ASF Cave Survey and Map Standards

by Edward G. Anderson and others, 1978
Replaces ASF Survey Standard of 1962
Ken Grimes, 1 March, 1997 ASF Survey Commission

Contents

1 Introduction

1.1 Design Context

The very concept of standardisation raises a number of fundamental conflicts in both aims and application. Space will not permit a full discussion of these issues here, nor would it be appropriate, but they must be stated, so that the context within which the following standards were designed is apparent and the areas of necessary compromise defined. Major areas of conflict may be enumerated thus:

1. Whether the map is regarded as: a club or personal record and/or working diagram, or an appendage or illustration in a publication.

2. Whether the map is intended for use in:

a) General speleology.

b) A specific scientific discipline.

c) An engineering application.

d) Tourist literature, educational or general publication.

3. Whether the advantages of uniformity gained by rigorous standardization outweigh the claims of professional judgement and personal skill, artistic freedom and originality.

4. The inherent differences between underground and surface surveying and mapping.

1.2 Scope of the Standards

These Standards are intended to provide the basis for sufficient uniformity to enable satisfactory comparisons of cave surveys and maps designed for general speleological purposes within Australia. Specific scientific, engineering, and social applications are considered beyond the jurisdiction of the Federation and are purposely excluded. If, however, the Standards evince a strong bias towards the requirements of publication of maps, rather than those of a localized record-keeping and documentation, then this is by definite intent. It is held that there exist numerous demonstrations of the foresight and practicality of a policy whereby the publication of cave maps is assumed from the outset, and all stages are designed with that goal in mind. There is little evidence to support the notion that such a policy detracts from the usefulness of such maps in any aspect of general speleology.

An emphasis has been placed on cave mapping in contrast to surface mapping as the latter is rightly the domain of the topographic geographer, however some basic information has been given for cavers preparing surface maps.

2. Units

The International System (SI) Units should be used for all surveys and maps. Surveys already completed in Imperial units should be converted for publication, or additional metric scales and information should be included. Future surveys conducted using Imperial equipment should be converted before computation and plotting.

Usage should conform with the current Australian Standard **(AS 1000 - 1970 The International System (SI) Units and their Application).** The relevant sections of this standard are as follows:

1. **Length:**

millimetre	mm
metre	m
kilometre	km

2. **Area:**

square metre	m2
hectare	ha (=10 000 m2)
square kilometre	km2

3. **Volume:**

cubic metre	m3

4. **Volume Flow**

	litre/second L/s
cubic metre/second	cu m/s

5. **Temperature:**

degree Celsius	°C

6. **Plane Angle:**

degree	°
minute	'
second	"

NOTE:

The correct length conversion factor is: 1 foot = 0.3048 metre (exactly).

The plural form of all units and their abbreviations is the same as the singular. Do not add "s" to abbreviations as this stands for "seconds" of time. Litre abbreviation "L" is approved alternative to script "l".

3. Scales

All map scales should be multiples of powers of ten of the following ratios:

1:1 1:2 1:5

The following scales are recommended:

1:100	1:200	1:500
1:1000	1 :2000	1:5000
1:10 000	1:25 000 (Note 2)	1:50 000
1:100 000		

1:200 is preferred for all cave mapping and should be regarded as the **common standard scale.**

1:100 should not generally be used (particularly when the sole aim is to fill the page with a small cave), and is included only for applications with a specific need for such a scale.

It is recognised that the scale ratios 1:1.25 1:2.5 1:4 and 1:8 may arise from the convenience of photo-reduction or enlargement. However, they should be avoided in all original cave map drafting.

NOTE:

The use of a series of adjoining sectional maps (the so-called street-directory method) to facilitate presentation of extensive caves at a large scale is strongly recommended. In such cases, the common scale of 1:200 should be used for sectional maps which should be prepared on A4 sheets. One or more key maps at a suitable smaller scale should be used to index the sectional maps.

