Managing the Survey Information of the Caves of Judbarra/Gregory National Park, Northern Territory

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Abstract

The extensive caves in the Judbarra/Gregory National Park have been surveyed using traditional techniques since 1990. The techniques used have developed over time, as new technologies have become available to cavers. With the introduction of hardware such as Global Positioning System handheld units and electronic survey equipment, surveying has become easier, especially in small physically restricting passages. The use of computers and cave data reduction software since the mid-1990s has automated the calculation and plotting of survey shot data. Software that enables the production of maps is time-consuming to learn to use; however, the maps are of high quality, and are easy to maintain and adjust as subsequent expeditions continue to add cave survey data. As the amount of data and the number of users of the data grow, a set of protocols has been developed to ensure the integrity and security of a master data set.

Keywords: Cave surveying; map production; data management; expeditions; Australia.

INTRODUCTION

The exploration of the caves in the Judbarra/Gregory National Park (J/GNP) in the Northern Territory has yielded more than 219 km of surveyed passage in the various areas within the region. The Bullita Cave System has reached 122 km of surveyed passage since exploration first commenced in 1991 (Kershaw, 2012). The growing amount of data collected by cave surveyors during the annual expeditions to the J/GNP has necessitated the change from earlier, paper-based methods of recording and map production, to more modern, computer-assisted methods.

To conduct scientific studies, or exploration and surveying of the karst in the J/GNP, a permit under By-Law 18 'Disturbance Of Natural Features' must be obtained from the Northern Territory Government's Department of Natural Resources, Environment, The Arts and Sport. Numerous permits could be issued per year under the by-law; however, the Australian Speleological Federation's Judbarra/Gregory Karst Research Special Interest Group (J/GKR SIG) only conducts one expedition per year during the cooler months of June or July. The issuing of these permits should continue under the new joint management arrangements with the Traditional Owners of the region. The J/GKR SIG is now responsible for the exploration and surveying of the karst in the region, since the Top End Speleological Society (TESS) has ceased to exist and Canberra Speleological Society (CSS) is no longer the manager of the annual expedition. See Kershaw (2012) for more information on the J/GKR SIG.

For annual expedition members, managing the survey is a team effort that progresses from the in-cave survey techniques, through data reduction in the Compass Cave Survey Software (*Compass*), to map production utilising software such as *AutoCad*, ESRI's *ArcGIS* (Geographic Information System) and Adobe *Illustrator*. Additional management of the electronic data includes backing up the survey data, maps, and entrance and aerial photographs to offsite depositories around Australia. There are, however, problems associated with these steps that will be discussed here, to assist future speleologists to avoid problems encountered during the 21 years of surveying caves in J/GNP.

FIELD SURVEY METHODS

This section describes the collection and recording of field data in J/GNP, commencing with the first TESS and CSS expeditions, through to the methods employed today.

Survey Stations

Each survey station in the J/GNP is identified by a piece of flagging tape tied to the wall, ceiling, or a rock on the floor, with the station number written on it. These numbered tapes also assist in navigation when traversing the caves. In one of the early years of surveying, the surveyors ran out of survey tape, so they used toilet paper to identify the stations. This has now disintegrated and so surveyors renumber the stations if they traverse those areas. At present, fluorescent pink flagging tape is used as it is easy to see, and aluminium garden tags, as shown in Figure 1, are used for significant junctions or routes within the cave systems. Ken Grimes (pers. comm., May 2011) has found that these aluminium tags corrode quickly when in contact with moist soil. In J/GNP, however, these tags have been used since 2003 and our surveyors have not found any corrosion to date. Some speleologists may perceive that leaving the flagging tape in the cave is a form of litter or vandalism but because of the complex maze nature of the cave, the surveyors would be unable to determine their location within the cave system without the station tapes.

Figure 1: Station number designation, using aluminium garden tags.

Figure 2: Deteriorating survey flagging tape.

Of late, surveyors have found that at some stations, the flagging tape has fallen down, or been eaten by rock wallabies or insects (see Figure 2), making it harder to locate the station. Many survey tapes from the mid-1990s were only 10 centimetres in length and were simply placed under a small rock. Many of these have disappeared due to water movement during the wet season. When a poorly labelled survey station is relocated, a new piece of flagging tape is attached.

