ICSM GUIDE NG71

GUIDE TO ICSM QA SPECIFICATION G71
ROAD CONSTRUCTION SURVEYS

NOTICE

This is a guide to QA Specification G71 *Road Construction Surveys*, which is a companion document to SP1 *Standards and Practices for Control Surveys*. The Specification is approved for publication by the Intergovernmental Committee on Surveying & Mapping (ICSM).

ICSM's QA Specification G71 is based on the NSW Roads & Traffic Authority's Specification G71 *Construction Surveys*.

The author of this document and Specification G71 is the Transport Authorities Survey And Mapping (TASAM) Group, comprised of the chief surveyors of road authorities throughout Australia. The QA Specifications were developed for use with roadworks and bridgeworks contracts let by a roads authority or local council. Roads authorities only use the QA Specification in conjunction with their other standard form documents and under the supervision of professional civil engineers who are trained and experienced in roadworks and bridgeworks. Roads authorities do not use the QA Specification for any other purpose and do not consider it suitable for use for any other purpose.

If you use this document for any purpose which is not consistent with the above (including, without limitation, for carrying out any construction, engineering, maintenance or other work), you do so at your own risk.

Alterations, amendments, additions and revisions to this document may only be made with the approval of the RTA Manager Surveying, representing the TASAM Group.

The Controlled Copy of this document resides on the ICSM website. Printed copies of the document are uncontrolled.

ICSM GUIDE NG71

GUIDE TO ICSM QA SPECIFICATION G71
ROAD CONSTRUCTION SURVEYS

REVISION REGISTER

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 1/Rev 0		Initial issue	SM, RTA	12.11.09

ICSM GUIDE NG71
GUIDE TO QA SPECIFICATION G71

GUIDE TO ROAD CONSTRUCTION SURVEYS

VERSION FOR: Publication
DATE: 12 November 2009

CONTENTS

CLAUSE **PAGE**

PART I - GUIDE NOTES AND MODEL PROCEDURES FOR PREPARATION OF SURVEY DOCUMENTATION

The initial section of this Guide contains guide notes for the preparation of documentation to comply with the requirements of G71 and quality assurance requirements set out in AS/NZS ISO 9001.

It also contains sample procedures that are considered to be capable of achieving the standards of accuracy specified for the Survey Control Network and the Orders of Accuracy by traditional survey methods and by GNSS techniques as set out in Specification G71.

In the sample procedures, the corresponding clause numbers in Specification G71 which the procedures relate to are quoted in the headings.

Contractors may use these sample procedures to meet the requirements of G71 or develop their own procedures provided they can verify that their procedures are capable of achieving the specified Order of Accuracy.

A GUIDE NOTES

A1 PURPOSE OF GUIDE NOTES

The aim of these guide notes is to guide contract surveyors on how to set up a quality system for survey in accordance with G71 and to create a consistent approach for surveillance bodies.

Documentation for survey must be provided in accordance with the AS/NZS ISO 9001 and Specification G71. The survey quality system, although written for survey, should be integrated into the quality documentation for the whole project. This is to ensure that the quality documentation encompasses all work carried out on the project.

A2 SCOPE OF SURVEY

G71 defines the scope of survey as all measurement, calculation and record procedures necessary to:

(a) set out the Works;

(b) verify conformity to the Drawings and Specifications in relation to dimensions, tolerances and three dimensional position; and

(c) determine lengths, areas or volumes of materials or products, where required for measurement of work.

As defined by (b) and (c), all surveys for conformity verification and determination of quantities require preparation of procedures for each product such as batters, pavements, kerb lines or earthworks, wherever conformity and/or quantities are specified by the contract.

For surveys covered by (a), a particular set out is defined as part of survey whenever it requires measurement and calculation to set out. The critical point is to determine if calculations are necessary. Where measurements for a set out can be made by other people on the project, without calculation or the use of specialised surveying equipment, and still attain the required accuracy, then that set out is not considered as part of survey.

Generally, set out not covered by survey would be that part of the Works not having a critical spatial tolerance and is in close proximity to a verified feature, which can be either a product or a set out mark.

Example: To set out batters requires both measurement and calculation to determine the existing ground level, and it is therefore considered to be part of survey. But where the batters have been built, it is not likely that measurements and calculations would be required to set out unlined catch drains that run parallel to the batter. If the catch drains are to be constructed after the batters, as explained, the set out of them would not be considered to be part of survey.

However, if required by the specifications, survey may be necessary to provide level control where the slope of the ground approaches 1% grade.

A3 PREPARE PROCEDURES FOR EACH ACTIVITY INVOLVING SURVEY ON THE PROJECT.

The link between survey and quality control provides an understanding why each activity involving survey on the project requires a separate survey procedure.

The set out requirements of survey controls the spatial requirements of the project. This role is critical to ensure that all components of the project mesh together by ensuring that individual components will meet their specified tolerances for position, size and shape. This will enhance quality by enabling such outcomes as:

- Drainage structures that are constructed in segments joining correctly and linking with existing drainage structures or features.
- Pavements surface levels that will provide the desired ride quality and design pavement thickness.
- Clearing lines that will require only the minimum amount of vegetation to be cleared.
- Earthworks carried out to produce pavement of correct width with minimal waste of materials or labour.
- Precast girders placed correctly in position on previously constructed bearing pads.

Survey's role for set out is to promote quality by providing set out that is capable of delivering conformity of the products' spatial tolerances. This should be the objective when preparing surveying set out procedures.

Conformity surveys provide verification of the spatial tolerances for payment purposes as well as measurements to track improvement in construction processes. This allows development of specifications that reflect industry standard.

Separate surveying procedures must be prepared for each individual activity rather than one generic procedure for set out and one generic procedure for conformity, due to the following reasons:

1. The different Orders of Accuracy required for different construction activities requiring different surveying procedures. For example, heights for batters have a much larger tolerance than heights for pavement surface control.

2. Clarification of the information that is provided to construction crews for the next stage of process after the survey is completed. This includes: marks placed, what is written on the marks and if any reports or diagrams are produced. This information also aids surveillance crews.

3. Providing a complete record of how each process was carried out, including survey. This aids problem solving, process analysis and improvement.

A4 SURVEY PROCEDURES MUST BE CAPABLE OF ATTAINING THE SPECIFIED ORDERS OF ACCURACY

Survey procedures and equipment used must relate to the attainment of the spatial tolerance nominated in technical Specifications.

Factors that will affect accuracy of traditional survey techniques include:

- Equipment;
- Lengths of sight lines (due to the effects of curvature, refraction, sighting accuracy, angular error of instrument)
- Height of sight lines (for refraction);
- Integrity of the Survey Control Network;
- Method of measuring angles;
- How many times distance observed, and by what method;

- Atmosphere corrections;
- Conversion to the grid datum;
- Stability and suitability of marks placed;
- Nearby traffic/construction disturbances.

Procedures must adequately address the relevant factors listed above where traditional survey methods are used. If an item has been left out of the procedure, it cannot be assumed that the item will automatically be carried out during the survey. Hence, it should be included in the procedure. The amount of information provided should be appropriate to the accuracy required. Generally, for traditional survey techniques, the higher the accuracy required for the work, the more of the points listed above should be addressed.

There is no need to rigorously describe basic survey methods, such as the four-fold method of reading angles. Competent surveyors should understand such methods. What is more important is to say when that method will be used.

Similarly, if applying atmospheric corrections, no extra explanation is necessary. The field notes should show what readings were taken and the calculations show how it was applied.

A5 INCLUDE SURVEY CHECKS TO VERIFY THAT THE SURVEY IS CORRECT

This reflects the QA philosophy of "right first time". Checks should be included in survey procedures to assure that they have achieved the required accuracy without error.

Survey checks should identify the following types of errors:

- Systematic errors;
- Instrument errors or equipment calibration errors;
- Errors in information such as control marks, or design information;
- Human error.

Preferably the checks should be independent of the surveying process being checked. Redoing the same survey process as a check is discouraged and should only used as a last resort (as too often the same mistake is made again).

Examples of independent checks include:

- Closed traverse loops;
- Checking distances between points radiated;
- Check shots to survey control marks in electronic tachometry surveys;
- Checking distances to other features whose position has been verified.

The objective is to assure that the survey is correct when completed. In this regard, an honest effort must be made to identify parts of the survey process that could produce errors and make every effort to assure against this happening. Examples of errors during the survey process include: measuring the heights of instruments and targets, transcription and reading errors, document and data control, markings placed on stakes, offset measurements and disturbance of the survey control network.

Surveyors should describe the survey check adopted and state the tolerance for rejection of the survey. The tolerance should reflect the checking method and the required accuracy for the survey. The procedure must ensure that the survey is not used by the next stage of the process before all checks have been carried out and the survey is verified as being correct.

Information supplied by the surveyor to construction personnel should be defined in the project's quality documentation to ensure that notations on pegs, and reports, are understood. This information also assists site surveillance.

A6 PREPARE DIFFERENT PROCEDURES FOR SET OUT AND CONFORMITY VERIFICATION

This reflects the requirements of G71 which requires that:

1. Product conformity surveys must adopt methods that ensure independence from methods used to set out the work.
2. Where possible, measurements are to be taken directly from survey control marks and not from marks used to set out the product.
3. Sampling of the product for verification purposes should not be restricted to the location of points used for set out.
4. Sampling is to be undertaken in a random or unbiased manner.
5. The contractor must submit a Survey Report verifying conformity for each lot or component where design levels, position and/or tolerances have been specified.

The Drawings and Technical Specifications must be carefully studied to determine which products need Survey Reports verifying conformity. These are generally, but not limited to, such products as pavement courses, batters, kerb lines, longitudinal and transverse drains.

Survey Reports verifying conformity are to be issued for each conforming product lot. The contractor must issue a Nonconformity Report (NCR) where a survey for conformity verification purposes finds that a lot does not conform, with the conformity verification survey attached.

When nonconformity is found, a Survey Report verifying conformity can only be issued after the Principal has agreed to the disposition and the NCR closed out by the Contractor. This may be the original conformity verification survey if the Principal accepts the product "as is". If rework is necessary, then a new survey to verify conformity is also necessary.

For pavement courses, if a construction procedure requires the surveyor to assist in positioning of the layer during construction, or during reworking, then those observations must not be used in the Survey Report verifying conformity. A fresh survey must be completed to verify conformity, independent of the construction personnel, of the whole lot after set out is completed and the course constructed to ensure that readings are unbiased.

B SAMPLE PROCEDURES

B1 SURVEY ACCURACY OF THE SURVEY CONTROL NETWORK

(Refer G71, Clause 2.2.)

Note: All Class standards of accuracy refer to SP1.

