

**In the Matter**

Of the Resource Management Act 1991

**And**

**In the Matter**

of applications by the Central Plains Water Trust (CWPT) and the Ashburton Community Water Trust (ACWT)

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**Statement of evidence of Walter Clive Clark**

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*There are more things in heaven and earth, Horatio, than are dreamed  
of in your philosophy.*

Hamlet.

**Introduction**

- 1 My name is Walter Clive Clark. I live at 9 Thornley Place, Woodend.
- 2 I am an Emeritus Professor of Zoology in the University of Canterbury. Before my appointment at Canterbury I was professor and Head of the Zoology Department at Massey University.
- 3 I have been admitted to the degrees of:
  - Bachelor of Science in the University of New Zealand (advancing in zoology and geology);
  - Master of Science with First Class Honours in Zoology in the University of New Zealand, (in marine biology);
  - Doctor of Philosophy in Zoology (Nematology) in the University of London. My doctoral thesis was on New Zealand nematodes (roundworms) and aspects of their biology as it contributes to an understanding of soil biology and plant pathology.I have been awarded the Diploma of Membership of Imperial College of Science and Technology in the University of London for studies in Plant Nematology. For this diploma I did a practical course of work in the use, recovery and identification of pesticides used in plant protection; further I prepared a thesis in applied toxicology concerning the use, and limitations of use of chloropicrin (a tear gas) in the control of seed borne diseases. I have gained other diplomas.
- 4 I have been admitted to the fellowships, life memberships and memberships of a good number of learned scientific societies: e.g. the Zoological Society of London, the Linnean Society of London, the Marine Biological Association of Great Britain, the

Royal New Zealand Institute of Horticulture, the New Zealand Society for Parasitology (and several other “worm clubs”), the New Zealand Society for Soil Science, and many others. These memberships indicate that my scientific interests are diverse. I have published papers relevant to them all. I have published more than 100 papers in refereed scientific journals.

5. In New Zealand I have served in a variety of capacities in the Royal Society of New Zealand. For many years I was Vice President of the North Canterbury Acclimatisation Society and Chairman of its Water Resources Committee, and later of its successor, the North Canterbury Fish and Game Council. I also served for some years on the Freshwater Fisheries Advisory Council, and was Minister’s nominee on the Wildlife Research Advisory Committee. Since retirement I have worked with the Waimakariri Environment Society and played a significant role in their opposition to Waimakariri District Council’s bid for Resource Consents that would allow the continued discharge of effluent from the Rangiora STP into the minuscule South Brook, a tributary of the Cam River (and the Waimakariri). I played a major part in the Cam River Consent Group Inc. (as a founder and Secretary). We obtained an enforcement order in the Environment Court which ultimately required the construction of the ocean outfall to dispose of sewage effluent from the eastern Waimakariri District. I was one of the four retired academics who presented the case for the Christchurch Estuary Association that resulted in the decision to build the Ocean Outfall.
6. Professionally, I have spent a great many hours at the microscope, and so feel I may claim a greater than average awareness of the importance and roles of minute organisms in human affairs. As a parasitologist I know that one must be constantly aware of all three: the parasite, the host, and the environment, for the environment is the stage upon which they enact their dramas.
7. I appear before this hearing because my wife and I have a great concern for the health of the freshwater bodies of this country in particular, and in environmental matters generally. I have had a long involvement in water matters in connection with fisheries, and local bodies; particularly of late in connection with sewage effluent disposal, and in agriculture (ever since my service with DSIR). All this experience has generated in me profound concerns and fears for the management of the water resources of Canterbury in particular, where water quality and supply often appear to be in a precarious state. I have been concerned by the apparently ever-present prospect of ignorance in action.
8. Our community has accumulated many, often disparate, and unconnected pieces of information about our region’s water resources, and too often, I am afraid that as a society we are prepared to take potentially irreversible decisions, when our ignorance is the most impressive quality prevailing. I propose to address primarily some aspects of the biology of water where such ignorance is truly frightening to those who believe they may be beginning to see some of the implicit relationships. I am very conscious of the dilemmas that you face.

### **Expert Witness - Code of Practice**

9. I have been informed that I am considered to be an expert witness. I have read the “Expert Witnesses - Code of Conduct” on the Justice website and I have no reservations about agreeing to comply with the provisions of the code as downloaded.

## **Groundwater**

- 10.. Groundwater is a resource of very great importance in Canterbury. A great many people rely upon groundwater for their necessary domestic water supplies. Still others use well water to satisfy the needs of their animals, their gardens, for food production, and for their commercial activities whatever they are. We play ducks and drakes with this resource at our peril.
11. I enquired of Ecan how many wells they administered between the Ashley River in the north and the Rakaia River in the south. They informed me that they knew of 13,500 wells in that region, but that they believed that there were an unknown number of additional wells of which they had no official knowledge. Thus we may assume that there is a very wide dependence upon groundwater for a variety of absolutely vital purposes in the Plains region
12. Because the Canterbury groundwater, for the most part falls on and flows over and through very insoluble greywacke rocks and their derivatives, the water naturally contains very little by way of soluble pollutants (or plant nutrients). It is said to remain “pure.”
13. It is widely believed that more than 90% of the Earth’s liquid freshwater is not visible from space. That is, that less than 10% of the world’s liquid freshwater lies at the surface in lakes, ponds, rivers and streams. More than 90% of the world’s water is said to lie below the surface. We call it groundwater. We know and understand little of it, but are crucially dependent upon it.
14. It has been estimated that in New Zealand 80% of the freshwater resource exists as groundwater.<sup>1</sup>
15. It is indicative of fairly recent past attitudes to groundwater that Robert Bowen’s 1980 textbook<sup>2</sup> devoted just 6 lines to bacteria, and said absolutely nothing on any other aspect of biology elsewhere in the book.
16. The Assessment of Environmental Effects (AEE) prepared for the present applications reveals that in this respect at least, for some workers, matters have not changed much, for in section 6.6 on “The Biological Environment” it took 7 lines to dismiss the

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<sup>1</sup> White, P. A. 2001. Groundwater resources in New Zealand. *Pp. 45 - 75 In Rosen, M.R., and White, P.A (Eds.) Groundwaters of New Zealand*, New Zealand Hydrological Society, Wellington.

<sup>2</sup> Bowen, Robert, 1980. *Ground Water*. 227 pp. Applied Sciences Publisher, London.

“Groundwater Ecosystems” as areas of scant knowledge. (Actually, half of the space was devoted to hyporheic zones of streams). The groundwater was categorised simply as “dominated by Crustacea.” Thus the report writers tacitly displayed their ignorance by ignoring, for example the 70 stygobitic mites known from New Zealand groundwater<sup>3</sup> (of 102 formally described animals known from N.Z. groundwater as listed in Scarsbrook, Fenwick et al. 2003<sup>4</sup>). The assessment of the groundwater ecosystem provided in the AEE can be dismissed as grossly inadequate.

17. We do not know in detail where groundwater lies, what volumes are involved, nor do we fully understand its circulation, or how much of it we may safely remove. We know little of the life that exists in it, or the roles such organisms play in maintaining or degrading its quality. We show scant concern for the part that groundwater, and the organisms it contains play, or do not play, in community health. I am very doubtful if there is an adequate understanding of where the groundwater comes from, or goes to, or what is added to, or taken from the water, and how long those processes take.
18. Given the huge changes that have occurred in the obvious above ground fauna and flora in the last few hundred years, why should we think that the stygofauna has been immune from change, no matter how unintentional those changes that probably have occurred, and are occurring, in the subterranean environment may be. Such changes may well have been “natural” consequences of events such as the destruction of the Canterbury-wide forests, and the imposition of foreign grasslands and large numbers of alien mammals and other foreigners like the European earthworms. Usually the weight of earthworms in the soil of New Zealand lowland sheep country is about equal to the weight of the sheep above the soil. I do not have comparable figures for dairy land.
19. In the region that the Canterbury Regional Council and its predecessors have administered, they have issued, or assumed responsibility for the operation of a great many wells, including the 13,500+ mentioned above, many of which lie in the region likely to be affected by the present application. The scale of the matters for consideration is massive. Unfortunately the knowledge available to underpin the management of this asset is lacking in confirmed detail. Much of that which we “know” consists of generalisations often based on very limited pieces of specific information or experiences. This is not a matter of shame to be laid at the feet of present and past staff and researchers. It is a consequence of the limited resources made available for investigating matters that have not hitherto been judged to be of crucial importance. Will anything change?

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<sup>3</sup> The literature on New Zealand stygobitic mites essentially consists of the following papers by D. R. Cook. 1983. Rheophilic and hyporheic mites of New Zealand. *Contributions of the American Entomological Institute* 21: 1-224. 1991. Water mites from driven wells in New Zealand, the subfamily Notoaurinae. *Stygologia* 6: 235-253. 1992. Water mites (Hydracarina), mostly from driven wells in New Zealand: taxa other than Notoaurinae Besch. *Stygologia* 7: 43 - 62.

<sup>4</sup> Scarsbrook, M. R., Fenwick, G. D., Duggan, I. C., and Haase, M. 2003. *A guide to the groundwater invertebrates of New Zealand*. 59 pp. NIWA Science and Technology Series No. 51 ISSN 1173-0382.