When TESS members began surveying in the region in 1991, they used an alphanumeric system to designate survey stations, such as 'AA10', and changed a letter when they reached a branching passage,
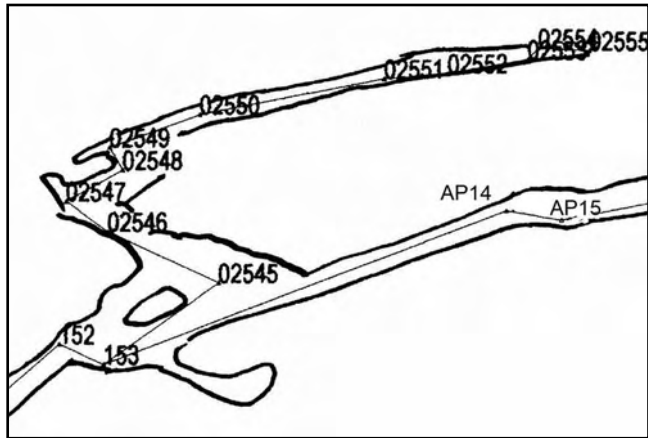
Figure 3: Section of cave map, showing both the old station numbering systems (152 & AP14) and the new style (e.g. 02545)

e.g. 'AB01'. CSS began by using a simple numerical system incrementing from one. In 1995, Don Glasco, a member of CSS, implemented a year-and-station-number designation which used the last digit of the year, followed by 3 or 4 station number digits. For example '9768' is year 1999 station number 768 and '81245' is 1998 station 1245. From 2000, the last 2 year digits were used: for example '08987' is year 2008 station number 987 and '113456' refers to 2011 station 3456. The leading zero is written on the survey station marker in the cave as well. Examples of these numbering systems are shown in Figure 3. In 2000 the J/GKR SIG asked Larry Fish, the programmer of *Compass*, to modify his software to display the leading zeros in the 'from' and 'to' station columns, as seen in Figure 4.

Instrumentation

The survey instrumentation used at J/GNP has changed progressively since 1990, as technology has improved and become more affordable for cavers. Early surveyors used *Suunto* or *Silva* compasses and clinometers and fibreglass tapes to measure the shots between survey stations. Today, we use combinations of *Suunto* equipment and laser distance measuring devices such as the *Leica Disto*. The more technologically savvy J/GKR SIG members have introduced the *Disto X* , which measures survey shot length, compass bearing and vertical angle, and the *Digital Underground Surveying Instrument (DUSI)* and *Shetland Attack Pony (SAP)* which measure only compass bearing and vertical angle. These newer devices have been used with varying degrees of success, depending on the calibration of the instrument.

At the beginning of surveying in 2010, Deborah Hunter conducted an exercise to compare the surveyors, their instruments and their readings (Hunter, 2010). The results were consistent between instruments but the surveyors' use of the *Suunto* equipment caused minor discrepancies; parallax errors in using the compass were found to be the main problem. This shows that surveyors

back.dat - Cave Editor 32

File Surveys Heading Shots Block Options Help

Select Survey | Edit Heading | Edit Survey

#	From	To	Tape	Comp	Inc	Left	Right	Up	Down	Flags	Comment
11	09350	09351	6.2m.	201.0	2.5	1.1m.	0.5m.	1.8m.	0.3m.		s1
12	09351	09352	10.5m.	313.0	1.0	0.4m.	Pass.	2.5m.	0.9m.		s1
13	09352	09353	13.2m.	321.5	-0.5	2.2m.	0.3m.	2.0m.	1.0m.		s3
14	09352	09354	6.7m.	264.0	-5.0	2.2m.	0.3m.	2.0m.	1.0m.		s3
15	09354	09355	11.4m.	229.0	-1.0	1.1m.	1.1m.	1.2m.	0.1m.		s3
16	09355	71048=09356	23.2m.	211.0	1.0	2.0m.	2.0m.	2.0m.	0.3m.		s3
17	71048=09356	09357	26.6m.	141.0	1.5	Pass.	Pass.	3.0m.	0.3m.	X	s3
18	09357	09357/70690	0.7m.	0.0	-90.0	0.0m.	0.0m.	0.0m.	0.0m.	C	70690=ad28
19	09355	09358	3.5m.	223.0	9.0	2.0m.	2.0m.	2.0m.	0.3m.	PL	s3 pl shot
20	09358	09359	15.1m.	311.0	1.0	Pass.	Pass.	2.0m.	0.3m.		s2
21	09359	09360	3.6m.	253.0	-4.0	2.5m.	0.4m.	1.2m.	1.0m.		s3
22	09360	09361	5.7m.	218.0	10.0	0.6m.	0.6m.	0.6m.	0.6m.		s3
23	09361	09362	6.5m.	232.5	-8.0	2.0m.	1.2m.	0.3m.	6.0m.		s3
24	09362	71050	4.7m.	311.0	0.0	0.0m.	0.0m.	0.0m.	0.0m.	PL	pl shot
25	09351	09363	6.5m.	218.0	-7.0	0.5m.	Pass.	2.5m.	0.9m.		s2
26	09363	09364	7.1m.	123.0	2.0	Pass.	0.0m.	0.0m.	0.0m.		
27											

