AN INVESTIGATION OF A "WATER TABLE" IN THE BUNGONIA LIMESTONE

by

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Introduction

Referring to Figure 1 it can be seen that the limestone plateau south of the Bungonia Creek Canyon consists of one very large eastern outcrop and several narrow belts separated by shale bands. The strike is fairly constant at 10° with the dip averaging about 45°. The limestone is enclosed by folded slates in the east, and quartzite and other metamorphics in the west. In the south, the limestone becomes lenticular and eventually disappears.

The watershed of the eastern outcrop can be sufficiently well defined to indicate that all rain falling on it is directed to one of four major depressions, having a total area of about 200 acres. Four major caves reach a static water level which has been described as the water table. This level shows little change during rain or drought.

Resurgences in the area are very small, many no more than a trickle, except for one, the "Efflux", which flows at a significant, though still small, 0.05—0.1 cusecs. Unfortunately this would appear to drain one of the smaller lenses to the west being separated from the major outcrop by a thick shale band.

In an endeavour to find out what happens to the 29 inches of rain which falls on the limestone each year and drains into the caves, the University of New South Wales Speleological Society with the help of members from the Sydney Speleological Society and the University of Sydney Speleological Society has been collecting information which will eventually indicate how to approach the problem most effectively.

By far the most publicised of our activities in the area has been the introduction, at Easter, of 9.75 kg (about 22 lbs) of the dye, Rhodamine B into the Grill cave (B44) and the monitoring of the red colour through the phreas.

Despite the fact that the stream at the injection point has a discharge of only 0.003 cusecs (about 1 gallon per minute), in less than two days the dye had migrated to the second sump of the Grill cave, a distance of approximately 400 feet. (This cave has two branches, each reaching water.) One week later, the dye was detected in the Drum cave (B13), approximately 700 feet further on.

After nine months of careful observation no sign of the dye has been found in either of the other two major caves – B31 (Argyle Pot) and B4/5 extension (Fossil/Hogans) or at any of the resurgences in the area.

Technique

Existing surveys of the caves at Bungonia are of little use for our purpose, and so we have found it necessary to level through the caves (using hydrostatic or manometric methods) in order to measure very accurately their depth. At the same time due to lack of low level aerial photographs of the area we have had to run compass and tape traverses around the major dolines to determine their catchments.

Fortunately, near to the cave area, there is a farmer who reads a rain gauge every morning and has been able to supply rainfall figures for the whole year (and every year since 1928). Early in the coming year we should be able to install an automatic pluviograph on site and thus enable the exact time of rain to be registered.

Rhodamine B was chosen as most suitable because it can be detected at lower concentrations than can fluorescein or other similar dyes. It is also more stable under alkaline conditions, and is not so readily absorbed into clay (a very important factor for long term work). Furthermore, it is essentially a coloured dye and can therefore be estimated using a colourimeter or similar instrument.

All the dye was dissolved in methylated spirits and transported to the injection point in plastic jerry cans. Monitoring was carried out by the two classical methods, observation and activated charcoal. The latter was placed in all the cave sumps and at all resurgences in the area.

Observations and sampling were limited only by access to the caves. We would have been very fortunate if we had been able to sample every hour for 2000 hours but as it turned out we were lucky to get a sample every two weeks. Whilst none of the caves are particularly severe there is foul air in the deep ones and sometimes samples were taken when the CO_2 concentration was above 3.5%.

Sampling has continued up to the present but all those which are not discussed were either negative or too dilute to allow estimation of their dye content with a spectrophotometer.

Results

The catchment of the Grill cave is 2,200,000 sq. ft. or about 51 acres, while that of the Drum cave is 720,000 sq. ft. or about 16.5 acres. Therefore, one inch of rain represents 180,000 cu.ft. (for the Grill) and 60,000 cu.ft. (for the Drum) of water over the catchment. Estimating how much of this water is available for flow or percolation through the limestone, to the aquifer, is beyond the scope of this paper and so I am presenting the figures only for reference, not for inference.

