

On the application of sanitary science in public works of irrigation and works for the relief of towns / by Edwin Chadwick.

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Publication/Creation

[London] : Printed by Emily Faithfull, [1858?]

Persistent URL

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*On the Application of Sanitary Science to Public Works of
Irrigation and Works for the Relief of Towns. By EDWIN
CHADWICK, ESQ., C.B.*

I SUBMITTED to the Public Health Department, at the meeting of the Association held at Liverpool, a paper on the application of sanitary science to the protection of our army in India—a subject of imperial importance. One object of that paper was to show the necessity of the cultivation of the special engineering required for the practical application of that science, without which special engineering enormous expense, as well as failure in the production of the sanitary effect, is too commonly incurred.

I have received a communication on the subject of the irrigation works of India, which have recently occupied public attention, showing on a large scale the evil consequences of the prosecution of such works in ignorance or in disregard of sanitary science. This communication appears to me to be so highly important as to render it incumbent on me to solicit the particular attention of the Association to it.

Where a clear money profit from any works is in prospect, any evidence as to evil effects produced on others, we find, meets only with inattention or hostility on the part of those by whom the profit is derived. In my own experience and investigations I have, however, found no case of works, attended with evil to the public health, which are not of a low state of structural or engineering art, and at the same time excessively expensive, and in various ways wasteful of money. Thus, the poison pit—the cesspool—in its original cost of construction, in the cost of repair and maintenance, and in the cost of constant cleansing, apart from all foulness and offensiveness, and all noxious influences, I have proved to be more expensive than a properly constructed, self-cleansing watercloset, the expense of the water included.* Thus, too, the old brick house-drains, which accumulate noxious deposit, are more than double the expense

* *Vide* "Minutes of Information on the Drainage of Dwellings and of Towns," published by the General Board of Health, 1852, pp. 12, 155, 166; also paper on "The Drainage of Towns," by Robert Rawlinson, Sanitary Engineer, published in the *Transactions* for 1857.

to construct, and are still more expensive to cleanse, than properly-adjusted tubular drains, which are self-cleansing and do not decay. So of large, flat-bottomed brick sewers which accumulate refuse, and are, in fact, only extended cesspools. Three houses or three towns may now be drained well at the expense of old works to drain one ill.* Water, good at its source, when stored in close habitations, in houses and towns, absorbs the mephitic gases, and becomes unwholesome in proportion. When we have examined the expenses of waterbutts and cisterns for separate houses, of the space they occupy, and of the walls to bear them, and the cost of maintenance and repairs, the cost of this injurious arrangement exceeded that of a constant supply of water delivered direct and fresh into every room.†

The first application of the sewerage of towns to agricultural production was by the old agricultural method of irrigation, by submerging the grass or other produce grown on panes or tables of ground levelled to receive it. To this method strong sanitary objections were raised at Edinburgh and other places, where the irrigation was by sewage water, holding considerable portions of foul matter in suspension and in solution. On examination, I found that these sanitary objections were well-founded, not only as against irrigations with sewerage, but as against the common irrigations with plain water, containing only such earthy or animal matters as may be found in the rainfall upon grazing and tillage lands.

In the first place, it was proved that the excess of moisture on the wide irrigated surfaces produced damp, and was attended with the effects of damp and cold in reducing temperature. They produced rheumatism and ague in men; and as more or less of the decomposition of animal and vegetable matter takes place in the process of drying up stagnant pools which are found in all but the most expensive constructions, the rot or typhus is produced in sheep. There was once a demand in London for what were called "Brucksey hams,"—that is to say, for the hams of sheep which had been killed in a state of fever or the rot. A farmer found out that he could meet the demand at pleasure after May, by flooding and afterwards stocking his water meadows, when they were saturated with moisture. From the experience of the noxious effects of irrigations in the Lombardo-Venetian provinces, permanent irrigations are prohibited within five miles of towns.‡

Where the sun is more powerful decomposition will be more rife, and the noxious effects upon the living, from this method, will be greater. Such effects have been traced upon a great scale in India

* *Vide ibid.*

† *Vide* "Report of the General Board of Health on the Water Supply of the Metropolis."