20. We do not know how much water was accessible from those wells, or was drawn from them in any given period. Recording is in its infancy. However, I judge it safe to assume that access to groundwater is incredibly important to a great many of the operators of those wells. They will be concerned that their well(s) continues to deliver quality water in quantities appropriate to their needs. That is a huge responsibility, and it is in furtherance of that goal that we are here. Collectively, we have assumed the duty to ensure that the people will be able to meet their vital needs for quality water. Section 5 of the Resource Management Act (RMA) is very clear in its definition of “**sustainable management**” which must “enable people and communities to provide for their social, economic, and cultural well being **and for their health and safety...**” I do not believe that it is possible to argue that the legal draughtsman responsible for the wording of the section believed that he was arranging the list of desiderata in any order of importance. However, I would argue that little else matters if provision for health is absent.
21. It seems that in the past, the right to take groundwater has often been given, or assumed, with a light heart, and scant, if any concern shown for the consequences, or for their effects on third parties. In practice the takers are scarcely required to account for their actions, or inactions, and certainly not to accept financial responsibility for the consequences of their actions. What happens after the consents are signed, is not really anybody’s business..... This has, in the past, been called “water management.”
22. The consequences of taking water must be carefully considered, and these need to be able to be predicted with considerable certainty before decisions are taken to allow more water to be taken, or the quality of that which is there, to be subject to near random alteration. This view rests firmly upon the notion that one man should not be put in a position where he is able to force another to take actions to defend his life, wife and family. Actions which can be logical initiators of events that result in the deprivation of adequate supplies of water of appropriate life sustaining quality must not be permitted lightly. The actions that confer permission must also exact duties and responsibilities.
23. It seems an odd intrusion, or limitation of privilege (a more modest word than “right”) to grant to one man the right to deprive his neighbour of water, through a new abstraction. That, I understand has been a common consequence of the marked draw-downs of wells in say, the West Melton area, in recent years. The grant of consents to take, have at the same time conferred the power to force neighbours to drill new, or deeper wells. I am sure there must be a nice set of legal arguments available to cover this situation, but I am untrained in the law, and must just wonder at the apparent inequity.
24. It is most unusual to find that groundwater takes in the area of the old North Canterbury Catchment Board have in the past been measured, or recorded. After the consent is signed off, who checks on the volume taken, the duration of the take, or where the water is discharged, or the effects of the discharge? I recently found that in Ecan’s realm nothing is monitored at night, so consent conditions really only apply (or are enforced) during daylight hours!
25. I have not been able to gain a clear picture of the proposed fate, or management of the groundwater in the “Central Plains” area. It seems that those with consents to take

groundwater in that area will remain free to please themselves whether they continue that activity, despite the nominal availability of water from the CPWT scheme. They may hold, and operate, those consents at least until they expire. What then? If CPW water is available and cheap, CPW member farmers will take it. If there is none available, or if it is costly, the groundwater will be thrashed, and as often in the past, without a care for the consequences. The goal seems to be to get in before the activities of your neighbour render water unavailable. There are huge questions as to whether the existence of (CPW) will in fact enable others to irrigate new areas using “newly liberated” groundwater, or whether existing holders of consents that allow the abstraction of groundwater will strive mightily to retain that “right of access” as an affordable water access insurance. We do not know what factors will enter into future determinations of the fates of applications. Will the results even approach the chaos that I fear?

26. I believe that it will be necessary for the Commissioners to enquire very closely into the future management of groundwater. What levels are expected, and how they see those levels being maintained. In the course of reaching those views they will of necessity need to form a firm, and clearly stated view as to whether the stygofauna is:
- (1.) part of the natural resources that are to be sustained;
  - (2.) part of the ecosystems that are to be safeguarded, and
  - (3.) clearly how they will be able to avoid or repair adverse effects on such an important, but ill-understood element of the environment’s resources.
27. There is a general assumption that as the large rivers (e.g. Rakaia and Waimakariri) emerge from their gorges onto the Plains the water in their beds diffuses laterally into the voids between the gravels and sands of the Plains to follow the gravitational gradients wherever they may lead, and that usually, and eventually, the water flows towards, and into the sea. Different parts of the Plains will vary greatly with the size of the connections between the adjacent voids, and steepness of any gradients. From time to time the moving water will encounter beds of low porosity and the flow will slow. On occasion the flow will “disappear” beneath a layer of markedly reduced permeability - a confining bed - and so such a stratum will become largely “remote” from events at more superficial levels.
28. Many people do not even vaguely realise how the lithology varies texturally, area-ly, and in depth beneath the plains. We have all seen how the nature of the most recent and superficial sediments currently on view in these braided rivers (Waimakariri and Rakaia) vary in texture, depth and extent. Because the nature of the gravels in a river bed vary from side to side of a single braid, and especially at the bends, as a result of different current velocities prevailing at the same instant in time, it is quite unreasonable to expect that the sediments deposited over longer periods will be constant from spot to spot, or that they will vary in a precisely predictable fashion. It is for these reasons that precise predictions about the movement and occurrence of water and the things moved by, and in the water are not possible. The depth of “soils” over the gravels is equally variable and unpredictable.

29. It may be helpful to think of the groundwater of the Plains as a sort of three dimensional braided river with the different braids able to exist at different levels and velocities, and on occasion, flowing in different directions. There is no reason why all of the semi-vertical streams should all flow upward or downward. If some of the braids are isolated by low permeability sediments from others, they may experience different hydrostatic pressures which may support different speeds and directions of flow and so forth. Assumptions of uniformity in such parameters may make for simplicity of understanding, but there is no compelling case for believing that such a state approaches reality. For these reasons I find it difficult to be convinced by some of the “evidence” that has been produced. Uniformity of flow may happen, but it is unlikely to be universal, or nearly universal.
30. From the preceding considerations it is inevitable that the distribution of sediments of different grades will vary profoundly in terms of area, and depth, and of course for the period over which they are deposited (and eventually re-distributed). Thus reliable predictions become impossible. The speed of percolation of irrigation water through the soil will vary enormously, from place to place, and it would be unrealistic to expect nature to conform to the picture painted in the AEE etc.
31. I have read much of the evidence placed before you as to the nature and behaviour of the soils and the groundwater in the area potentially affected by this application. I am sure that your informants have done their best to describe *what they see as the probabilities* in the circumstances that they describe, but you must recognise that that was the best they could do. They are dealing with matters that vary greatly and in essentially unpredictable fashions. Profound variations may occur over short distances. The descriptions may therefore depart markedly, but probably not deliberately, from reality.
32. It seems reasonable to assume the water will leave the rivers as opportunity (as determined by porosity and gradient) allows. Where the river bed has aggraded (built up) it may be assumed that much water will mostly flow laterally, if this provides the steepest gradient. It will flow down the gravity gradient, often away from the stream and into the groundwater, especially where this is at a distinctly lower level than the obvious “main bed” of the river. Thus, it is probable that river water will not be restricted to leaving the river only in the upper levels. It may well be a near continuous process, greatly influenced by the height of the river channels relative to the groundwater and the permeability of the “banks.” Movement of water away from the active river braids will not be inhibited to any marked extent by the presence of stop-banks.
33. Commissioners will need to reassure themselves about the existence and nature of gravity gradients that extend from *both* sides of the Rakaia and Waimakariri Rivers. (In the applicant’s evidence that I have read, the effects on areas to the north of the Waimakariri and to the south of the Rakaia rivers have been generally ignored.) The evidence of Mr Donald Young of the Waimakariri District Council is relevant in this connection. This existence of two banks to each river will be most important factor in appreciating the role of the rivers, not only in conducting water to the sea, but also in determining where gravity and porosity can unite to supply and re-charge the plains aquifers.

34. Because of considerations of the kind enumerated above, the Commissioners will need to be especially cautious in their determinations of the probabilities of the consequences for water quality of events that may or may not occur. I refer here to the AEE **8.6 Christchurch City Groundwater**. This section describes the risks to the quality of the Christchurch City Groundwater, and goes on to speculate on the possible activities of land-holders in the area. I submit that there is no justification for what I think of as an imputation of doubt in such speculations. It is important, that since the issue in question is the quality of the drinking water supplied to some Christchurch citizens - residents of a city that is proud of the fact that its civic water supply is not treated in any way - **you will need to assume that the worst that *might* happen, *will* happen**. In the past the non-essentiality of water treatment has been a justifiable matter of pride, but here we must ask will it be reasonable in the future to endanger that status for the alleged financial benefit of the applicants and their share-holders or clients? Clearly, in my view the risk is too great to be countenanced. Deciding on the fate of the application must not be reduced to the status of a lottery, with the health, or otherwise, of the citizenry regarded as some sort of prize, but none-the-less a disposable prize.
35. It is worth noting that in recent times there have been great increases in the volumes of groundwater pumped to supply irrigation needs. We may assume that as far as she is able Nature has, without the benefit of a Regional Council consent, made extensive drawings upon the water flowing in the surface streams to restore groundwater levels. We may note that it would appear from the records of groundwater levels that "Nature's claim" has not been met in full, or promptly, for the records of groundwater levels as displayed in the Ecan web-site show a very widespread lowering of the groundwater levels, often for long periods, in some assay wells.
36. It is important to bear in mind that the total actions of the CWPT will not add one drop of additional water to the Central Plains ecosystem. The water that is stolen from the main braids of the rivers was there previously. There is nothing new. All that is new is that much water has been taken from the rivers and from the groundwater resources, and exposed to new, and additional means of diminution. Thus water will be sprayed through the drying air, and much will be lost, even before it can land. Water on the ground will be more available to the action of the sun to increase its temperature for it is spread very thinly and exposes maximal surface to the incident solar radiation, again maximising evaporation.
37. In the ground it will be available for uptake by the forage vegetation so that it can be maximally available for loss through evapo-transpiration at maximal rates. Because the water is available, even when conditions for loss through evapo-transpiration are not optimal we know that the forage plants will lose water through the process of guttation, and at night water of guttation will exude from the tips of the grass blades in the liquid state and not in the gaseous state. Again water loss will be maximised. The soil animals will also be enabled to be unrestrained in their activities by water shortage, and its loss can be unrestrained.
38. Because the farmers will aim to maintain their soils at near field capacity there will be minimal death rates of soil organisms and other organisms in transit through the soil. The

movement of microorganisms will be maximised as to speed, and the mortality from desiccation will be minimised. Of great importance to many of us will be the more efficient movement of microorganisms through the soil profile in such a way as to maximise survival.