Cell: 3,11   Shots: 26   Modified: No   Errors:

Enter: Meters

Figure 4: A screen capture of a *Compass* file showing old and new station numbering (e.g. #16 and in the Comments field of #18), as well as composite numbers for the 'to' station of vertical shots (e.g. #18) and use of cave cross-sectional codes (e.g. 's1') in the Comments field.

need to take care and not rush their readings within the cave environment.

The use of handheld Global Positioning System (GPS) devices has greatly assisted in positioning cave entrances accurately (to within a few metres) and providing fixed control points for the cave plots in *Compass*. GPS locations are also used to 'georeference', or correctly align, aerial photographs using *ArcGIS* software. This process has assisted surveyors in identifying unsurveyed areas and so added many hundreds of metres to the maps of existing cave systems.

However, in 1994 there was a shift in the reference datum used for Australian map coordinates. When that happened, the J/GNP cave surveys effectively 'moved' in relation to local map coordinates. The J/GKR SIG adopted the new GDA94 (WGS84) datum in October 2004, in readiness for the 2005 expedition, which meant that many hours were spent in redrawing the earlier mapped parts of the cave system to align with the new datum.

Data Recording

The survey shot information is collected on cave survey data sheets (standard, A4 sized, forms), with heading information as shown in Figure 5. As much information is collected as possible regarding the surveyors and to distinguish between the many surveys that are conducted on a daily basis. The 'sheet number' refers to the index maps as shown in Figure 10 and the 'quadrant' information assists the map drawer to determine the location of the survey in the GIS mapping software. The 'station numbers allocated' section allows the planner to supply the survey sheets to the surveyors with pre-assigned station numbers so that there is no duplication, which, if it occurred, could cause havoc in the *Compass* program.

Passage wall information is collected at each 'from' survey station: that is, left, right, up and down distances (LRUDs) which are recorded on the survey data sheets. Cave systems in J/GNP tend to have a maze-like structure in the horizontal plane, with many intersecting passages. Where a surveyed passage includes a station situated at an intersection, the left and right distances are now recorded as P/# (P = passage, # = distance as if the wall continued there). The distance value is entered into *Compass* to better define the shape of passage walls, particularly at the 1:1000 or 1:500 scales at which we sketch. This method of recording passage wall data was established at J/GNP in 2010.

Survey Code (8Char): _ _ _ _ **12** _ _ **Cave Tag number:**_____ **Page # of this survey**_____

Location: (SHEET No: _____ QUADRANT:- [NE SE SW NW] _____) **Date:** ___ **JULY 2012**

Survey Members: Recorder: …………………………… Compass/clino: …………………………..

Distance: ………………………… Point: ………..………………… *GPS References to be written over page*

