial salary was 170 rupees per month, plus travelling expenses. He was also provided with necessary equipment. He was directed 'to acquire a competent knowledge in one of the native languages' of India. Within a few years he passed both the Lower and Higher Standard Examinations in Hindustani.

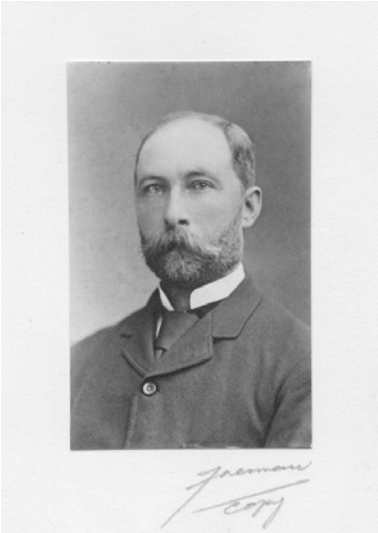

Figure 1: Hugh Giffen McKinney (1846-1930) photographed in Sydney in the early 1880s. Source: David Ash (reproduced with permission).

Upper India

India had a long history of irrigation based on perennial and inundation canals. However, canals along the principal rivers of Upper India (Ganges, Jumna and Indus) obtained water only when the parent streams were in flood. Ancient canals had also fallen into disrepair. In 1820 the British began to re-develop the Eastern Jumna Canal. Soon they recognised the need for new irrigation schemes to increase food production and reduce the risk of famine. Development was especially needed on the vast northern plains where rainfall was irregular. A massive program began in 1836, which saw the following systems come into operation in Upper India: Upper Ganges Canal (1847-54), Bari Doab Canal (1850-59), Agra Canal (1868-74), Sirhind Canal (1869-71) and Lower

Ganges Canal (1873-78). The Upper Ganges, the first of these new canal systems completed, was 900 miles in length.

In March 1869 McKinney began work in Punjab, in northern India (Fig. 1). Punjab, meaning *the land of the five rivers*, is enclosed and watered by the Bias, Sutlej, Ravi, Chenab and Jhelum Rivers. They are fed from catchments in the Himalayas. Near Ferozepur, the Bias and Sutlej merge into one (Sutlej), and eventually join the Indus River. McKinney's duties were on the Bari Doab Canal, which takes water from the Ravi River near Mahdopur. Its upper section came into operation in 1859. Through the 1860s engineers were undertaking new and rehabilitation works along the canal. As a result of the extreme fall, the bed of the channel was being cut out by erosion and endangering the masonry works. When McKinney arrived there was still much work to be done to improve the existing canal and to extend it.[4]

McKinney served on the Bari Doab Canal until 1875. He was based at Amritsar and worked directly under several well-known colonial civil engineers. During this time, according to engineer J. Doyle Smith, McKinney assisted 'in getting up the project for submission to Government; afterwards in surveying and levelling, and marking out the work on the ground. Subsequently he held charge of a sub-division, which included the preparation of materials and constructing works — bridges, falls, inspection houses, and the excavation of the channel.' In May 1871 McKinney was promoted to Assistant Engineer, 2nd Grade. Lieut.-Colonel E.L. Earle, Superintending Engineer for the Bari Doab Circle gave an additional description of his work. He wrote that McKinney 'carried out the lining out of a branch canal and the construction of masonry work on it. These works have turned out well, showing they were carefully executed.' Subsequently, according to Major R.H. Palmer, McKinney was in charge of a portion of a working canal, where he had to take charge of water and general management of the details of a sub-division – about 70 miles of canal channel.[5]

McKinney also worked on the construction of the Sirhind Canal in Punjab. This canal was the next stage of the Bari Doab irrigation development, designed to provide water to the rainless district between the Sutlej and Jumna Rivers. The Kasur and Sobraon Branches of the Sutlej were major components of this project and located a little north of Ferozpur.[6] McKinney states that he was responsible for the construction of a regulator for the Kasur and Sobraon Branches at Sathiali, and for a bridge and fall at Maan. The Executive Engineer for this division, W. Andrews, described both these works as 'of first-class construction'. He commented on the excellence of the concrete and the careful execution of the brickwork, and noted that many miles of earthworks were in a more or less finished state in 1873.[7] In Punjab McKinney also gained practical experience in distributing canal water to fields.

In 1876 McKinney transferred to the Irrigation Department of the North-Western Provinces (NWP). This district included the rich agricultural lands of the Ganges valley, stretching from Bengal in the east to the edge of the plains of Punjab in the west. McKinney was located at Saharunpur. He was employed in preparing several land-drainage projects, including masonry and earthworks, in connection with irrigation for the Eastern Jumna Canal. This was the original Mogul canal restored by the British in 1830. McKinney worked under the direction of Major Fredrick Home, Royal Engineers. Years later he would draw on Home's experience in New South Wales.

To be qualified to deal with matters under the *Northern India Canal and Drainage Act, 1873*, McKinney passed the Higher Standard Examination in Canal Law. In 1877 he was appointed a Canal Magistrate for the NWP. His last position in India was as Assistant Engineer in charge of the development of irrigation from the Fatehgarh Branch of the newly opened Lower Ganges Canal. This canal was designed to apportion a better distribution of available water between the upper and lower sections of the Ganges-Jumna Doab.[8] He was located in the Etah district (Fig. 2).