39. Clearly, different views are held as to the amounts of water available to transport organisms, but from consideration of the evidence advanced in favour of the application, the conditions of life will be optimal, and this will essentially result from the ready availability of water, oxygen and plant nutrients. It seems to me that these conditions favouring forage growth are just those favouring microorganism survival.
40. It must be expected that each dairy cow will deposit her 25 kg of faeces per day (or 9.125 tonnes per annum) onto the pasture. If replacements are reared within the Central Plains area it may be assumed that they will produce dung at about half that rate for their non-productive life time.

### **AEE - Citing Data - a niggle**

41. It is only with the greatest difficulty that readers of the AEE can gain a reasonable impression of how the various aspects of water flows etc. in the Plains region, and how the various factors interact. The consequences of factor interactions are difficult to discern. One matter that I think bears upon these difficulties is the pronounced enthusiasm for the report's writers for the use of means or averages when discussing flows and availability of water. It should have been second nature, long before this for all posing as scientists, when stating means to also state the range of the measurements, and hopefully, to also provide some useful measure of the central tendency of the data - such as the standard deviation. With that equipment readers will often be able to realistically assess the nature of the data to which reference has been made. I think we have travelled a long way since biologists first initiated the study of statistics as a means of coping with variable data. As a biologist I am very conscious of the fact that in biological matters the extreme values, even if they be of rare occurrence, are especially important. I do not recall hearing of anything being slain by an average!
42. It needs to be fully understood that means, and modes are not realistic measures of magnitude. Citing the range of data is very important, for it limits the ability of people to get away with citing only the median or the modal value when they think that will favour their case, and obscure unfortunate truths. Sound judgement requires sound inputs.

### **Life in the Groundwater: the stygofauna**

43. In Canterbury we may derive a little ill-deserved pride from the fact that back in 1882, the then professor of Biology, at Canterbury College, Charles Chilton drew attention to the presence in groundwater of what he called "well shrimps." Strictly these were crustaceans of the order Amphipoda (the group that includes the familiar sandhoppers of our sandy beaches). I append near here a copy of his 1883 illustrations of the morphology of *Phreatoicus typicus*, a large (20 mm long) amphipod from Canterbury groundwaters (Fig. 1). Importantly, Chilton brought knowledge of the existence of these then mysterious

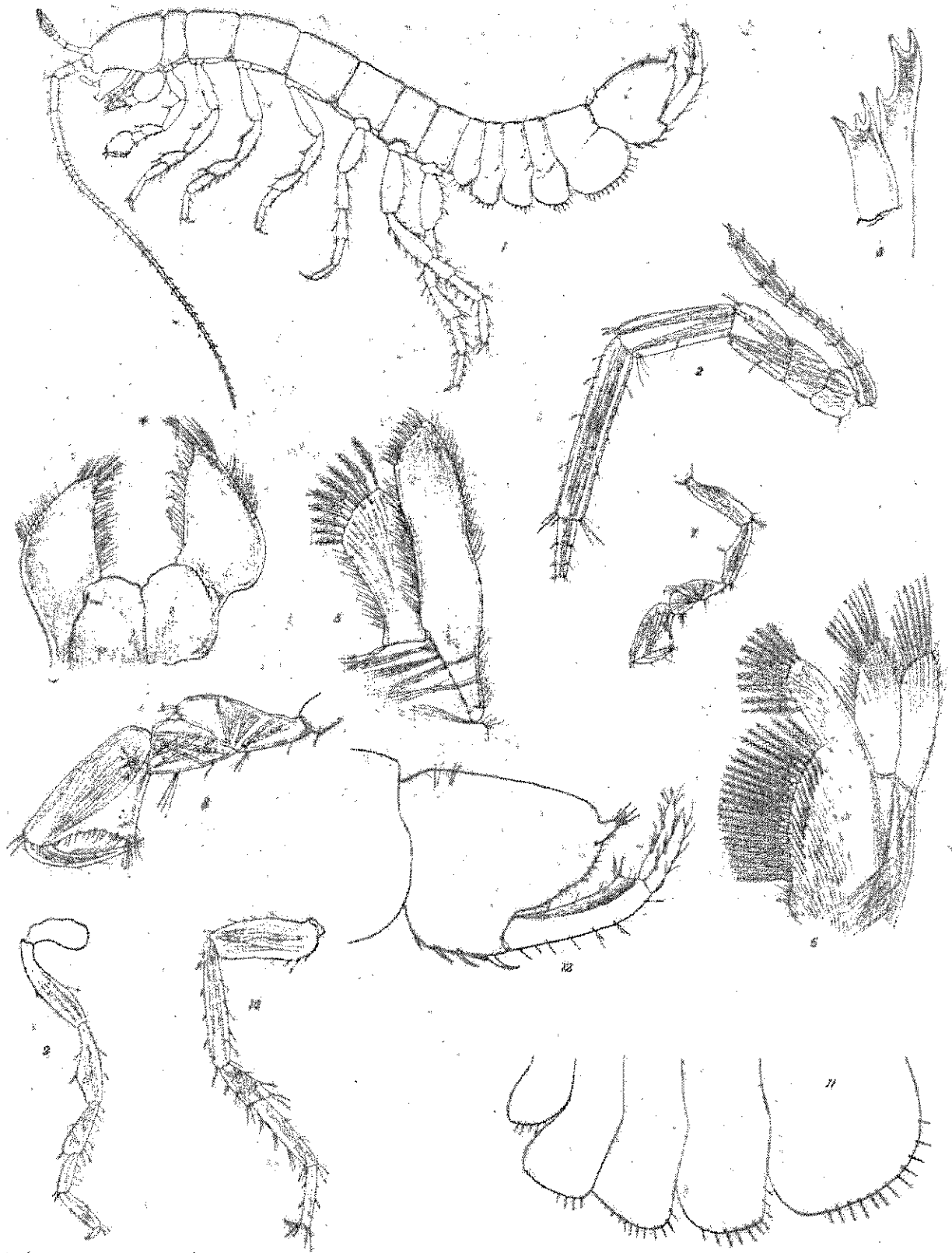


Figure 1. Chilton's illustrations of *Phreatoicus typicus* reproduced from the Transactions of the Linnean Society (Zoology) London

creatures that inhabited the underground waters of this Province to the attention of the scientific, and thinking community in this land, and to the world in general. He published in European scientific journals accounts of the animals he had strained from the artesian water under his farm at Eyreton. These accounts appeared in the Transactions of the Linnean Society of London, and in the Transactions of the New Zealand Institute (which later became the Royal Society of New Zealand).

44. It is entirely to our disadvantage that I report to you today, that Chilton's discoveries and his reports were essentially ignored, for the next century.
45. In recent years, NIWA has taken up the challenge represented by this rather mysterious fauna, and their scientists have commenced the task of characterising this remarkable assemblage of animals that live in our groundwater. Its scientists have published accounts of some of these animals<sup>5</sup> that live in total darkness, a few or many metres below the soil's surface. Nowadays all the animals that inhabit these light-less waters are known collectively as the *stygo fauna*. The name is derived, as you will guess, from the River Styx of the legendary Greek underworld of Hades.
46. As might be expected, living in constant darkness, the inhabitants of these depths are universally blind, and essentially without pigmentation. Because there is no light in their habitat there can be no photosynthesis. This is then, no place for plants that use the energy of the sun's light in the synthesis the carbohydrates that we photic zone animals depend upon as a source of energy. The stygo fauna is wholly dependent, at however many removes, on the small fragments of biological material that are conveyed down into the groundwater by the surface waters that percolate, often intermittently, through the interconnected voids that link the groundwaters to the photic zones above. Of course some of the organic material in the groundwater may originate in the darkness of the root zone of the overlying vegetation, but the energy it contains originates in the photic zone.

### **Faunal Diversity**

47. The first animals to attract attention were the larger, macroscopic crustaceans like the almost 2 cm. long kinds that Chilton first described. He found a number of kinds of amphipod and isopod crustaceans, and some related copepods. Being already a student of the Crustacea, and with an established international reputation in that field, it was natural that he immediately recognised the novelty of his finds, and immediately set about alerting the zoological world to his discoveries. About a century later other workers with other skills and interests soon found numbers on insects, a most impressive array of mites, a number of small snails, and other diverse and often minute relatives of the familiar earthworms - other annelid worms. Other "wormy" inhabitants include flat-worms related to the planarians of our gardens, and the flukes that parasitise other animals, and the many different kinds of round-worms or nematodes that also abound in the superficially "drier"

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<sup>5</sup> See:: Scarsbrook, M.R., Fenwick, G. D., et al. Referred to in footnote 4. This publication records the recent growth of interest in such animals and the purely random fashion in which knowledge has grown.

soils above. (In fact the “soil” nematodes all rely on the thin films of water that mostly surround soil particles for their locomotion. If the water film around the soil particles vanishes, the nematodes are totally immobilised.)