B1.1 Control for General Construction Activities (G71, Clause 2.2.1.1)

B1.1.1 Horizontal Control - by Traditional Survey Methods

Table NG71.1(a) – Class C Horizontal Control by Traditional Survey Methods

Distance Measurements	Angular Measurements	Calculations
(a) Measure pressure to nearest 3 millibars. (b) Measure temperature to the nearest 1°C. (c) "Dial in" appropriate atmospheric correction for pressure and temperature readings. (d) Measure lines from both ends to tripod mounted reflectors. (e) At least 5 readings from each end. (f) Remeasure line if difference between measurements from each end of the line exceeds 5 mm + 7 ppm (parts per million).	(i) 1. Two arcs for each angle or direction, where one arc is one reading on face left and one reading on face right. Reject and re-observe if difference between the two arcs exceeds 12 seconds for lines greater than 30 metres and more than one (1) minute for lines less than 30 metres. or, 2. Four fold angle method Reject if difference between mean of first two readings differs from the mean of all four readings by more than 5 seconds, for lines greater than 30 metres and more than 20 seconds for lines less than 30 metres. (ii) Close angles by a closed traverse or commence on two established survey control marks and close bearing onto two other established survey control marks. No survey control mark shall be left "hanging" at the end of a radiation. Investigate if angular misclose is greater than $10\sqrt{n}$ seconds of arc, where n is the number of angles measured.	(A) Apply appropriate grid conversion to reduce all distances to the datum plane specified by the Contract. Include correction for N*, the spheroid / geoid separation, when reducing distances to the datum plane. (B) Where the survey places additional survey control marks by establishing a braced network with redundant measurement, use a least squares adjustment program, such as HAVOC. (C) Bowditch adjustment is not recommended for long thin traverses that traverse either side of a road but may be suitable when placing additional marks by traversing between established marks with an independent angular close. (D) Carry out a return traverse to the start mark if the misclose between established marks is greater than 1:20,000. (E) Reduce all coordinates to the datum shown on the contract Drawings.

* Dividing N by 6 gives the correction in parts per million to distances, e.g. where N = 36, (in north-east NSW) the ppm error is 6. State and Territory bodies responsible for geodetic control surveys can provide assistance calculating N

B1.1 Control for General Construction Activities (cont'd)

B1.1.2 Horizontal Control - Class B by GNSS Techniques

Equipment:

(a) Use only GNSS receivers capable of recording carrier phase observations.

(b) If using real time GNSS equipment, authorisation for frequency to operate a two-way radio is required from Australian Communication Authority for GNSS operation.

(c) Braced support for the antenna pole.

Procedure:

(i) The survey control network must have a configuration based on established survey control techniques that is well braced with redundancies.

(ii) Completed horizontal measurements must form a closed figure.

(iii) Apply threshold setting of 10 mm for horizontal and 20 mm for vertical coordinates for real time GNSS techniques.

(iv) Observe two independent baselines to each survey control mark, plus three independent baselines to 10% of the survey control marks. The minimum time recommended by the manufacturer between occupations of the same survey control mark applies.

(v) Antenna heights between re-occupation of the same station must be changed by at least 0.1 metres unless set up on a pillar or fixed length pole.

(vi) For each kilometre of the Works, occupy at least two established marks of the State Control Network with published coordinates by the relevant State or Territory land management authority, of accuracy of at least 2 for horizontal and 3 for vertical.

(vii) Investigate where difference is greater than 15 mm + 3 ppm (parts per million) for horizontal and 25 mm + 8 ppm for height. Reject control where difference is greater than 25 mm + 5 ppm for horizontal and 60 mm + 12 ppm for height.

(viii) Compute the parts per million component using distance to the nearest site with fixed coordinates.

(ix) Adjustment must be by least squares and not the arithmetical mean value.

(x) Adjustment must show quality checks for both horizontal and vertical coordinates.

(xi) Where practical, check distance between adjoining survey control marks by conventional survey methods to verify coordinates.

(xii) The effects of multipath (bounced GNSS signal that affects the horizontal and height values) must be understood and appropriate actions taken. Multipath environments include; traffic lights, microwave repeater towers, tree foliage, metal fences, surfaces and signs, grassed or steep slopes and near structures, such as buildings and bridges.

These GNSS procedures have been developed from Roads & Traffic Authority (NSW) procedures, SP1 and Surveyor General's Direction (NSW) number 9 and are applicable to Real Time GNSS equipment. Static GNSS procedures are acceptable but these do not offer the speed and flexibility of Real Time (RTK) GNSS.

Please note that heights by Real Time GNSS are not suitable for the General Construction Activities Control.

B1.1 Control for General Construction Activities (cont'd)

B1.1.3 Vertical Control - Class LC by Differential Levelling

(a) Use equipment to at least the standard of an optical automatic level and calibrated wooden staffs.

(b) Use a staff bubble.

(c) Use stable change points.

(d) Carry out a two peg test daily when in use; adjust the instrument if error is equal to or greater than 3 mm in 60 metres.

(e) Use equal backsights and foresights to within an accuracy of 10% where practical.

(f) If using two staffs, use the levelling technique that involves one staff remaining at a particular change point for both fore and back sightings. To avoid staff index error, ensure an odd number of change points between benchmarks and use the same staff for the first backsight of the level run and the last foresight on the closing benchmark.

(g) The maximum sight distance is 60 metres (refer definitions).

(h) Close run onto established bench mark or level both ways if misclose is greater than $12\sqrt{d}$ mm, where d is the length of the level run in kilometres.

(i) If available, use at least 3 known benchmarks for proving the height datum.

(j) Where the survey is not completed in one level run, level at least two survey marks to verify any disturbance of the marks before continuing the level run.

B1.1.4 Vertical Control - Class B by EDM Trigonometrical Heighting

(a) Use only one ranging pole without adjusting its height during each survey.

(b) The minimum height of sight lines is 1.5 metres, (refer definitions).

(c) The maximum sight distance is 100 metres, (refer definitions).

(d) Restrict angle of elevation or depression to less than 8 degrees where possible.

(e) Set up the total station at the approximate midpoint between two survey control marks.

(f) Sight face left and face right to the ranging pole placed in turn on each of the survey control marks.

(g) Use the height differences shown on the instrument display as the height difference between the total station and the targets.

(h) Determine the mean face left and face right readings on both survey control marks. The difference between the mean readings of both survey control marks determines the height difference between the survey control marks, by subtracting the backsight from the foresight, taking into account the algebraic sign of the means.

(i) If carrying out a level run, move beyond the second mark to the mid point between the second and third marks and repeat steps (i) to (viii).

(j) Close the run onto an established bench mark or level both ways if the misclose is greater than $12\sqrt{d}$ mm, where d is the length of the level run in kilometres.

(k) If only the height difference between two survey control marks is being determined, adjust the height of the total station and repeat steps (i) to (viii), determining the height difference from the second survey control mark back to the first survey control mark.

B1.2 Earthworks Control (G71, Clause 2.2.1.2)

B1.2.1 Horizontal Control - by Traditional Survey Methods

Table NG71.1(b) – Class E Horizontal Control by Traditional Survey Methods *

Distance Measurement	Angular Measurement	Calculations
(a) "Dial in" appropriate seasonal atmospheric correction for temperature and pressure (b) Measure lines from one end to a stable reflector. (c) At least 3 readings for each line (d) Remeasure line if difference between measurements exceeds 10 mm + 7 ppm (parts per million)	(i) 1. One arc for each angle or direction, where one arc is one reading on face left and one reading on face right, or, 2. Four fold angle method Reject if difference between mean of first two readings differs from the mean of all four readings by more than 20 seconds, for lines greater than 30 metres and more than 60 seconds for lines less than 30 metres. (ii) Check angles by a closed traverse or commence on two established survey control marks and close bearing onto two other established survey control marks. No survey control mark shall be left "hanging" at the end of a radiation. (iii) Investigate if angular misclose is greater than $20\sqrt{n}$ seconds of arc, where n is the number of angles measured.	(A) Adjustment by Bowditch or PO. Carry out a closed traverse mark if the misclose is greater than 1:6,000. (B) Reduce all coordinates to the datum shown on the contract Drawings or determine coordinates using ground distances.

* Radiations from two established survey control marks are acceptable, provided the distance and angle procedures in Table NG71.4 are followed and differences between coordinates by measurements from the two survey control marks are less than 30 mm for both the easting and northing.

B1.2 Earthworks Control (cont'd)

B1.2.2 Vertical Control - Class LE by Differential Levelling

(i) Use equipment to at least the standard of an optical automatic level and calibrated wooden staffs.

(ii) Use stable change points.

(iii) Carry out a two peg test daily when in use; adjust the instrument if error is equal to or greater than 3 mm in 60 metres.

(iv) Use equal backsights and foresights to within an accuracy of 10% where practical.

(v) The maximum sight distance is 100 metres, (refer definitions).

(vi) Close run onto established bench mark or level both ways if misclose is greater than $36\sqrt{d}$ mm, where *d* is the length of the level run in kilometres.

B1.2.3 Vertical Control - Class E by EDM Trigonometrical Heighting

(i) Set total station over survey control mark or remote from survey control marks. Where set over survey control mark measure height of total station above the survey control mark.

(ii) The minimum height of sight lines is 0.2 metres.

(iii) The maximum sight distance is 250 metres.

(iv) Sight face left and face right to the ranging pole placed in turn on each of the survey control marks.

(v) Allowing for the instrument and target heights, use height differences shown on the instrument display to calculate the height differences between the total station and the survey control marks.

(vi) Use height differences to calculate heights of survey control marks.

(vii) Verify the calculated heights of the survey control marks by adjusting the height of the total station and repeating steps (i) to (v), or repeat steps (i) to (v) using a different bench mark.

(viii) Repeat if the misclose is greater than $36\sqrt{d}$ mm, where *d* is the length in kilometres.

B1.2.4 Vertical Control - Class B by GNSS Techniques

Procedures used for horizontal control for the General Construction Activities Control for Class B by GNSS also apply for vertical control for the Earthworks control.

B1.3 Control for Specialised Construction Activities (G71, Clause 2.2.1.3)

B1.3.1 Horizontal Control - by Traditional Survey Methods

Table NG71.1(c) – Horizontal Control by Traditional Survey Methods to Achieve Local Uncertainty of 4 mm

Preliminary	Distance Measurements	Angular Measurements	Calculations
Design the control network following established control survey practices with well braced geometry and sufficient redundancies to achieve the required accuracy of a Class B network.	(a) Set the instrument's atmospheric correction to zero in the field. (b) Measure temperature using a calibrated thermometer with readings estimated to 1°C. (c) Measure pressure using a calibrated barometer with readings estimated to 1 hPa. (d) Take wet bulb readings or relative humidity readings. (e) Take meteorological measurements at both ends of each line before and after measurement. (f) Allow sufficient warm up time of the EDM as specified by the manufacturer. (g) Take 10 readings for each line then re-point and electronically realign instrument and take another set of 10 readings. (h) Measure each line from both ends. (i) Remeasure if range of fine readings is greater than 2(5+d)mm, where d is the distance in kilometres. (j) Measure lines between 2 hours before local noon and 2 hours before sunset.	(a) Observe angles at any time other than between 1200-1500 (LMT). (b) Measure two sets of six rounds of directions using zero settings for each round of: - 00° - 30° - 60° - 90° - 120° - 150° (c) The residuals in any set should seldom exceed 3" of arc and never exceed 5". (d) Range between sets should seldom exceed 3" and never exceed 4" of arc.	(A) Calculate atmospheric corrections and apply to each line. (B) Apply appropriate grid scale factor to each line. For the Bridge Survey Control the grid scale factor is one (1). (Refer Clause 5.5.1). Include correction for N*, the spheroid / geoid separation, when reducing distances to the datum plane. (C) Carry out a rigorous least squares adjustment using software that calculates standard (1σ) line error ellipses (relative ellipses) and verify that statistical tests are satisfied. (D) The software must provide evidence that the local uncertainty is less than 4 mm. * Dividing N by 6 gives the correction in parts per million to distances, e.g. where N = 36, (in north-east NSW) the ppm error is 6.