Australian Standard AS 1100.7 recommends the scale 1:25 000, but not 1:20 000.

4. Mapping Sheet Sizes

Metric paper sizes are recommended as follows:

A4 (210 x 297mm) A3 (297 x 420mm) A2 (420 x 594mm)

A4 is preferred for all published maps and should be regarded as the **common standard sheet** size.

In all cases a minimum clear margin of at least 5mm should surround the map. For applications involving filing, or "folding in", a filing strip of at least 20mm should be retained.

NOTE:
Suitable sizes and layouts are fully defined in the relevant Australian Standards: **AS 1100.3 Sizes of Drawing Sheets, and AS 1100.4 Layout of Drawing Sheets.**

5. Survey and Map Records

To ensure their future availability, all original readings, sketches, and calculated data should be filed in a recognized location, such as in the records of the society holding the map original.

To facilitate uniformity of map sheets and associated survey and field records, it is recommended that forms approved by the Federation be used for these purposes. Standard designs for the following forms may be approved by the Federation from time to time:

1. **Survey Field Record Form** A generalized form for recording survey observations.

2. **Survey Abstract Form** A generalized form for recording an abstract of survey results. (Not a computation form.)

3. **Field Mapping Sheet** A generalized sheet for field mapping, with a grid and provision for entry of all required information.

4. **Map Sheet** A set of generalized sheets for final drafting, conforming to size and layout requirements, and with provision for entry of all required information.

NOTE:

The use of standardized forms is the best way of ensuring that all necessary information has been recorded. This is a significant advantage in the field, when reference to the appropriate standards may not be possible and the problems of the survey demand full attention.

6. Survey Datums

Every effort should be made to connect area and cave surveys to a standard datum and to compute survey results with respect to such a datum. Preferably the national datum, called the **Geocentric Datum of Australia (GDA)** should be used, or alternatively one the of State datums. Complete connection requires that horizontal co-ordinates, height and orientation are all defined in terms of the datum. Thus, in the case of national or State datums the following information is essential:

Horizontal co-ordinates

either

1 Projection co-ordinates:

1. Australian Map Grid (AMG) co-ordinates.
2. Transverse Mercator (TM) co-ordinates, in some States.
3. Integrated Survey Grid (ISG) co-ordinates in NSW.

or

2. Geographical co-ordinates, i.e. latitude and longitude.

Height

either

1. Height with respect to the Australian Height Datum (AHD).

or

2. Height with respect to a State "standard" datum.

Orientation

either

1 In terms of grid azimuth.

or

2. In terms of true azimuth.

If it is not practical to connect to a standard datum, provision should be made for connection at a later date by adopting one or more local datums. Preferably, only one datum should be adopted in each area, and all surveys in the vicinity integrated. However, failing this, as an absolute minimum each survey should have a fully defined and physically recoverable datum.

The definition of a local datum requires two distinct components:

1. One, but preferably more, permanent marks defining physically recoverable points, with adequate nearby reference marks to ensure recoverability of position in case of loss or damage of the main mark.

2. A set of co-ordinates and azimuths defining the relationship between the adopted co-ordinate system and the permanent marks. The minimum information necessary to define this relationship comprises:

a. Horizontal co-ordinates and height of at least one permanent mark (probably in a plane co-ordinate system).

b. The orientation of the co-ordinate system (i.e. grid) with respect to true north, or at least magnetic north at a known date.

Use of the Australian Map Grid should be considered standard practice, and exceptions - such as avoidance of publication of cave locations - treated as a special case. For instance the AMG should be used for caves which are reasonably protected by means of reserves or similar entry restrictions. In cases where publication with the grid is considered unwise, a grid referred to a local datum with arbitrary co-ordinates may be employed, and a note appended informing users where details relating the local and standard datums can be obtained. In many cases, adequate protection is afforded by merely suppressing the high order digits of the standard co-ordinates.