48. A few nematodes have the ability to persist in a more or less desiccated, anabiotic state, from which they recover when wetted, perhaps months or decades later, but the vast majority do not have this property.
49. By chance, the scientists who collected from the groundwater, and described their “catches,” were generally workers whose experience was with “small animals,” but not with microscopic ones. I believe this probably contributed to the probable under representation to date of the predictable micrometazoans such as the nematodes, tardigrades and rotifers - animals not visible to the naked eye.
50. I have not found records of wheel animalcules (phylum Rotifera) or water bears (Tardigrada) in the New Zealand stygofauna as narrowly defined. Freshwater species of both groups are well established as part of the general fauna. I know that rotifers live in New Zealand soils for I have often seen their sclerotised (horny) masticatory apparatus, which resists digestion - at least for a time, in the guts of predatory nematodes (Mononchidae - roundworms about a millimetre long and a fortieth of that wide). Since both rotifers and water bears are often parthenogenetic (reproduce without males) and are often anabiotic (can suspend animation, and dry out for indefinite periods) they have life histories that seem eminently suited to life in a fluctuating environment such as that inhabited by the stygofauna may be. Both kinds of animals are common elsewhere in New Zealand<sup>6 7</sup>.
51. The absence of rotifers and tardigrades from records of sampling the stygofauna (like the general failure to record the presence of nematodes) may result from their very small size and from the fact that many of these animals are able to attach to the substratum by means of the adhesive organs found in many nematodes and rotifers. The prehensile claws on the tardigrades may also enable them to “hang on”, thus inhibiting their presence in samples.
52. In New Zealand over 100 metazoan (multi-celled) stygofaunal species (including at least 15 crustaceans) have been formally named. It has not been customary to regard the small animals that live in the soil, and are dependent on the films of water around soil particles and crumbs as part of the stygofauna. Thus this tally of 102 stygofaunal species in Scarsbrook, Fenwick et al. ignored the 40 odd species of nematodes that Dr. Gregor Yeats

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<sup>6</sup> Horing, D. S., Schuster, R. O., and Grigarick, A. A. 1978: Tardigrada of New Zealand. *New Zealand Journal of Zoology* 5: 185 - 280.

<sup>7</sup> Duggan, I. C., Green, J.D. Thompson, K. and Shiel, R. J. 1998. Rotifers in relation to littoral ecotone structure in Lake Rotomanuka, North Island, New Zealand. *Hydrobiologia* 387/388: 179 - 197.  
Duggan, I. C., Green, J.D. and Shiel, R. J. 2002. Distribution of rotifer assemblages in North Island, New Zealand. *Freshwater Biology* 47: 195 - 206.

reported in his study of those animals in the fore-slopes of sand dunes<sup>8</sup>, or the many other very small animals reported by other workers. Currently, such animals are usually regarded as part of the ill-defined “soil fauna.” The many other soil dwelling nematodes, and small oligochaetes that are known, were not considered either. About another 100 stygofaunal species are held in NIWA collections awaiting baptism. A current conservative estimate of the stygofauna of New Zealand is “about 500 species”. This tally excludes those much larger, strictly, soil-dwelling invertebrates that do not require appreciable volumes of free liquid water, such as earthworms, and insect larvae (e.g. porinas, grass grubs and cicada nymphs.) It goes without saying that our knowledge of the detailed biology of the truly stygofaunal animals is almost non-existent.

53. It is also important that we recognise that the soils, and the soil water is often the habitat for much smaller organisms, which of course includes all the soil and groundwater single celled animals, the Protozoa, (studied by the late Dr John Stout formerly of the Soil Bureau, DSIR) and the acellular microorganisms that we can conveniently categorise as bacteria. These organisms may be active in the soil, or they may be merely “in transit.”
54. The microorganisms, protozoal and bacterial that are reported from groundwater from time to time include a number of forms that have parasitic and pathological relationships with us and other animals. The forms that can and do live in us, and our animals as parasites are commonly typified as “zoonotic”, and the resulting diseases are called “zoonoses”<sup>9</sup>. Fungi are absent from these reports.
55. The more familiar members of this group of pathological microorganisms include Protozoa such as *Giardia*, *Cryptosporidium*, and *Entamoeba*, and bacteria such as *Salmonella*, *Campylobacter*, *Escherichia coli*, *Yersinia* and *Shigella*. These can be very important human and livestock pathogens.
56. However, the little that we do know of the stygofauna should awaken us to the probable great significance of that which has previously been ignored, and categorised as “insignificant”, or of “no account”. I share with many others a conviction that we have tended to ignore, or downplay, the role that water quality can play in human health. It is interesting how a changed view point can often bring about a huge change

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<sup>8</sup> Here I refer to the series of papers published by G. W. Yeates in the *New Zealand Journal of Science* vol.10, 1967 - 1968 under the general title “Studies on nematodes from dune sands “ nos. 1 - 9 and his 1968 paper : An analysis of annual variation of the nematode fauna in dune sand at Himitangi Beach, New Zealand *Pedobiologia* 8: 173 - 207..

<sup>9</sup> Interested readers of this statement of evidence may find a New Zealand Veterinary Association publication on this subject useful, and a guide to putting such matters into perspective, despite being a little dated. The work is: Wilks, C. R. And Humble, M. W. 1997. *Zoonoses in New Zealand. A Combined Veterinary and Medical Perspective*. Second Edition. Publication No. 178 Veterinary Continuing Education, Massey University, Palmerston North, N.Z.

in perspective. Recent reports of multiple deaths of fawns from *Cryptosporidium*<sup>10</sup>, a common parasite of calves, and almost certainly destined to be the bane of mussel farmers in New Zealand as elsewhere, may cause a serious reappraisal of this pathogen<sup>11</sup>.

57. When parasitic infections are infrequent, and recovery is usual, episodes can be bypassed with a comment such as “Geez! I wuz crook!” When infections become more commonplace, as recently when southern parts of Canterbury have become known for having the highest rates of infection with *Campylobacter* in the developed world, health authorities should properly become concerned. They might even reconsider the importance earlier placed on poultry as the predominating source of infection. In Canterbury a high incidence of campylobacteriosis is apparently a phenomenon that is coeval with the recent intensification of the dairy industry (despite an incomplete rate of notification of cases). The writing is “on the wall,” and regulators should no longer try to turn a blind eye.
58. Along with other readers, I have noticed in recent years a good number of reports of *Campylobacter* in various water bodies. As noted above, for reasons that I have never understood, the health authorities have shown a predisposition for predominantly attributing human *Campylobacter* infections to poultry, but rarely if ever, with any convincing evidence to support this view. I am unaware of any evidence of higher than usual consumption of poultry in the affected region.
59. Infections are not usually outbreaks of the dramatic epidemic kind, but it seems more commonly a case here, and a case there, which in my views is entirely consistent with a moderately, but fairly persistently infected water supply, or one that is subjected to repeated episodes of infection. It seems reasonable to expect that where 25 kg of fairly liquid, bacteria-rich faecal material per cow per day is deposited on the surface of free-

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<sup>10</sup> See pages 34 and 35 of Quarterly Review of Diagnostic Cases - January to March 2008 [*In* *Surveillance* 35: (2) June 2008. [*Surveillance* is the journal published by MAF Biosecurity New Zealand]]

<sup>11</sup> It may be relevant for Commissioners to know that in the U.S. about 55% of young calves are infected with *Cryptosporidium* for the first few months of life. (I have not found any New Zealand data on incidence in calves.) Infected calves usually produce about a billion infective agents per day, and experimentally, a single cyst which rapidly divides into several infective stages, can establish an infection. These are essentially association cysts enclosed in a stout capsule which prevents control by chlorination of water supplies. They must be sieved out of the water. The “cysts” are readily dispersed by flies, and by water. This organism produces a fairly profound diarrhoea in most mammalian hosts. The protozoan also infects marine molluscs: oysters are notoriously affected in Chesapeake Bay, and the Spanish and other mussel farmers have serious problems too. People do like eating their molluscs raw! The recently approved very large mussel farm in Pegasus Bay can be expected to have *Cryptosporidium* problems (originating in the onshore dairy farms) once harvesting commences. From the literature, the mollusc infections are persistent and cannot be controlled by the usual 96 hours in clean seawater as can most bacterial infections. There are no rules or regulations governing disposal of wastes from calf rearing facilities, so problems, and human misery, appear to be stacking up!

draining, rather shallow, and regularly irrigated soils, the passage into the groundwater of sufficient numbers of bacteria will occur, and some will evade being eaten by the stygofauna, and thus remain available to cause human infections. Some of these infections will be professionally diagnosed and some will be reported to the health authorities. It is to be expected that such reports will be somewhat sporadic in nature, and will thus understate the intensity of the enteric ill-health by an unknown extent.

60. After reading the present application, the precautionary principle leads me to a scenario in which markedly increased cow numbers supported by irrigation over these free draining soils will release more and more *Campylobacter* (and other minute pathogens) from the cow dung. Fine particulates from the dung and adjacent soil organic matter will be moved into the groundwater. If the CPW scheme goes ahead, we must expect considerably increased numbers of pathogens in water supplies, and increased numbers of cases of diarrhoea of zoonotic origin in the above ground human population. Of course, as is usual in such situations, vast numbers of pathogens will not make it into a human host.
61. There is no reason to dismiss the idea that in the past some infant sicknesses, and perhaps mortality, were properly attributable to zoonotic infections acquired from the house cow. That which is not examined, or searched for, is rarely discovered.
62. The cow owner will have no necessary priority in the matter of infection. Dispersion of infective materials will be a matter of chance in terms of the location, speed, and direction of movement of groundwater, and the intensity and distribution, or presence or absence of bacterial feeding stygofaunal elements. Some bacteria will be eaten, some will perhaps expire of old age, or from modified, and now intolerable environmental conditions. Numbers of pathogens may well be greatly reduced the further they are transported in the groundwater, but from the public health records, it will be virtually impossible to deny that many human cases probably originated with bovine infections.
63. Considerations of the present kind bring to mind section 8-19 of the AEE “**Microbes and Pathogens**”. This section requires close examination. It starts with a statement “*Microbes and pathogens have a relatively short lifetime in the groundwater system.*” Relative to what? What sort of a period are we discussing here? Under what conditions? Is there any evidence to support this assertion? Why was it not cited? Then the passage goes on: *Given the travel times from the irrigated land under the Central Plains Water Enhancement Scheme to significant potable water extraction sites, it is highly unlikely that microbes or pathogens will be a significant risk for water quality.*” But I must place this statement alongside the statements in section 8.6 referred to earlier in my para 34 where the AEE describes land in the Christchurch Groundwater Recharge Zone, adjacent to the Waimakariri River where the water apparently flows southeast. By their statement the author apparently considers it acceptable to potentially, or in fact, to imperil the quality of the groundwater that will flow towards urban Christchurch.
64. It should not be necessary to draw attention to the naive expression “significant potable water extraction sites.” I fear that this expression implies that it is probably quite OK to imperil the equanimity of a few family’s guts, but that would not do for a whole city!