Controls for Specialised Construction Activities have limited application on road construction projects, but are applicable for some bridge construction. Class C procedures will be sufficient for most road projects.

Controls for Specialised Construction Activities reduction procedures require the use of rigorous least squares software and output that provides evidence that the nominated local uncertainty has been achieved. The Principal may ask to view the output as evidence of the integrity of the coordinates.

B1.3 Control for Specialised Construction Activities (cont'd)

B1.3.2 Vertical Control - Class LA by Differential Levelling

(a) Use electronic digital level and compatible calibrated staffs, the combination of which has a specified accuracy of equal to or better than 0.5 mm standard deviation for a 1 kilometre double level run.

(b) Use staff bubble.

(c) Use stable change points.

(d) Carry out two-peg test and calibrate using instrument's calibration routine if error is equal to or greater than 0.5 mm in 50 metres.

(e) Equal backsights and foresights to within an accuracy of 5% where practical.

(f) The minimum ground clearance of sight lines is 0.5 metres, (refer definitions).

(g) If using two staffs, use the levelling technique that involves one staff remaining at a particular change point for both fore and back sightings. To avoid staff index error, ensure an odd number of change points between benchmarks and use the same staff for the first backsight of the level run and the last foresight on the closing benchmark.

(h) The maximum sight distance is 40 metres, (refer definitions).

(i) Use two way level runs.

(j) The maximum misclose permitted is $4\sqrt{d}$ mm, where d is the length of the level run in kilometres.

(k) Use at least 3 known benchmarks for proving the height datum.

(l) Where the survey is not completed in one level run, level at least two survey marks to verify any disturbance of the marks before continuing the level run.

B2 SURVEYING TECHNIQUES

B2.1 General (G71, Clause 4.1)

Note: All Class standards of accuracy refer to SP1.

Procedures in this Clause were developed from Part B of SP1 and the NSW Surveyor General's Directions to reflect industry standards.

B2.2 Radiation (G71, Clause 4.2)

For radiations, you may set the total station directly over a survey control mark or set it remotely from survey control marks and determine its position by a resection procedure. For the purpose of this Clause, the position of a resected station is considered to be a temporary unmarked survey control mark.

B2.3 Radiation from Survey Control Marks (G71, Clause 4.2.1)

(a) Set total station over a survey control mark.

(b) Place tripod mounted prism over another survey control mark for a backsight and at least one other survey control mark as a check.

(c) Apply appropriate grid scale factor to convert all ground distances to the required datum.

(d) Measure temperature and pressure with a calibrated thermometer and barometer and apply appropriate atmospheric correction to all measurements.

(e) Compare measured distance to backsight with calculated distance before commencing radiations, as well as bearing and distance to the check survey control mark.

(f) Ensure distance to backsight is at least twice the distance of the longest radiation sight distance.

(g) The maximum radiation sight distance permitted is 70 metres, (refer definitions).

(h) Read one arc to place set out marks or to determine position of features, where an arc is one reading on face left and one reading on face right of the total station.

(i) Sight directly to the mark/feature, or to a short ranging pole or a tripod mounted prism placed over the mark/feature.

(j) Measure the distance on both faces to a short ranging pole or a tripod mounted prism.

(k) For setting out features, measure directly to set out mark when set in its final position, and

(l) Check radiations by comparing field measurements between radiated marks or feature points with calculated distances.

The local uncertainty of this procedure is 5 mm. Where the radiation distance is increased from 70 metres to 130 metres, then the local uncertainty is estimated to be 12 mm.

B2.4 Radiation from Resected Stations (G71, Clause 4.2.2)

Table NG71.3 lists the techniques for different orders of accuracy when the radiations are made from a resected station. Where the radiation is made from a survey control mark the survey will achieve at least the same order of accuracy as that from a resected station.

The following techniques apply to Orders of Accuracy 1H to 5H in addition to those listed in Table NG71.3:

(a) Re-sight backsight at completion of each survey or hourly, whichever is the lesser.

(b) Read angles for radiations on one face only, subject to the checks listed in Table NG71.3.

(c) Measure distances once only, subject to the checks listed in Table NG71.3.

(d) Electronically record all radiation measurements and include these in the quality records for the Contract.

(e) Distance to the survey control mark adopted as the backsight must be greater than the longest radiation of the survey for Orders of Accuracy 0H, 1H, 2H, and 3H. For lower Orders of Accuracy the distance to the backsight must be more than the greater of 70 metres or half the longest radiation.

Table NG71.3 – Orders of Accuracy -Radiation Techniques

Order of Accuracy (1)	Local uncertainty (2)	Sight Distance Range (m) (3)	Ranging Pole (4)	No. Survey Marks for Resection (5)	No. of Arcs (6)	Grid Scale Factor (7)	Backsight To (8)	Survey Checks, one of (9)
0H	5 mm	00 – 70	See Clause NG 4.2.1 for procedure. Where sight distance is 130 m accuracy is 5 mm.					
1H	5 mm	00 – 70	Short	3	1	Apply	Tripod	a, b or c
2H	12 mm	00 – 100	Standard	3	1	Apply	Ranging pole	a, b or c
3H	25 mm	0 – 100	Standard	2	1	Apply	Ranging pole	a, b, c or d
4H	125 mm	200 – 400	Standard	2	0.5	Apply	Ranging pole	a, b, c or d
5H	500 mm	250 +	Long	2	0.5	N A	Ranging pole	c, e or f.

Notes for Table NG71.3:

(1) A reference notation for each Order of Accuracy.

(2) Ninety five percent confidence level of relative uncertainty with respect to adjacent survey control marks, (see Clause 1.3 Definitions).

(3) Range of sight distances from the total station, including to survey control marks used to establish coordinates of the total station.

(4) Ranging Pole:

- Short ranging pole – less than 300 mm in length;
- Standard ranging pole – calibrated standard metal pole as part of ancillary equipment of the total station extended to height not greater than 1.9 metres;
- Long ranging pole – generic arrangement that may include a reflector attached to top of a 5 metre pole or surveyor's levelling staff.

(5) Number of survey control marks necessary for the resection for each Order of Accuracy.

(6) Number of arcs to the survey control marks used for the resection, where one arc is one reading on face left and one reading on face right of the total station.

(7) The Grid Scale Factor converts ground distances to equivalent distances on the grid datum adopted on the Drawings.

(8) Shows what is placed on survey control marks used for a backsight.

(9) Survey Checks that can be used to verify the accuracy of radiations:

(i) Set over mark placed, or feature radiated, and check to two other known marks, either angle, distance or both;

(ii) Radiate marks/features from a different survey control mark;

(iii) Measure between marks placed or points radiated;

(iv) Recheck angle, on other face, and distance from the same survey control mark;

(v) Measure between mark and a known feature or a survey control mark;

(vi) Visual inspection; and

(vii) Checks contained within software for checking radiations when locating existing features. The use of this check will vary depending on the software and purpose of the survey.

B2.5 Height Determination (G71, Clause 4.3)

B2.5.1 Differential Levelling

Order of Accuracy 1V

The procedure described in Clause NG 2.2.1.3, using a calibrated digital level and staff, is capable of achieving the accuracy required for Order of Accuracy 1V.

Order of Accuracy 4V

The procedure described for differential levelling of survey control marks in this Guide (Clause G71, 2.2.1.1), using an optical automatic level and staff, has an estimated local uncertainty of 6 mm, provided the height difference between the benchmark and surveyed points are less than 10 metres. For height differences greater than 10 metres, instead of calibrated wooden staffs, use precise levelling staffs with calibration certificates. This procedure is capable of meeting the requirements of Order of Accuracy 4V.

B2.5.2 EDM Trigonometrical Heighting Procedures

Table NG71.4 contains procedures for achieving Orders of Accuracies 2V to 6V using EDM Trigonometrical Heighting procedures. The table shows two methods of determining the height of the total station;

(a) By direct measurement by tape from the total station to the survey control mark over which the total station is set, and

(b) By a resection procedure using direct measurements by the total station to established survey control marks.

Resection procedures provide the higher order of accuracy for height determination and must be adopted for Orders 2V and 3V. Direct Measurement by tape to the survey control mark over which the total station is set is allowable for Orders 4V and 5V. However, the estimated accuracy for 4V is changed to 10 mm but the accuracy of 5V is unchanged. Resection procedures for Order 6V are allowable but this does not change their estimated accuracy.

Table NG71.4 – Orders of Accuracy for Vertical Control Height Determination Procedures

Order of Accuracy (1)	Local Uncertainty (2)	Max. Sight Distance (m) (3)	Ranging Pole (4)	Min. Height of Sight Line (5)	Height Determination of the Total Station (6)		Vertical Circle Index Error (7)	
					Method	No. of Marks for Resection	No. of Arcs	Frequency of Measurement
1V	0.7 mm	Differential levelling procedure for digital level – see Clause NG 4.3.1.1						
2V	1.5 mm *	00 – 75	Standard	1.5 m	Resection	3	3	Each set up
3V	3 mm *	00 – 100	Standard	1.5 m	Resection	3	1	Each set up
4V	6 mm *	00 - 100	Standard	1.5 m	Resection	2	1	Each Set up
5V	20 mm	100 – 200	Standard	1.5 m	Resection	2	1	Daily
6V	100 mm	200 – 300	Long	Nil	Tape	NA	1	Daily

* See Note (8) Angle of Inclination and Declination

Notes for columns in Table NG71.4:

(1) Notations of Order of Accuracy.

(2) Ninety five percent confidence level of relative uncertainty with respect to adjacent survey control marks, (see Clause 1.3 Definitions).

(3) Range of Sight Distance.

(4) Ranging pole:

- Standard ranging pole – calibrated standard aluminium pole as part of manufacture's ancillary equipment included with the total station.
- Long ranging pole – reflector attached to top of 5 metre pole or staff.
- For 2V, 3V and 4V use only one ranging pole and reflector combination for each set up of the total station, including observations to the survey control marks to determine the height of the total station. To negate staff errors, the length of the ranging pole must not change during height determination for each set up of the total station.
- For 5V, two ranging poles are acceptable, provided they are set to an equal height by sighting to each in turn placed on a the same point at a short sight distance and adjusted to give the same height difference to the total station.

(5) Minimum Height of Sight Line sets the height below which the sight line should not fall. No minimum height is set for 6V.