NOTES:

1. Survey results which are not related to a physically recoverable datum in the field are almost worthless. By the simple process of adopting and permanently marking a datum within the survey its usefulness is preserved. Connection to a local or standard datum can be established in the future and the survey integrated with other work.

2. Connection of a survey to a datum requires observations to relate both position (horizontal co-ordinates) and orientation (a bearing or azimuth).

3. The most convenient method of physically defining orientation is to adopt and mark at least two intervisible points, with as much separation as can be practically achieved. Orientation is then expressed as the bearing or azimuth between these points.

7. Map Grids

Grid lines should be shown at an appropriate interval on the face of the map. In some circumstances it may be necessary to show only grid return lines at the map border.

Grid lines should be the lightest lines on the map. Identification figures should be in the margins, but may in some instances appear on the face of the map.

7.1 Grid Intervals

The grid interval, at equivalent ground distance, should be related to the scale of the map as follows:

SCALE	GRID INTERVAL Ground distance (m)
1:100	2
1:200	5
1:500	10

Multiples of powers of ten of these intervals should be used for smaller scales, e.g. 1:1000, 20m.

8. Symbols

A basic set of standard symbols for general speleological mapping is illustrated in a second document ***Table 1 Map Symbols***. The symbols in the first column are intended for use in plan views. The second column contains the equivalent symbol for use in vertical sections or views, when this differs from the plan symbol.

These symbols are intended for use at relatively large scales (such as the standard scale, 1:200) and it is recognised that some modifications may be necessary to accommodate the requirements of very small scales. However, detailed maps are unlikely to be required at such scales.

It is recommended that symbols for surface mapping be in accordance with the current edition of Topographic Map Symbols, Division of National Mapping, Australia.

If a more extensive set of symbols is required for a specific mapping project, the following criteria should be observed:

1) The symbol should as far as possible bear a recognisable relationship with the actual feature it represents.

2) Symbols representing features which may be logically classified within a group should likewise bear a common relationship to each other and, if appropriate, to one of the basic standard symbols.

3) Standard symbols should not be redefined with a different meaning.

4) As far as possible, symbols commonly used with a well-established meaning in other disciplines should not be employed for a totally different purpose.

5) A brief note or phrase may obviate the need for a new or complex symbol.

NOTES

1) Because of possible confusion with other symbols, the use of shading in association with outlines should be avoided.

2) Various line thicknesses can be usefully applied to distinguish between outlines, detail symbols, and special lines such as grid and section lines.

3) Confusion between plan symbols at different cave levels and between roof and floor details should be avoided by using separate detail plans, with accompanying outline diagrams to define the correct vertical relationships.

4) The capital letters "R", "W", or "F" may be appended generally to other symbols to indicate location on roof, wall, or floor respectively, and they should be reserved solely for this purpose.

5) The design and use of symbols is well documented in Elements of Cartography, Arthur H. Robinson, 2nd ed., 1963, John Wiley & Sons, Inc, which is also a useful reference for all general cartographic information.

6) The symbols for dip, strike, change of rock-type, doline, fence, etc. have been included only for convenience as they have already been laid down elsewhere.

7) Similarly, some electrical symbols have been shown for convenience. All electrical symbols used should conform to **AS 1102.8 Location Symbols - Power Supply Systems and Electrical Services for Buildings and Sites**.

9. Survey and Map Detail Grades

9.1 Survey Grades

Recommended grades are listed in Table 2.1 below. The grade number, ranging from 0 to 9, appears in Column 1. Grades are assessed primarily on the basis of the instruments and methods employed, as defined in the second column. This definition is further qualified by the degree of observational precision adopted in using the instruments. Required precisions of angular and linear readings are set out in Columns 3 and 4 respectively. In most instances these values may be taken to mean simply the degree of fineness of each individual reading, e.g. if a compass is read to the nearest whole degree, the observation precision is assumed to be 1° - but see also *Notes 1 to 3*. Centring errors, which may be a most significant source of error, are assumed to be kept within the requirements for linear precision. Expected accuracies, in Column 5, are intended only as a rough indication of the overall accuracy of the whole survey (*See Note 4)*.