Did the writer really mean that a succession of rural cases of bovine-originating diarrhoea are acceptable (to whom?), but apparently not when the cases are counted in scores or hundreds?

65. We necessarily return to the question: Who has the right to pollute water that may be used for human consumption? Who has the authority to confer such a right or privilege? I suspect it does not matter to what use the water is to be put. It will rarely be improved by being polluted, or degraded in any way. Then of course the next questions are: Can the contamination be cleaned up? Who will pay to clean it up? If there is a problem about that, then who can fly in the face of the requirements of Section 5 of the RMA, and agree to imperil the quality of water when faced with the likely sequelae?
66. I have no hesitation in advancing the view that in the past, with relatively low cattle numbers - perhaps only the house cow, and therefore only a small amount of semi-liquid faeces being dropped onto essentially dry pasture, the prospect of bacteria being conveyed alive through the soil and into the groundwater in significant numbers was very slight. Once there of course, they would most likely have encountered a "full strength" stygofauna ready to devour them. The virtual absence of irrigation ensured a situation that is vastly different from today where at many sites cowshed effluent is regularly spray irrigated onto adjacent pasture. The water is now available to carry any pathogens down into water-supply groundwater in numbers sufficient to satiate the resident stygofauna. True the organic matter inputs could conceivably improve the food supply for the stygofauna, but researchers have noted how more food can increase numbers, but if it goes too far, decomposition of that organic matter demands too much oxygen and the stygofauna declines markedly. In one-cow situations the threats to human health were slight indeed. Under those circumstances there were probably few pathogenic bacteria, and as many bacteria feeding stygobites as the habitat could maintain. The risks of infection may have been very low. Today's irrigation of cow shed waste is a very different story.

## **Sampling**

67. It is very evident that understanding of the stygofauna has been greatly impeded by the absence of affordable, widely applicable, and effective methods of sampling. Would-be samplers cannot see what they are doing, and it is also very difficult to get there! The spaces are often small and forcible entry of sampling gear does "who knows what" damage to the habitat and its occupants. Techniques that sample large crustaceans will most commonly fail to sample minute mesozoans like nematodes and rotifers. The mere act of intrusion to take a sample may destroy the habitat that was to be sampled. It is probably much easier to obtain knowledge of the abyssal depths of the oceans, than it is to gain accurate knowledge of the groundwater and its fauna a few metres beneath your feet!
68. To make matters more difficult, many animals have adhesive or prehensile organs that make it possible for them to adhere to the substratum, and thus avoid capture. At best, the sampler recovers a random sample of what might be "floaters" that bears no known relationship to the whole spectrum of the resident populations.

69. Difficulties that face an investigator who would seek representative samples of the whole fauna are huge. I have found several references claiming that many animals avoid iron pipes<sup>12</sup> which are of course commonly the route of access to the stygofauna. Narrowness of the openings (1.0 mm.) in many well casings also exclude larger animals like some crustaceans from samples. Unusually large flushes of organic material (as in sewage effluent disposal, or irrigating with cowshed washings - effectively the same thing!) can enhance population numbers, but too large amounts of added organic matter can devastate populations too, as was observed at Templeton by Sinton<sup>13</sup>. Studies at Templeton disclosed that additional availability of carbonaceous material in groundwater can support greater numbers of animals, but clearly one can have too much of a good thing, for intrusions of much organic matter can lower the oxygen availability and thus markedly decrease stygofaunal abundance.
70. There are few data available on the sensitivity of New Zealand species to metals and pesticides, but data from overseas show some marked, but variable sensitivities between species.
71. Experimentally, it has been found that “baiting” bores with potentially attractive materials (e.g. ) can radically alter the numbers and kinds of animals obtained at the next sampling (G. Fenwick pers.com.)
72. There are huge difficulties in using sampling to determine the effects of abstraction of groundwater on the populations. Comparability between samples is important, but what effect does the removal of large quantities of water - the habitat - have on the fauna? Is this effect temporary or enduring? To what extent is the effect of pumping distributed across the different faunal groups? If the water level is lowered, and animals are in effect stranded, are they doomed? Is the effect permanent, or can some perhaps survive in “inactive forms” - perhaps even ones that are currently unknown? Or is such an event - the removal of the surrounding water - fatal? We do not know. Since at present, many organisms seem very difficult to cultivate in the laboratory, how will we find out?
73. Almost since European settlement began, people have drawn water from the ground. As far as I am aware, we know nothing of the *natural* range of variation in water levels. Measurements only started when people began to fear the effects of earlier actions. What variation can be considered “normal”? One may presume that water entered and left the subterranean voids as controlled by permeability of the land (the effect of the strictures between the inter-connected voids) and the hydrostatic pressure of the contained water, but such a statement contributes nothing to the scientific, or intelligent management of the resource. We have no idea of the natural regimes of change in the stygofauna’s habitat.

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<sup>12</sup> see page 29.13 of Fenwick, G. , Thorpe, H. and White, P. 2004. Groundwater Systems (Chapter 29) In Harding, J., Mosely, P., Pearson, C. And Sorrell, B [Eds] *Freshwaters of New Zealand. New Zealand Hydrological Society & New Zealand Limnological Society.*

<sup>13</sup> Sinton, L. W., 1984 The macroinvertebrates of a sewage polluted aquifer. *Hydrobiologia* 119: 161 - 169.

74. We know very little of the stygofauna, or of the habitat in which it currently persists. Before there can be any claims of intelligent or wise management of this resource, we must fill the vast gaps in our knowledge, or perhaps more modestly aim to reduce our crass ignorance concerning the diffuse biological filter and “purifying system” that appears to play a vital role in safeguarding our health. If we throw away all the lifebelts, and hole the life boats, who could claim surprise if we perish?

### **Activities and attributes of the stygofauna**

75. As indicated earlier, the groundwaters of the plains are thought to be very variable as to depth, confinement, flow rates, physical dimensions and in other parameters of the water-containing voids. It is useful to bear in mind that the fact of water flow means that local modifications of habitats maybe ephemeral locally, as the current transfers the new habitat conditions downstream. Things may not be static. Our knowledge of the stygofauna is very limited, but we must use that which we have, and that which can be deduced.
76. The animals derive their energy from the organic materials that are carried by and in the ground water from their places of origin, usually, ultimately in the photic zone at the surface. It seems reasonable to think that as in surface waters, the organic material is comminuted by a variety of organisms, which are usually designated as “shredders”; others that gather fine particles and faecal materials are “collectors,” whilst those that browse on biofilms are probably roughly equivalent of grazers in more familiar environments. Much of their food is bacterial in nature.
77. It is probable that a number of these animals contain within their guts populations of bacteria that secrete enzymes that are able to digest refractory materials such as wood, and cork. No doubt the small snails in the stygofauna will, like other snails, secrete enzymes capable of digesting wood. Most probably, no other animal in the stygofauna can do that using its own enzymes.
78. Undoubtedly, the diverse kinds of animals found in the groundwater are able to ingest and digest diverse kinds of foods, with many able to ingest materials at least as small as bacteria. The view has been expressed that in groundwaters the stygofauna constitutes a very important, active, if somewhat diffuse, “biological filter” that progressively removes much of the particulate biological matter that is either suspended in the water, or attached to the mineral substratum as a biofilm. By eating, and removing the digestible fraction, the stygofauna keeps the percolation passages open, thus facilitating and preserving the movement of water, whilst at the same time ingesting considerable numbers of microorganisms of diverse origins, and probably, in many situations tending to lower, to an unknown extent, the numbers of microorganisms in the water.
79. Fenwick has reported that at Templeton the *Phreatoicus typicus* population processes between 7 and 28 tonnes of sediments per hectare per annum, and in the course of that activity removes 0.2 to 1.0 tonnes of organic carbon per hectare per annum. Results like these give credibility to the notion that the stygofauna may well be an important ally in the battle to sustain human health, and to avoid pathogenic microbial contamination of

the water. Such processes diminish the probability of communication of pathogenic organisms to humans (and to domesticated mammals).

80. Fenwick also reported that at Templeton, the amphipod *Phreatoicus typicus* ate large numbers of bacteria, so it does not automatically follow that large animals eat only, or are restricted to large dietary items.
81. There appear to be good grounds for believing that before the major vegetational and faunistic disruptions occurred above ground, and before large scale abstraction of groundwater for irrigation, the groundwater habitat had in fact been a resource poor (little food), but stable habitat. The populations then would in effect be adapted to a slow rate of replacement, unlike the populations of the river beds above, where major disruptions following floods and other cataclysmic events could often devastate populations. In those circumstances a capacity for abundant regeneration of numbers is important, and the habitat provided the resources to sustain prodigious reproduction when needed. The stygofauna's existence depended upon an ability to keep the water flowing and the food coming, but of course we have no case for imputing such sentience to them.
82. What are the probable consequences of a stygofaunal die-off? Is it likely that there will be greatly enhanced survival of bacterial populations such as *Campylobacter* and *E. coli*? How widespread, or localised; or ephemeral will these potentially burgeoning population changes be? It might be presumed that if mortality is diminished the survivors will spread in greater numbers to domestic or community water supply wells. Is there any sound basis for tacitly assuming that all will be well? Because water moves through the aquifers (in the direction of abstraction?) will the reduced faunal and bacterial numbers also spread? It may simply be that the water-ways will choke in the absence of their animal cleaners.
83. It has been reported that the constituents of the stygofauna are typically slow breeders. Low reproductive rates are to be expected in animals living in an environment which is thought to have been very stable for long periods. High reproductive rates are typically associated with animals that live in unstable, or frequently devastated habits (as adjoining large rivers, or violently fluctuating situations) . In unstable habitats continuity of populations can be very precarious, and speedy recovery of population numbers serves as an "insurance policy." Such prolific reproduction would be inappropriate in stable, but often "resource poor" habitats, like groundwater. Where food may be short, or temporarily limited, it can be an adaptive reproductive tactic to produce small numbers of well provisioned (yolky), direct-developing eggs - that is, eggs that develop directly into small adult-like young, whilst avoiding transitional larval stages. By producing a small number of "high survival" young, rather than a vast number of tiny, high mortality eggs that develop into adults often via long series of larval stages often with specialised food requirements, a stable population may result.