(6) Height Determination of the Total Station:

Orders of Accuracy 2V, 3V, 4V and 5V

- Determine height by measuring zenith angles and slope distances to survey control marks.
- Sight to each control mark on both face left and face right of the total station.
- Use the same ranging pole with its height fixed for sightings to each survey control mark, with the exception of 5V as outlined under note 4, Ranging Pole, above.
- All slope distances to the survey control mark must be less than 100 metres.
- Orders of Accuracy 2V and 3V require a minimum of three survey control marks and a rigorous adjustment by least squares with weighting of $^{1}/_{d_i^2}$, where d_i is the sight distance to the survey control mark.
- Orders of Accuracy 4V and 5V require observations to two survey control marks with the mean of the four height determinations adopted as the height of the total station.
- Orders of Accuracy 6V may determine the height of the total station by setting over a survey control mark and by tape measurement down to it.

For Orders of Accuracy 2V and 3V, if the total station is set over a survey control mark, measurement of its height above the survey control mark must not determine the height of the total station. Nor is it be used in any adjustment with heights by EDM trigonometrical heighting to determine the height of the total station. This also applies to 4V when a resection procedure determines the height of the total station.

(7) Vertical Circle Index Error

Order of Accuracy 2V

- Requires measurement of the vertical circle index error and application to the measured correction for each resection.
- The mean of three (3) arcs shall determine the vertical circle index error, where an arc is one measurement on face left and one measurement on face right of the total station to a stable horizontal reference point.
- The same vertical circle index correction applied to the total station for the resection must also be used for determining heights of surveyed features.

Orders of Accuracy 3V and 4V

- Require measurement of the vertical circle index error and application of the vertical circle index correction for each set up,
- by measurement of a single (1) arc to a stable horizontal reference point.

Orders 5V and 6V

- Require measurement of the vertical circle index error and application of the vertical circle index correction daily,
- by measurement of a single (1) arc to a stable horizontal reference point.

(8) * Angle of inclination and declination

Estimated accuracies assume that the angle of inclination or declination is less than 10 degrees.

Where angle inclination or declination is greater than 10 degrees, following the procedure described in Table NG71.4 will give local uncertainties of 2V = 3 mm, 3V = 6 mm and 4V = 8 mm.

Where EDM trigonometrical heighting is used to transfer heights with a local uncertainty of better than 6 mm and the angle of inclination or declination is greater than 10 degrees then follow procedures for 2V, 3V or 4V with the following changes:

- Use a calibrated ranging pole with an accuracy of at least 1 mm for the resection;
- Note the height of the total station by the resection procedure;
- Sight to a tripod mounted prism set up on the area to which the height is being transferred;
- Determine the height of the reflector by EDM trigonometrical heighting by reading one arc to the reflector;
- Set up the total station at a location at the approximate height of the reflector and in its close proximity;
- Use the total station and the calibrated ranging pole to transfer the height of the reflector to marks and/or features in the area as required.
- Close the level run onto at least one survey control mark by using a tripod mounted reflector to transfer heights, as described above.

PART II - COMMENTARY ON CLAUSES IN SPECIFICATION G71

FOREWORD

ICSM COPYRIGHT AND USE OF THIS DOCUMENT

When this document forms part of a contract

This document must be read with all documents forming the Contract.

When this document does not form part of contract

Printed copies of this document are not controlled. Observe the notice that appears on the first page of the copy controlled by ICSM. A full copy of the latest version of the document is available on the ICSM website.

REVISIONS TO EDITION 1

This document is ICSM Specification G71 Edition 1 Revision 0 — November 2009

All future revisions to ICSM G71 Ed1/Rev0 (other than minor editorial and project specific changes) will be indicated by a vertical line in the margin as shown here.

PROJECT SPECIFIC CHANGES

Any project specific changes have been indicated in the following manner:

(a) Text which is additional to the base document and which is included in the Specification is shown in bold italics e.g. ***Additional Text***.

(b) Text which has been deleted from the base document and which is not included in the Specification is shown struck out e.g. ~~Deleted Text~~.

Guide ICSM NG71 has been prepared it assist readers of ICSM G71 with guidance in the application of G71 to road construction projects.

Normal shaded text *replicates ICSM G71. The text in italics provides commentary on the various G71 clauses.*

QA SPECIFICATION G71

ROAD CONSTRUCTION SURVEYS

1 GENERAL

1.1 SCOPE

This Specification details the survey requirements for meeting spatial tolerances and quality assurance requirements specified in QA road construction contracts, including:

(a) Developing and maintaining the quality management system requirements for survey, including equipment, in accordance with the relevant clauses of ISO 9001 as set out in this specification;

(b) Maintaining the integrity of the Survey Control Network;

(c) Survey techniques for attaining the accuracies required by tolerances specified in the technical specifications;

(d) Additional survey requirements to meet specific needs of the Principal.

1.2 STRUCTURE OF SPECIFICATION

This Specification includes a series of Annexures that detail additional requirements.

1.2.1 Measurement and Payment

The method of measurement and payment is detailed in Annexure G71/B.

1.2.2 Schedules of HOLD POINTS and Identified Records

The schedules in Annexure G71/C list the Hold Points that must be observed. The records listed in Annexure G71/C are Identified Records.

1.2.3 Planning Documents

The Quality System must include each of the documents and requirements shown in Annexure G71/D and must be implemented.

1.2.4 Referenced Documents

Unless otherwise specified the applicable issue of a reference document is the issue current at the date one week before the closing date for tenders, or where no issue is current at that date, the most recent issue.

Standards, specifications and test methods are referred to in abbreviated form (e.g. AS 1234). For convenience, the full titles are given in Annexure G71/M.

.

1.3 DEFINITIONS

The terms “you” and “your” mean “the Contractor” and “the Contractor’s” respectively.

The following interpretations apply to terms used in this Specification:

"**Angle of inclination and declination**": angle of the line of sight above or below horizontal, respectively.

"**Drawings**": means the drawings that may be supplied to you at any time by the Principal, or the use which may be permitted by the Principal, for the purpose of the Contract;

"**Height of sight lines**": when used in relation to survey procedures, it refers to the minimum vertical distance from the line of sight to the natural surface.

"Hold Point:" a point beyond which a work process must not proceed without the Principal's express written authorisation;

"**ICSM**": Inter-Governmental Committee on Surveying and Mapping; the body responsible for coordinating Commonwealth and State agencies which contribute to surveying and mapping at a national level to ensure continued cooperation and technical standards. Its role includes developing survey standards and specifications.

"Identified Records": are records identified by the Principal as necessary to provide evidence of compliance with specified requirements and surveying procedures.

"**Line of sight**": straight line joining the total station, or any other survey instrument, to the target.

"**Local Uncertainty**": is the universally accepted measure of the quality of measurement by quoting a confidence interval about derived measurements. The ICSM defines Local Uncertainty in SP1 as: "the average measure, in metres at the 95% confidence level, of the relative uncertainty of the coordinates, or height, of a point(s), with respect to the survey connections to adjacent points in the defined frame". In this Specification, the Orders of Accuracy for horizontal and vertical measurements are also quoted as a local uncertainty.

"**Model**": refers to the electronic representation of the design prepared by CADD software to produce the Drawings. It also refers to surface models for conformance verification and quantity surveys.

"**Permanent marks**": survey control marks that are permanent by nature and are uniquely defined by alphanumeric characters to store attributes of the mark in State or Territory government records. They provide the framework for all surveys to be brought onto the State's Territory's geodetic survey.

"**Primary Survey Control Marks**": survey marks identified on the Drawings as primary survey control marks.

"Quality System": System to direct and control an organisation with regards to quality

"**Resection**": is a survey technique for determining the three dimensional coordinates of the total station, when set remotely from survey control marks, by measurements to more than one survey control mark. In this Specification, resection procedures must measure sufficient redundant data to enable a statistical adjustment, preferably by least squares, that calculates residuals for each measurement.

"**Residuals**": the difference between the original field measurement and the adjusted measurement when carrying out adjustments (least squares) where there are redundant measurements.

"**Sight distance**": when used in relation to survey procedures refers to the length of the sight line.

"**Survey Control Network**": the Primary Survey Control Marks plus any additional survey control marks placed to extend the Survey Control Network or to replace the primary survey control marks.

"**Survey infrastructure**": permanent marks and cadastral reference marks that reference the State or Territory's cadastre, as defined in their Surveying legislation. This may or may not include survey marks identified on the Drawings as primary survey control marks.

"**Survey Mark**": a survey peg, bench mark, reference mark, signal, alignment, level mark or any other mark used or intended to be used for the purpose of setting out, checking or measuring the work under the Contract.

"**Survey procedures**": methods to control parameters that affect the accuracy of survey techniques, such as a radiation procedure or height determination procedure.

"**Survey techniques**": a survey method, such as radiation, height determination or tacheometry surveys.

1.4 QUALITY ASSURANCE

1.4.1 Work Process Control

Treat survey as a separate application of work process control, and prepare documented procedures covering all measurement, calculation and records necessary to:

(a) set out the Works;

(b) verify conformity to the Drawings and Specifications in relation to dimensions, tolerances and three dimensional position; and

(c) determine lengths, areas or volumes of materials or products where required for measurement of work.

The term "Work process control" is used to signify that survey is a stand-alone activity (although integrated with other work processes on the project) that must be controlled in a similar manner to any other activity contributing to construction, such as soil testing or earthworks.

Where either an employee surveyor or a subcontract surveyor is engaged to carry out all or part of the survey, the survey procedures must describe how the survey process is controlled so that all the requirements of the Drawings and Specifications are met.

Include in the Quality System the survey procedures to be implemented.

Survey work must conform to this Specification and guided by ICSM NG71. Comply with the HOLD POINT described in Clause 4.1.

Include in your Quality System the responsibilities of qualified surveyors for survey control (refer Clause 1.4.2). Detail all construction activities requiring survey work. List the surveying tasks that are assigned to qualified surveyors and list the personnel who will perform survey work that is not assigned to qualified surveyors.

The contractor is required to document the procedures for surveying, which demonstrate that survey will be conducted as a controlled process. The procedure must include selection of survey equipment and surveying methods to achieve appropriate accuracy for specified construction tolerances. The documentation must include details of any surveying that is to be undertaken by other than qualified surveyors (e.g. a Foreman levelling from the survey control points placed by a surveyor) see notes under Clause 1.4.2..

See the Guide Notes at the front of this Guide for assistance in preparing survey documentation.

The survey procedures and equipment used must be appropriate for the attainment of the tolerances nominated in the Specification. The procedures must address all errors introduced by survey methods, including due allowance for the effects of:

(a) survey equipment capability and adjustment,

(b) integrity of the Survey Control Network,

(c) vertical refraction,

(d) the grid scale factor,

(e) the earth's curvature, and

(f) the geoid-ellipsoid separation.

1.4.2 Qualified Surveyors

Use only qualified surveyors to direct and take responsibility for all surveys. Surveyors must hold as a minimum a Diploma in Surveying qualification, or recognised equivalent, from a recognised tertiary institution, and possess at least two (2) subsequent years satisfactory practical experience in surveying. For surveys required under Clause 2.3.1 and Clause 3.4, use only a surveyor who is registrated or licensed to conduct land title surveys by the relevant Surveying Board and comply with the relevant Surveying legislation. Annexure .G71/A contains the relevant Surveying Board and Surveying Regulation for this Contract.

Because of the importance of survey, Clause 1.4.2 nominates minimum competency requirements for survey personnel who manage this work process (refer ISO 9001 Clause 6.2.1).