Comment_____

Station numbers Allocated: **Station numbers used:**

From	To	Dist	Azi	Dip	Left	Right	Up*	Down	Flag	Shape	Comment

Figure 5: Heading information on cave survey data sheet. The '*' in the 'Up' column refers to the height of an open roof, as if the roof were still in place.
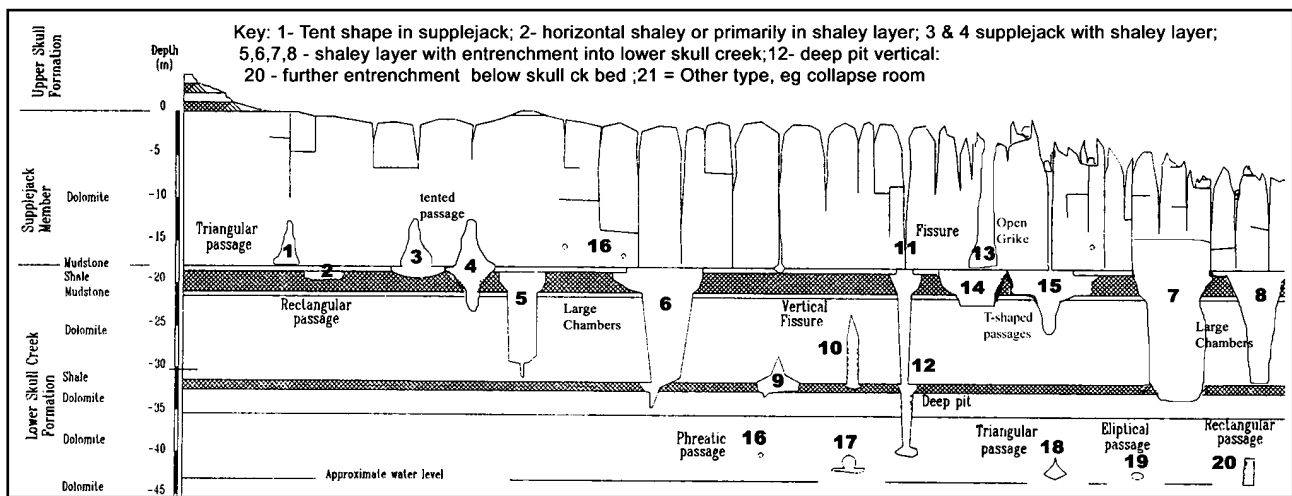

Figure 6: Coded passage cross-section types, using a generalised cave section based on a diagram in Bannink et al. 1995. This appears at the bottom of each survey data sheet.

Tag Number Info	CAVE TAG number:	
Zone:	Cave name:	
Elevation:	GPS datum: WGS 84/DGA94	
EPE:	Easting:	
No of averages:	Northing:	
Entrance Photograph	Date:	Time:
	Direction Looking:	Distance to cave:
Description of cave Entrance:		

Figure 7: Cave entrance and GPS information will now be recorded on the back of survey data sheets

Figure 8: Part of a map sheet in the SOGS karst block showing different layers. Blue features are at the highest elevations, black are intermediate and red are at the lowest elevations.
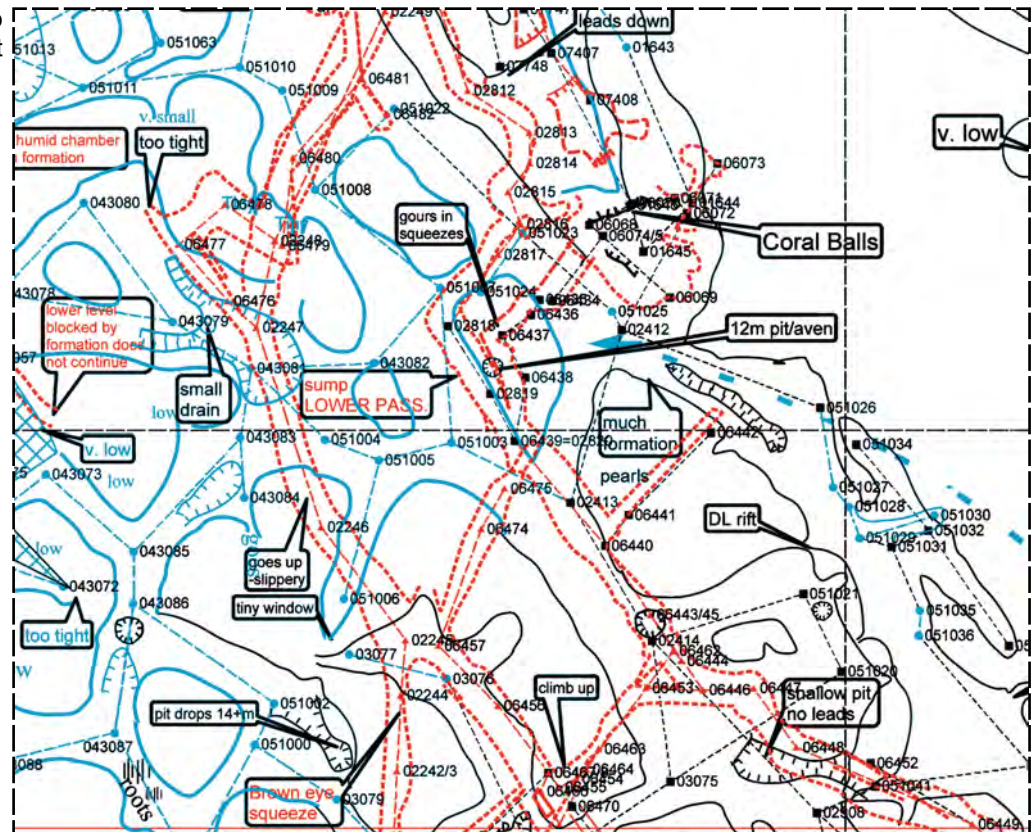
As revealed in the *Compass* data files, and confirmed by John Dunkley in 2011 (pers. comm.), the CSS surveyors during the early 1990's did not collect vertical angles between stations because the Cave Exploration Group of South Australia (CEGSA) software program being used at that time did not make use of the vertical angles that were entered into it. As surveyors re-enter these areas today, they sometimes resurvey the stations and record vertical data to correct the cave survey.