To indicate that magnetic anomalies have been checked and corrected for in magnetic surveys (e.g. by reading foresight and backsight bearings for each line), and that the effects of these and other systematic errors have been removed, the letter "C" (for checked/corrected) should be suffixed to the grade number.

To indicate that "gross" errors (mistakes) have been detected by closing the survey, and have been removed, and that the effect of the remaining "accidental" errors has been minimized by adjusting the survey, the letter "A" (for adjusted) should be suffixed to the grade number *(See also Notes 5 and 6)*.

If electromagnetically determined survey stations have been used to improve the accuracy of a cave map, then the letter "E" should be suffixed to the grade number.

TABLE 2.1

GRADE	TYPICAL INSTRUMENTS AND METHODS	OBSERVATION PRECISION		EXPECTED ACCURACY	COMMENTS
		ANG.	LIN.		
0	Ungraded	-	-	-	-
1	Sketch or diagram from memory. Not to scale.	-	-	-	-
2	Map compiled from notes, sketches and estimates of directions and distances made in the cave. No instruments used.	-	-	-	If Grade 3 un-attainable
3	Significant directions measured	5°	0.5m	10%	Preferred grade

	by compass. Distances measured by chord (e.g. waistloop, safety line, ladder) of known length, or by careful pacing or body dimensions. Significant slopes estimated.				for quick surveys
4	Compass and tape traverse, using deliberately chosen stations (not necessarily permanently marked, but preferably indicated by natural or artificial marker). Distances by tape, marked cord, or rangefinder. Slopes estimated by simple clinometer or horizontal and vertical components of line measured.	2°	0.1m	5%	If Grade 5 un-attainable
5	Compass and tape traverse. Directions by calibrated compass (e.g. liquid-damped prismatic or semi-supported Brunton). Vertical angles by calibrated Abney level or similar clinometer. Distances by metallic or fibreglass tape, or tacheometry.	1°	5 cm	2%	The preferred minimum grade. Highest possible grade if magnetically unchecked.
6	Traverse and/or triangulation using calibrated, tripod-mounted instruments for directions and vertical angles (e.g. forestry compass). Distances by calibrated tape or precise tacheometry, or subtense.	15'	2 cm	1%	-
7	Controlled traverse and/or triangulation using small theodolite (e.g. Wild T12 or T0, adjusted forestry compass with vernier) for directions and vertical angles. Distance by calibrated steel or fibreglass tape.	5'	1 cm	1/1000	-
8	Conventional theodolite traverse and/or triangulation conforming with requirements for acceptable cadastral survey accuracy. Directions and vertical angles by glass arc theodolite (e.g. Wild T1). Distances by standardised steel tape or band or electronic distance meter (EDM). All normal precautions for the elimination of systematic errors should be taken.	20"	5mm	1/5000	-

	Levels may be made by differential levelling.				
9	Precise control traverse and/or triangulation and/or trilateration. Directions and vertical angles by "one-second" theodolite (e.g. Wild T2) with constrained centering. Distances by standardised steel or invar tape or band or EDM. Levels preferably by differential levelling.	1"	0.5mm	1/25 000	-

9.2 Map Detail Grades

Recommended grades, ranging from 0 to 5, are listed in Table 2.2. The grade is assessed on the method used to compile the detail information and the type of information included in the map as defined in the table *(See also Note 9)*.

TABLE 2.2

GRADE	METHOD
0	Ungraded
1	Sketch from memory. Not to scale but indicating approximate proportions.
2	Map compiled from notes, sketches and estimates of directions and dimensions made in the cave.
3	Map compiled from drawings made in the cave, based on approximate measurements of major details. Lesser details added by sketching and estimation.
4	Map compiled from drawings made in the cave, based on measurements of significant details with respect to surveyed points (usually at least Grade 4). All details of general speleological interest should be shown with sufficient accuracy so as to not be appreciably in error at the mapping scale.
5	As for detail Grade 4, with the addition of significant morphological features and details of primary and secondary deposits.

