Water Loss in Caves of the Yanchep Region

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INTRODUCTION

This paper does not pretend to be a comprehensive statement on the problem, as the author has to this point in time not by any means fully digested, nor indeed accessed, all relevant material; however it presents a line of thought that needs to be aired.

The author's own experience began as a youth exploring caves with a torch in 1949; at that period a stream in the cave now known as Gilgi Cave (YN27) was running, as it was again in 1954. In that period it was just the place to pop down and quench ones' thirst. Yet both those years had well below average rainfalls. In 1988 when the author's systematic documentation of the area began, all cave streams were running normally; in fact, since by that stage the water in Jewel Cave at Augusta had long gone, the contrast between this and what over forty years experience was seen to be the *total reliability* of Yanchep cave streams could not be missed.

The cave streams afford a habitat for a wide range of aquatic fauna, including watermites, aquatic worms, leeches, hydra, crayfish, midge larvae, snails, flatworms, rotifers and fish. Some species of Amphipoda and Isopoda yet to be named occur only in these caves, and some, including a crangonyctoid from Crystal cave, have ancestry dating back to Gondwanan times. Tuart (*Eucalyptus gomphocephala*) trees on the surface send taproots down into the streams, and these mats of fine rootlets provide shelter and food for the invertebrates. Of particular importance is the fact that significant species differences have been noted between various cave groups, indicating that populations have been isolated for a considerable time.

The Gnangara Mound - which supplies the karstic formations with their water - peaks southeast of Yanchep at over sixty metres above sealevel. An extensive area of planted pine forest lies along the western flank of the Mound, a large portion of it being directly up the groundwater gradient from Yanchep. Since the early 1990's there has been a progressive loss of water from the Mound, with by far the most serious effect being in the Yanchep karst. At the point of writing (2002) every stream cave in the region has dried out, and even the deeper phreatic caves such as Water Cave are at critically low levels.

CHANGES SINCE LATE 1980's

The first caves to be affected by the drop in water table were the easternmost caves: those in the Cave Source Zone, because these lost their hydrostatic head as soon as the Gnangara Mound began to drop. Crystal Cave, with a water table at 13 metres was one of these. In effect, the Cave Source Zone has been gradually shifting westwards, and the eastern caves are now in the Dry Substrate Zone. In these caves all solutional activity has ceased, the water is well below the stream beds, and the caves have effectively "died".

Caves farther west, such as those adjacent to Loch McNess, with water table around 7-8 metres, were not affected at first, because there was still a hydrostatic head available. However, the effect has now reached Loch McNess itself. The east-west zonation no longer functions, no caves are now operating under paraphreatic conditions, and the Cave Source Zone has shifted almost completely out of the main cave belt. The lake, which in living memory had never varied significantly through all climatic conditions, has now begun to fall markedly in the summer dry period. Water Cave, with its levels closely connected to the lake, is at its lowest level ever.

Of critical import is the loss of cave stream habitats. Fauna has been completely lost from drying out of the Gilgi Cave and Cabaret Cave streams: despite the development of artificial ponds in the latter, into which tuart root mats have been encouraged to grow, the creatures have not reappeared. In other caves such as Crystal Cave a small population of the endangered crangonyctoid has been maintained artifically.

Government authorities such as the Water Corporation and Water and Rivers Commission have attributed loss of water primarily on a recent period of lowered rainfalls, however it will be shown below that this is not the prime cause of the problem, and it is debatable whether it is even a significant secondary factor, for reasons which will be explained.

ANECDOTAL BACKGROUND

First references to streams in the caves date to 1838 and 1841, when both Grey and Roe encountered strongly flowing streams. Little is known about the level of water in the caves for the next sixty years, however rainfall records show that there was a dry spell in the 1890's to 1915 comparable to the present lean period. Despite this, during the early 1900's water levels in the streams were holding well. Comments made during that period include the following:

A letter to "The West Australian" by J.A. Grant, a local farmer who in early 1903 was the discoverer of Yanchep Cave. The letter appeared on page 10 on Saturday March 28th 1903. After general praise of the region and its attractions he went on to say:

> *"As there is one fairly large and several small underground streams going into the lake, and flowing from thence to the sea, there must be miles of subterranean galleries yet undiscovered."* He went on to add*: "this running water makes the lake a suitable place for several species of fish."*

The next one comes in a detailed description of the discovery of Mambibby Cave by Mr H.E.B.Gull of Guildford. This article appeared in "The West Australian" on page 7 on January 19th 1904. After describing the cave's main chamber he continued:

> *"In the far end of this chamber is a miniature lake, with a tiny island of rock in the middle. Turning from this chamber in a N.W. direction one comes to a running stream of spring water, and, after crossing this, there is a sandy beach, which leads to the beauty spot of the cave."* etc.