By 1879 McKinney was experienced in irrigation matters as practised in Upper India, where wheat and barley were the winter staples, and sugarcane and indigo the hot weather staples.[9] During his ten and a half years in India he was employed on some of the largest canal works in the country. Speaking of his Indian experience later, he expressed pride in his association with the British engineering effort on the Upper and Lower Ganges Canals. These works constituted by far the most extensive irrigation systems in existence at that time.[10]

McKinney described the position of canal engineer as 'one of very considerable responsibility'. A canal engineer 'has not only to see that the main canal and distributaries are in thorough working order, but he has to supply the water without fail to the cultivators according to an appointed rotation, to punish any attempt to interfere with this rotation, to decide regarding applications for new supplies or for the transfer of the position of outlets, and to prevent any kind of waste.' In addition, as a canal magistrate, McKinney exercised powers to hear and determine matters involving offences under the canal legislation.[11]

The life of an irrigation engineer employed in the Indian Civil Service was arduous, and the remuneration poor compared with that of members of the Royal Engineers in military service. For example, an executive engineer spent as much as 24 days a month in the field. One former Superintending Engineer of the Bari Doab Canal, E.C. Palmer, described the difficult conditions under which McKinney worked. He wrote: 'Visited at long intervals by your Executive Engineer, you were left very much alone and dependent on your own good sense to bring your work to a successful issue.'[12] Many years later McKinney referred to the isolation of field work: 'During a

lengthy period of my life I had not an opportunity of speaking English to anyone for two or three weeks at a time.'[13]

Glimpses of life for an engineer in India also come from Alfred Deakin. Deakin (1856-1919) 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, Deakin 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*.

Later, Deakin recast these newspaper articles for his book *Irrigated India* (1893). His description of the field accommodation for engineering staff at Mahdipur, provided by the Irrigation Department on the Bari Doab Canal, would have changed little since McKinney's day. Deakin wrote:[14]

> These bungalows or rest houses are built every few miles along the canals for the accommodation of the officers, a great portion of whose time has to be spent in the open air, or in immediate proximity to the several parts of the scheme under their charge. There are neither hotels nor dwellings habitable by Europeans in the country, and it proves to be cheaper to erect these cottages with a few large bare rooms, and a few simple articles of furniture, than to provide for a movable camp such as required to be employed upon long reaches of less important canals. Each officer receives a small travelling allowance, and carries his food and servants with him, finding a caretaker in the bungalow to assist in its preparation.

Deakin described inside a typical bungalow where he slept in a room 'bare of all but a charpoy, or bedstead of netted string, a few chairs, a lamp and fireplace'. In the fireplace part of a broken cart-wheel and some chips were being blown upon by 'the barefooted, turbaned, rag-twisted khitmagar, one of whose type is met in every rest-house'. Sleeping arrangements were simple. 'A servant unstraps a rug, spreads the zerail, or native quilt, upon its blanket, places a pillow at its head and the rug at the foot, and leaves me to the dying light of the leaping fire, flickering up the high bare walls of white plaster to the cloth ceiling, introduced so that snakes may not drop from the thatch upon the unsuspecting visitor.' The canal officer's day began with a chilly embrace in 'the invariable zinc tub upon the invariable cement floor of the little bath-room' followed by eggs, toast, and tea.[15]

By the late 1870s work in the irrigation branch had gained the reputation of being more unhealthy, isolated and expensive than that in any other branch of the Public Works Department. This was

particularly so for married men. As the rate of new public works slowed down, promotion possibilities began to decline. Career prospects were also affected by a depreciation of the rupee, which reduced the value of pensions. By the end of the nineteenth century there were fewer recruits to the branch, and many civilian engineers were anxious to leave the canal service.[16]

By 1879 Hugh McKinney and David McMordie had completed their contracted ten-year term with the Public Works Department in India, and each now had an Irish wife. McKinney had married David's sister, Marian McMordie, at St Andrew's Cathedral in Bombay in 1877. Engineer Palmer told McKinney that he believed 'the prospects of a young man with brains and energy [were] far and away better in a colony than they would be in the future P.W.D. [in India]'.[17] For these reasons the two families left India at the end of 1879 to pursue careers in the colony of New South Wales. They sailed from Bombay on 8 November and arrived in Sydney on the *Avoca* on 12 December 1879.[18]

New South Wales

The Riverina

McKinney first came to New South Wales on leave in 1876.[19] He visited his sister, Sarah, and her husband William John McGaw in the Riverina. In the 1870s McGaw was manager of *Pomingalarna Station* near Wagga Wagga. Later, he joined his brother Joseph McGaw who had taken up *Kooba Station* in 1875 on the Murrumbidgee near Whitton.[20] In the absence of McGaw descendants willing to take their place at *Kooba*, several McKinney nephews came from Carnmoney to work on and, later, to manage the pastoral property.[21] When Joseph McGaw took up *Kooba* run it comprised more than 90,000 acres. By 1884 the Crown Lands Act had reduced his lease holdings to 44,313 acres.[22] This major Riverina property remained in McGaw ownership and under McKinney management until 1926. Consequently, when Hugh McKinney moved permanently to New South Wales at the end of 1879 he came to a country where his close relatives had acquired significant local knowledge of the biophysical environment in the Riverina, and expertise in pastoralism in that district.

Sydney Water Supply

McKinney already had an introduction to the NSW Department of Public Works on his arrival in Sydney (Fig. 3). Writing about her father, Lorna Darbishire states that he had met the Engineer-in-Chief, E.O. Moriarty, on his earlier visit to New South Wales when Moriarty 'sent his private boat to bring the visitor across to his home at Kurraba Point, Neutral Bay'.[23] By 1880, when McKinney was settling in Sydney, the Department was about to embark on the fourth phase of development of

Sydney's water supply.[24] The Upper Nepean Scheme tapped the headwaters of the Nepean River and its tributaries, the Cataract, Cordeaux and Avon Rivers. It comprised a number of diversion weirs which fed a series of tunnels, canals and aqueducts, known as the Upper Canal. This canal supplied Prospect Reservoir.[25] The Harbours and Rivers Branch of the Department of Public Works had responsibility for this project, and McKinney took up a position under Moriarty in early 1880.[26]

McKinney was in charge of all engineering works south of Prospect. A description of his work on the scheme comes from his membership application to the Institution of Civil Engineers in London. It states that initially, as Resident Engineer, he was in charge of one contract, two miles in length. Then he became responsible for five contracts of an aggregate length of 12¾ miles of canal and tunnel work, and with a monthly expenditure of £6000 to £9000. After promotion to District Engineer he was in charge of eight contracts extending over a length of more than 33 miles, and including all subsidiary works, such as aqueducts, bridges, culverts and syphons.[27]

McKinney remained with the Public Works Department on the Upper Nepean Scheme until November 1884 when he joined the staff of a Royal Commission established to investigate issues of water conservation and irrigation across the colony.

