FLOOD EFFECTS IN MCKEOWNS VALLEY AND MAMMOTH CAVE, JENOLAN CAVES, NSW.

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Introduction.

The author has been putting his archive of caving reports on to the hard disk of a new computer with a view to making the information more generally accessible. In the process all the flow measurement data from the Jenolan hydrology project has been put together, and enough new concepts have emerged to make this paper on the subject worth the effort. The hydrology project flourished from 1960 onwards, tapering off after peaking in 1972. But since the author is now ageing and living in Tasmania it really needs some dedicated successors to train themselves in the velocity head measurement technique, and vow themselves the quest of collecting the necessary better and missing data. The heroes of my vision will take on Northern Mammoth in full flood conditions, laugh as they descend the Ninety Foot pitch, splutter their way through the no longer dry "Dry Siphon" roof sniff, grunt their way through the North Tunnel crawlway and arrive gasping at Great North Cavern. And there they will collect the measurements considered "too hard to get" in 1972.

The original hydrology work was oriented around water tracing and became a "learning experience" in which less was achieved by the work with fluorescein than would be possible now with more developed technique. But the flow measurement data taken at the time, and not then regarded as very important got figures when critical and rather rare flow situations were observable. These now appear to hold most of the answers that the fluorescein tests were supposed to find. A core concept developed during the work is that of the limited capacity choke. In essence a conduit with a limited capacity choke accepts increasing flow up to a critical point, then spills any more into an alternative route, like a partly blocked drain. In this paper the author attempts to place true capacity values on all the limited capacity chokes that affect Mammoth Cave and to check the total flow of a notional standard Mammoth Cave Flood against a notional standard flow for the Jenolan Underground River efflux.

A fix on the capacity of the Jenolan Underground River

On 17th January 1963 the creek ran through the Devils Coach House for about a day following a day of heavy rain, reaching a peak flow of 200 l/sec. The Jenolan Underground River built up in flow after this and reached a flow of about 1000 l/sec (estimated) with some time lag as measured at the efflux into Blue Lake. This estimate is based on a mix of measurement and extrapolations, and is less reliable than I would like. At this time the weir at the efflux was set up so that a substantial proportion of the flow went over the top and could be measured, and it moved out into the lake as a separate stream alongside the portion going through a hole in the weir. This relationship meant that a figure could be obtained indirectly for the total. At still higher stages previously known figures for the flow under the weir gave a basis to work an estimate from when the flow over the weir interfered with the relationship. It was a far from ideal set up to work with but changes since then have made it impossible. Later and after dark that same day other figures were collected at the bridge in Imperial Cave, then well under water with the flood still rising. This allowed an estimate of 40 cusecs, say 1150 litres/sec. It is a bad measuring point having a drowned bridge in it, but this value would better approximate the "full capacity" of the underground system. It is compatible with the earlier figure on the day, and these data are all there is in the author's records for the situation where there is flow through the Devils Coach House. Yet the average of 1075 litres/sec has a certain value (see below).

Of course “full capacity” is a concept that wobbles. Considerably higher floods in the Imperial Cave have occurred; up to the thirty second step in the floods of 1954 (F. Harman pers. Comm.) What the conditions of the day probably revealed is the situation in which unexceptional levels of base flow; (that is, the slowly diminishing drainage from groundwater storage) was supplemented suddenly by unexceptional inputs from all the watersinks along McKeowns Creek; that is, the typical situation.

The flood response to an advance to Wiburds Bluff.

In December 1960 an advance of McKeowns Creek to the vicinity of Wiburds Bluff produced something like a doubling of the flow in Lower Level River (160 to 370 litres/sec), with little effect on Central Level River (a rise of 4’ 1.2m in Central Lake). A measurement of 1.5 cusecs = 42 litres/second was taken first crossing appearance of the river. The more usual figure taken for the Central Level River around this time was 0.5 cusecs = 14 litres/second), a figure the author got repeatedly during the early 60’s but at the second crossing or Ohmeneez measuring point.