Finally, from the Yanchep "Visitors Book" which was kept by Henry White, (and now on display at the Gloucester Lodge Museum) there comes this entry dated March 28th 1905:

> *"The stream of running clear, fresh water, in the limestone cavern near Mr White's homestead is a real boon to visitors, and a charming sight for those who dwell on the Goldfields where the precious* fluid is so scarce." etc. (signed) John Kenny.

At a somewhat later (although uncertain) date, E.S. Simpson wrote the following about Yanchep:

> *"The coastal limestone hills immediately east and south east of Lake Yanchep contain a number of caves decorated by secondary growths of stalactite and stalagmite, and in some instances further beautified by underground streams of crystal clear water."* Published posthumously, the text was substantially written for his Doctoral thesis at the University of Western Australia in 1919, and doubtless indicates no noticeable changes to the streams had occurred in the previous low-rainfall years.

The author's own experience dates back to a childhood visit to Crystal Cave in1942, during which the bases of the "Elephants Feet" were seen to be just above the water. This group of suspended columns - planed off at the base where they are (or used to be) laved by the waters of the stream - has for many years been a faithful guide to the normal water level of the cave stream; which until the 1980's had never been seen to vary significantly.

By the late 1980's the author had arrived at the conclusion that any general lowering of water levels over the Gnangara Mound is automatically countered by slower drainage downslope, because the gradient has flattened off. This variation had been noticed in the small variations in stream depths that occurred seasonally: lower levels of late summer with their slow flow alternating with deeper and more swiftly flowing streams in winter and spring. The difference in stream depths had always been in the order of centimetres. Hence the Mound may be said to be "self-buffering"; this is why there was no significant change in the caves' water in the earlier dry period. Doubtless the streams would have run slower, but they were never lost.

FACTORS AFFECTING WATER LEVELS

(i) Climate change

If we look at *climate* as a possible cause for the recent disastrous collapse of the cave streams, there has certainly been a marked drop in rainfalls within the past third of a century; commencing in1969. However, the actual recent performance of the water levels has not matched the climatic changes at all.

In the 1975-1990 period no significant drop in cave waters occurred. Yet a detailed examination of the records shows that the most serious rainfall deficit occurred in the first five years of this period (1975-1979), during which the rainfall for Perth averaged 697mm, as against the normal long-term mean of 869mm. (Rainfall over the Mound as a whole is less - probably in the order of 800mm, however the pattern is closely similar to that of Perth.) The major drop in the cave streams began in the 1990's: not only was this twenty years after the rainfall shortage began, but the drop actually commenced during two wet years 1991 and 1992. In fact, rainfall in Perth for the five years1988-1992 averaged 868mm, almost identical to the long-term mean; which - had natural factors alone been operating - should have ensured the water table would have stabilised in the karst systems. My own appraisal of the data suggests that by the conclusion of the 1992 season, water tables - had they been operating naturally - would have fully recovered to pre-1975 levels.

The actual drop experienced has been so rapid and unprecedented that only an extremely severe drought - far worse than that of the pre-1915 period - could have achieved it. The rainfalls from 1992-on cannot by any imagination be described in these terms, for the nine years 1993-2001 averaged 770mm, well above the 1975-1979 drought. Furthermore, the fact that the drop has continued during these modestly below-average years does not obscure the fact that it commenced in the very years where it could least have been expected, had climate been the prime factor.
It can be concluded that the drop in water tables has been mainly a result of human-caused influences. Yet authorities such as the Water and Rivers Commission continue to blame climate as the primary cause of the problem.

(ii) Pine plantations

There are 23000 hectares of pines in the region. These are situated in three main plantations:

(i) the Yanchep pines, north of the Park, which were planted in the 1950's and 1960's;

(ii) the Gnangara pines, much closer to Perth, which also were planted in the 1950's and 1960's; and

(iii) finally the Pinjar pines, immediately east and southeast of Yanchep, which were planted in the late 1970's and 1980's.

The approximate location of these pine plantations is shown in the accompanying figure.