Water Conservation and Irrigation

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'.[28]

This situation prompted the government to set up a Royal Commission into Water Conservation (1884). The terms of reference of this Commission 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 government appointed William Lyne its President, with Hugh McKinney Engineer to the Commission, and David McMordie one of its nine members.[29] The inquiry lasted three years, taking lengthy evidence from 137 witnesses over a wide area of the colony, and published three reports in 1885, 1886 and 1887 respectively. At the same time, Victoria conducted the Royal Commission into Water Supply (1884) under Deakin, and produced results in a far shorter time.

The first attempt at a scientific investigation of the colony's rivers was initiated in 1879. The Government Astronomer, H.C. Russell, established gauges on the major rivers in New South Wales and began to publish river-height data. Nevertheless, in 1884 McKinney found that very little information existed on the colony's rivers. Some studies had been made relating to navigation, to flood prevention on the Hunter River, and to the development of the Nepean and Cataract Rivers for Sydney's water supply. There were no records of river discharges, and the only levels available were those taken by the Railways Department.[30]

During his term with the Lyne Royal Commission McKinney 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.[31]

McKinney was a strong and outspoken advocate for the abolition of the inappropriate English Common Law of Riparian Rights. He drafted the *Water Supply and Irrigation Bill, 1886,* to abolish riparian rights and to provide for the conservation and utilisation of water for irrigation and other purposes. For the 1886 Bill he drew upon the principle 'that all great natural supplies of water belong to Government' which was well established in the laws of Northern India, Spain, Italy and France.[32] Nevertheless, for ten years, a combination of political, administrative and environmental circumstances delayed the Bill's progress into law. The *Water Rights Act, l896*, finally put in place some of his recommendations for management of the colony's water resources.

One immediate result of the Lyne Royal Commission was the creation of a water conservation branch of government. With only a clerk, a draftsman and an assistant draftsman, all of whom had worked for the Commission, McKinney set up the first government agency responsible for water conservation in New South Wales. On 11 May 1887 this team of four moved in with the Public Watering Places and Reserves Section under the Secretary of Mines. Here McKinney was able to continue his hydrographic work begun in 1884. An administrative re-arrangement saw the branch moved to the Department of Public Works in October 1892. It returned to the Department of Mines in 1894-1896, and finally settled in Public Works in June 1896. Despite administrative disruptions, inadequate funds and insufficient staff, McKinney made progress in collecting river data throughout his 13 years of association with the branch. Nevertheless, this situation left him with the

strong view that the government did not take water conservation seriously. Such a view he shared with Alfred Deakin, who wrote to McKinney in 1891:[33]

> . . . The Report is admirable and of itself reviews the reproach under which New South Wales has been lying for some time to the effect that she has neglected her great water resources. I can congratulate you upon it with all sincerity as an admirable piece of work.

Despite inactivity on the part of politicians, McKinney worked with vigour through the 1890s. In the first Annual Report of the branch (referred to above by Deakin) McKinney was in a position to recommend the construction of three irrigation canals from the Murrumbidgee River. He produced survey plans for possible irrigation schemes on the northern side of the Murray River, and on the southern and northern banks of the Murrumbidgee. His plan of the Murrumbidgee Northern Canal (1891) evolved into the existing Murrumbidgee Irrigation Scheme.

In 1890 McKinney was appointed Commissioner-in-Charge of the Murray River. This position was created following an examination of the whole Murray system to find an equitable way for Victoria and New South Wales to share its waters. McKinney produced an elaborate map of the river and its tributaries. At the time his work was seen as leading to 'far more accurate knowledge than is present possessed regarding its capabilities'.[34]

During the 1890s McKinney undertook a range of work in the dry western division of the colony, where the responsibilities of the Water Conservation Branch were chiefly focused. Developing the rivers west of the Great Dividing Range was vital to the colony's future. McKinney was involved with the development of the proto-irrigation schemes begun by the Irrigation Trusts at Hay and Balranald on the Murrumbidgee and at Wentworth on the Murray. With F.W. Ward he completed a six-week survey along the Darling River to identify suitable locations for locks and weirs. Among his major engineer works were the Willandra and Middle Billabong Weirs on the Lachlan River, the Yanco Cutting in the Riverina,[35] and the weir at Bourke on the Darling River. On the Macquarie River he was responsible for the Warren Weir, and on the Lachlan River a self-acting flood-gate in Lake Creek. This flood-gate maintained a permanent water supply into Lake Cudgellico. The Branch also was in charge of innumerable surveys of the major rivers for flood mitigation works, for water supplies (for hydraulic sluicing) to mining settlements in the colony, and for improvement works on the coastal rivers. After 1896 the Branch administered the long-awaited *Water Rights Act*, and issued licences under the Act. McKinney was directly and indirectly involved with all these activities. In addition, his many years of field work resulted in the first map of the Murray-Darling Basin in 1900.

McKinney was passionate about reducing the risks involved in farming operations, and to this end he was dedicated to promoting irrigation development in the colony. In 1890 he wrote: 'In short, irrigation in a large measure gives farmers freedom from risk, and removes from their operations that speculative character which is generally considered the great drawback to Australian farming'.[36] But the 1890s were years of economic depression and then drought. Believing it was too difficult to achieve his aim within the government service, McKinney left the Department of Public Works in 1901,[37] and continued to work in a consulting capacity. The Department retained his services to analyse the evidence taken before the Interstate Royal Commission on the River Murray (1902), and he compared the evidence with notes he had produced in previous years.[38] His reputation in river management had extended across the Tasman Sea: he was appointed 'to advise on a Commission in Auckland in 1901'.[39] This was the Rivers Commission of 1900-1901, which inquired into the proclamation of certain rivers as channels for the discharge of waste from mining operations, and examined claims for compensation.[40]

The Murrumbidgee Irrigation Scheme

McKinney's main purpose in leaving the government service was to promote a private irrigation scheme from the northern bank of the Murrumbidgee. He said this step was prompted largely by 'political inertia'.[41] Government inactivity also fostered his strong support for private enterprise in irrigation development, as was common practice in the United States of America at the time.