The interpretations that follow from this behaviour are that the rivers are separate. Lower Level River has its main source up the valley from the vicinity of Wiburds Bluff and that Central Level River has a different and more local source. Prior to these observations it was possible to argue that Central River floods were evened out to produce the flow of Lower River. A clue that was missed at the time concerns chemistry. Central River is a borderline case for carbonate saturation. Portions of its bed upstream from first crossing have stones coated with travertine, and calcite flottante can appear on the surface of Central Lake; its downstream continuation. Lower River is always lime dissolving.

The drying of Central River at second crossing.

The flow measurements considered standard for Central River at this period were taken at the second crossing. As the 60’s and 70’s progressed generally drier conditions prevailed, leading to lower values for the stream at 3 l/sec or even 1.5 l/sec and scepticism with regard to earlier measurements. Fewer measurements were taken at the first crossing and the hints of a larger flow were attributed to poor measurement technique. Eventually the Central River dried up at the second crossing on at least two occasions while continuing to run at first crossing. A hidden and more permanent tributary or anabranch is needed to account for this behaviour.

The flood response to flow reaching Serpentine Cave.

A series of three trips in February-March 1972 produced good data set for resolving the relationship of the water sinking outside Serpentine Cave to the response in Mammoth Cave. The point to be made (see table below) is that there is a very close match indeed between what goes down here and what appears in the Northern River passages. Other points are that water comes out of the Infinite Crawl before the Serpentine Cave itself starts to operate, and that although the Infinite Crawl gets most of the water, some goes to second crossing and boosts the flow going to the Bypass. I would guess that this is what comes through the ceiling of Great North Cavern. Serpentine Cave is fairly well over to the west of the limestone belt but the Woolly Rhinoceros Cave must lie even further to the west.

The flow measurements also revealed the notional unseen permanent tributary of Central River more clearly. It is effectively an underground river below you even when you are underground. The author has taken to calling it the Sarasvati after the Hindu sacred river believed to join the Ganges from underground at Varanasi. It is interesting that early 60’s flow measurements show the same difference of 1 cusec extra for the First Crossing site detected in the 1972 data.

At the second crossing measuring point an example of a limited capacity choke can be seen in operation. Normally the Central River goes down a floor hole but once the critical capacity is exceeded, any additional flow is spills into the normally dry Bypass, and the route through the floor hole operates as a constant volume conduit.

Flow in the Northwest Passage through to the Overflow in full flood is very confusing with streams entering and leaving the accessible passage at several points. Both the Hidden Branch from second crossing (Ohmeneez) and the Sarasvati apparently join and cross underneath the Northwest Passage to get to the points near the Overflow Lake where all bar about 7 litres/sec of what got to first crossing on 26-2-72 was visible.

Table of Flow data: Serpentine Submergence point and Mammoth Cave

Location	Date and amount sinking (in l/sec) shown by colour: 29-2-72, *26-2-72*, 12-3-72.			
	Measurement point for flow in McKeowns Creek which sinks in the stream bed in the vicinity of Serpentine Cave.			
Serpentine area, surface & S. Cave		U/s cnr. M.Ck.	Serp. Cave	
		8.5 l/sec	No flow ?	
		20 l/sec	*trickles*	
		100 l/sec	28 l/sec	
Ohmeneez	Measurement points/inferred flows taken beyond the Dry Siphon in the Northern River Passages of Mammoth Cave			
	Hidden branch	Bypass stream	Infinite Crawl	"Sarasvati"
	25.5	2.8	11.5	28.5 (indirect)
	25.5	*7*	*14*	*28.5 (indirect)*
	25.5	20	85	28.5 (indirect)
	Measurement/inferred flow of Central River at First Crossing, below the junction of all the separate streams above			
1st crossing	Below 90 foot			
	68			
	78			
	159 (indirect)			

The Hidden branch is determined from the difference between the Ohmeneez measuring point and the flow in the Bypass. The Sarasvati from the difference between first crossing and Ohmeneez plus Infinite Crawl Streams; it includes some identifiable minor streams as well as the larger concealed stream(s). From these relationships the First Crossing indirect measurement is calculated for the situation occurring on 12-3-72 when the measuring point was under floodwater and not measurable.