‡ *Vide* "Minutes of Information on the Practical Application of Sewer Water and Town Manures to Agricultural Productions," printed by the General Board of Health for the information of local Boards of Health, 1852, pp. 8—11.

by Dr. T. E. Dempster, Deputy Inspector-General of Hospitals in Bengal, and are described in the very important paper which I herewith submit.

The difficulties attendant upon the subject of the disposal of the refuse of towns—the noxious effects of the products of decomposition upon the populations exposed to them, the expense of the constant removal of faecal matter in the solid form, the inconveniences of mounds of it, or laystalls, near towns, the objections to the pollution of rivers—forced me to the investigation of remedies, in which I was led to propose the method of distribution in suspension in water, by steam or other power, through underground pipes and by jets, and enabled to impeach the method of distribution by submersion, for waste.

The outlay of capital for engine power and pipe distribution is about £5 per acre,* and the working cost of distribution on a large scale about 1s. 8d. for 100 tons; on a small scale, about 3s. 4d. per ton. The outlay of capital for the formation of water meadows ranges from £1 to £40, and £100 even, per acre.

In Italy the expenses of the chief works averaged £40 per acre. In England the average was £30 per acre, and the working expenses were £3 7s. per acre: the expenses of the cheapest method of distribution, by open gutters on natural inclines, was 14s. per acre, whilst an equivalent distribution by jet was 7s. per acre.†

But by the method of distribution by water meadows at Edinburgh, upwards of sixty inches deep of sewerage was put upon the surface in the year; whilst upon what may be called the gardeners' method of applying water and manure at the same time by the water-pot,—except that the jet is impelled by steam power,—about thirteen inches, or nearly one-third of the manure, produces an equivalent productive result.

The first applications of the principle of jet distribution, whether for towns or for farms, have been made without or against due advice, and have been made rashly and wastefully. Thus, in the application of the sewerage of Rugby, a town of about 6000 inhabitants, for which about seventy acres would have sufficed to receive about thirteen inches of sewerage in the year, the apparatus was extended over 450 acres, or three times the area which would have sufficed, with the result of distributing little more than four inches per acre per annum, and that, too, with a great waste of manure, by distributing it over the uneven surfaces of old ridges and furrows, in which the gutters got the chief benefit, instead of upon ground properly levelled; and it was applied upon old grasses, a large proportion of which were the least nutritious, and more than half of them the least fitted to profit by liquid manure; added to which, the mains for the distribution of the manure are so small as to occasion an expensive waste of engine power. Nevertheless, the proprietor declares that the results are a greater profit than on the old method of cultivation, and that he is "satisfied" even as it is. And

* *Vide* "Minutes of Information" last cited.

† *Vide* p. 49.

so with liquid manure farms, where the farmers are satisfied with comparatively inferior effects. Those who are desirous of studying the later experience, as to the economics of the question, will find them exemplified in some evidence which I have cited from Mr. James Blackburn, a practical agriculturist and engineer, given in the *Gardeners' Chronicle* of the 18th and 25th of May, and the 1st and 16th of June last, including an exposition of trials by Dr. Kirkpatrick, of the Albert Agricultural Institution at Glasnevin.

Whilst a better economical result is obtained by the method of distribution by jet, the sanitary result is insured by operating upon a small portion of land at a time, by giving that land only as much as it can absorb at each dose, and by reducing any surface evaporation to the minimum. At higher rates of expense for apparatus, which may nevertheless in many cases of high culture be eligible, the surface evaporation may be altogether avoided.

Whatever may be the merits of the water leading in the main trunk lines of canals for irrigation, I aver that the method of subsidiary distribution, on which the evils described by Dr. Dempster are attendant, is ignorant, barbarous, and wasteful—wasteful of water and productive of inferior agricultural effect. It is true, that in India steam power will be more expensive and may for a long time be inaccessible, but they may have horse powers, which are in extensive use in America, and which in this country, for many cases of intermittent use, and for scales where less than a four-horse power is required, are cheaper than steam.* It is true, that in India they have not iron pipes, but they have the bamboo, which, hollowed out, serves for water leading, under low pressures, and might be made to suffice, in the method of water leading, by spouts and hollowed trunks of trees carried on tressels to movable troughs, whence it is distributed by scoops with great rapidity, as in use in Sweden and Norway.

I have had evidence that the rice culture by stagnant irrigation, so injurious to the health of populations, is one which an improved culture having no such insanitary effects would supersede.