In 1897 Colonel Frederick Home (from India) had given the government his expert assessment in a report on possible irrigation developments in New South Wales. Home had endorsed McKinney's two options. One was for an off-take from the northern bank of the Murray River at Bungowannah, near Albury. The other was for an off-take from the southern side of the Murrumbidgee River below Yanco Creek, and included a storage site at Barren Jack. McKinney had identified both of these options by 1885, during the course of investigations for the Lyne Royal Commission, and subsequently developed the details of each scheme. Yet by the late 1890s he concluded that the construction of such works by the Government 'was not within the range of practical politics'.[42] In the Department of Public Works Annual Report for 1899 the Engineer-in-Chief for Public Works, C.W. Darley, confirmed this view. He wrote:[43]

> While I am of opinion that the importance of conserving water in the arid districts of the Colony cannot be over-estimated, I, however, cannot help thinking the time has not yet arrived for carrying out very large schemes, involving expenditure of many hundred thousand pounds. There is not, I think, sufficient population to warrant such works at the present time. The policy of the Department at the present stage should, to my mind, be in the direction of making small inexpensive dams, somewhat on the lines of those erected by pastoralists and others, on stock routes and other public thoroughfares, as well as in proximity to small centres of population. These dams would meet the existing and immediate

> demands, and induce settlement, and in due time, would be followed up by larger and more important works.

The Government took no action on Home's report. McKinney interpreted its inactivity as placing no obstacle in the way of private enterprise carrying out a large scheme on the northern side of the Murrumbidgee. In 1901 he prepared a business proposal and placed it before Robert Gibson.[44]

Robert Gibson (1855-1936) was a grazier and successful land and stock agent in Hay, in the Riverina. He had supported the experimental Hay irrigation scheme, which began in 1892, and was President of the Hay Municipal Irrigation Trust in 1902-6. Through his association with the local works, he became an advocate for a large irrigation scheme to water the district between Narrandera and Hay.[45] It is said that while travelling from Hillston to Hay during the devastating drought of 1895-1902 in company with McKinney that 'their conversation turned to the possibilities of what might be done if water from the Murrumbidgee could be run across the country they were traversing.'[46]
Gibson agreed to take up the scheme as promoter, and he and McKinney 'working in conjunction brought the irrigation question on a large scale within the range of practical politics. We set to work in the latter part of 1901 or early in 1902 and secured the guarantee of the necessary capital to carry out the work.'[47] The Gibson-McKinney proposal for a Northern Murrumbidgee Irrigation Scheme was based on the plan McKinney had prepared in 1891 for the Public Works Department. The proposal was to use the water where the rainfall was least, and where they believed the land to be most suitable, between Whitton and Gunbar. There would be an off-take from the river at the western boundary of Narrandera, with a branch canal to serve the country around Hay and Booligal. As noted above, the plan included a storage dam at Barren Jack.

A private member's bill introduced the Gibson-McKinney proposal to Parliament as the *Murrumbidgee Northern Water Supply and Irrigation Bill, 1903*. Its path through the parliamentary and political process was slow. Two Parliamentary Select Committees examined the Bill, in both 1903 and 1905, then it went before the Parliamentary Standing Committee on Public Works in 1906. The Public Works Department also held a conference in Sydney in 1905. The result was a considerably altered plan. It called for the scheme to be developed, financed, owned and managed completely by the State Government. The enabling legislation was passed as the *Barren Jack Dam and Murrumbidgee Canals Construction Act, 1906*.

Thereafter, McKinney and Gibson were effectively excluded from further involvement in the project. They received little credit for their contribution during the years before 1906. Nevertheless, in later years, one rural community recalled their contribution: 'The district knows that without the efforts of Mr McKinney and Mr Gibson there would be no Burrenjuck to-day. Such is the story of

the Irrigation Scheme. Mr McKinney and Mr Gibson blazed the track and they have been paid the price of the pioneer, which always has been and still is – nothing.'[48]

Irrigation and the Environment

Throughout his working years in the colony, McKinney travelled widely, wrote much and spoke often on the subject of water conservation and irrigation.[49] In particular, he promoted irrigation to the pastoral industry as a way of providing a degree of insurance against the effects of drought by irrigation of grasslands. He was personally familiar with all the major rivers in New South Wales. Darbishire described her father travelling frequently by night coaches where he managed to sleep rugged up and wearing his deerstalker cap.[50] His survey of the Darling River from Walgett to Wentworth in 1892 was an enormous undertaking that illustrates his stamina. His technical papers, map and plans in government reports, his publications in the *Journal of the Royal Society of New South Wales* and in other professional journals, his papers delivered at conferences, contributions to newspapers, and evidence at public inquiries all capture the depth of his knowledge of irrigation. They also show his passionate commitment to long-term investment in water conservation in New South Wales.

McKinney was well acquainted with a wide range of issues concerning water conservation and irrigation. His experience in irrigation law gave him as understanding of equitable rights and 'reasonable use' of water. His training in India provided him with the skills to draft at least one piece of legislation which became the *Water Rights Act, 1896,* and the conditions for granting licences under it. As a civil engineer he was responsible for supervision of public works for Sydney's water supply, and for the design and construction of irrigation and flood control works on several river systems in New South Wales. He was judge of the farms and orchards in the National Prize for Irrigation, a competition run in 1891 and 1892 by the Department of Agriculture to promote good irrigation practices.