The flow at second crossing was already up abruptly from the "healthy" base flow of 14 litres/sec by an extra 17 litres/sec when the flow at surface was barely reaching the Serpentine streamsink complex. This implies another streamsink like that feeding Serpentine Cave, and located in the limestone bluff (containing J 76) near where Hennings Creek has its normal sinking point. It may be worth digging here.

The flood response to flow getting to Bow Cave.

The Bow Cave is an unusual in that there is an obvious inflow cave going off from the surface creek. Its open arch is subject to clogging with vegetable debris making its intake capacity inherently more variable than the gravel drain conduits that are usual in the valley. For years it has been known that water goes via Sand Passage to the Cold Hole where flow splits. It goes first to the Forty Foot and at slightly higher stage also to the Railway Tunnel. But water emerges first

from the Rockpile at the foot the Forty Foot and in quantity. The author has witnessed a situation (June 1960?) where the waterfall going down the Forty Foot took about 1.5 l/sec but pouring out of the Rockpile was a flow of some 100 l/sec. This must be fed from a route diverging from Sand Passage. In 1960 the author suggested that the base of the Eighteen Foot shaft was the likely take off point.

The behaviour of the Bow Cave has fascinated other speleologists. The quote below is from someone else's typescript found loose in the archive:

"Behaviour of flood passages deriving from Sand Passage depends entirely on how much surface flow is diverted into Bow Cave. As Peck (1956) has observed, it is possible for the route to Southern Section to be dry with a foot of water in McKeowns Creek, or for Southern Section to be flooded with little or no surface water downstream of Bow Cave inlet. For example, in June 1963 McKeowns Creek was flowing its full length through the Devils Coach House and the Southern Section was dry at least to the base of the Forty Foot. Yet within two hours of a party industriously diverting the bulk of the flow into Bow Cave, the surface downstream was dry and there was water flowing over the Forty Foot. Clearly, then, this system is hydrologically independent of conditions elsewhere in the cave, yet it is clear that minor adjustments to surface bed configuration either now or in the past would have induced significant differences in lateral water flow."

Base flow in Sand Passage escapes to the foot of Forty Foot by an impassable gravel conduit, but increased volume produces a pressure flow which debouches water into the Cold Hole. Here the stream bifurcates; some of it may proceed directly to the lip of the Forty Foot, and the rest makes its way to the great mud sink in Horseshoe Cavern. In exceptional conditions, this latter may overflow to another sink 60' north up the Railway Tunnel. In previous times this flow may have proceeded to the palaeo-Central River via the Skull and Crossbones."

But there is also evidence that water sinks in the bed of the creek outside the Bow Cave. In the 12-3-72 flood situation by afternoon about 115 l/sec was sinking partly in the cave and partly outside it, about evenly split. That morning the flow had been 132 l/sec with indications that the flow had only just ceased going on to Mammoth Flat and retreated to the vicinity of Bow Cave. Between these measurement times Mammoth Cave was visited and, going by memory alone – this is not in the trip report record – there was a loud noise of running water coming from Sand Passage on the way in, but no noise on the way out. (confirmed by Julia James, pers. comm.).

The explanation the author suggests is that the first 115 l/sec of water sinking in the vicinity of Bow Cave, both that going through the creek bed outside, and in the entrance zone of the cave itself must go directly to the Woolly Rhinoceros Cave by an independent route. Only flows in excess of this and penetrating past the entrance zone can get into Sand Passage. The situation for Sand Passage is like that for the Serpentine where the flow going directly through the creek bed to Infinite Crawl has priority over the route through Serpentine Cave. This mechanism can adequately explain the reports of biggish floods passing the Bow Cave without causing a flood in Lower Level (= Southern Section). The reports imply enough water in the creek for some to have got past the leaky barrier of flood debris at the cave's entrance.