84. I have argued elsewhere<sup>14</sup> that very small body size often limits the number of well provisioned eggs that an individual can produce. In such situations simultaneous hermaphroditism (presence of functional organs of both sexes in the one body at the same time) is a commonly encountered tactic. It effectively doubles the number of egg producers in the population at any time. The energetic costs, and spatial requirements of male reproductive systems are typically minor by comparison with those of direct developing eggs, so both activities can be accommodated within a single individual..
85. Hermaphroditism is a very common reproductive stratagem in animals that are not very mobile, or which live at low frequencies, and so may have infrequent encounters with potential mates. This life history pattern is the norm for very small annelid worms (Annelida), and for flat worms (Platyhelminthes) and for small snails, and other very small animals that at larger sizes are typically gonochoristic (have separate sexes).
86. Very few investigations have been undertaken into stygofaunal biology. The difficulties of access to the animals in their habitat: of observing them *in situ*, in darkness, and even representatively sampling them, are formidable. Such studies are often costly, so why bother when no-one cares:?

### Habitat Stability

87. Even the briefest perusal of the groundwater data provided on the Environment Canterbury website discloses that the range of levels of water encountered within the groundwater system have a propensity for marked variation. The range, magnitude, and speed of such variations apparently varies very widely. From scanning Environment Canterbury website data it is evident that the greatest draw-downs of the underground water usually coincide with very low river levels. At such times farmers may be denied water from river flows, and so turn increasingly to the groundwater resource.
88. Changes in farming pattern have also brought changes in water demand. The sudden and pronounced changes in draw-down at well M36/0355, near Leeston, (for example) which are reproduced here (Fig. 2), may well have been influenced by more than a single predisposing cause. It is noteworthy, however, that the well levels recorded after 1988 have been up to 6 metres lower than any of the earlier records. What interpretation is to be placed on such records?
89. With examples like this, we do need to know how the stygofauna populations operate; whether we can expect them to recover from major changes in their habitats as produced

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<sup>14</sup> Clark, W. C. 1973. The ecological implications of parthenogenesis. *Pp. 103 - 113 IN* Lowe, A.D. [Ed.] *Perspectives in Aphid Biology* Bulletin No.2. New Zealand Entomological Society (Inc.) Auckland, N.Z.

Clark, W.C. 1978. Hermaphroditism as a reproductive strategy for metazoans: some correlated consequences. *New Zealand Journal of Zoology* 5: 769 - 780.

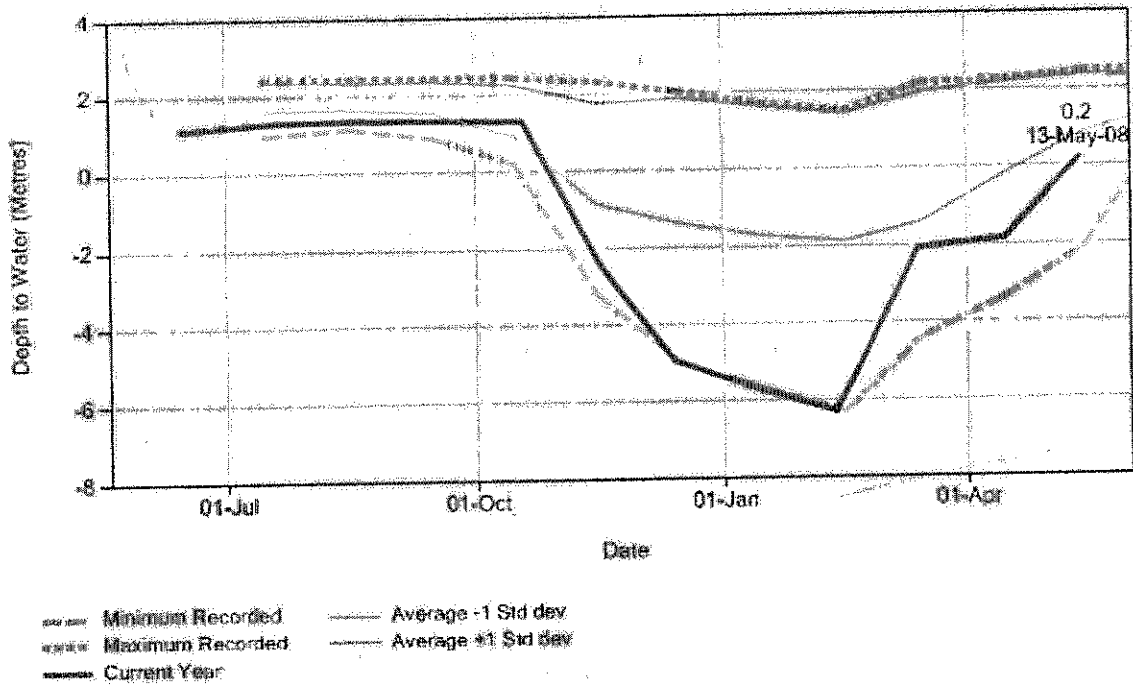
Clark, W. C. 1981. Sperm transfer mechanisms: some correlates and consequences. *New Zealand Journal of Zoology* 8: 49 - 65.

## Groundwater level plots for well M36/0355

View well card, borelogs and download data

Grid Reference M36:55125-17966 Well Depth 61.0 m

### Groundwater envelope plot for well M36/0355



### Full record for well M36/0355

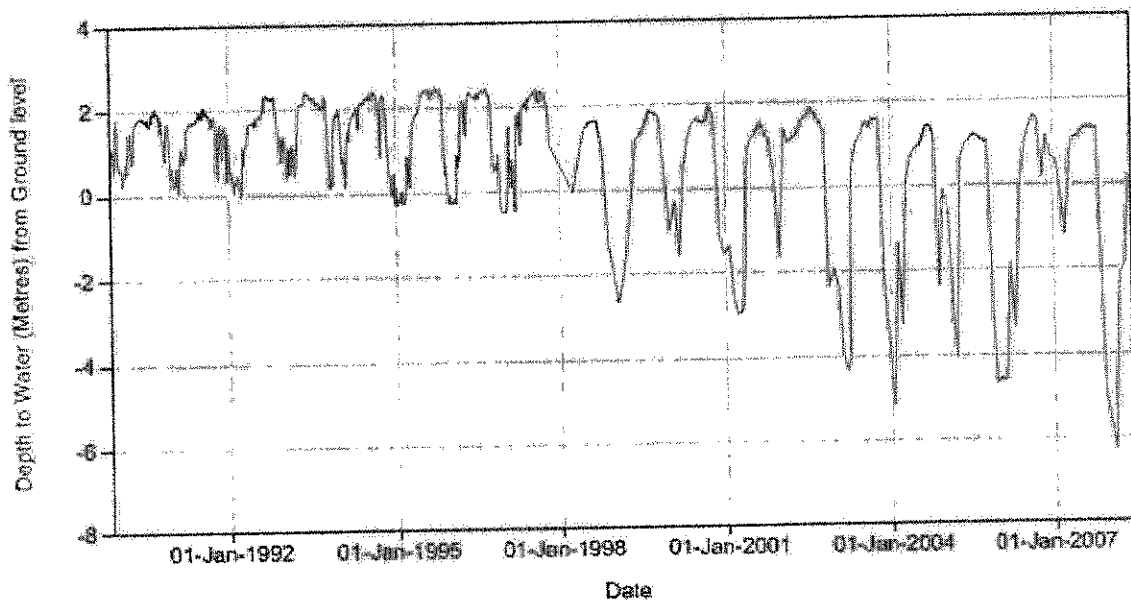


Fig. 2 Groundwater Levels from well near Leeston (Ecan web site figure).

90. I am unaware of any studies concerning the fate of the stygofauna in times of marked lowering of groundwater by abstractions. No doubt some organisms are discharged with the abstracted water to die on the surface, or be minced in the pumps. But what of those that are left behind? What happens to the fauna then? Do they simply recede with water levels, but generally survive none-the-less, or is there any considerable, or selective mortality? Which forms are stranded, starve, and die? Which are able to move down and survive? What roles within the stygofauna that are played by these fractions? I submit that reliable answers to such questions must be a *sine qua non* for the responsible water management in the region. If the stygofauna plays a significant role in the mortality of pathogens, as we know *Phreatoicus typicus* does, then it is entirely irresponsible to approve the creation of conditions whose consequences are unknown, or which may impose significant disadvantage, sickness, and discomfort, on third parties.
91. I have no knowledge of the possible toxicity of ammonia or related nitrogenous materials or pesticide residues to specific members of the stygofauna, or to that fauna as a whole. It appears inevitable that if there is a marked intensification of dairy, or other farming that could raise nitrogen levels in the groundwater, then this will be a prominent consideration in arriving at any decision on this matter. If the knowledge is not available, then the Commissioners may wish to requisition such research, if they have that capacity, or to deny approval. On present knowledge the survival of the stygofauna must not be put at risk.