Survey activities such as lower order measurements and levelling from close established survey control marks or recovery pegs, setting of profiles etc, may be performed by appropriately trained and experienced personnel who do not have formal surveying qualifications, providing the qualified surveyor verifies that the methods being used are acceptable.

Contractors must verify that their work process documentation for survey control methods and equipment (see ISO 9001 Clause 7.5.1) addresses the construction tolerances specified for the project, before incorporating this information in the project quality plan. Under ISO 9001 Clause 7.4.3, Contractors have a responsibility to review survey control documentation provided by subcontract surveyors.

1.4.3 Equipment

Comply with ISO 9001 Clause 7.6 and any additional survey requirements listed in Annexure G71/A, in relation to survey equipment used for the works. The term “monitoring and measuring devices” in ISO 9001 Clause 7.6 applies to all survey instruments and ancillary equipment used for work under the Contract.

Electronic total stations and ancillary equipment used for survey tasks must meet the following standards:

(a) Electromagnetic Distance Measuring device (EDM) with the capability of measuring distances with the error having a standard deviation of less than 5 mm + 5 ppm;

(b) angular measurement error for both horizontal and vertical circles with a standard deviation of less than 3 seconds of arc;

(c) one second of arc minimum count;

(d) diametrical vertical circle reading and automatic tilt compensator; and

(e) a capability to electronically record and store field data such as horizontal and vertical angles, distances, point notation, target and instrument heights.

The electronic total station must have a calibration procedure and must be calibrated within 12 months prior to it being used for any survey task carried out for work under the Contract. It must also be calibrated immediately after repair.

All other survey equipment used on the project must have a calibration procedure and be in calibration at all times.

This Clause defines the minimum requirement for the total station and highlights the requirement that all survey measuring equipment must be calibrated. Other survey equipment requiring calibration includes:

- *Steel tapes*
- *Thermometers*
- *Barometers*
- *Levelling staffs.*

All parts of the quality management system element referring to monitoring and measuring devices as specified in ISO 9001 must be addressed to ensure equipment used is capable of obtaining the required accuracy. Survey equipment must be included in a Calibration Register, which may be specifically for survey or with other measuring and test equipment as part of a Project Calibration Register.

The Calibration Register should include the following:

- *Equipment identification label*
- *Serial number, Brand name and model number*
- *Calibration interval*
- *A calibration date, either due date or date of last calibration*
- *Calibration status (in or out of tolerance)*
- *Reference to calibration procedure.*

Calibration procedures should state:

- *How the equipment will be calibrated (work instruction)*
- *The calibration interval*
- *The acceptance criteria*
- *Actions to be taken where it is found to be out of tolerance*
- *Environmental factors to be addressed (e.g. atmospheric corrections)*
- *The procedure for the removal of uncalibrated equipment.*

Label equipment for identification of its calibration status. Calibration settings on the equipment must be secured.

1.4.4 Records

Treat survey records as quality records generated by the project in accordance with ISO 9001 Clause 4.2.4. Prepare procedures that describe the records system. The procedures must include the method of storing and indexing electronic records and name all computer software used for reduction of survey measurements and calculations.

Conformity verification field book pages must be clearly labelled, dated and signed by the surveyor with cross-indexed references to equipment used and lot/component identification. The Survey Reports generated must reference conformity verification field book page numbers.

Where automatic data recording systems are used for verification surveys, a print-out of both raw (field) data and reduced data must be retained in a similar manner as conventional field books, in addition to the electronic data.

1.4.4.1 Audit Trail

Survey records must be sufficient to provide objective evidence that the surveyor has completed all surveys in compliance with procedures and that all surveys attain the required accuracy. The survey records system must be indexed for easy retrieval of information and provide a clear audit trail for all surveys.

1.4.4.2 Storage

The surveyor must store survey records in a similar manner to other quality records generated by the project, in accordance with ISO 9001 Clause 4.2.4.

1.4.4.3 Hard Copy

At the time of survey, provide signed paper copies of survey reports verifying product conformity. Provide also paper copies of electronically collected survey data used for set out and product conformity surveys when requested by the Principal.

Survey data collected manually in traditional survey field books are part of the survey records. Survey field books must be clear and legible, showing the date, purpose, and location of the survey. Each survey field book must be indexed.

The surveyor must sign all paper copies of survey field measurements, data and reductions, survey reports, field books, diagrams and sketches used to set out the work, test the product for conformity or to determine quantities in accordance with the Specifications.

Where the surveyor radiates or determines height difference by EDM trigonometrical heighting to set out marks and uses computer software as an independent survey check, the field measurements, data and resulting computer reductions are part of the survey records.

Surveyor's field notes are a record of field observations and are therefore part of the quality records. As such they must be filed and kept with other quality records. On completion of project duties, surveyors must leave behind their original field notes, or a photocopy of them, on site when they leave.

Where the surveyor radiates or determines height difference by EDM trigonometrical heighting to set out marks and uses computer software as an independent survey check, the field measurements, data and resulting computer reductions are part of the survey records.

If any other survey information is produced electronically (e.g. by personal computer, pocket computer or work station) and is required to provide objective evidence that the procedure has been followed, then treat these results in a similar manner as other survey records.

1.4.4.4 Calibration Records

Calibration records of survey equipment are part of the survey records.

1.4.4.5 Nonconformity Register

The surveyor must maintain a register of any Nonconformity Reports raised on survey work carried out as part of the Contract in accordance with the Contractor's Quality System.

Records are an important component of any quality management system and survey records must be included with or linked to project records. They must show how the process will be, or was, carried out and evidence that the survey met requirements.

Nonconformity reporting is an important part of the improvement process . Survey nonconformities must be reported in a similar manner to other nonconformities that arise on the project.

1.5 SAFE SYSTEM OF WORK

Carry out all work in compliance with safety systems of work regulations and/or specifications listed in Annexure G71/A1.8. As a minimum, this requires documentation of a risk assessment of safety issues affecting survey work and the development of controls to reduce the safety risks to an acceptable level.

1.6 CARE OF SURVEY MARKS

Preserve and maintain in their true positions all Survey Marks. Unless the disturbance or obliteration has been caused by the Principal, its employees or agents, the cost of rectification will be borne by you.

2 THE SURVEY CONTROL NETWORK

2.1 INTEGRITY OF THE SURVEY CONTROL NETWORK

The Principal will provide you with the Primary Survey Control Marks and information necessary for setting out the Works. Take responsibility for these marks and additional marks that form the Survey Control Network and verify their integrity before commencing any survey activity.

HOLD POINT

Process Held:	Use of a survey control mark forming part of the Survey Control Network.
Submission Details:	Survey Report verifying coordination and level values of the survey control marks. Where requested, submit the procedure for replacing the affected primary survey control marks.
Release of Hold Point:	The Principal will consider the submitted documents and may inspect the mark, prior to authorising the release of the Hold Point.

All surveying procedures must include checks to verify that coordinates of survey control marks shown in the Survey Control Marks Register are correct at the time of survey.

The Survey Control Network defines the accuracy of all survey work carried out on the project and hence the spatial accuracy of the final product. The Drawings contain the Primary Survey Control Marks that are suitable and sufficient for setting out the works. These marks may include survey control marks that form part of the state's geodetic survey and additional stable marks placed for the *project. The Primary Survey Control Marks, plus additional survey marks placed throughout construction form the Survey Control Network, as outlined in Clause 1.3, Definition.*

The responsibility for verifying coordinates of the survey control marks lies with the Contractor. While Principal ensured all care was applied in placing and coordinating the Primary Survey Control Marks, it is not possible to guarantee that they will not be disturbed prior to their use for construction activities. This HOLD POINT is to ensure that the Contractor verifies the supplied coordinates of the survey control marks before using them.

Verification of coordinate values of the Primary Survey Control Marks is good survey practice and is therefore considered part of the project cost.

2.2 SURVEY ACCURACY OF THE SURVEY CONTROL NETWORK

2.2.1 Standards of Accuracy

When verifying, extending or breaking down the survey control network you may apply three standards of accuracy for procedures depending on the survey activity and the stage of the project. You must use surveying procedures that are commensurate with the following construction activities.

2.2.1.1 Control for General Construction Activities

General construction activities covers most of the work on the Contract including; earthworks, drainage, pavements, road furniture and most of the bridgeworks. The Primary Survey Control Network must be verified as suitable for general construction activities (refer Clause 2.1).

However, survey control marks of a lower order of accuracy may on occasions be appropriate; conversely survey control marks with a higher order of accuracy may be necessary for some specialised work, as outlined below.

Generally, all survey work carried out on road projects will use a Survey Control Network with coordinates determined to the accuracy specified for the General Construction Activities Control. Coordinates of the Primary Survey Control Network issued with the Drawings are surveyed to accuracy suitable for General Construction Activities.

However, in order to expedite the initial start-up phase of the project, some earthworks and clearing activities may use survey methods of a lower order of accuracy than that for general construction activities. However, you will still require procedures to ensure that the process is suitably controlled and does not introduce gross errors.

Similarly, some bridge Specifications, such as incrementally launched girders, specify a higher order of accuracy than that which is capable using survey control marks measured to an accuracy suitable for the General Construction Activities Control. These are specialised requirements, which are not often required on road construction activities.

2.2.1.2 Control for Bulk Earthworks

When placing or verifying survey control marks for bulk earthworks, you may use survey procedures with a lower order of accuracy than that required for general construction activities.

Survey control marks surveyed for these purposes will form the Earthworks Control. Construction activities where the Earthworks Control may be used include bulk earthworks quantities, clearing and grubbing, and initial set out of the earthworks. The uncertainty of the coordinates of the marks of the Earthworks Control must be less than one-third of the tolerance of the survey for which they will be used.

As soon as practical, all survey control marks must be placed and surveyed to the accuracy required for General Construction Activities. Field markings of survey control marks are to distinguish those marks that have accuracy suitable for the Earthworks Control from those marks suitable for General Construction Activities.

The Earthworks Control must not be used for General Construction Activities that requires a higher order of accuracy, such as:

(a) pavement courses;

(b) final earthworks surfaces supporting pavement courses;

(c) any feature placed on or above the pavement course such as kerblines;

(d) concrete structures; or

(e) concrete drainage components.

Do not include the Earthworks Control in the Survey Control Marks Register (refer Clause 2.4).

All survey marks placed for the Earthworks Control must have survey check measurements to established survey control marks or coordinated features. No adjustment to survey measurements is required for atmospheric conditions, including refraction or conversion to the grid datum.

2.2.1.3 Control for Specialised Construction Activities

You may be required to carry out survey work to a higher order of accuracy than that which is possible using survey control marks coordinated to accuracy suitable only for General Construction Activities. This applies to some bridgeworks, or specialised surveys that you may be directed by the Principal to carry out.

2.2.2 Ground Distances for the Bridge Survey Control

Where you establish a control for General Construction Activities or a control for Specialised Construction Activities specifically for bridgeworks use ground distances in place of grid distances for all lines when calculating coordinates of the survey control marks (refer Clause 5.5.1).