9.3 Format of Grade Number

These grades should be referred to as the Australian Speleological Federation Survey and Map Grade, abbreviation ASF Grade *(See Note 10)*.

The grade should be expressed as a two digit number, the first digit representing the survey grade and the second digit representing the map detail grade. Qualifying letters should be appended as required (Table 2.3below).

SUFFIX	METHOD
A	Suffix the letter "A" if the survey is closed and adjusted.
C	Suffix the eletter "C" if the survey is dependent upon magnetic bearings which have been checked and corrected for the effects of possible magnetic anomalies.
E	Suffix the letter "E" if the survey has been checked and corrected by electromagnetic methods.

Usage of the total grade designation should conform with the format illustrated by the following examples:

1. ASF Grade 64
2. ASF Grade 53C
3. ASF Grade 84AC
4. ASF Grade 42ACE
5. ASF Grade 02 *(See Note 8)*

NOTE:

1. A deliberate distinction exists between the meaning of the terms *"precision"* and *"accuracy",* which may be illustrated by the following:

   Three angles of a plane triangle are measured by two parties, A and B, and the results, for the sum of the angles, are thus:

   1. A 180° 01' 40"

   2. B 180° 01'

   If A observed the angles to the nearest 20", while B made readings to the nearest whole minute, then A is more *"precise"* than B, but, since the correct sum of the angles should be exactly 180°, B is more *"accurate"* than A.

   Note that *accuracy* can only be assessed in relation to some standard (known or adopted), whereas *precision* is determined by the quality of instruments and methods employed.

2. The observation precision quoted for the higher grades (7 to 9) may not be simply the precision of a single reading. In such work it is common practice to improve the precision of the results by repeating observations. The final precision is then determined by a statistical analysis of the readings.

3. In arriving at a relationship between angular and linear precision, a reasonable balance has been assumed to be desirable. The values given for grades up to 7 would be approximately balanced for relatively short survey lines (of the order of 5m) such as might be expected in cave surveys. However, this does not hold for Grades 8 and 9, where better quality angle measuring instruments are used, and linear precision tends to become the limiting factor.

4. In deriving the expected accuracies, a tendency towards pessimism was adopted, mainly to allow for the poor observing conditions encountered in most cave surveys, and the common necessity for short survey lines.

5. Errors are of three basic types:

   a) **Gross errors** (mistakes): Elimination involves remeasurement.

   b) **Systematic errors**: Repeatable errors caused by known physical laws and which can therefore be calculated and removed. They include local magnetic anomalies and instrument maladjustments.

   c) **Accidental errors**: Unpredictable errors, such as the unavoidable inaccuracy in reading the instruments. When mistakes and systematic errors have been removed, accidental errors remain; their effect can then be minimized by adjustment.

6. Adjustment of the survey may be achieved by either closing the survey on itself (as in a loop traverse), or better still, by closing it between survey stations whose positions are known to a higher accuracy. Such a closure may be obtained using electromagnetic position fixing apparatus (Radio Direction Finding).

7. Cave surveys may be classified as either "premeditated" or "unpremeditated", where the former is intended to mean that some degree of preparation preceded the execution of the survey. The dividing line falls between Grades 4 and 5, so that Grade 4 is probably the highest grade that could normally be achieved without deliberate preparation. Conversely, Grade 5 should be considered the lowest grade to be attempted when purposely organising a cave survey.

8. Grade 0 (zero) should be used to indicate that the grade of the survey or map is unknown.

9. In recording cave detail, advantage is gained by sketching the detail around a plot of the traverse at the final scale while the survey is actually proceeding, namely:

a) Improved accuracy of sketched details.

b) Early detection of gross traverse errors while there is still an opportunity to correct them.

c) A working map of the cave is available immediately it is surveyed.

d) The details are more easily traced on to the final map because the scale is the same.