Despite ten years experience in the salt-affected lands of northern India, McKinney made scant mention of the danger of salinisation in irrigation development. In 1878, the year before he left India, the first government inquiry into the problem of salt-affected lands took place in the North-Western Provinces. Salinisation of agricultural fields had long been a problem in the dry lands of northern India and the Middle East. By the middle of the century, decades of canal irrigation had made the problem acute. In 1878 the *Reh* Committee examined the voluminous evidence describing the problems of salt-affected lands and canal irrigation in the North-Western Provinces.[51] It examined cases of land degradation in the Aligarh district (near Delhi), as well as in the nearby districts of Etah, Meerut and Karnal. The Committee concluded that the damage to the soil was directly attributable to excessive irrigation. The Director of Agriculture, and Secretary of the *Reh*

Committee, warned that the cases which had been examined 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'.[52] Chemists and geologists shared these concerns. The Committee's findings should have served as an early warning for all those involved in intensive irrigation development in arid and semi-arid environments.

By 1878 an enormous body of information on the subject of *reh* had been gathered by Indian revenue officers, engineers and scientists, and existed in government reports. One scholar captured the extent of the problem when she wrote that, by the 1870s, correspondence was said to be 'large enough to fill a Government Blue Book'.[53] Nevertheless, in this author's research to date, only five references to salinity have been found in McKinney's writings. These references do, however, throw some light on his attitude to the problem.[54]

The first reference was made in 1883, when McKinney read a paper *Irrigation in Upper India* at the Royal Society of New South Wales. He described how he was in India at the time of the *Reh* Committee of Inquiry, and that he read all the information he could obtain on the subject. He rightly added that salt-affected plains were in existence before canal irrigation, and disputed the claim that 'the efflorescence was due to deposits from canal water'.[55]

By the 1890s, analyses of the chemical content of artesian water in New South Wales were becoming available. Among scientists a debate was under way about the suitability of artesian water for irrigation in the colony. The chemical analysts advocated a precautionary approach to the use of artesian water for agriculture, because of the injurious effects of alkaline salts found in a lot of artesian water.[56] Men like McKinney, with a keen interest in irrigation development, were less cautious.

In this context McKinney referred to salinity a second time, in 1892 in the *Report on Utilisation of the River Darling*. Referring to the high alkaline content of some artesian water, he wrote: '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'.[57]

The third reference occurred in *The progress and position of irrigation in New South Wales,* read before the Royal Society of New South Wales in 1893. McKinney acknowledged that during the early days of intensive irrigation in India, poor irrigation practices caused saline efflorescence to

spread in some instances, but precautionary measures were subsequently instituted. This was an over-simplification of the issues and the risks. It seems that he was prepared to accept the risks when he wrote that, in some cases in India, 'irrigation was adopted as the best of a choice of evils ─ possible privation on the one hand and probable injury to the land on the other. A similar choice of evils may have to be met sometimes in the western districts in this Colony'.[58]

McKinney's fourth reference to salinity was made in a talk delivered at a Farmers' Conference in Sydney in 1895. The text of his talk was later published in the *Agricultural Gazette of NSW*. McKinney spoke of the hydrological conditions in India: 'It is quite true that the level of springs has risen materially in districts which have long been under canal irrigation, and that in some cases extensive drainage works have been rendered necessary. This rise in the level of the underground water has doubtless a tendency to carry up the salts in the subsoil; but admitting all this, it is necessary to state that some writers have exaggerated the mischief done, and have quite overlooked the compensating benefits conferred.' Describing the situation in the district of the Western Jumna Canal, he claimed that 'lands most affected by the *reh* . . . had not only never been irrigated, but were actually above the level at which the water could be supplied'.[59] In the nineteenth century the distinction between irrigation salinity and dryland salinity was unknown. The resulting confusion enhanced the problem.

The fifth reference to salinity by McKinney appeared in a paper delivered at a meeting of pastoralists, and published in 1896 in Sydney's *Daily Telegraph*. Describing the introduction of irrigation from the Lower Ganges Canal in 1878, he said: 'No applications for water were entertained if it was found that the land proposed to be irrigated was in any degree impregnated with salts'. Applications were similarly refused, he added, if it was found 'that the small channel leading from the distributaries would have to pass through any land in which traces of salt were known to exist'. Other grounds for rejecting an application were the lack of 'a fair natural surface drainage' and the presence of heavy clayey soil.[60]

Along with most engineers at the time, McKinney did not fully understand salinity, its causes and its long-term consequences. At the time of the *Reh* Committee the Superintendent of the Geological Survey of India, H.B. Medlicott, commented on the engineers. He referred to his long experience of the problem of salinity, and said:[61]

> I have never known a canal officer [engineer] to speak rationally on it, i.e., with a knowledge of the many conditions involved in the production of *reh*. I do not mention this to blame any one. A man cannot give what he has not got; and it is hard for a professional man to disown a knowledge imputed to him. The responsibility rests with higher authorities who had not intelligence to see that the *reh* question is not primarily one of engineering.

On the other hand, McKinney's colleague and fellow irrigation-enthusiast, Alfred Deakin was alert to the problem of salinity as a result of his tour of irrigation works in India in 1890-91. Based on his own observations, Deakin wrote:[62]

> To visitors who have no previous acquaintance with irrigation, the *ryot* might teach a great deal . . . The lessons of the danger of over-watering, of the necessity for adequate drainage, of the value of unremitting cultivation . . . will bear much repetition and continuous illustration. . . [T]he reiteration of warnings on these heads may have become trite and commonplace, but nevertheless, the manner in which writers for agricultural journals still find it necessary to repeat them, is an evidence that, often as attention has been called to them, these simple principles are still ignored in many countries. They are not yet universally mastered in India. In all newly watered districts . . . crops can be seen which have been impaired or destroyed by untimely and excessive soaking. In some older districts patches of snow white *reh* . . . tell their own tale of neglected drainage.