The cave wall is sketched at the same time as surveyors record survey shot data and these in-cave sketches are drawn at a scale of 1:1000, or more recently at 1:500. The sketch maps are used to compile and update electronic versions of the maps, ready for future use. A problem with the sketching, especially when done at 1:1000, is that some information is not included on the maps. For example, the daylight holes and unroofed sections are generally not shown; or where they are shown, the symbol used is often that of a floor pit or, depending on the sketcher, an aven.

Passage cross-sections are not sketched at J/GNP. Instead, survey data sheets include diagrams of generic passage cross-sections found throughout the cave systems (Figure 6). The surveyors record the number of the closest matching cross-sectional shape, which is later transferred into *Compass*.

The lack of true cross-sections and long profiles makes it difficult to interpret the shape of the cave from plan maps, especially in the complex multi-level areas. Figure 8 depicts such a confusing 3-dimensional area in

the SOGS block. The cave surveyors perceive that as their time is limited to the annual expedition, they are better off not measuring cross-sections and long profiles.

From 2012, the reverse side of the survey data sheets will have a table for GPS entrance data as shown in Figure 7. Previously, GPS information was placed anywhere on the data sheet and was often overlooked when cave survey data were entered into *Compass*.

DATA REDUCTION

Compass Cave Survey Software

The survey data are manually entered into *Compass* and a master set of project '.mak' and data '.dat' files is maintained by the J/GKR SIG's Mapping Coordinator. After input, each survey's data-set is printed and checked against the original data for errors. *Compass* generates a plot of survey lines, which is also compared to the in-cave sketch map for errors.

The Bullita Cave System has six major blocks with limited connectivity between them – sometimes just a single passage (Kershaw, 2012). This allows the data to be grouped into six project files – Neighbours, Frontyard, Backyard, Bain/SOGS, Mikes and BAA34 – which are processed separately in *Compass* to reduce the computational time and enhance overall accuracy. In 2011 these six project files incorporated 400 separate surveys with over 12,000 survey legs, 11,000 stations, 1,400 loops and more than 40 entrances, giving a total of over 122 km of surveyed passage.

To assist *Compass* to compile the loop closure adjustments as accurately as possible, high-accuracy traverses of the cave system have been measured in the field. These traverse files are placed first in the survey list so that *Compass* closes these loops first, then goes on to compile the less accurate loops to produce its final plot. More information on this process can be found in the 'Help' files associated with *Compass* (Fish, 2012).

Each year the *Compass* data-set from J/GNP is updated and saved in a new folder and all old data-sets are kept. The survey legs are examined to see if any of the old data have been duplicated. If so, the *Compass* records are updated, to indicate that the old data should not to be counted in the total length ('L' flag), not plotted on the map ('P' flag), or not included at all ('X' flag).

Survey stations that have been 'lost' in the caves are given a new station number when relocated. Reconciliation takes place in *Compass*, noting the old station number and the new, for example '71048=09356'. Also, vertical survey shots are not closed ('C flagged') during loop compilation, as shown in Figure 4, and are entered as station 09357 to station 09357/70690, for example. This means that 70690 is directly above (or below) station 09357. The logic of this process is that the vertical survey shot will not be moved during *Compass* loop adjustment and that it is easier to read the survey stations in both the *Compass* plot and the final paper map. These steps require a lot of reviewing of old surveys, to correlate the station numbers.