I might, if it were necessary to do so, here give extended illustrations to support my principle; that special sanitary engineering, which prevents such evils as Dr. Dempster describes, does so with an improved productive and economical result, and that where it is otherwise, it is the default of the engineer, in the want of proper knowledge of agricultural as well as sanitary science.

Finally, I would give warning, that for India and the tropics, comparatively inferior general sanitary improvement will be obtained by mere changes of stations from unprepared sites and ill-constructed barracks and habitations on the plains to improved barracks and huts on the cool, but sometimes sharply cold, unprepared, un-

* *Vide* a description of these powers, with other cheap powers, in a paper which I read at the Royal Agricultural Society of England, on June 17th, 1857, and given in the *Gardeners' Chronicle*.

drained upland sites, often on swampy hills ; nor by the mere appointment of officers, with the name of health officers, without any special training and testing by competitive examinations in sanitary science. Where such qualifications are absent, such appointments often serve only to indorse expensive apologists for the maintenance of evils which are preventable, with which the persons appointed have no capacity to deal properly or efficiently. Nor will the appointment of properly qualified health officers avail much more than for the reiteration of remonstrances, unless those officers are provided with the means and invested with the power of getting their prescriptions made up, which prescriptions for prevention must be, I repeat, not for drugs from the apothecary or the medicine store, but for well-devised works from the engineer. For these works a special training is needed for our military engineers, whose present peculiar training is only for old works for war, and for those imperfectly ; works for the maintenance of the health of an army being necessary means to the maintenance of its military strength. The one-sided character of the common training of our military engineers was displayed in the Crimea, in the proved need of a special sanitary commission to give instructions for the selection and for the practical drainage of proper sites for healthy encampment—for the choice, collection, and the proper distribution, of wholesome water—for the construction of wholesome huts, and the proper shelter and treatment of horses as well as of men ; it also demonstrated to the public the need of an army works corps, under civil engineers, to construct military roads. Even now, young military engineers complain that the application of sanitary principles is expected of them, for the amendment of old constructions and the planning of new ones, for which they have had no preparation. The defects of practical engineering and construction is partially supplemented by clerks of works, at great expense, who really give an imperfect command to workmen which ought to be given perfectly by officers. In remote dependencies clerks of works are not to be had, though artisans are to be found in the ranks even of the line, if there were engineer officers competent to lay out works for them, and directly superintend their execution. On the Continent, engineer officers in the best armies are not such very fine gentlemen that they cannot dirty their hands with mortar ; and although they are men of science and gentlemen in our sense, they are head work masters and practical leaders of artisans, ready to apply sanitary science, if sanitary science were there provided, which it has yet to be, and to be placed in its proper position. The needed preparation and practice of our engineer officers in the application of sanitary science to works during peace would save the country much expense and loss of force, would relieve the officers of the ennui of useless routine occupation, and would give them higher qualifications than they now have for meeting the changing exigencies of war. At home, instead of servilely yielding place to the expensive and blundering empiricism of civil practice, they would correct it. In our remote colonies,

whilst they would prevent such defaults from the absence of sanitary science as Dr. Dempster's paper in part displays, they would become the pioneers of civilization by rendering countries habitable by a higher order of colonists and civilized races, and give us the advance due to our age upon the colonizing legionaries of Rome, in the times of Frontinus and Agricola.

Communicated by T. E. DEMPSTER, Late Superintending Surgeon, Bengal Army.

Two most important subjects connected with British India are at present engaging public attention, viz.—first, the sanitary management of our European troops in the East; and secondly, such an extension of the existing works of irrigation as guard the native inhabitants from the famines which periodically devastate certain provinces, and at the same time enable India to raise an ample and certain supply of raw material for our cotton manufacturers at home, instead of allowing them to remain, as they now are, almost wholly dependent on the precarious political and commercial condition of the States of South America.

Very probably, few will reflect that these two widely different objects may have a most important relation to each other; and it is almost certain that the classes whose minds are directed to the second may be wholly careless of the first, and that they will be disposed to resist any attempt to modify or otherwise interfere with their favourite schemes, on account of sanitary considerations in which they feel no direct interest or personal concern. Circumstances have given me special opportunities of making observations and recording facts in India, relating to both these very subjects. I have long desired to turn the experience so acquired to some useful practical account, and if the opinions I have formed shall be found to rest on carefully observed and scrupulously recorded facts, I think they cannot fail to be regarded as of some value at the present time.