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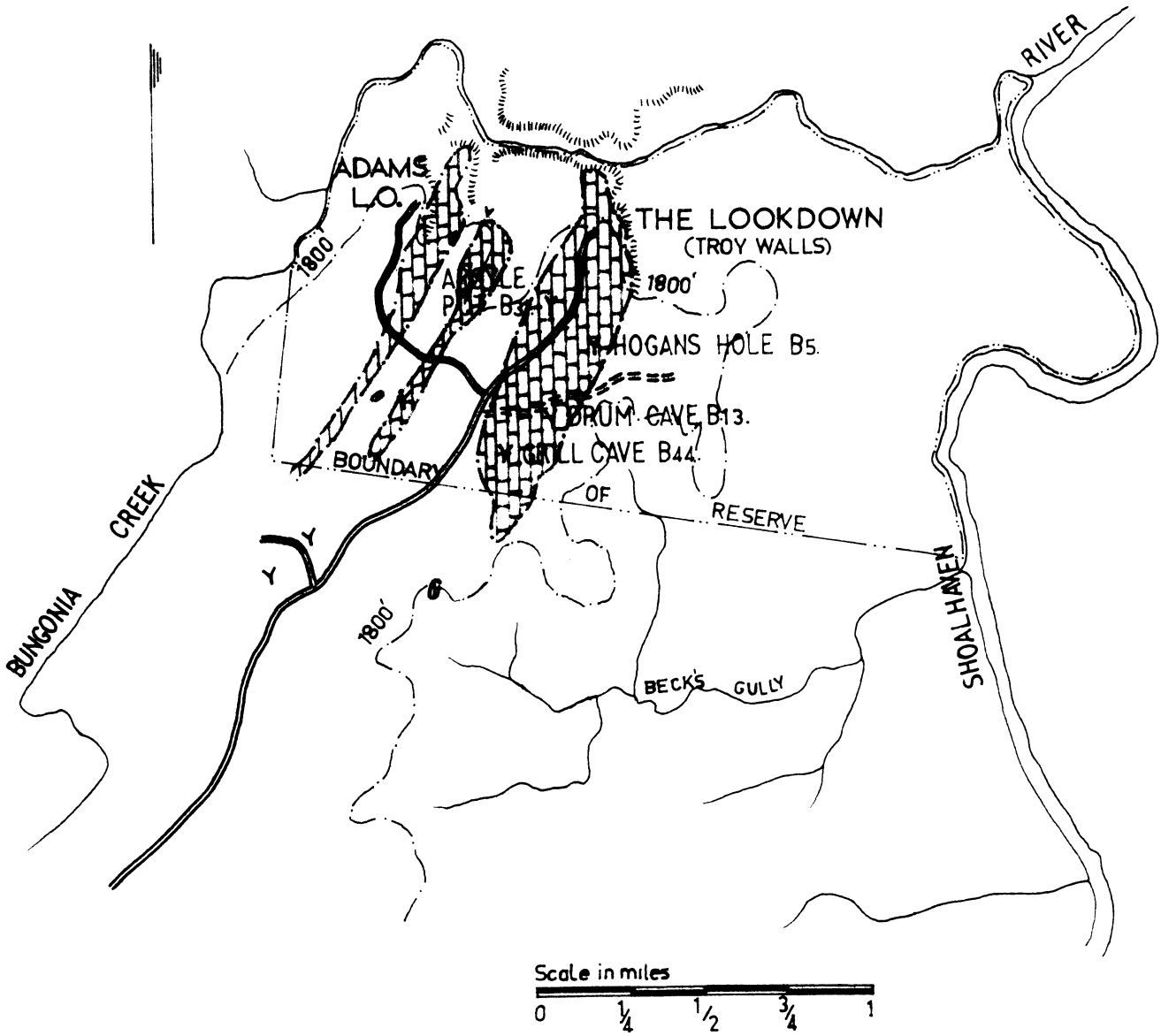
Figure 1



LEGEND
CAVES - - - - - - - Y
ROADS - - - - - - -
CREEKS - - - - - -
CONTOUR - - - - -
CLIFFS - - - - - -
RESERVE BOUNDARY - - - -

BUNGONIA CAVES N.S.W.