This is included here as part of the Survey Control Network requirements and specifies that survey procedures for the Bridge Control must also address the requirements of this Clause. The scale factor for conversion of ground distances to grid distances is therefore one (1). Further details for the Bridge Control are contained in Clause 5.5.

2.2.3 Specified Standards of Accuracy

When verifying, breaking down or extending the Survey Control Network, use survey methods that achieve the Classes for each standard of control (refer Clause 2.2.1) as set out in Table G71.1. The Classes listed in Table G71.1 are defined in Part A of the ICSM Publication No.1 on Standards and Practices for Survey Control (SP1).

Table G71.1 – Standards of Accuracy for the Survey Control Network

Standard of Accuracy	Horizontal Control		Vertical Control		
	Traditional Survey Methods	GNSS Techniques	Differential Levelling	Trigonometrical Levelling	GNSS Techniques
General Construction Activities	Class C	Class B	Class LC	Class B	N.A.

Earthworks Control	Class E	Class B	Class LE	Class D	Class B
Specialised Construction Activities	LU 4 mm	N.A.	Class LA	N.A.	N.A.

Provide evidence that the local uncertainty for horizontal control developed for Specialised Construction Activities is no more than that shown in Table G71.1.

ICSM NG71 contains procedures derived from Part B of SP1 considered suitable for compliance with Table G71.1. You may use these procedures or other procedures that you can verify as achieving the required standards of accuracy.

Clause B1in the front of this Guide contains the procedures referenced in Specification G71 for verifying, extending or breaking down the Survey Control Network. The procedures listed in Clause B1 are not mandatory but if they are not used, the Contractor must submit details of alternate procedures to the Principal for approval before using these alternative procedures.

The Clause includes standards of accuracy using GNSS techniques as well as traditional survey methods. However, the Classes define a standard of accuracy not survey methods, therefore this Clause does not restrict the use of developing technology, where its capability can be verified.

The Class of a control survey, as stated in SP1, is based on, amongst other things, the survey field methods, reduction techniques and network design adopted. Class C horizontal control for general construction activities is based on good survey practices adopted by surveyors when carrying out normal control surveys, including control for survey investigation and cadastral control surveys.

For Specialised Construction Activities, a higher precision than Class C is required. However, adoption of survey techniques described in SP1 for Class B survey control is not applicable to road construction projects due to the shorter lines on these projects. To ensure the precision of each survey control mark, local uncertainty is adopted for the acceptance criteria for the control for specialised Construction Activities. Adoption of local uncertainty gives greater confidence in the absolute precision of each survey control mark.

Class B control survey by SP1 has a more precise determination as a proportion of length of lines than a Class C control. However, the precision of each survey control mark may not be better than a Class C control survey with shorter lines and therefore, may not be acceptable for some road or bridge works.

The magnitude of the local uncertainty in Table G71.1 is based on the spatial tolerances contained in most road and bridge specifications that require more precise control, such as some bridgeworks.

2.3 CARE, PROTECTION AND PRESERVATION OF THE SURVEY CONTROL MARKS

2.3.1 The Survey Infrastructure

Prior to commencement of any construction activities that may affect the Survey Infrastructure, contact the relevant body responsible for the State or Territory geodetic survey to gain authority to disturb those survey marks forming part of the Survey Infrastructure affected by the works. Annexure G71/E lists the relevant body and Annexure G71/A1.5 contains the name of the state geodetic survey for this Contract.

Comply with any additional survey requirements for the treatment of permanent marks and cadastral survey marks that may be affected by the works, as listed in Annexure G71/A1.6

You are responsible for the preservation of permanent marks and the preservation of state geodetic survey (Annexure G71/A1.5) in accordance with relevant Surveying Legislation (Annexure G71/A1.3), as amended.

Identify any cadastral survey marks and monuments that are likely to be disturbed by the works. Take sufficient measurements and submit sufficient information to enable re-establishment of the position of the cadastral infrastructure within the accuracy specified in the surveying regulation listed in Annexure G71/A1.3, in accordance with any additional survey requirements listed in Annexure G71/A1.6.

Notwithstanding the qualification requirements for survey activities specified in Clause 1.4.2, activities carried out under this sub-claues must be undertaken by a registered or licensed surveyor (in accordance with the requirements of the body described in Annexure G71/A1.2) or made under the supervision of a registered or licensed surveyor or by staff a surveyor authorised by the relevant body (Annexure G71/E).

HOLD POINT

Process Held.	Construction activity in areas that will disturb the Survey Infrastructure.
Submission Details.	Survey measurements for locating cadastral marks, calculations of coordinates of located cadastral marks and current property search; as well as measurements and calculations for replacing affected permanent survey marks or disposition where replacement is deferred.
Release of Hold Point.	The Principal will consider the submitted plans and survey field measurement and may inspect the site, prior to authorising the release of the Hold Point.

Surveying legislation in States and Territories specifies that a person must not remove, damage, destroy, displace, obliterate or deface any permanent survey mark or cadastral reference mark, as defined by the legislation, unless authorised to do so. In addition, penalties of of the order of $10,000 towards the cost of reinstatement plus up to $10,000 towards any loss or damage suffered may apply.

Cadastral reference marks are fundamental to the definition of each State's or Territory's property cadastre ("register of property"). The loss of these marks and permanent marks can significantly degrade the integrity and accuracy of the property cadastre and significantly add to the cost of subsequent surveys and delay infrastructure projects.

2.3.2 Survey Control Network

Where practical, ensure that construction activities do not disturb the survey control marks defining the Survey Control Network. Where practical, place 1.5 metre long stakes, painted in a conspicuous manner, around the survey control marks to assist in their protection.

Additional survey control marks placed to break down the Survey Control Network must be positioned with due regard to maximising their use and protection against disturbance by construction activities. This includes placing survey marks that are substantially stable. Where a survey control mark is affected by the execution of works, establish other stable marks of the same order of accuracy, clear of the works, prior to the commencement of the works in the affected area.

Ensure that at Completion, a Survey Control Network of similar integrity as the one shown on the Drawings, including distribution and standard of accuracy, is in place.

Carry out the actions detailed in Table G71.2.

.

Table G71.2 - Actions for Developing, Maintaining and Extending the Survey Control Network

Time Line	Actions by Contractor	Details	Outcome
Start of Contract	Receive from the Principal the Primary Survey Control Marks.	Primary Survey Control Marks contained on the Drawings.	Sufficient survey control marks to set out the works.
	Protect the Primary Survey Control Marks from construction activities.	Place stakes, markers or other means to highlight location of survey control marks for their protection.	Survey control marks protected to assist construction activities.
	Verify coordinates of the Primary Survey Control Marks before use.	HOLD POINT for release of the Survey Control Network.	Survey control marks verified and HOLD POINT released.
	Identify and recover permanent marks and cadastral reference marks likely to be affected by the works.	These marks are part of the Survey Infrastructure. Contact the relevant body for authorisation to disturb survey marks. This work must be done by a registered or licensed Surveyor. HOLD POINT to allow construction activity in affected area.	Collection of sufficient measurements and actions taken for the preservation and protection of the Survey Infrastructure. Survey information verified for protection of cadastral survey marks and HOLD POINT released.
Clearing & grubbing and initial earthworks activities	Initial breakdown of the Primary Survey Control Marks to form the Survey Control Network.	May use Earthworks Control procedures for these construction activities. Use different marking notation for Earthworks Control.	Initial construction activities are expedited by using survey control applicable to the works.
Completion of earthworks and initial pavement construction commences.	Continue to breakdown the Survey Control Network. Monitoring of survey control marks is ongoing.	All survey control marks placed for the Earthworks Control should be now surveyed for use in General Construction Activities.	The Survey Control Network is now suitable for General Construction Activities.
Specialised construction activities.	Break down the Survey Control Network using higher order procedures.	Use procedures relating to Specialised Construction Activities to place extra survey marks or survey existing marks.	Tolerances set out in bridge specifications or specialised surveys as directed can be achieved.
Contract completion	Provide Principal with Survey Control Network of similar integrity of the Primary Survey Control Marks.	Replace survey control marks destroyed by the works in safe positions if not possible during construction.	The Primary Survey Control Marks are available for future works.
	Close out outstanding actions for compliance with relevant surveying regulations and/or specifications.	Replace destroyed permanent marks in safe positions if not possible during construction. Prepare and submit plans, locality sketches and diagrams as required by the relevant body.	The Survey Infrastructure is preserved to assist future capital works programs and the property cadastre is protected.

Table G71.2 is a flowchart of the processes for receiving, verifying, extending, breaking down and protection of the Survey Control Network from start to finish of the project for compliance with Clause 2 of Specification G71.

2.4 SURVEY CONTROL MARKS REGISTER

Maintain an up-to-date Survey Control Mark Register of all survey control marks that make up the Survey Control Network.

The register forms part of the quality records of the project and must be controlled in accordance with the Quality System. The surveyor must issue the Principal with a controlled copy of the register and retain superseded copies for verification of procedures and to assist problem solving.

Information contained in the Survey Control Marks Register must include where practicable:

(a) a unique number/identifier for each survey control mark;

(b) any other identifier such as an permanent mark number as part of the state or territory geodetic survey;

(c) Easting, Northing and Height of each survey control mark, except marks used for reference sightings only;

(d) chainage and offset of each survey control mark in relation to a main control line of the project where it is practical and one exists; and

(e) a description of the physical nature of each survey control mark, such as peg or drill hole.

The Survey Control Marks Register assists site surveillance by ensuring that all surveillance surveys work from the same datum as the contract surveyor.

The impracticality of providing chainage and offset to a control line may exist where the project is a complex interchange with several design control lines are present without simple geometric relationships such as being parallel. However, where there exists a main centre line, such as for freeway or arterial road construction, provision of chainage and offset of survey control marks to such a design control line would greatly assist locating marks.

Disturbance of existing survey control marks or the addition of extra survey control marks will require updating the register.

The survey control mark description assists locating marks in the field.

3 GENERAL SURVEY REQUIREMENTS

3.1 SOFTWARE

Where the Contract requires setting out or measuring of pavement courses for conformity purposes, use software that converts grid Easting and Northing to chainage and offset in relation to design control lines.

The software must also:

(a) have the capability to calculate design heights of the pavement surface at randomly selected points and give comparisons with field heights;

(b) be the primary method for calculating design heights of pavement surfaces for both set out and conformity verification surveys of pavement surfaces; and

(c) use algorithms with the capability of calculating design pavement surface heights with an error of less than one millimetre compared to the Specifications and Drawings.

Include the name and version of the pavement software in the survey quality sytem documentation.

Where required by the Specifications, the thickness of a pavement course must be determined by a comparison of the conformity verification surveys of the top and bottom surfaces of the pavement course.

Where the Contract specifies quantity payments of earthworks volumes by survey, use surface modelling software that compares surveyed surfaces with previously surveyed surfaces and/or design surfaces. Include the name and version of the quantity software in the survey quality system documentation.

Computer software is an integral part of surveying and should be included with the survey documentation .

3.2 JOINT SURVEYS

Where an engineering construction specification requires, or the Principal directs, that a survey be undertaken as a joint survey, carry out the survey in accordance with this Specification. Supply all personnel and resources necessary to carry out, record and report the survey.