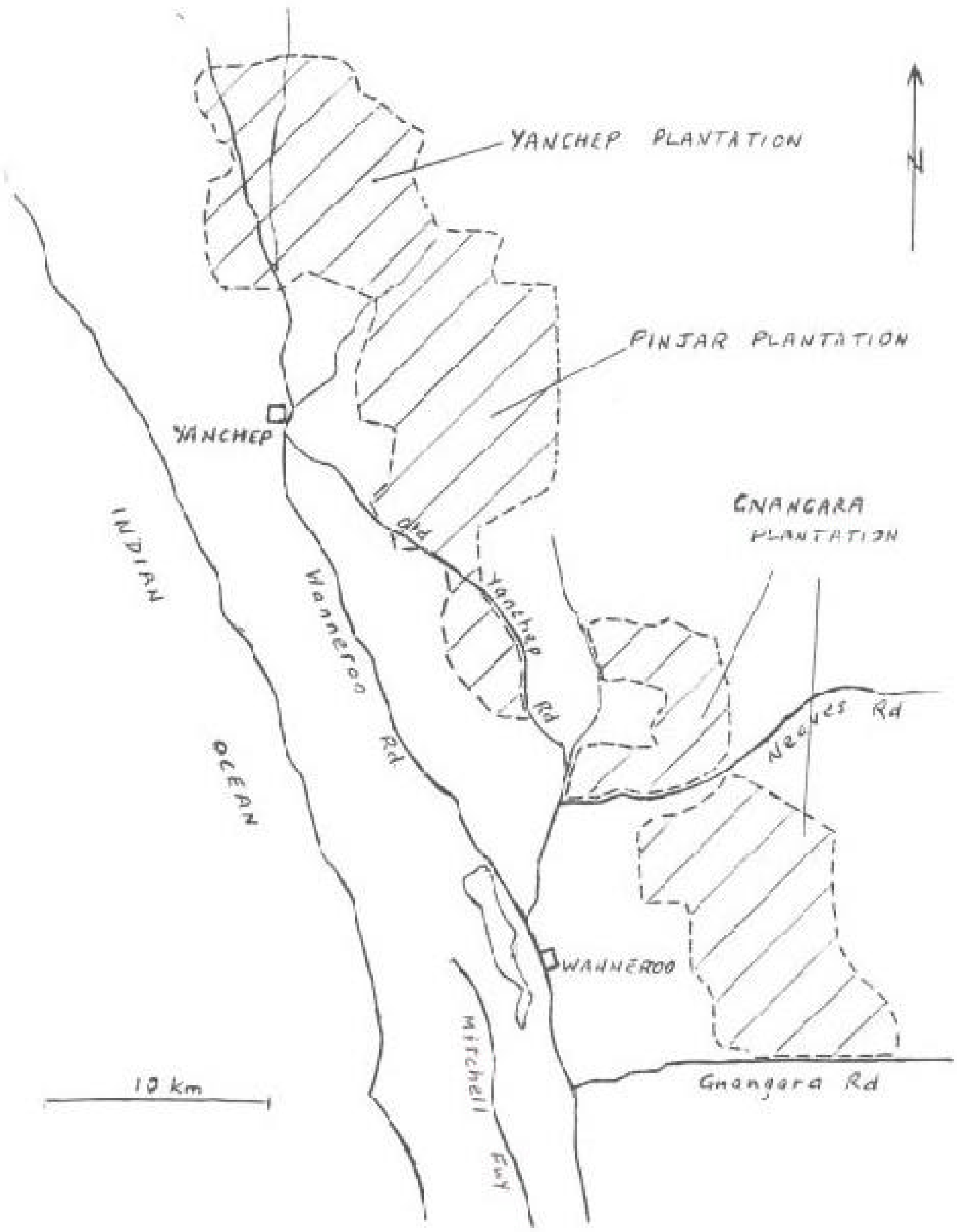

Figure 1 - Pine plantations in the region north of Perth

Monitoring bores in the region show that the most dramatic drop in water levels centres around the top (eastern) edge of the Pinjar plantation. This feature is so marked that it can not unfairly be described as a "hole" in the Mound, with drops as much a five metres. It is surely self-evident that climatic factors could not cause such a highly localised feature as this.