Once the survey data-set has been updated in *Compass*, it is then compiled to show a plot depicting the stations and survey shots. The plot file is then exported from *Compass* in ESRI 'shapefile' format for map production in *ArcGIS* software.

MAP PRODUCTION

TESS placed its J/GNP survey data into the *AutoCad* program but had problems with vertical angle survey shots with that software. Their data-set was then exported to *ArcGIS* software to produce its cave maps. More recently Peter Bannink, who is an ex-TESS member and also a GIS professional, has entered the TESS data into *Compass* for easier use with *ArcGIS*.

ESRI ArcGIS software – ArcMap

In the mid-1990s, CSS drew the cave wall of each passage by hand onto A3 map sheets. This caused problems when new passages were surveyed and a new piece of hand drawn map was glued over the same area: much information was 'lost' as maps were redrawn. From 2004 to 2010, cave walls were drawn 'free-hand', using a computer mouse, with as much information from *Compass* and the in-cave sketch maps as possible. Today, a digital photograph is taken of the in-cave sketch map (which is quicker than using a flat bed scanner and of higher resolution), and that is then georeferenced as a layer in the *ArcMap* software. The cave walls and other information are then traced accurately, on-screen, onto a new layer (Figure 9). A paper copy of this map is checked by another member of the J/GKR SIG to ensure that nothing from the in-cave sketch map has been inadvertently omitted. The internationally recognised cave survey symbols are included within *ArcMap* which makes cave drawing easier, and our own interpretations or symbols can also be made using this software.
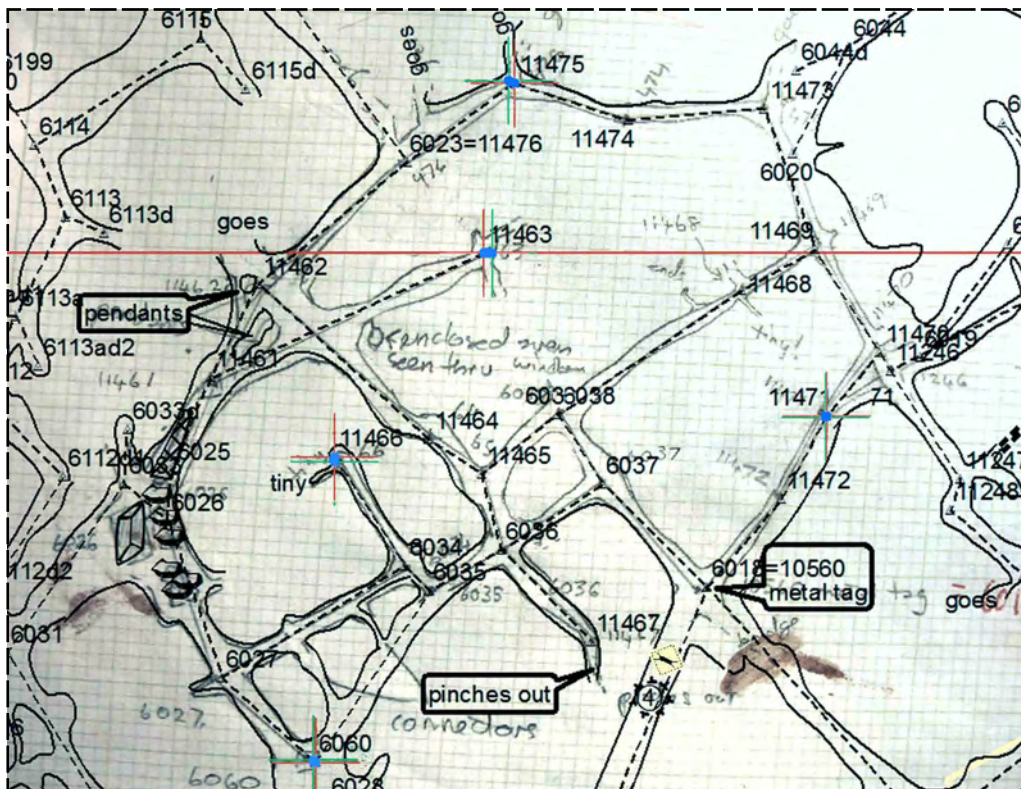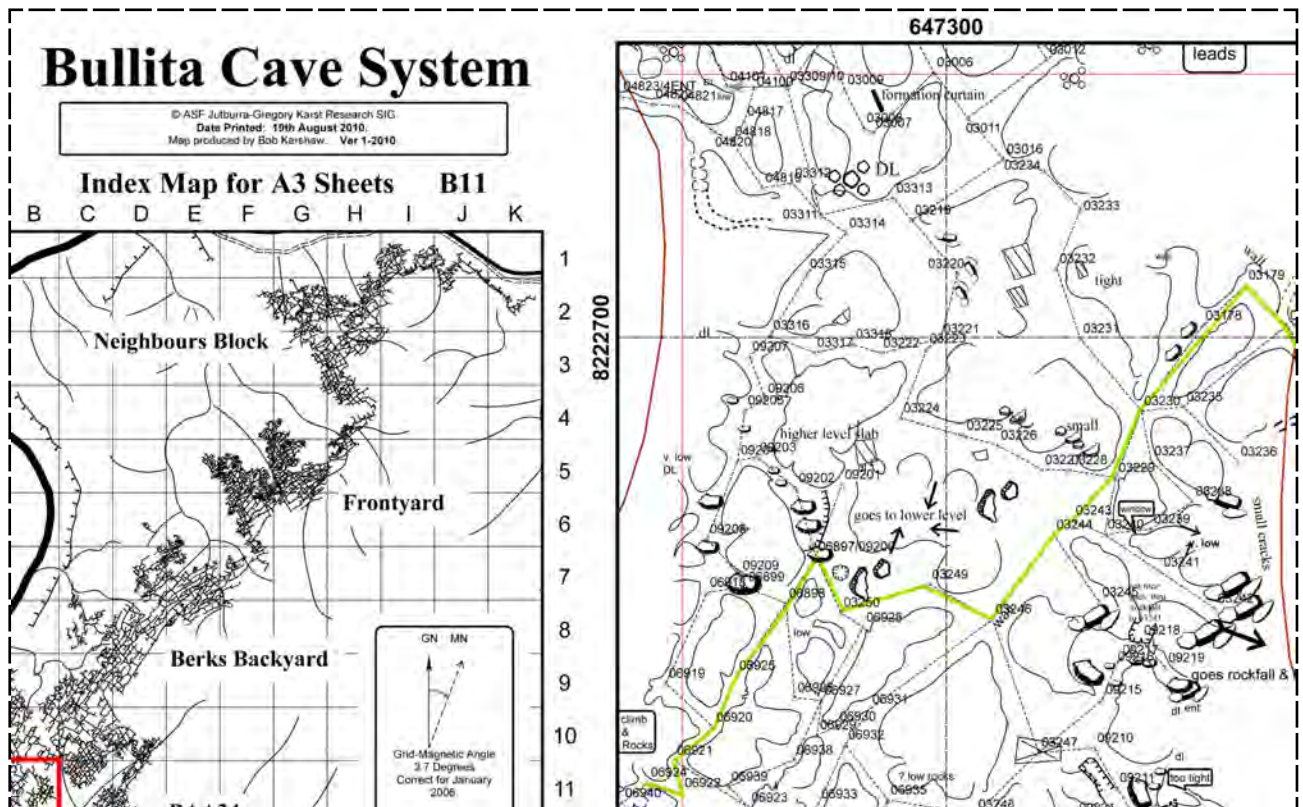

Figure 9: Part of an in-cave sketch, scanned and georeferenced in *ArcMap*, ready for drawing. The light grey lines are the original sketch.

Figure 10: A part of an A3 map sheet. The red area at bottom left shows the location within the system of the sheet area which is plotted to the right. The green line shows a route through the cave.

The elevation information that is included with the survey data allows *ArcMap*, after much manipulation, to display colour-coded survey lines and passage walls at various levels, as shown in Figure 8.

Adobe Illustrator

The Spring Creek Karst area maps have been drawn in the past few years by Alan Pryke of the J/GKR SIG. He uses Adobe *Illustrator*, to encourage members of his club to use a drawing program to produce cave maps. *Illustrator* integrates the cave symbols into the drawn maps. A copy of these maps is sent to the J/GKR SIG Mapping Coordinator, to update the *ArcMap* drawings as well.