UNIVERSITY of N.S.W.
SPELEOLOGICAL SOCIETY

INFORMATION TAKEN FROM MAPS BY FLINTER & N.S.W. DEPT. OF LANDS. DECEMBER 1970

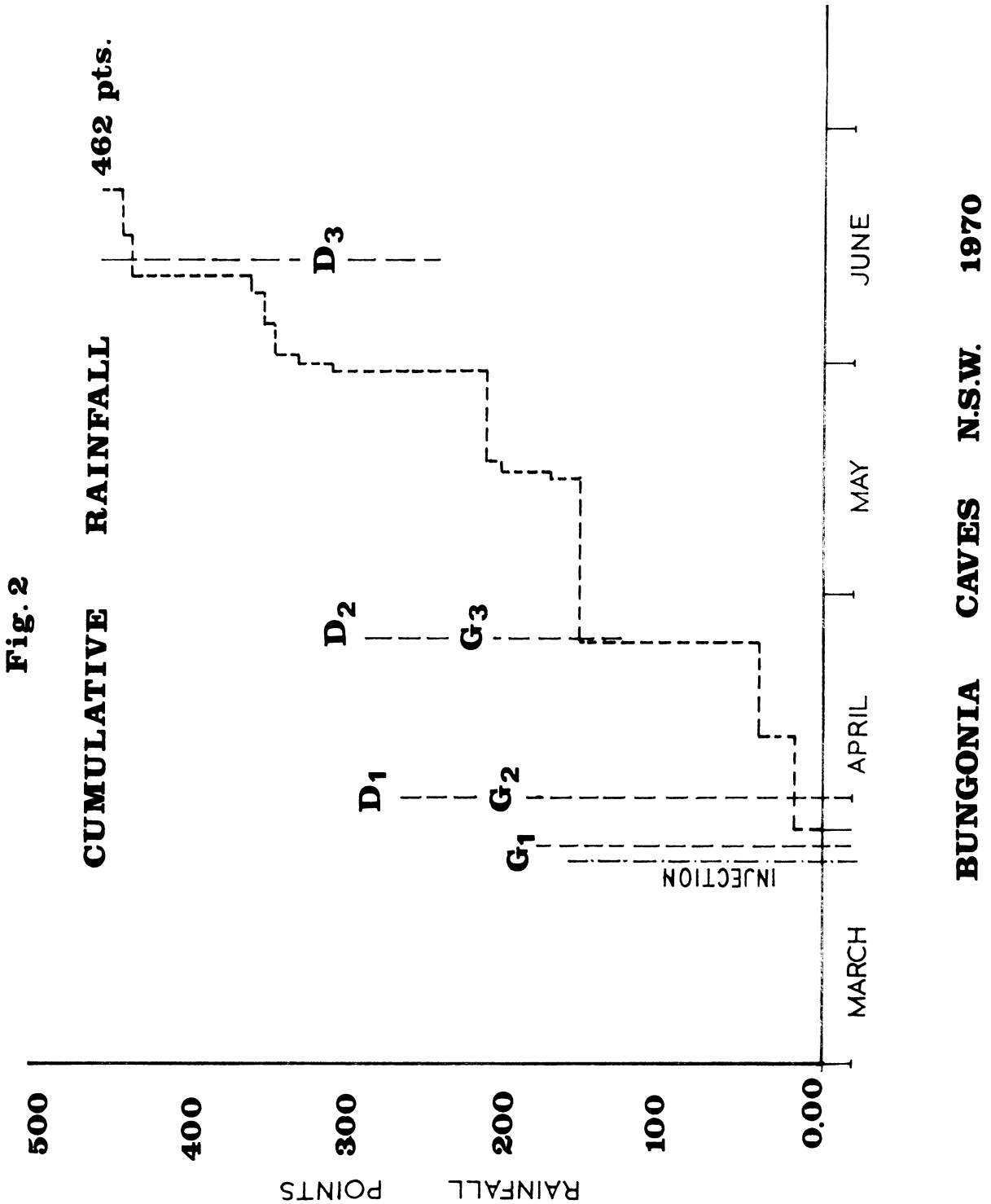


Fig. 2
CUMULATIVE RAINFALL
462 pts.
D3
D2
G3
D1
G2
G1
INJECTION
BUNGONIA CAVES N.S.W. 1970
RAINFALL POINTS
500
400
300
200
100
0.00
MARCH
APRIL
MAY
JUNE

TABLE I

Sample Date	Grill		Drum		Rainfall	Comment
23/3/70		6.1 kg/cu.ft.		–	–	Initial injection
28/3/70	G_1	24.5 gm/cu.ft.		–	Zero	40 hours
4/4/70	G_2	220 gm/cu.ft.	D_1	2.8 gm/cu.ft	17 pts	
25/4/70	G_3	2.8 gm/cu.ft.	D_2	37 gm/cu.ft.	136 pts	
20/6/70		–	D_3	7 gm/cu.ft.	292 pts	

Table I lists the sampling dates and the absolute concentrations of the useful samples as taken from *both* caves. It also includes the rainfall between sample dates.

TABLE II

Date of Sample	Grill		Drum	
28/3/70	G_1	400 cu.ft.		–
4/4/70	G_2	44,000 cu.ft.	D_1	–
25/4/70	G_3	3,500,000 cu.ft.	D_2	264,000 cu.ft.
20/6/70		–	D_3	1,400,000 cu.ft.

Table II states the volume of water which would need to have been added to the original injection of 9.75 kg. to produce the observed concentration of each of the samples.

Discussion of Results

Of prime significance in Table II is the effectiveness of the 136 points of rain which fell between the 4/4/70 and 25/4/70 in flushing most of the dye from the Grill cave into the Drum cave. This indicates very effectively that the Grill is actually "upstream" of the Drum. Also of significance is the fact that despite considerable further rain there is no evidence of flushing of the dye from the Drum further "downstream".