The pines have two effects: they draw more water than the natural vegetation, and they intercept large amounts of rain from reaching the ground. Past studies in other regions (eg. Holmes and Colville 1970, Allison and Hughes 1972) had shown virtually no recharge occurred to an aquifer beneath pine forest. If we bear in mind that most of Perth's winter rain comes in the form of showers, then the rain from each shower tends to evaporate off the pines prior to the next.

The pines meanwhile continue to draw water, hence they cause what is in effect a huge "cone of depression", which in this region happens to be mainly on the western flank of the Mound. The pines in effect may be said to have "turned off the tap" on the most critical part of the Mound. This has a repercussion further down the gradient: the downslope water levels in the karst belt have dropped, and are continuing to drop.

The Forest Products Commission is commencing harvesting of the oldest pine plantation, the Gnangara Pines. However this is well south of Yanchep, and the resultant recovery of water table will only have its impact on the southern end of the Mound: it will have no effect upon the Yanchep area. The Pinjar pines closest to Yanchep - and the ones doing all the damage - have not even reached the "first thinning" stage. They are not intended to be harvested until such time as their profit potential is maximised, whch will be some decades into the future. It is transparently clear that the forestry body have taken on board the view that the recent collapse of the water table is climatically caused, hence "not our problem". This can be no more than a whitewash, to deflect blame away from the pines, which are the real culprit. This poses a real potential for disastrous loss not only of the cave streams but of the whole wetland environment.

(iii) Public and Private Extraction

Supplementary factors in the drop in water levels that have been mooted are the effects of public and private extraction. However, although the Water Corporation is drawing large volumes of water from the Mound, its main borefields are farther south, and mostly well to the south; no currently producing bores are situated on the groundwater flow path upslope from Yanchep.

As for private extraction, water is taken regularly by private bores in the region, mainly for market gardens, turf farms and horticulture. However, none are located directly up the water table gradient from the central part of Yanchep where the main threatened-species habitats are located. A lateral effect from private extraction farther south has been mooted; the main usage being in the Carabooda area, a little to the south.

It needs be noted that these bores operate on cleared terrain. Thus there is an elevated input to the water table during the winter season, which will at least partly compensate for the summer period of heavy usage. Furthermore if this were a significant factor, then the "hole" should be centred round the area where there are most bores. This is not the case. Thus, although these bores take a significant amount of water, it is certainly far less than the effect of the pines.

THE CDFM

A method of rainfall analysis which has been widely accepted by Governmental agencies in WA has been the CDFM (Cumulative Deviation From Mean). Taking the mean rainfall of a site, the analysis compares this with the current year's rain to yield a plus/minusdeviation, which is then accumulated. The deviations for the period from 1969 on have now accumulated a considerable deficit. Using this as its pointer as to how the water table should perform naturally, the CDFM has led these agencies to the conclusion that it would have gone down parallel to the accumulated deficit, hence that falling water tables in recent times are mainly the result of natural climatic change. Inevitably this downplays the impact of the pines.

The main fallacy of the method lies in the fact that, as a strictly *linear* treatment of the rainfall data, it does not really simulate the performance of a mounded water table. In a typical mounded water table, the outflows are low-pressure seepages at the surface of the water table itself, having minimal hydrostatic pressure. Thus they are finely tuned to variations in the water table gradient, and are constantly adjusting to it. If rainfall is deficient for a period, the water table does not continuously subside to match the cumulative rain deficiency, but almost immediately will begin to compensate by reducing the rate of flow down the gradient. This compensating effect is then transmitted down to the seepage outflows. CDFM may only work if the outflow remains more or less constant; a scenario which may occur where there are springs discharging under pressure, such as does occur in major karst regions. In that case the rate of flow is controlled more by the size of the conduits, and thus can be more or less constant regardless of the variations in pressure.

The contrast can best be described in terms of a "leaking tank" versus an "overflowing weir". (Assume other variables such as evaporation and human exploitation are excluded.) In the first case the leak is well below the water level in the tank, hence is under high pressure, but the flow is restricted by the size of the leak. The critical point here is that if the water level subsides the leak will continue unabated. Hence a CDFM plot of the system may at least approximate the situation, as rainfall pulses top up the tank erratically from time to time, whilst the leak continues to drain it. On the other hand the overflow scenario has minimal pressure, and will fluctuate to match stream pulses. A strong influx raises the level over the top, the flow increases, then subsides again to the point where it is barely overflowing. The weir may then sit at top level even with no fresh inputs. A CDFM plot will not resemble the situation at all.