In 1846 the Government of Bengal directed a Special Committee—of which I was the sole medical member—to investigate and report on the causes of the unhealthiness which had prevailed at Kurnaul and other portions of the country along the line of the Delhi Canal. In the course of our inquiry we examined the irrigated and unirrigated districts on both sides of the river Jumna; we visited the notorious “Nugufghur Jheels,” and followed the course of the then projected Ganges Canal for eighty-three miles, viz., from Hurdwar to the latitude of Meerut. We travelled in all about 1,460 miles; inspected more than 300 inhabited localities; and personally examined 12,000 individuals of all ages. I do not now possess any complete copy, either of the official report, or of the appendix subsequently written by myself alone. Both these documents were originally printed at the public expense, and were at one time sold at the Government Press at Agra. But in 1854, when the new Ganges Canal was publicly opened by the Lieutenant-Governor of Agra with great pomp and ceremony, amidst a vast assemblage of British officials and natives of rank, all allusion to our Committee or its results was scrupulously avoided, and from that time forward not a single copy of the official report or appendix has been anywhere procurable. It is not, therefore, in my power to supply complete copies of these documents; but I submit the following brief account of the nature and objects of our inquiry, and some of the principal conclusions to which it led.

When we commenced our labours, public opinion was violently divided on the subject. One party—chiefly consisting of medical men—held that all the notorious unhealthiness of certain districts was solely to be ascribed to the influence of existing canals and canal irrigation; another party as confidently maintained, that no sanitary question at all was involved in the construction of works of this nature. Among the latter were persons of high position and great influence, who did not scruple to talk openly of the “sanitary humbug.” Such was the state of

the question when it was proposed to construct the Great Ganges Canal, "the most magnificent work ever undertaken in India—one of the most magnificent works in the world."* Lord Hardinge, then Governor-General of India, wisely hesitated to sanction the scheme until he had satisfactorily solved the sanitary question. He, therefore, appointed a Committee minutely to investigate and report upon the subject.

The task assigned us was one of no ordinary difficulty, nor was it a matter of ordinary importance to decide whether such a vast undertaking as the Great Ganges Canal was likely to bring with it a blessing or a curse to the people of India. But how was the inquiry to be conducted, seeing that the sickness had, for the time being, passed over; that medical or vital statistics in any authentic shape or form had no existence among the people to be subjected to examination; that certain obvious reasons rendered the oral testimony of the natives themselves absolutely worthless; and that any conclusions drawn mainly from the alleged aspect of the inhabitants could carry no weight. In this perplexity I thought of applying the test of organic disease of the spleen as a probable measure of the extent to which the people had previously suffered from endemic fevers. The manner in which this test was applied, and the singular and unexpected results it gave, are fully set forth in our Report. "Without it the inquiries of the Committee, based as they must have been on oral testimony, on which no credit could have been placed, would have ended in vague and unsatisfactory conjecture, and without a single fact collected among the agricultural population on which they could depend."† To preserve and improve the drainage of the country through which the canal was to pass would doubtless have been considered desirable objects if attainable at a moderate cost, but had it not been for the test I hit upon, and the incontrovertible nature of the evidence obtained, chiefly through its careful application, I am persuaded that the Government of India and the Court of Directors would never have consented to set aside all consideration of expense, and to make these main and indispensable conditions of the whole of this vast undertaking.

Our inquiry appears to me to have sufficiently established the following positions, viz. :—

1st. That canal irrigation carried on in the north-west provinces of the Bengal Presidency, under certain unfavourable conditions noted in the Report, is uniformly productive of endemic diseases, which from time to time assume the form of widespread and often fatal epidemics.

2ndly. That canal irrigation, carried on under certain favourable conditions, may consist with a very moderate amount of endemic disease, and a healthy and vigorous condition of the inhabitants generally, while it most certainly obviates that most formidable of all the accessory causes of sickness and mortality—the want of the comforts of life.