The printed maps

After the wall drawings and other information have been completed, cave maps for the Bullita Cave System are printed in 250 m by 250 m blocks on A3 sized paper; an example of part of one sheet is shown in Figure 10. Each sheet has an index map showing the location of the map sheet in relation to the whole karst area. This index map method was established by Don Glasco from CSS in 1995/6 and continues today. The maps for field use in the Spring Creek area have been printed without an index map.

These printed maps are then taken into the field the following year and used as 'road maps' through the cave systems, as well as to find unsurveyed areas or connections between existing caves. *ArcMap* is also used to construct small scale, overview maps of the whole region, which are printed on A0 sized paper for the cave surveyors to use at camp. Important landform information such as rivers, creeks and surface contours has been obtained from the Northern Territory Government, to enhance the overview maps and sometimes the A3 maps. An example is shown in Kershaw (2012, figure 3).

Copies of the A3 'road maps' and the overview maps have been given to the local Rangers – in case someone enters and becomes lost in the cave system, but fortunately the maps have not had to be used for search and rescue purposes to date.

Backing up the data

The original cave survey data sheets are stored with the earlier CSS survey information in a J/GKR SIG member's residence and the master electronic data-set is copied to two external hard drives, which are held offsite. After the maps are drawn, copies of the *Compass* and *ArcMap* files, and other data such as GPS locations, are burnt onto DVDs. These are sent to other members of the SIG as a further backup safeguard.

MAPPING PROTOCOLS FOR THE J/GKR SIG

In 2011, a draft set of mapping protocols was developed, as more than one person is now involved in the data entry and mapping of survey data. The protocols are included below, as a guide for cavers involved in other major survey programs:

- There shall be one set of master '.mak' and '.dat' files for use with *Compass*, which is held by the Mapping Coordinator (MC). Backup copies will be distributed to SIG members in various locations in Australia.

- From time to time the MC may provide a copy of a karst area map or block of *Compass* files to a SIG member, to input data after an expedition.

- Any paper survey data sheets given to a SIG member must be copies. The original data-set remains with the MC or stored with the original CSS survey information.

- The electronic data and survey files must be returned following the expedition to allow the MC to prepare maps for the following year.

- Any alterations to old survey files in *Compass* are restricted to an 'X' being placed in the flag column - any new data must be entered within the new year's survey file.

- No data will be overwritten or deleted by any SIG member, including the MC. Old data must be 'X flagged' only.

- Alterations to fixed locations using *Compass* node editing shall be made in consultation with the MC.

- A SIG member not familiar with *Compass* software will consult the MC before entering or altering any survey data.

- A SIG member who uses the data-set to draw maps of their area of interest shall abide by the following:

  - Copyright is vested in the J/GKR SIG.

  - The maps or data shall not be published in any club journal or distributed to anyone without consent of the SIG committee.

  - The maps must be sent to the MC in a format that can be imported into the *ArcGIS* map production software.

CONCLUSION

The use of technology in the field, such as handheld GPS units, electronic measuring equipment and laptops, has made the collection of cave survey data in J/GNP more accurate and easier, especially in challenging situations. After the expedition, in the comfort of home, computers and survey reduction programs such as *Compass* can be used to find surveying blunders and duplicate legs, and export data to map production software. GIS and other drawing programs have made easier the massive task of managing survey information and producing excellent quality maps. This technology, however, has made the whole process more time consuming, as SIG members progressively perfect their methods and the all-important final product – the cave map.

It is unfortunate that these map drawing processes are a 'one-person show', in that any shared data have to be imported into the Mapping Coordinator's computer and software for continuity of the maps. A draft set of protocols has been agreed upon by several users, however, as to how the data-set is to be shared and maintained.

Updated 'road maps' and overview maps are generated, as time allows, for use on future expeditions to J/GNP. These maps are also available for park management use.

Surveying in J/GNP is by no means completed. There is the potential for the isolated caves in the Southern Karst block at J/GNP (see figure 3, in Kershaw 2012) to become one major system exceeding 25 km of surveyed passage. It is important that the quality and quantity of data be maintained along the lines outlined in this paper, for without such protocols and use of technology, the exploration and mapping of these caves would not be as well-organised and could result in loss of data and poor quality cave maps.

ACKNOWLEDGEMENTS

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