It should be noted that several engineers, with extensive experience of Indian irrigation, played a significant role in water conservation and irrigation development in the colonies of Victoria and New South Wales.[63] Despite their Indian experience, engineers like McKinney were not good vectors for conveying a sense of caution when promoting intensive irrigation in the semi-arid regions of Australia. Engineers were focused on water delivery, rather than the long-term effects of irrigation on soils and groundwater.

Conclusion

McKinney's achievements brought acknowledgment from several professional bodies. He was elected a member of the Royal Society of New South Wales in 1880, and for over 20 years he was active in the regular discussions and debates of the Society. During that time he delivered nine papers on aspects of irrigation. In 1881 he was appointed an associate member of the Institution of Civil Engineers, London. Darbishire states that for his work in India, Queen's College Belfast awarded him an honorary degree of Master of Engineering in 1882.[64] By 1885 he was eligible for full membership of the Institution of Civil Engineers, London, and in 1887 he was elected a member of the recently formed Engineering Association of New South Wales. His expertise with the technical aspects of surveying for irrigation resulted in his membership of the Institution of Surveyors, New South Wales in 1892.[65] He was chairman of the Royal Society's Engineering Section in 1902. In the annual address to that Section he presented a comparison between Government initiative and private enterprise in the construction of engineering works in various countries. This topic, no doubt, was prompted by what he regarded as delay on the part of the New South Wales Government in developing irrigation.

McKinney's professional contribution can be summarised in the words of Joseph Davis, Under Secretary in the Department of Public Works. Davis gave a fitting description of the man as 'a kind of personal embodiment of everything in connection with irrigation in this State'.[66]

After the failure of the Gibson-McKinney proposal for a private irrigation scheme in the Riverina, McKinney closed his Sydney office at 56 Pitt Street, and made an extended visit to Ireland, England and Europe during 1907-08. When he returned to Sydney he went into retirement, but took occasional consulting work, or acted as an expert witness. He lived in the harbour-side suburb of Neutral Bay, where his association with E.O. Moriarty had begun over 30 years earlier. After enjoying a long retirement with his wife, two daughters and their families, he died in Sydney in 1930.

Acknowledgment

I particularly thank David Ash for assess to family papers and for his enthusiastic interest in my research on his great-grandfather. I have enjoyed discussions with Isabel McKinney Harrison and Joe McKinney about their memories of *Kooba Station*, and with Julie Williams for her family's memories of David McMordie and Hugh McKinney. Thanks also to Carol Morgan, the archivist at the Institution of Civil Engineers in London.

Appendix: Identified publications of H.G. McKinney

Technical Publications on Irrigation in Government Reports

1885	*First Report of the Lyne Royal Commission* Reports on 1. river gauges 2. railway and other levels in the interior of the colony 3. further report on levels 4. Mr C. Haylock's survey of the Tantangara Basin 5. the river Murrumbidgee as a source for canals 6. the river Murray as a source of supply of canals 7. the Barwon River, and Tarrion and Cato Creeks 8. Macquarie River and the district between the Macquarie and Bogan Rivers	1885-86, NSW Votes and Proceedings, Legislative Assembly, 6, 387-948.
1886	*Second Report of the Lyne Royal Commission* Report on the Gunbower and other works	1885-86, NSW VP 6, 949-981; at 967.
1887	*Third and Final Report of the Lyne Royal Commission* Irrigation and water conservation in the Riverina	1887, NSW VP 5, 715-1041; at 988-1012.
1891	First Annual Report of the Water Conservation Branch for 1890, Department of Mines and Agriculture	1891-92, NSW VP 6, 45.
1893	Report on Utilisation of the River Darling (with F.W. Ward)	1892-93, NSW VP, Part II.
1893	Proposed canals south of the Murrumbidgee River	1892-93, NSW VP, Part II.
1893	Report of the Chief Engineer for Water Conservation and Irrigation for 1891-92, Annual Report, Public	1893, NSW VP, Part II.

	Works Department, p.103-117	
1894	Report of the Chief Engineer for Water Conservation and Irrigation (dated 6 July 1894)	1894, Annual Report, Public Works Department, p.101-103.
1897	Report of the Principal Assistant Engineer for Water Conservation (dated 10 March 1897)	Report of Department of Public Works for year ended 30 June 1896, p. 40-41.
1898	Report of the Engineer-in-Chief for Public Works – Water Conservation, Irrigation and Drainage	Report of Department of Public Works for year ended 30 June 1898, p.41-42.
1899	Report of the Engineer-in-Chief for Public Works	Report of Department of Public Works for year ended 30 June 1899, p.40-42.
1900	Report of the Engineer-in-Chief for Public Works	Report of Department of Public Works for year ended 30 June 1900, p.37-39.

Evidence before NSW Government Inquiries

1888	Royal Commission into the Construction of Public Tanks and Wells of NSW	1888-89, NSW VP 3, 659.
1892	Parliamentary Select Committee on Broken Hill Water Supply Act Amendment Bill	1891-92, NSW VP 6, 147.
1896	Parliamentary Standing Committee on Public Works on Proposed Water Supply for the Town of Tamworth	1897, NSW VP 3.
1902	Interstate Royal Commission on the River Murray	1902, NSW VP 4, 637.
1903	Parliamentary Select Committee on the Gibson Proposal for the Murrumbidgee Northern Water Supply and Irrigation Bill	1903, NSW VP 1, 789.
1905	Parliamentary Select Committee on the Gibson Proposal for the Murrumbidgee Northern Water Supply and Irrigation Bill	1905, NSW VP 1, 585.
1906	Parliamentary Standing Committee on Public Works on Proposed Barren Jack Storage Reservoir and Northern Murrumbidgee Irrigation Scheme	1906, NSW PP 5, 531.
NSW PP = NSW Parliamentary Papers		

Publications in the *Journal of the Royal Society of NSW*

1883	Irrigation in Upper India	*J. Roy. Soc. NSW,* 17, 139-148.
1887	Notes on the experiences of other countries in the administration of their water supply	*J. Roy. Soc. NSW,* 21, 60-73.
1889	Irrigation and the pastoral industry in NSW	*J. Roy. Soc. NSW,* 23, 75-93.
1893	The Progress and Position of Irrigation in NSW	*J. Roy. Soc. NSW,* 27, 384-400.