The "leaking tank" scenario is most likely to apply to the abovementioned large karst systems in thick limestone formations, because the water flows through interconnected phreatic complexes and exits via strong resurgences on the sides of gorges. These typically will be well below the top of the phreatic water level in the massif, and the strength of the resurgences will be determined by the size of the conduits feeding them. Outflow will continue unabated even if there is a drought situation in the hinterland. On the other hand, the Gnangara Mound clearly fits the "overflowing weir" scenario, because there is minimal hydrostatic pressure in the cave seepages, and outflow will cut back very quickly with any rainfall shortage.

Again, by using the long-term mean rainfall as its yardstick the CDFM is in effect giving equal weight to all past years' rainfalls. For example, the notable drought year of 1914 is supposedly still exercising its own significant influence upon the current water table performance, as do the wet years 1945/46. It is surely self-evident that the Perth region now has a new mean rainfall; and that the water tables should already have adjusted to it. The actual performance of a stable mounded water table must be a greatly subdued version of the rainfall variations, one which progressively reduces the impact of past rainfalls. If the rainfall drops off for some time - as it has done in this case - then it will in due course stabilise at a level appropriate to the altered rainfall regime.

- The water table is constantly adjusting (with a backlog) to increases or decreases in rainfall from the mean, and if those changes are reasonably consistent over a period of time then a new stable level will be the result. CDFM cannot simulate such a stabilising performance.
- Hence the real performance of the water table over extended periods such as the above, *will not be linear*: it will be in effect a curve which tends to flatten off exponentially, towards an asymptote which will be the stable water table for that altered pattern of rainfall.

If we are looking at rainfall as a guide to how the water table would perform without human influences, then for stable mounds such as the Gnangara Mound a realistic rainfall analysis plot must incorporate a "memory factor" that adjusts the rainfall year by year away from the (old) mean, thereby reproducing the above tendency for the water table to stabilise. Such a plot must yield a far closer approximation to the actual performance of the water table.

Not only does it show the stabilising outcome, but also will show that the water table is capable of restoring itself without having to have a rain surplus equalising out to the cumulative deficiency of the lean years. This is most important: even if rainfalls have been deficient for a considerable time, then since the Mound will have stabilised to the reduced rainfall it will need only a relatively short period of good rainfalls will "top it up". In the case of the region there were two above-average rainfall years in 1991/2, which - *had the Mound been running naturally* - should have been sufficient to restore it fully to pre-1969 levels.

The inability of CDFM to depict the way stable mounded water tables can not only stabilise but then quickly restore, was evident in a paper by Boehmer (1998). An accumulated rainfall deficit over three dry years (1984 to 1987) recorded over a small aquifer in Burkina Faso, did not reverse but only *levelled off* when the dry spell ended (because 1987 was a year of approximately average rainfall) whereas the actual water table performance in that year *raised* it fully to the1984 level. On the other hand, a plot for a site in the Colesberg region of South Africa reproduced in the above paper apparently followed a CDFM pattern. However the author did not notice the hydrological contrast between this and the other site; notably in the highly erratic fluctuations of the water table, and a spring (not a seepage) only three kilometres from the observation bore, indicating that the Colesberg aquifer was not a stable mound, but was behaving more like a "leaking tank".

The proposed alternative treatment of the rainfall data was trialled by using a reduction factor of 55%, based on an arbitrary choice to reduce to minimal the impact beyond ten years antecedent to the current year. The actual factor must depend on how far back a realistic impact of a former year may be considered reasonable, and also may vary with different aquifers. Using rainfall data from Perth, a plot was obtained which indicated that the water table - were it to have operated entirely naturally, without human-caused changes - would not have dropped greatly within the past thirty years of reduced rainfalls.

CONCLUSION

In view of the fact that the authorites are at present laying the primary blame for the water loss on climatic factors, and have in effect sanitised the pine plantations, the prognosis is exceedingly bad for the Yanchep karstic belt. The challenge facing the speleological/environment fraternity is a double one: because the Government instrumentalities are not seeing the pines as the major culprits of the crisis, there is a pressing need to firstly enlighten them on this crucial point before one can expect to see any balanced appraisal of priorities coming from the decision-makers.
If this does not eventuate, and the threatened disaster runs its inevitable course, then blame for it can and should be placed not only on the pines but also on the public servants and politicians who kept them there for reasons of pure greed.

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