TABLE III

	Date of Sample	Sample		Expected *
GRILL 3(a)	28/3/70	G_1	400 cu.ft.	400 cu.ft.
	4/4/70	G_2	44,000 cu.ft.	31,000 cu.ft.
	25/4/70	G_3	3,500,000 cu.ft.	250,000 cu.ft.
DRUM 3(b)	**Date of Sample**	**Sample**		**Expected ***
	25/4/70	D_2	264,000 cu.ft.	380,000 cu.ft.
	20/6/70	D_3	1,400,000 cu.ft.	1,100,000 cu.ft.

Table III compares the actual recorded dilution with the expected dilution, the latter calculated from catchment areas and recorded rainfall. It will be noted that for dilution in the Grill it is necessary to include only the Grill "injection", but for the Drum, being "downstream" from the Grill it is necessary to include both the Drum and the Grill. The figure for dilution of G_1 is calculated by considering the discharge of the stream at the point of injection as 0.003 cusecs for 40 hours.

* **For reference only.** There are insufficient results to observe the effect any unit amount of rain has on the dilution.

No consideration is being made of the dye losses due to absorption and dissociation which are taking place continually.

The dye moved through the phreas at more than 200 feet per day and with an influx of water to flush it along probably at a considerably faster rate. Yet it failed to appear in B4/5 extension (the sump of which is only about 400 feet away from the Drum) or B31 (1200 feet away), nor did red water resurge at the major efflux in the area (3,000 feet away).

Conclusion

Any preliminary study such as this cannot provide sufficient data for a prediction of relationships between, say, rainfall, catchment and phreatic movement. It can, however, expose a few facts which offer directives to further investigation.

Dye has been used with limited success under conditions of extremely low discharge to show that there is significant flow within the phreas. Despite this evidence of flow, dye does not migrate to the lakes in all caves, nor does it appear at any known resurgences.

There is a definite flushing effect due to large influxes of rain water yet this effect is not uniform, for example, it is not evident in the sump of the Drum cave.

Until accurate levelling proves that there is a common water level in the caves at Bungonia, there is little to indicate that they are all freely connected, or that a water table (perched or otherwise) is present.

Acknowledgments

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DISCUSSION

C *I think your dilution factors are doubtful. Seventeen points wouldn't have provided very significant rain. I don't think you have proved your water flow from Grill towards Drum Cave. You have not disproved water tables being common to all the other caves because the others could flow towards the Drum too.*

A That is right, if the Drum dye lasted for so long it had obviously not been diluted. Now the catchment of the Grill and Drum Caves is a total of about 2,900,000 sq. feet while the total catchment of the four major depressions is in the order of 9,000,000 sq. feet. If you are interested in the technique that I use for estimation of why there would be even dilution throughout the whole lot I will discuss it later. The expected dilution if they were flowing towards the Drum would be many times greater than what we did get.

Q *O.K. The connection is downstream from where you put the dye in the sump then where is the connection between the other two caves?*

A If it is true that means that none of the caves there are level. Now if they are not level and this is not a water table there is no flow. The water that was in the Drum just doesn't move even after the 20/6/70 that is, three months later, the dye that was in the Drum was still at quite a high concentration so obviously there is no downstream. If something represents a watertable there then it is the Drum level, that is the only thing it can be. The other caves can't be upstream because if they were upstream there would be more water than there is. If they are downstream then either the water in the Drum would move faster because it would continue into this hypothesized further link or otherwise the dye from here would have to move into them.

Q *My suggestion is, the Drum is the furthest downstream of all the caves you have seen, the Drum water could well be a backwater . . .*

A It is almost certainly a backwater.

Q *. . . but that any connection between the caves occurs downstream of the Drum Cave. Now the next question is: Have you seen the dye since . . . ?*

A No, it has not appeared anywhere.

C *. . . because I have for many years had a hypothesis that the water would not appear in the Bungonia efflux.*

A Of course it won't appear in the Bungonia efflux. This is something Joe Jennings has mentioned. It is quite clear that the efflux does not drain this since it runs at approximately 30 times the flow of the little stream in the Grill. If the water can travel 700 or 800 feet in a week then surely it is going to get there in at least a month since it is only another 500 feet further, but there is no sign of this. We have monitored every efflux in the area, but this study is not to investigate which efflux. It is to investigate exactly what the watertable is like and it proves that there is just not a watertable.

Q *Did you expect otherwise?*

A The thing is that one has got perched water. Whether it is a perched watertable or just puddles is something that is important to what we are trying to do. We intend to put level recorders at each sump and we are negotiating with the Water Board to install a pluviograph to continuously monitor the exact time of the rainfall. Then by the momentary rising of the sump, if it rises, we will know when it is reaching the actual aquaflow and this is important.