Give written notice to the Principal at least three working days prior to carrying out the survey together with the name of the surveyor and a description of the methods and equipment to be used.

HOLD POINT

Process Held:	Undertaking joint survey.
Submission Details:	Three working days written notice of date, work and location, surveyor's name, description of methods and equipment to be used for the survey.
Release of Hold Point:	The Principal will consider the submitted documents and arrange and notify the Principal's participation, prior to the release of the Hold Point.

Proceed with the survey only in the presence of the Principal, unless otherwise agreed.

Report the results of the survey together with relevant calculations to the Principal within five working days of completion of the survey.

HOLD POINT

Process Held:	Disturbing or covering up location of joint survey.
Submission Details:	Survey Report with relevant calculations of quantities.
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point.

Joint surveys may be used to allow the Principal to carry out its responsibility to measure quanities of work constructed for payment. Joint Surveys also allow the Principal to carry out surveillaince of the Contractor's survey.

Where the specifications call for joint surveys, the Contractor must use qualified surveying personnel. Specifications may require joint surveys for bulk earthworks, pavement courses constructed under different contracts and bridgeworks. However, the Principal may at any time direct that a high risk activity be surveyed by a joint survey.

Where required for bulk earthworks, joint surveys may be conducted with two independent total stations, one operated by the Principal's surveyor and the other by the Contractor's surveyor. Both surveyors simultaneously sight to the same ranging pole, which is placed in an agreed position to model the surface. This method ensures agreement on sampling of the natural surface to determine quanities.

The Principal may require access to the Contractor's survey measurements and/or computer models to resolve any survey discrepancies. When requested, this data must be in a format that is suitable for creating accurate models using the Principal's current CADD software, which is given in Annexure G71/A.

Where specifications require joint surveys for other than bulk earthworks, survey methods that use two independent total stations and ranging poles may be more suitable.

The Principal can, on a risk assessment basis, decide on its level of participation that can be as little as witnessing the contractor's survey activities and reviewing results.

3.3 PRODUCT CONFORMITY SURVEY

Adopt methods for product conformity surveys that ensure independence from the methods used to set out the Works. Where possible, take measurements directly from survey control marks. Avoid taking measurements from subsidiary survey marks established to set out the Works. If the use of subsidiary survey marks is unavoidable for verification purposes, then their position and level must be re-established.

Sampling the Works for conformity verification purposes must not be restricted to the locations used to set out the Works but must be undertaken in accordance with Clause 5 or in a random or unbiased manner at any location of the Works to verify conformity with the Drawings and Specification. All sampling must be sufficient to provide a valid representation of the product's spatial qualities.

See comments under Clause 5.1 for further guidance on pavement courses.

Perform conformity verification survey for concrete base, concrete sub-base and bound pavement layers as soon as practicable but in any event not later than one working day after the pavement lot has become accessible for survey, unless otherwise agreed by the Principal.

Submit a Survey Report for each lot or component where design levels, position and/or tolerances have been specified. The Survey Report must show the specified value versus the actual value for position (defined by grid co-ordinates or chainage and offset), level and tolerance as appropriate and must be certified by the surveyor responsible for the verification survey.

Submit a Nonconformity Report to the Principal (ISO 9001 Clause 8.3) and implement Corrective Action (ISO 9001 Clause 8.5) where survey identifies a nonconformity.

HOLD POINT

Process Held:	Covering up of work subject to a conformity survey.
Submission Details:	Survey Report verifying conformity.
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point.

3.4 MARKING LAND PROPERTY BOUNDARIES

Where the contract drawings, models or specifications indicate construction activity within 300 mm of a property boundary, determine the property line using the most current cadastral information supplied by the relevant lands titles office as listed in Annexure G71/A1.7. The survey must be carried out by or under the immediate supervision of a registered or licensed surveyor, in accordance with the relevant surveying regulation (Annexure G71/A1.3).

This Clause is in accordance with the surveying legislation in the States and Territories, which states that a registered or licensed surveyor is the only person authorised to mark property boundaries in their State or Territory. This protects the Principal from possible litigation where structures are placed on or near property boundaries.

4 SURVEYING TECHNIQUES

4.1 GENERAL

This Clause contains Orders of Accuracy for horizontal (two dimensional) coordinates and height or vertical control (the third dimension). Comply with these Orders of Accuracy for construction activities listed in Clause 5 to assure that spatial requirements are met.

The Orders of Accuracy listed in Clause 5 use the notation contained in this Clause. Procedures must attain the Orders of Accuracy specified in Clause 5 regardless of the survey technique adopted.

For the purpose of this Clause, an EDM Tacheometry survey is considered to determine horizontal coordinates and vertical coordinates simultaneously.

Apart from surveys for the survey control network, practically all survey activities completed on road construction projects can be carried out by radiation surveys, height determination procedures and EDM tacheometry surveys.

ICSM NG71contains surveying procedures using traditional survey techniques of radiation and height determination, as well as GNSS procedures, that are considered capable of meeting the Orders of Accuracy listed in this Clause. Use these procedures for traditional survey techniques or use other procedures that you can verify as capable of meeting the required Orders of Accuracy.

Where you use procedures other than those contained in ICSM NG71, present evidence that the alternative procedures are capable of achieving the specified Order of Accuracy to the Principal for approval before use.

HOLD POINT

Process Held:	Work process surveys.
Submission Details:	Survey procedures applicable for the Contract and evidence that they are capable of achieving the specified Order of Accuracy.
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point.

4.2 ORDERS OF ACCURACY FOR HORIZONTAL COORDINATES

Table G71.3 – Orders of Accuracy for Horizontal Coordinates

Order of Accuracy (1)	Local Uncertainty (2)
1H	5 mm
2H	12 mm
3H	25 mm

4H	125 mm
5H	500 mm

Notes for Table G71.3:

(1) A reference notation for each Order of Accuracy.

(2) Ninety five percent confidence level of relative uncertainty with respect to adjacent survey control marks (see Clause 1.3 Definitions).

ICSM has adopted the international convention of quoting the local uncertainty as a 95 % confidence interval, in lieu of quoting accuracy as one standard deviation of the estimated measurement error. However, for two dimensional measurements one standard deviation gives a 39% confidence interval. Therefore, a multiply factor of 2.45 is required to convert one standard deviation to the 95% confidence interval adopted for a local uncertainty for this Specification. As horizontal coordinates are two dimensional, the quoted local uncertainty appears large, however, if converted to one standard deviation they are more in accordance with accuracies with which surveyors are familiar. For example, for Order 1H, one standard deviation is 2 mm.

Most survey technical material and survey instrument manufacturers quote accuracies as one standard deviation. Surveyors must be aware of this difference with the local uncetainties quoted in this specification when considering procedures to comply with the specified Orders of Accuracy.

4.3 ORDERS OF ACCURACY FOR VERTICAL CONTROL

Table G71.4 – Orders of Accuracy for Vertical Control

Order of Accuracy (1)	Local Uncertainty (2)
1V	0.7 mm
2V	1.5 mm
3V	3 mm
4V	6 mm
5V	20 mm
6V	100 mm

Notes for Table G71.4:

(1) A reference notation for each Order of Accuracy

(2) Ninety five percent confidence level of relative uncertainty with respect to adjacent survey control marks (see Clause 1.3 Definitions).

The use of terminology Horizontal Control and Vertical Control is consistent with SP1.

Similar to horizontal measurements, this Specification quotes a 95% confidence interval for each Order of Accuracy for vertical control in lie of one standard deviation of the estimated measurement error. However, for one dimensional measurements, for height measurements, one standard deviation gives a 68% confidence interval. The multiply factor for converting one standard deviation to the 95% confidence interval for this specification is 1.96 ..

Optical automatic levels and standard staffs do not have the capability to meet the requirements of 1V. For this Order of Accuracy a digital level and compatible equipment is considered necessary.

Calibrated invar staffs, or staffs of similar accuracy, plus a parallel plate micrometer with a suitable optical automatic level may achieve the accuracy of 1V provided suitable procedures are developed *and followed. However, evidence verifying its capability must be provided before acceptance, in accordance with Clause 4.1.*

4.3.1 EDM Trigonometrical Heighting Procedures

This subclause applies where EDM Trigonometrical Heighting procedures are developed for vertical control Orders of Accuracy.

For EDM trigonometrical heighting procedures, control errors caused by determining the height of the total station, as well as determining the height difference between the total station and the surveyed point. Where a resection procedure determines the height of the total station, it must measure redundant data and calculate heights by an adjustment that calculates residuals.

The use of EDM trigonometrical heighting is not mandatory but where it is used, it must meet the requirements of this Clause. Resection procedures must use redundant data to verify the survey and also improve the accuracy of the procedure. Residuals provide a valuable quality check on the survey and are the basis of some acceptance criteria in this Clause.

4.3.1.1 Survey Checks for EDM Trigonometrical Heighting

(a) Survey Checks by Residuals

Use the residuals calculated by resection software to verify the accuracy of the height of the total station. This check is mandatory for Orders of Accuracy 2V, 3V, and 4V where a resection determines the height of the total station.

For 2V, 3V, and 4V, investigate where the difference between the means of the residuals (see Clause 1.3) of any two survey control marks is greater than 5 mm. The mean of the residuals applies where there is more than one sighting to the same survey control mark.

For 5V, when using a resection procedure, the difference between the residuals for any two stations must not exceed 9 mm.

Carry out investigation and take appropriate Corrective Action where residuals exceed the limits listed in this Clause.

Notify the Principal of any changes to the coordinates of the survey control marks as a result of the investigation, in accordance with Clause 2.5.

This check is for higher order work and verifies the height of the total station by analysing all measurements to the survey control marks. Where there is significant difference between residuals from two survey control marks, it may indicate some disturbance in the survey control network and this should be investigated. Where this leads to a re-determination of heights of one or more survey control marks, the new values must be entered into the Control Marks Register.

Where the surveyor wishes to permanently mark the position of the total station, this should be done by first placing the mark and setting the total station over it before carrying out the resection. Placing a peg under the total station after the resection, by surveying principles, is subject to greater inaccuracy and in addition, hammering in the peg may disturb the total station. Therefore, this action should be avoided.

(b) Survey Check by Survey Control Marks

Before commencing measurements after establishing the height of the total station, determine coordinates of a survey control mark by EDM trigonometrical heighting and compare its measured height with its recorded height. This survey check applies where ever EDM trigonometrical heighting is used for vertical control.

Comply with the maximum sight distance and minimum height of sight lines when determining differences to recorded heights of control marks shown in Table G71.5 for Orders of Accuracies 2V to 6V.

This check should be applied to all Orders of Accuracy but is the main check for lower Orders of Accuracy. Where the EDM trigonometrical heighting is part of a Tacheometry survey, it also checks the horizontal coordinates.

Table G71.5 – Allowable Height Differences with Survey Control Marks for Orders of Accuracy

Order of Accuracy	Max Sight Distance	Min Height of Sight Line	Allowable Difference
2V	70 m	1.5 m	5 mm
3V	100 m	1.5 m	5 mm
4V	100 m	1.5 m	5 mm
5V	150 m	1.5 m	10 mm
6V	200 m	1.0 m	25 mm

(c) Timing

The survey checks for 2V to 6V must be carried out immediately after determining the height of the total station and before commencing measurements from the total station.