10. The ASF grades have been designed to be compatible with the old Cave Research Group of Great Britain (CRG) grades, now British Cave Research Association (BCRA) grades, within the limits of the latter systems. However, it is specifically recommended that conversion of existing CRG or BCRA grade allocations to the ASF system be not undertaken.

10. Cave Mapping Terminology

To avoid ambiguity, use of the following technical terms on maps should conform with the accompanying definition

1. Plan
A representation of the details to be mapped resulting from parallel projection on to a horizontal plane.

2. Elevation
A representation of the details to be mapped resulting from parallel projection on to a vertical plane.

3. Section (generally)
The trace or outline of the details to be mapped representing their intersection with a chosen section plane.

4. Cross (or Transverse) Section
A vertical section which is substantially perpendicular to the general direction of the greatest dimension of that part of the cave in the near vicinity of the section plane.

5. Longitudinal Section
A vertical section which substantially coincides with the general direction of the greatest dimension of that part of the cave in the near vicinity of the section plane.

6. Developed
A qualifying term used to indicate that a particular section comprises several contiguous, but non-parallel, section planes, which have been artificially rotated into a common plane. The technique is commonly applied to longitudinal sections.

7. Horizontal Section
A section where the section plane is horizontal. This technique may be usefully applied when the cave development is predominantly vertical.

NOTE:

It is important to the correct interpretation of cave maps that both the draftsman and the user understand the distinction between projections and sections, e.g. that an ***elevation*** is a projection of the ***maximum dimensions*** on to a plane behind a cave passage, whereas a ***longitudinal section*** shows where the passage ***intersects*** the particular section plane, which may or may not be at the maximum dimension. Similarly with plans and horizontal sections - a plan shows the projection of all the maximum passage widths on to a plane below the cave, but a horizontal section shows only that part of the cave which intersects the section plane, i.e. only at one particular level. The cave draftsman should therefore take care both to label the various views on his map and to use the terminology appropriate to his method.

11. Information Required on Maps

The following information is considered necessary on every map:

11.1 Identification

1. Cave name and number, area name or locality.

2. ASF map number, and sheet number if appropriate.

3. Location diagram or description, and/or superimposed grid (refer end of Section 6 re location suppression).

11.2 Survey Details

1. Details and physical description of the horizontal and vertical datums adopted, including the geographical and Australian Map Grid (or other standard) co-ordinates if known, or the local co-ordinates if arbitrarily adopted.

2. Details of any associated control surveys, including the method of connecting to the datum and determining the orientation.

3. Details of the grid employed, including its relationship to the datum (such as the use of a false origin), its orientation with respect to true and/or magnetic north, and the grid interval. Orientation is best depicted diagrammatically, and such a diagram, indicating the direction of true and/or magnetic north, is essential if there is no grid.

4. ASF Survey and Map Grades. Details of instruments and methods employed. Accuracies and closure errors if known, and details of any peculiar survey difficulties.

5. Names of surveyors and dates of surveys.

11.3 Map Details

1. Scale:

a. A statement of the original scale as a representative fraction in the form map distance to ground distance, e.g. Scale of Original - 1:200.

b. A graphic scale bar comprising a coarse and fine section. The coarse section should be of sufficient length to facilitate physical scaling of distances from the map. The fine section should be at least as long as one coarse division and should be subdivided to a level consistent with the general accuracy of the map. The zero of the scale should be located between the fine and coarse sections. Use of a scale bar enables correct scaling even after photo reduction or enlargement.

c. A statement of the original sheet size, e.g. A4.

2. Table of symbols, illustrating all symbols used.

3. Units:

a. A statement of the units for any quantities used, e.g. dimensions, temperatures, etc.

b. The contour interval if appropriate.

4. Relationship to adjoining or index sheets if appropriate.

5. Compilation details, including source of material, names of draftsmen, and dates of compilation and drafting. A revision number if necessary.

6. Name and address of map publisher.