### **Concluding Groundwater Considerations**

92. I expect it will take much effort to resolve problems relating to the effects of falling groundwater levels on the stygofauna. We need to know how and if groundwater levels can be maintained by management? The extent and timing of abstractions both from the wells and from the recharge resources in the rivers may be crucial. We must discover if the biological filter function of the stygofauna can be reliably maintained? Can the destruction, or the imperiling of the bio-filter to enrich farmers, whilst at the same time sickening or imperiling the public health be approved?
93. The Commissioners will need to resolve whether it is a proper exercise of their functions to compel the ratepayers in general to invest large sums in an attempt to restore and protect water quality, and potentially their own health, from the consequences of attempts to safeguard dairy-farmer's profits? We must also determine who will pay for all the research that will be needed to make it possible for you and your successors to determine the steps necessary to avoid, remedy or mitigate the consequences of any approval that might be recommended? Without secure, and hopefully reassuring results, a desirable outcome will probably be impossible. We must not act in ignorance.
94. It is essential to remember the explicit duty in S. 5 (2) **to protect** the resource, and not merely to provide, after an adverse event, to try to repair the damage, which given the dearth of reliable information, that may not be possible, except by the costly, uncertain, and continuing process of trying, on a huge, and dispersed scale, to *restore* water

quality. (Will restoration be possible?)

95. We will need *certain* knowledge of the ability of the rivers in future to restore groundwater levels (and quality?) during the winter when river flows may, from time to time be fairly consistently low - refer to Appendix 1 derived from Environment Canterbury's river flow records, noting particularly 1969, 1971, 1976, 1977, 1982, 1985, 1989, 2001, 2005, 2006, 2007. The "winter water" that so many foolishly see as "running to waste to the sea" is now required to restore groundwater levels. According to the applicants, they wish to divert up to 40 cumecs of the winter flow in both the Waimakariri and the Rakaia rivers to storage, where it will not be available to restore the groundwater levels after the summer takes. You will need to be very confident indeed, that there really are, and will continue to be available at the appropriate times, the resources needed for this purpose, without at the same time imperiling the matters specified in Section 5. I have grave doubts.
96. It is most important that it is realised that from time to time river flows are very low, and that at times no river water may be available for abstraction (other than for domestic and stock water purposes) and very little available from active braids for groundwater recharge. This state of affairs may persist for several months. The groundwater itself maybe markedly lowered by farmers using existing consents to take, and the resulting consequences may be grave indeed.
97. If there is good cause to believe that any action will, or is likely to bring impairment of conditions upon a third parties, or on the environment, it is most important that the decision-makers refer again to Part II: Purpose and Principles of the RMA.
98. Section 5 of that Act is of paramount importance in this connection.
99. If falling groundwater levels are likely to be reflected in lower quality of groundwater, possibly or probably resulting from time to time in ill-health in the groundwater-dependent human communities; then any consents to take winter river water that would otherwise have recharged the groundwater, and maintained the health of both the stygofauna, and the human population, must be most carefully reconsidered.
100. The complications and potential injustices that could arise from any attempt to impose retrospective conditions, *after the consent holders have expended funds on unsustainable developments*, it would, I consider, be unwise to grant the consent in the present dearth of reliable knowledge. If a crisis arose, the consent authority could face a huge dilemma, and would need to consider, draft, establish, and *punctiliously enforce revised conditions* on the exercise of any such consent so as to **guarantee** the preservation of human health and environmental interests. Such conditions may well include requirements for the establishment, operation, and maintenance of water treatment facilities to ensure that in future any water taken from the ground for domestic supply will not endanger the health of the public - but at whose costs? Water taken from both community, and private supply wells could need protection.
101. The consent authority may consider it necessary, or prudent to require a very substantial

financial bond that would adequately finance the creation and operation of any urgently required measures.

102. I do not raise this issue lightly. I am sure that this matter is relevant to the Purposes and Principles s.7 of the Act. That section established the paramount importance of “sustainable management” and in defining that concept, specifically stated:

*“(2) In this Act, sustainable management: means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while----*

*(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*

*(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*

*(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.”*

103. The present application impacts on Section 5 of the Act at several points. Firstly, I believe that I have established a *prima facie* case that the proposed activity does threaten the integrity and survivability of the potable groundwater resource, including its biota, and the area whose groundwater resources are influenced or affected by the flows, or lack of flows in the Waimakariri and Rakaia rivers. The effects of the proposed operation which will not be limited in extent to the area of the CPWT activities, but will include the areas of lateral and downstream groundwater. The effects may be summarised as:

1. Abstracting up to 40 cubic metres of water per second **from each** of those rivers in the winter months to recharge an artificial reservoir. That action will on many occasions, as demonstrated by winter flow records for those rivers in recent years, greatly limit the availability of water to recharge the groundwater reservoir beneath the Canterbury Plains over a much larger area than that in which the applicant proposes to operate. It appears that many of those who may have resources taken from them will have no way benefiting at any time.
2. By interfering with, and limiting the recharge of the groundwater resource the applicants may imperil the abundance of the stygofauna, which at the present time acts as a diffuse, but generally effective biological filter in the groundwater, and thus plays an important role in minimising the polluting effects of microorganisms carried down by irrigation water and rainwater from the pathogen-containing cow dung. Such action pollutes the groundwater resource and imperils public health. When the “bio-filter” of the stygofauna is reduced, and bacterial contamination is enhanced, public health can only be expected to deteriorate further.

3. The company proposes to take such a volume of water during the winter that, because of the limitations they impose on the recharge of the groundwater they will in fact limit the supply of groundwater to other irrigators. You must be satisfied that this is not a “backdoor route” to gaining access to water that has in principle already been allocated to other abstracters.
  4. It is no secret that cows are not part of the native fauna of Canterbury, so we must concede that an abundance of infected cow dung is an “artificial” or non-natural means of altering of the environment to the potential harm and ill health of susceptible mammals, including mankind. Disposal of cow shed wastes by spray irrigation will need close supervision to avoid excessive deposits of organic matter over limited areas adjacent to milking sheds. (Such deposits of organic matter may intensify competition for oxygen in the groundwater to the extent that will imperil the stygofauna.)
  5. The harmful effects of polluting waters in the area by faecal contamination has probably existed in the area at a fairly low and apparently acceptable level for some time, but the odd “house cow” and sheep farming did not constitute a health hazard of anything like the same magnitude. The recent exacerbation of the health risk has followed closely upon the great increase in the bovine population which produced vastly more infected, dung, and the application of large quantities of water by way of irrigation which greatly assisted the presumed movement of the zoonotic organisms through the soil and into the groundwater which is used for human domestic purposes. It is very unlikely that any significant quantity of viable pathogens escaped from the pelleted, and much drier sheep dung.
  6. There can be no doubt that the use of the groundwater for domestic purposes predated the intensification of cattle farming on the plains, therefore, it may be reasonably assumed that the present (recent) higher incidence of campylobacteriosis in Canterbury plains (reputedly the highest in the civilised world) is not unrelated.
104. Section 5 (2) (c) of the Act mentions “*Avoiding, remedying, or mitigating any adverse effects of activities on the environment.*” It is clear that the effect envisaged could be avoided, by not taking the large volumes of water, thereby leaving sufficient water in the river to provide for adequate recharge of the groundwater. At what level the groundwater would need to be maintained needs to be determined. In other words, regulated inaction, leaving the water levels as they are, (or have been until recently) would probably help secure the future quality of the groundwater. Limiting the number of bovines may also be necessary.
105. I do not know how one would remedy the destruction of the stygofauna if that did occur. It may be possible. I doubt if the knowledge required is available anywhere in the world. Remedying is not an option at the present time. Loss of the biological purifiers may well be permanent: I do not know.

106. Mitigating the effects of the proposed actions may at first seem possible, but I am sure that it is not a practical response. One would first need to decide whether to attempt to restore the stygofauna and its habitat, or to perform the water purification process by other means. Any attempted restoration of the stygofauna's habitat would probably involve revocation or radical modification of consents to take groundwater in the affected area. That would be unwelcome. To mitigate the destruction, whether partial or complete, of the stygofauna by providing substitute purification of the groundwater, would require the installation, operation and maintenance of water quality restoring facilities at potentially every well in Canterbury where water is drawn for drinking. I have no idea how many wells would need such installations and appropriate, regular, servicing, but Environment Canterbury advised me that there are currently at least 13,500 wells in existence between the Ashley and the Rakaia, but many would not be involved in domestic supply.
107. Before any such action is contemplated, a careful assessment of the desired effects must be compiled. For example, chlorination of water would satisfactorily control bacteria like *E. coli* and *Campylobacter* in some community supplies, but there is a need to realise that chlorination does not control the protozoan *Cryptosporidium* which is widespread in calves, and which is now known to be a serious pathogen of fawns. I do not remember whether *Giardia* can be controlled by chlorination.

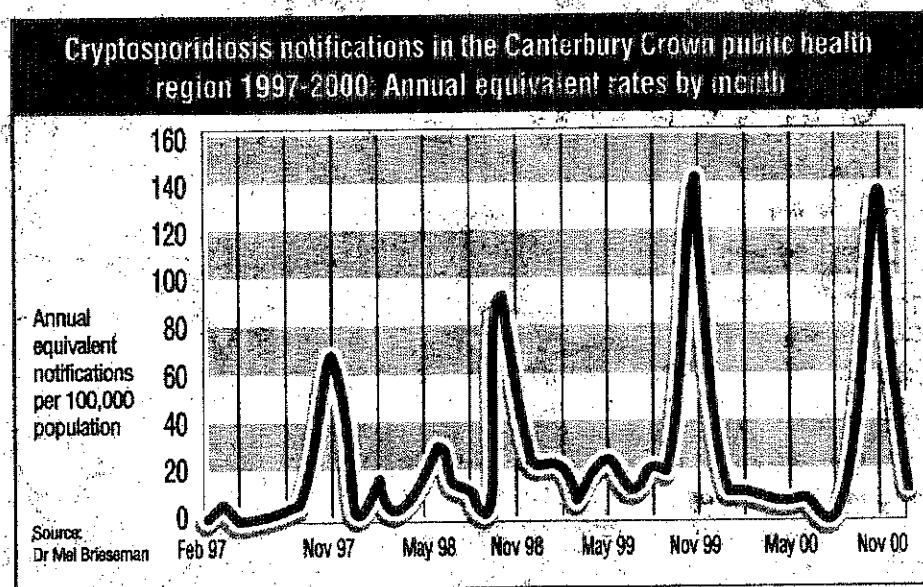


Fig.3  
g of  
oridiosis In Canterbury Crown Public Health region 1997 - 2000.  
Note peak incidence in November; lows in February after establishment of immunity in calves.