The next issue is what is the capacity of Sand Passage itself. There must be a choke capacity limit imposed by the gravel conduit between Bow Cave and Sand Passage itself, which applies whenever the cave is clear enough from vegetable debris for it to become the functional limit. In fact what is likely to happen in a flood is that the cave fills first to the limit imposed by the conduit's choke capacity. Then a lake backs up in the cave close to flood level in the creek outside. Any further increase in the creek flow simply runs past. But flood debris is swept in and can't get through the conduit so as the flood progresses less water goes down Sand Passage. As the lake tends to stagnate the characteristic dam of debris builds up at the entrance.

The automatic shut off mechanism in the Bow Cave has an effect in Mammoth Cave, which can be read in the effect on sediments in the Horseshoe Cavern area. It takes close to the maximum flood to fill and overflow the lake which forms in the Mudsink. The markings in the sediments indicate a modest though reasonable inflow, yet the lake often does not completely fill and overflow so hinting that the limiting factor is that inflow does not go on long enough.

There are flowmarks in sediments in the Mudsink and on to the point where the "unsurveyed connection" drops down to the Ice Pick and Central Lakes. This data is all there is to go on for putting a figure on "modest though reasonable." But from experience of relating measured streams to their effects on sediments, flows of 21 l/sec for what goes down the Mudsink and 7 l/sec for what overflows it are of the right order. The same approach can be applied to the very much larger branch of the Sand Passage stream which goes to the top of the Forty Foot. "Very much larger" can be put at 172 litres/sec. When it comes to the flow coming out of the rockpile next to the bottom of the Forty Foot there is direct observation to go on in a situation when there was just a waterfall over the top of the Forty Foot as well, thus giving the basic maximum flow. Unfortunately no actual measurement was taken but a retrospective estimate of 100 l/sec can be made (from a real underlying guesstimate of 3 to 4 cusecs – all these estimates are really converted from originals in cusecs). Putting all these together gives a convenient round figure for what can be delivered through Sand Passage of 300 l/sec. In any particular flood the utilization of this capacity can vary between all of it to none of it. But common situations include:

(a) Bow Cave starts clear of its debris dam, operates briefly at full capacity, then closes off as the flood progresses. At this point not enough water gets into the cave to overload the choke going to Woolly Rhinoceros and nothing runs to Sand Passage and Southern Section Mammoth. Next

(b) a following flood is "kept out" of Bow cave by a nicely plastered debris dam. Next

(c) the debris dam breaks down to allow water back into the cave but without overloading the choke capacity and going to (a) again. This last probably comes closest to a standard capacity approximated by the 100 litres/sec that can be delivered from the Rockpile.

Conclusions.

Barring problems with calibration a surprisingly good picture of how Mammoth Cave relates to its surroundings hydrologically comes out of these figures. Adding them up they come out as follows –

Flow source and comments	Standard flow delivered
From Woolly Rhinoceros north from Bow Cave	600 litres/sec
From Central River in full flood (includes Serpentine)	150 litres/sec
From Bow Cave to Woolly Rhinoceros conduit	115 litres/sec
From Bow Cave to Rockpile conduit	100 litres/sec
TOTAL FOR MAMMOTH	965 litres/sec
From sinks at Mammoth Flat (3, 15, 35)	53 litres/sec
From sinks at Playing Fields (15, 35)	50 litres/sec
From sink at Spider Cave (6)	6 litres/sec
INPUT TO JENOLAN UNDERGROUND RIVER	1074 litres/sec
J.U.R. IMPERIAL CAVE/BLUE LAKE (average)	1075 litres/sec

There is a believable difference between what comes out of the Jenolan Underground River at Blue Lake and what can be identified as passing through Mammoth Cave. Also there are some previously unsuspected leads for speleologists to follow up. In particular there is a potential lead to the Woolly Rhinoceros Cave from the vicinity of Bow Cave, and a possible route to the headwaters of Central River from the Bluff opposite Hennings Cave. Both areas should be examined for digging prospects. Finally it looks like Mammoth Cave accounts for even less of the notional total of cave passage in its vicinity than was previously thought.