3rdly. That canal irrigation under all circumstances, even the most favourable, is liable to be attended with a certain amount of contingent evil, but that, due precautions being taken, the good will far outweigh the evil; the famines which have from time to time devastated the country be rendered impossible, as far as irrigation extends; and canals prove, on the whole, a blessing to the people. I would fain hope, therefore, that our labours went some way to solve that most important problem, viz., how to obtain the maximum of good with the minimum of evil, in constructing works of this nature in those provinces of British India.

In pursuing our investigations, we carefully avoided all speculative reasoning, allowing facts and figures alone to guide us to the conclusions at which we arrived. We were, however, alive to the fallacies which might mislead inquiry, in thus estimating the effects of canal irrigation; and it will be perceived that, in the statistical tables, we separated, when necessary, the inhabitants of large towns from agricultural labourers, and further noted the caste and calling of every male adult subjected to examination.

The great bulk of the people who came under our observation were living in

* Kaye's "Administration of the East India Company."

† Baird Smith on Italian Irrigation.

small agricultural communities, composed, as nearly as possible, of the same classes—engaged in the same general occupations, having the same unchanging social and domestic habits; subject to the same climatic influences; and inhabiting a tract of country having throughout the same geological and botanical character. As communities they differed in little but in position with respect to the canals, and in cultivating soils of various quality, some of which possessed, while others were cut off from, the benefits of canal irrigation. Moreover, the same series of observations were carefully repeated a great number of times in a great number of situations. Our attention was especially directed to the condition of the people as regards “the comforts of life;” and it is worthy of particular remark, as affecting the value of our deductions, that those comforts were generally most abundant in the irrigated districts. We met with many localities, both in irrigated and unirrigated parts, the insalubrity of which could fairly be ascribed to local causes, totally unconnected with the canal or its waters. The most remarkable cases of this nature were specially noticed, but minor instances, being pretty fairly distributed over both descriptions of land, were sunk in general averages in the printed Report.

I would here prominently record my assent to the position, that the same kind of irrigation or obstructed surface drainage, which produces so much mischief in one part of India, is not necessarily attended with like consequences in other provinces, differently circumstanced as to climate, soil, level, &c. Observers in different parts of India may, therefore, widely differ in their report as to the effects of canal irrigation, without impugning the facts, or invalidating the evidence, independently brought forward by each other. For instance, in Rajpootana, the scene of Major Dixon’s philanthropic labours, inclined strata of hard rock underlie a scanty upper soil, and appear to secure a ready under drainage towards the numerous natural lakes in the vicinity. In Bengal Proper, and in some of the provinces adjoining, the country is low and the periodical rains abundant, regular, and long-continued. In such districts the very excess of moisture seems to ward off mischief. On the other hand, the country traversed by the Delhi, Jumna, and Ganges canals, though to the eye a vast level plain like Bengal, is really much higher and drier, and subject to seasons of excessive drought; while—unlike Rajpootana—the ground to a considerable depth from the surface consists of mould, clay, sand, and other alluvial deposits. So naturally dry is the soil of some of the irrigated districts that many wells are found from 100 to 300 feet deep. In the neighbourhood of Hansie and Hussar the accession of the canal permanently raised the water in the old village wells 60 feet, and yet left it at a considerable depth from the surface. It is in such districts that canal irrigation instantly changes a sterile plain into a luxuriant garden: but it is also precisely under such circumstances that neglect of certain precautions may bring about the greatest amount of mischief in a sanitary point of view. This is the consideration I would urgently impress on the minds of all concerned at the present time.

The over-zealous partisans of canal irrigation have ever been anxious to show that all the notorious insalubrity of certain places is sufficiently accounted for by collections of filth and general neglect of local and personal cleanliness; and they triumphantly point to stench, enough, in common parlance, to breed a pestilence anywhere. But they forget, or wilfully shut their eyes to the fact, that the nuisances alluded to are found to an equal extent in almost every large native community; while fevers of a particular type rage year after year in certain situations only.

All I witnessed during the canal sanitary inquiry, and all my previous and subsequent Indian experience, go to prove that there is no necessary connexion between malaria of the most deadly character and offensive odours of any kind, and that in many cases its worst effects are experienced just as we recede from the unavoidable impurities of large crowded native cities.

I have often feared that my statements regarding the extraordinary extent to which splenic disease exists in so many towns and villages in the old canal districts would be received by the profession at home with surprise—perhaps with incredulity. I can only say that these statements have now been before the Indian public for many years past; that they have never been impugned, and that wherever medical men have taken the trouble to go over the same ground in the

same manner, as in the "Zillas" of Delhi and Allyghur, my account has been fully verified.