1896	Water Conservation Surveys of New South Wales	*J. Roy. Soc. NSW,* 30, lxxiv-lxxxix.
1900	Intercolonial Water Rights as affected by Federation	*J. Roy. Soc. NSW,* 34, 233-255.
1901	Projects for Water Conservation Irrigation and Drainage in NSW	*J. Roy. Soc. NSW,* 35, 223-242.
1902	A Comparison between Government Initiative and Private Enterprise in the Construction of Engineering Works in Various Countries	*J. Roy. Soc. NSW,* 36, i-xxi.
1903	Water conservation and the equitable distribution of water for irrigation and other purposes	*J. Roy. Soc. NSW,* 37, v-xiv.

Other Publications

1887	Rivers of New South Wales	*Rept. Austr. Assoc. Adv. Sci.,* 1: 386-406.
1890	Irrigation	*Agricultural Gazette of NSW,* 1: 269-272.
1892	Report of the judge of the National Prize for Irrigation	*Agricultural Gazette of NSW,* 3: 597-603.
1893	Report of the judge of the National Prize for Irrigation	*Agricultural Gazette of NSW,* 4: 335-339.
1895	Irrigation Notes	*Agricultural Gazette of NSW,* 6: 59-61.
1895	Irrigation	*Agricultural Gazette of NSW,* 6: 543-549.
1896	Irrigation and the Pastoral Industry	*The Daily Telegraph*, 18 July 1896.
1896	The Wentworth Irrigation Scheme	*Agricultural Gazette of NSW,* 7: 469-470.
1896	Water Conservation, Irrigation and Drainage	*New South Wales: the mother colony of the Australias*, F. Hutchinson (ed), 246-254.
1897	Water Conservation Surveys of New South Wales	*The Surveyor*, 10: 61-66.
1899	The Wentworth Irrigation Area	*Agricultural Gazette NSW,* 10: 1107-1120.
1903	Irrigation	Report of Annual Conference, Farmers and Settlers' Association, Narrandera, Aug 1903, 37-41.
1912	Murrumbidgee Northern Irrigation Scheme	*The Sydney Morning Herald*, Letter to the Editor, 24 July 1912.

Notes and References

[1] Details of his early career come from *Testimonials in favour of H.G. McKinney, civil engineer, late of the Irrigation Branch, P.W.D., India*, an original pamphlet containing letters of reference from Ireland and India. It is held by the Ash family. Other details appear throughout his published works (see Appendix).

[2] The Institution of Civil Engineers, London. Transcript of applications for associate membership 13 Jan 1880, and membership 24 Feb 1885. I.R. Crozier, *William Fee McKinney of Sentry Hill: his family and friends,* (Northern Ireland, 1981), pp.69-74.

[3] The original Articles are held by the Ash family.

[4] A. Deakin, *Irrigated India*, (Melbourne, 1893), p.200.

[5] *Testimonials*. McKinney's appointments in India can also be found in the annual entries under his name in *Thacker's Bengal Directory* for years 1869-1879 (Thacker, Spink & Co, Calcutta).

[6] A.K. Banerji, *Finances in the Early Raj*, (New Delhi, 1995), p.161.

[7] *Testimonials*.

[8] G.W. MacGeorge, *Ways and Works in India,* (Westminster, 1894), p.161.

[9] *Testimonials*.

[10] NSW Lyne Royal Commission, Third and Final Report 'Irrigation and Water Conservation in the Riverina'. NSW Votes and Proceedings of the Legislative Assembly, 1887, **5**, 989.

[11] H.G. McKinney, 'Notes on the experiences of other countries in the administration of their water supply', *Journal of the Royal Society of NSW,* **21**, (1887), 60-73.

[12] *Testimonials*.

[13] NSW Public Works Department, *Official Report of the Corowa Water Conference*, (1902).

[14] A. Deakin, *Irrigated India*, (Melbourne, 1893), p.197.

[15] A. Deakin, *Irrigated India*, (Melbourne, 1893), pp.192-193.

[16] I. Stone, *Canal Irrigation in British India,* (Cambridge, 1984) p.66.

[17] *Testimonials*.

[18] McKinney gave the departure date from Bombay in a letter to his mother, quoted in B.M. Walker, *Sentry Hill – an Ulster Farm and Family,* (Belfast, 1981), pp.141-142. The *Avoca* was subsequently identified from NSW shipping records (NSW State Records, AONSW Reel 441).

[19] H.G. McKinney, 'The Progress and Position of Irrigation in New South Wales', *Journal of the Royal Society of NSW,* **23**, (1893), 384-400. NSW Parliamentary Standing Committee on Public Works, *Report and Minutes of Evidence on the Proposed Barren Jack Storage Reservoir and Northern Murrumbidgee Irrigation Scheme*, NSW Parliamentary Papers 1906, **5**, 469.

[20] *NSW Government Gazette*, 25 April 1876, p.1630.

[21] Three brothers came: Joseph and Thomas George in 1880, and William James in 1890. Their cousin, also named Thomas George, joined them from New Zealand in 1891.

[22] *NSW Government Gazette*, 31 July 1885, p.4916.

[23] L.M. Darbishire, *Hugh Giffen McKinney*. MS compiled by his daughter, in the State Library of NSW, Mitchell Library, MSS 706. (1963).

[24] The project had been recommended by a Royal Commission in 1867.

[25] M. Beasley, *The Sweat of their Brows, 100 Years of the Sydney Water Board 1888-1988,* (Sydney: 1988), p.11.

[26] McKinney's appointment was dated 13 January 1880 (NSW Blue Books). David McMordie joined the new Board of Water Supply and Sewerage in May 1880.

[27] The Institution of Civil Engineers, London. Transcript of applications for associate membership 13 Jan 1880, and membership 24 Feb 1885.