Reportin  
cryptosp


108. As there are currently no specific requirements governing the safe disposal of faecal materials from calf-rearing facilities, it is appropriate that there be very careful consideration of measures to be implemented to mitigate the evident risks that arise from this source. Figure X taken from evidence given by Dr Mel Briesman (until recently

Medical Officer of Health, Christchurch) at a hearing on the discharge of sewage effluent into the Avon Heathcote Estuary, shows the clear temporal association of human cryptosporidiosis and the birth of the autumn calves for winter milk, the birth of spring calves, and later in January/February, the dramatic decline in notified cases once the calves achieve immunity. Because of the relatively large size of the propagative cysts, establishing systems of fine (1 micron aperture) filtration could protect some potable water supplies.

109. The problems indicated above are not be lightly dismissed. The recent outbreak of *Escherichia coli* 0157 at Springston should serve as a recent, and most cogent reminder of the ability of such organisms to be disseminated via water supply installations.
110. I do not wish to create an impression that I believe that corporate farming firms have unlimited capacity to provide multitudinous water purification facilities, but it does seem that if they cannot reliably eliminate the risks of human infections stemming from their activities, then they should not be permitted to embark upon a profound intensification of them. What gives them the right to impose the misery of repeated explosive and bloody diarrhoeal infections on the populace at large? S.5 of the RMA most certainly does not authorise such actions.
111. In summary, I cannot see how, on the basis of the present knowledge, and the proposals advanced by the applicants, how anyone could justifiably recommend the grant of the consents sought. They must be denied.

### **An Additional Matter**

112. I do not know if it is possible for me to step aside from my status as an expert witness, but I would like to do so briefly. I have not had any formal training in legal matters, but I have read fairly widely in U.K. and U.S. law as it relates to situations covered by our Public Works Act. I find the present arrangement that seems to be being sought here to be totally reprehensible to anyone who understands that the Public Works Act was to be used **for public benefit** in difficult situations where there was no other way of securing particular benefits for the community at large. The Act was never intended to be used in situations such as the present one where the proposal is to use the Act to deprive ordinary citizens of their legally held property, against their will, for the special benefit of other independent parties. The notion that because two of the total number of shares in the applicant's company are held by two local bodies makes CPWT a public beneficiary is simply absurd. I beg that you take whatever action is available to you to remove the proposed gross injustice of compulsory seizure of private land for a private purpose and profit. Such an action is wrong, and must not be allowed.
113. If my speaking on this matter is wrong, I am afraid I am unrepentant. The proposed action is even more wrong.

  
Walter Clive Clark.  
30 July 2008

**Appendix 1 Flow data for Waimakariri River at Old Highway Bridge (data from Ecan)**

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual Monthly mean
1967	92	65	130	180	99	49	77	164	105	119	344	207	136
1968	92	111	109	126	140	76	97	110	103	277	227	137	134
1969	58	43	61	72	58	49	56	59	227	74	60	123	78
1970	100	48	64	68	46	62	70	158	429	134	116	262	115
1971	54	31	26	26	37	105	48	49	115	262	129	87	81
1972	67	36	79	101	136	64	95	64	157	307	172	104	115
1973	59	35	31	80	114	90	41	118	107	105	159	59	83
1974	60	72	67	223	82	103	147	83	138	184	179	81	118
1975	80	79	110	217	197	165	132	178	167	162	153	94	143
1976	103	88	60	45	99	154	96	90	109	142	118	183	107
1977	199	108	68	59	97	82	96	58	83	119	121	91	99
1978	81	40	69	139	145	86	115	195	234	196	146	107	130
1979	80	100	92	118	251	89	88	130	157	208	153	264	145
1980	227	134	141	121	99	136	83	157	230	158	174	127	149
1981	69	75	123	92	82	113	90	70	111	257	118	160	114
1982	139	68	59	48	142	112	60	99	114	72	286	203	117
1983	163	54	81	142	201	117	187	126	166	290	184	195	160
1984	122	123	107	66	70	65	120	138	71	174	315	244	135
1985	161	55	36	41	49	91	99	108	120	84	98	171	93
1986	101	88	103	113	85	138	114	170	138	205	118	104	123
1987	140	109	153	147	121	156	69	85	78	182	112	121	123
1988	70	94	98	63	163	194	208	187	333	399	219	124	124
1989	69	70	122	66	52	182	87	64	58	105	100	178	96

1990	119	50	64	77	183	87	102	157	81	140	121	176	114
1991	153	161	48	101	75	67	51	229	144	143	117	95	115
1992	89	75	88	49	50	51	94	229	123	182	156	133	110
1993	145	91	67	82	104	215	70	50	77	193	80	164	112
1994	296	65	102	79	142	131	186	191	148	118	459	133	172
1995	134	61	116	139	132	132	118	115	265	220	152	249	153
1996	102	102	97	213	135	99	101	87	164	284	175	135	141
1997	94	124	96	141	97	86	93	134	75	92	136	258	119
1998	87	96	148	141	68	80	226	168	138	335	118	87	142
1999	57	54	82	99	86	129	89	83	93	186	239	75	106
2000	114	84	62	146	91	178	121	180	228	265	97	113	140
2001	82	41	43	40	44	87	55	89	66	90	177	220	88
2002	217	65	104	65	51	192	101	98	146	139	164	121	122
2003	75	81	47	61	100	111	117	64	149	179	125	90	100
2004	124	147	108	62	115	168	79	137	132	135	111	90	117
2005	82	75	75	65	65	66	72	67	105	66	52	53	70
2006	100	54	41	131	87	166	96	84	127	182	365	173	70
2007	110	54	37	38	74	98	93	76	67	278	78	70	89

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## Appendix 2. Water Borne Enteric Diseases

Water borne enteric diseases of interest in this application are divisible into two kinds based on the nature of the infective agent.

Protozoa (single-celled animals) that cause diseases are: *Cryptosporidium* and *Giardia*.

Fairly commonly diseases are caused by the bacteria:: *Campylobacter*, *Escherichia*, *Shigella*, and *Yersinia*.

The protozoal diseases are enclosed in stout cyst walls and for this reason cannot be controlled by chlorination. The cysts wall often confers a greater degree of protection from the environment than is enjoyed by most bacteria. The key to avoiding infection is keeping the infective agents out of the water, or by filtering the water through filters with apertures of no more than one micron (thousandth of a millimetre). A human red blood cell is about 8 microns in diameter. For people using roof tank water a simple practical method is to keep all trees away from their house and thus keep possums off the roof. Once in a potential host, the infective cyst soon liberates a number (usually 6 or 8 daughter cells that soon set up the infection. A single invading cyst is sufficient to cause an infection, and often severe diarrhoea. The diseases will usually make themselves obvious about a week after infection, but may take up to a fortnight.

There is no cure for cryptosporidiosis, though medication may be used to relieve the symptoms. These infections are particularly serious for people with compromised immunity. Infection does not necessarily arise from infected water. Any other contact which allows access to the body via the mouth is to be avoided.

The bacterial infections are more diverse.

The bacterium *Escherichia coli* is widespread, common, and exists in at least 100 different forms, most of which are harmless. The form of interest in human health is a particular strain usually referred to as *E. coli* O157: H.7. (The H7 is often omitted.) The presence of an infection with this strain is often indicated by the presence of bloody diarrhoea, which is a signal calling for prompt medical attention. Sometimes humans can be like cows, and be symptom-free hosts to this bacterium. All people with a sudden bloody diarrhoea should seek medical attention. It can be a serious disease, especially in children under 5, the elderly, and the immune compromised.. The disease can progress to severe kidney complications and renal failure in children.

*E. coli* O157:H7 was recently involved in an outbreak at Springston that was traced to a cracked well pipe that admitted infected water. It is serious. Control is by boiling water, or by chlorination, or by keeping infective materials out of the water supply, and away from the food stream.

*Yersinia* infections reported by Wilks and Humble \* as second only to campylobacteriosis in frequency. The disease is probably significant enough for the victims since they can cause a bloody diarrhoea and abdominal pain. Infections mostly persist up to 3 weeks. I have heard of infections with *Yersinia* being fairly common in the dairying area on the north bank of the lower Waitaki River.

*Campylobacter* infections are probably the commonest water borne bacterial infections in the Province. The disease is very common in cattle. For some reason the MoH people seem very often pre-disposed to blame infections on consumption and handling of poultry. This does not, in my opinion explain the high incidence in southern Canterbury where I know of no evidence for a markedly higher than usual consumption of poultry. It seems that the increase in infections has paralleled the increase in dairying.

Infections are usually accompanied by diarrhoea, stomach pain, cramps, and fever. Infections usually take about 5 days to develop and last about a week. The diarrhoea is often bloody. In immune compromised persons the disease can be life threatening.

Salmonellosis is very commonly a matter of infected food materials and whilst waterborne transmission undoubtedly occurs I doubt if it is a predominant means of transmission.

I have no data on the frequency of *Shigella* infections in New Zealand. Since shigellosis is almost entirely restricted to primates, and transmission is mostly by the faecal-oral route, it is probably of vanishing importance in the context of this application.

This is not an exhaustive list of gut infecting microorganisms that we share with other animals, but it lists the commonest of them, and the ones that are commonly responsible for the contamination of water supplies. Not all cases arise from contaminated water: contaminated food and food processing surfaces can be very important too.

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\* Wilks, C. R. And Humble, M. W. 1997. *Zoonoses in New Zealand*.  
Publication No. 178, Veterinary Continuing Education, Massey University, Palmerston North,  
91 pp.