Apart from the special objects of the Committee, perhaps its most important results were—1. The confirmation of a truth, often told, but too often forgotten by medical men, viz., that the external features of the ground, if seen at one period of the year only, and without the experience of several seasons, will often fail to enable us to distinguish a malarious from a comparatively safe and healthy locality. 2. The successful application of a simple test, by which this question—often involving interest of vast importance—may, in many instances, be speedily and correctly determined. In the central and upper provinces of the Bengal Presidency, (I speak with confidence only of those districts I have myself carefully gone over,) a distance of a few miles will often separate a healthy site from one of the worst character; and if the external visible features of the country be hastily observed, and alone implicitly relied on, they may lead to the most fatal errors. If, however, there are inhabitants who have been long subject to malarious influences, they will carry in their abdominal regions marks which no apathy or cunning can conceal. A careful exploration of the regions of the liver and spleen, especially of the latter organ, in a certain number of the people taken at random from each of the surrounding villages, and an accurate comparison of the results, will probably settle the question at once. At all events, such an examination cannot fail to give important information in many cases, where no other of a reliable character is to be obtained.

I enclose a printed copy of a letter addressed by me to the editor of the *Medico-Chirurgical Review* soon after my return from India in 1857. This letter will be found to contain a remarkable illustration of the terrible consequences of ignorance, or culpable neglect, of the leading principles laid down in our Report. It also affords a striking, and to me most gratifying, corroboration of the statements I had long ago made regarding the marvellous prevalence of splenic disease in similar cases, and shows the practical use to which this fact can be turned, in determining the true character and causes of epidemics in that part of India.

I am fully persuaded that both philanthropic societies and commercial associations in England will now urge on the Government of India the necessity of greatly extending works of irrigation over certain districts in the upper provinces, usually singularly fertile, but, from time to time, subject to excessive droughts and consequent famine. But unless such works are undertaken on correct sanitary principles, unless the preservation and improvement of the drainage of the country through which they are made to pass be accepted as main and indispensable conditions of the whole scheme, it is my duty to warn the public that very lamentable consequences will most certainly ensue. We may apply all the modern improvements of sanitary science to our military cantonments, barracks, houses, and native towns; we may feed, clothe, and exercise our European soldiers on the best and soundest principles; but if we place them near the swampy banks of Indian rivers, on clayey and moist soils, or in the neighbourhood of badly constructed irrigating canals, all such precautions will prove of little avail to diminish the rates of disease and death now prevailing in India.

A few days ago I stumbled on the subjoined passage in the *Saturday Review* of the 13th of April last—article, "Prisoner of Burmah." It furnishes an undesigned and unexpected confirmation of opinions which I have long upheld, from a source at once authentic and above suspicion:—

"It is a curious fact worthy of the consideration of sanitary reformers, that this den of evil smells was actually wholesomer than the fresh air outside. After a time, Mr. Gouger was removed to a single cell, which being built of wood, after the artistic fashion of the Burmese, was unimpeachable in the article of ventilation. In this cell he caught a dysentery, which brought him to the point of death. It was the rule of the prison that any one who died in these cells should be buried at the cost of the keepers of the prison. With an eye to economy, therefore, the keepers, as soon as they thought his case was hopeless, brought him back to the inner prison, whose aromas he has so feelingly described. No sooner did he arrive there than he began to recover. He found by experience that no amount of putrefying abominations was so deadly to breathe as the uncontaminated exhalations of the Irrawuddi."

Having so often alluded to the Sanitary Committee on Canal Irrigation, it is proper here to explain that practically the whole inquiry was conducted by Major (now Colonel) W. E. Baker, of the Bengal Engineers, as president, and myself as member. The test we employed, the reasons for using it, and its practical application to the people, all necessarily belonged to my department. But the general plan of the investigation, the precautions taken to guard against fallacies, and the numerous and valuable tabular statements appended to the official report, were mainly due to my colleague. Both, I am sure, lay equal claim to a sincere and honest desire to arrive at the truth. It is further right to state that I alone am responsible for all opinions or shades of opinion not clearly expressed in the official report which may be found either in the present paper or in any other I may have written on the effects of canal irrigation.