[28] A.P. Wood, 'Tanks and Wells of New South Wales, Water Supply and Irrigation', *Journal of the Royal Society of NSW,* **17**, (1883), 149-186.

[29] *NSW Government Gazette*, 14 May 1884.

[30] H.G. McKinney, 'Irrigation', Farmers and Settlers' Association of NSW, Reports of Annual Conference, Narrandera, (August 1903), 37-41.

[31] Commenting on McKinney's contribution to the science, K. Swan wrote: 'The importance of McKinney's basic work still awaits detailed study', in H. Frith and G. Sawer (ed), *The Murray Waters: Man, Nature and a River System*, (Sydney, 1974), in the chapter 'The Middle Reaches since 1900', p.127.

[32] H.G. McKinney, 'Notes on the experiences of other countries in the administration of their water supply', *Journal of the Royal Society of NSW,* **21**, (1887), 60-73.

[33] Original correspondence Deakin to McKinney, 19 August 1891, held by the Ash family. The Report referred to is McKinney's First Annual Report of the Water Conservation Branch for the year 1890.

[34] A. Deakin, 'Irrigation in Australia', in *Yearbook of Victoria* (1893), p.53.

[35] Samuel McCaughey called this the McKinney Cutting. See P. McCaughey, *Samuel McCaughey* (Sydney, 1955) p.88.

[36] H.G. McKinney, 'Irrigation', *Agricultural Gazette of NSW,* **1**, (1890), 269-272.

[37] McKinney remained in the service of the water conservation branch (which had various name changes) from 11 May 1887 to 1901. On retirement he held the position of Principal Engineer responsible for Sewerage Construction, Water Supply and Water Conservation.

[38] Minutes of Evidence taken before the Select Committee on the Murrumbidgee Northern Water Supply and Irrigation Bill, NSW Votes and Proceedings of Legislative Assembly 1903, **1**, p.20.

[39] Minutes of Evidence, ibid. p.20. L.M. Darbishire, *Hugh Giffen McKinney,* (1963) p.15, said he attended this inquiry.

[40] McKinney presumably attended as an expert witness, but the Commission's final 14-page report of June 1901 does not contain the Minutes of Evidence to clarify his role. New Zealand Parliament, *Rivers Commission 1900-1901*, Appendix to the Journal of the House of Representatives **4**, part 2, H-21 (1901).

[41] An excellent account of the complex political, social and economic background of the MIA development is found in W.R. Cowper, *The Barren Jack Scandal,* (Bonnells Bay, NSW, 1987).

[42] H.G. McKinney, 'Irrigation', Farmers and Settlers' Association of NSW, Reports of Annual Conference, Narrandera, (August 1903), 37-41.

[43] NSW Department of Public Works, *Annual Report 1899*, p.7.

[44] *The Sydney Morning Herald*, 24 July 1912, p.6.

[45] *Australian Dictionary of Biography*, Robert Gibson, **8**, 653-654 (Melbourne).

[46] *The Harden Express and Central South-West Advertiser*, 10 Sept 1936.

[47] *The Sydney Morning Herald*, 24 July 1912, p.6.

[48] *The Harden Express and Central South-West Advertiser*, 10 Sept 1936.

[49] The Appendix contains a list of all McKinney's identified publications.

[50] L.M. Darbishire, *Hugh Giffen McKinney,* (1963).

[51] The vernacular languages of Upper India described the efflorescent salts which accumulate on the surface of large tracts of land as *reh* or *kallar*.

[52] North-Western Provinces and Oudh Revenue Department, Revenue Proceedings. *Report of the Reh Committee*, 218-309, Index No 117, para 15 (June 1879). These sources were studies in the India Office Records of the British Library, London.

[53] E. Whitcombe, *Agrarian Conditions in Northern India,* (Berkeley, 1972) p.10. The Blue Books are the large tomes containing official government records which were common to all administrations throughout the British empire.

[54] For an account of salinity in south-eastern Australia from 1880s to the beginning of the Murrumbidgee Irrigation Scheme, see K. Proust, 'Ignoring the Signals: Irrigation Salinity in New South Wales, Australia', *Irrigation and Drainage,* **52**, (2003), 39-49.

[55] H.G. McKinney, 'Irrigation in Upper India', *Journal of the Royal Society of NSW,* **17**, (1883), 139-148.

[56] The three strongest voices at the time were the chemical analysts, William Dixon and John Mingaye, and agricultural chemist, Frederick Guthrie. However, McKinney had support of geologist, Edgeworth David, who believed 'the danger had been much exaggerated'.

[57] H.G. McKinney and F.W. Ward, 'Report on Utilisation of the River Darling', NSW Votes and Proceedings of the Legislative Assembly 1892-93, Part II, 15 (1893).

[58] H.G. McKinney, 'The Progress and Position of Irrigation in New South Wales', *Journal of the Royal Society of NSW* **27**, (1893), 384-400.

[59] H.G. McKinney, 'Irrigation', *Agricultural Gazette of NSW,* **6**, (1895), 543-549.

[60] H.G. McKinney, 'Irrigation and the Pastoral Industry', *The Daily Telegraph*, 18 July 1896.

[61] North-Western Provinces and Oudh Revenue Department, Revenue Proceedings. *Report of the Reh Committee*, 218-309, Index No 115, para 21 (June 1879).

[62] A. Deakin, *Irrigated India*, (Melbourne, 1893), p.145.

[63] Those engineers identified in NSW include F.A. Franklin, Arthur Ritchie, as well as Hugh McKinney and David McMordie; and in Victoria W.W. Culcheth, John D. Derry and George Gordon.

[64] *Testimonials*; L.M. Darbishire, *Hugh Giffen McKinney,* (1963).

[65] Institution of Surveyors, *The Surveyor* **5**, (1892), 159.

[66] Minutes of Evidence taken before the Select Committee on the Murrumbidgee Northern Water Supply and Irrigation Bill, NSW Votes and Proceedings of Legislative Assembly 1903, **1**, p.96.