A further survey check must also be carried out hourly or at the completion of each set up, which ever is the lesser.

4.4 EDM TACHEOMETRY SURVEYS

EDM tacheometry procedures must record the following data and be included in the survey records:

(a) field measurements used to determine coordinates of all resected stations;

(b) residuals of measurements used to determine coordinates of resected stations;

(c) coordinates of resected stations;

(d) coordinates of all survey control marks used for each survey, including survey control marks used to determine coordinates of the total station by a resection procedure;

(e) all raw field measurements required to carry out the survey;

(f) the grid scale factor applied;

(g) survey checks to verify the accuracy of the survey;

(h) reduction of all radiated points to grid coordinates or chainage, offset and height for three dimensional surveys;

(i) the purpose, location and date of survey; and

(j) unique identification of each survey for traceability.

Where applicable, in areas such as pavement surveys, the survey records must also show a comparison of field coordinates of radiated points with their design position and/or height.

4.4.1 Survey Checks for EDM Tacheometry Surveys

When carrying out EDM tacheometry surveys apply the survey check applicable for the Order of Accuracy for EDM trigonometrical heighting component of the survey, as given in Clause 4.3.2.1. Also compare its measured horizontal coordinates with recorded values to verify horizontal Orders of Accuracy given in Table G71.3.

4.5 GNSS SURVEY

The term GPS has been replaced by the more generic term GNSS for Global Navigation Satellite System techniques. GPS, Global Positioning System, was the first GNSS system developed and for a long time was the only system available. However, other systems are now commercially available and the generic term is adopted so that no preferred system is implied.

The following requirements are applicable for surveys using Real Time GNSS equipment (RTK) for construction set out and/or conformity, as well as quantities for payment:

(a) The minimum standard GNSS equipment must have the following characteristics:

- (i) GNSS receivers capable of recording carrier waves;
- (ii) authorisation from Australian Communication Authority for frequency to operate a two way radio for GNSS operations;
- (iii) braced support for the antenna pole.

(b) For each construction activity, the instrument's threshold setting must be no greater than one third of the spatial tolerance of the product.

(c) Validate equipment and survey by occupying established survey control marks and comparing surveyed coordinates with recorded coordinates.

(d) Record all measurements including quality checks.

(e) Where possible and practical for construction set out, measure between surveyed points by traditional survey methods to verify survey.

(f) The methodology for modelling the geoid and its effects on heights must be documented and validated.

Real Time GNSS procedures must not be used for height determination where a construction accuracy of less than 30 mm is specified.

5 ADDITIONAL SURVEY REQUIREMENTS

This Clause sets out additional survey requirements, including sampling plans for verifying spatial conformity of road and bridge components.

This Clause contains also Tables of Orders of Accuracy that must be complied with to achieve tolerances contained within the technical Specifications for road and bridge works.

EDM tacheometry must achieve the Order of Accuracy to satisfy requirements for both the horizontal and vertical components of the survey.

This Clause may not include all surveys required for road construction . However, it has attempted to highlight all areas where road construction authorities have found specific survey requirements are necessary, such as pavement control. Additional Clauses may be added in the future where feedback suggests it is appropriate.

5.1 PAVEMENT SURVEYS

Table G71.6 provides Orders of Accuracy, survey checks and sampling details for conformity surveys for different pavement courses, including earthworks courses that support pavement courses.

Surveying procedures for setting out pavement courses must achieve an Order of Accuracy that is least equal to those used for conformity surveys for the same surface.

Traditional methods of using differential levelling and tape to set out and measure pavement surfaces are inefficient, time consuming, and can not achieve the required accuracy, particularly for concrete pavements. Therefore, these procedures are no longer acceptable for pavement surveys for both set out and conformity surveys.

Table G71.6 – Surveying Requirements for Conformity Surveys for Pavement Courses and Earthworks Courses Supporting Pavement Courses

Pavement Surface	Orders of Accuracy		Check Measurements to Survey Control Mark		Common Points Difference	Sampling Plan Chainage Difference	Specification Reference
	Horizontal (b)	Vertical (c)	Horizontal (d)	Vertical (d)			
(a)					(e)	(f)	(g)
Reinforced / Plain Concrete	3H	2V	20 mm	4 mm	5 mm	5 m	Lean-Mix Concrete Subbase, Plain Concrete Base, Continuously Reinforced Concrete Base
Bound Base & Subbase	3H	3V	20 mm	5 mm	5 mm	5 m	Heavily bound pavement course
Unbound Base & Subbase	3H	3V	20 mm	5 mm	5 mm	10 m	Unbound pavement course
Selected Material Zone	3H	4V	20 mm	5 mm	10 mm	10 m	Earthworks
Earthworks other than Selected Material Zone	3H	4V	20 mm	5 mm	10 mm	10 m	Earthworks
Cut Floor (for ripping)	3H	5V	20 mm	10 mm	N.A.	10 m	Earthworks
Cut Floor (for compaction)	3H	5V	20 mm	10 mm	N.A.	10 m	Earthworks

Notes for Table G71.6

(a) Pavement Surface of course being surveyed.

(b) & (c) Orders of Accuracy for horizontal and heights assigned to each pavement surface (refer Clauses 4.2 and 4.3).

(d) Measured Differences to Survey Control Mark columns show the allowable horizontal and height differences between survey control mark coordinates, by the survey and by the adopted values, for the survey to comply.

(e) Allowable height difference of common points by two abutting surveys before an investigation is required, (refer Clause 5.1.2).

(f) Sampling Plan Chainage Difference gives the difference in chainage of points along strings for sampling the pavement. Table G71.7 gives the offset (transverse) distance between strings across the pavement. Uniform points along approximately parallel strings define the grid pattern for sampling the pavement surface (refer Clause 5.1.3).

(g) Reference to engineering specification containing the survey tolerances.

N.A.: Not Applicable

Positional (horizontal coordinates) accuracy of sampling points is important as it affects calculation of design heights due to pavement cross fall and gradient.

5.1.2 Survey Checks for Pavement Surveys When Using EDM Trigonometrical Heighting

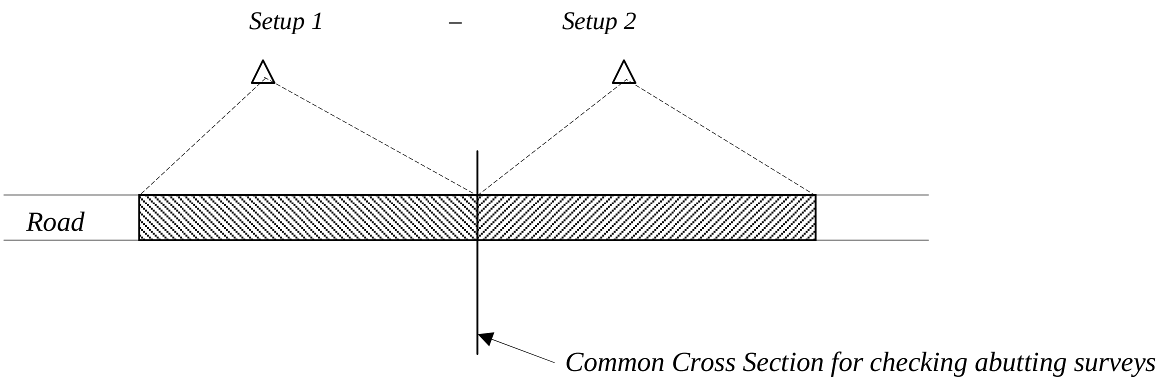
Where procedures for pavement surfaces use EDM trigonometrical heighting, in addition to the survey checks described in Clause 4.3.1, apply the following check for pavement surveys, including earthworks courses that support pavement courses.

Where surveys abut, at the next set-up of the total station, take measurements to the last cross section marked or measured from the previous set up location.

For set out surveys, take measurements to the closest set out marks placed from the previous set up of the total station. For conformity surveys, spot mark on the pavement the location of measurements at the final cross section of the previous survey.

Investigate the cause of differences in heights of set out marks or measurements of the pavement surface to the same spot, from the two total station set ups, if the difference is greater than the values shown in column (e) of Table G71.6.

For the purpose of this Clause, abutting surveys may be carried out on separate days.



Column (e) in Table G71.6 shows the allowable discrepancy between heights by the two surveys.

Diagram NG71.1 – Common Cross Section for Checking Abutting Surveys

Survey records are to include measurements to verify survey checks using the set out marks and spots marks common to any two set ups of the total station when surveys abut.

5.1.3 Sampling Plan for Conformity Verification Surveys of Pavement Surfaces

Select sampling points from a defined grid pattern. Form the grid by equally spaced points in strings that run approximately parallel to the centreline of the constructed pavement. Select sampling points in each string at the intervals shown in column (f) of Table G71.6.

Determine the number of strings across the pavement for different pavement widths from Table G71.7.

Table G71.7 – Sampling Plan for Pavements

Pavement Width W	Number of Strings
W ≤ 1.5 m	1
1.5 m < W ≤ 6.0 m	2
6.0 m < W ≤ 11.0 m	3

11.0 m < W ≤ 16.0 m	4
W > 16.0 m	See note below

Note: Add one string for each additional 5 metres, or part thereof, for pavement widths greater than 16 metres.

For pavements sampled by a single string, run the string along the approximate centreline of the constructed pavement. For pavements sampled by two strings, place each string between 0.5 and 1.0 metre from the edges of the pavement. For pavements sampled by more than two strings, place the additional strings between the two outer strings so that the transverse distances between adjacent strings are approximately equal. The maximum distance between strings across the pavement for any pavement width is 5 metres.

Select sampling points to within 0.7 metres of the location defined by this Clause and determine actual field coordinates by survey.

Include the sampling plan for conformity verification surveys of pavement surfaces in the Quality System documentation.

The sampling plan formalises industry practice over a number of years, which has been to sample pavements in grid patterns. The specified sampling plans must give uniform coverage of the pavement and provide a valid sample of the pavement.

Column (f) of Table G71.6 and Table G71.7 defines the sampling plans for conformity verification surveys for pavements. Sample the pavement with strings running approximately parallel and along the pavement pour. Column (f) gives the chainage distance between points in the string and Table G71.7 gives the number of strings across the pavement. For example, when sampling a concrete pavement pour that is between 6 and 11 metres wide there will be three strings across the pavement with points in each string five metres apart. This implies that for each 100 metres of the pavement there will be 60 sampling points.

Determine the horizontal coordinates of each sampling point to the accuracy shown in Column (b) of table G71.6. However, selection of sampling points need only be within 0.7 metres of the required position, the software then determines actual coordinates. Therefore, pacing accuracy should be sufficient for selecting points provided due care is exercised.

5.2 SURVEYS FOR DETERMINING QUANTITIES FOR PAYMENT

Adopt Orders of Accuracy of 5H and 6V or better, when using EDM tacheometry survey techniques, for determining quantities for pay items listed in the Earthworks Specification. Check measurements to survey control marks must have differences of less than 50 mm for height and 50 mm for horizontal position.

Where a Joint Survey is specified, the survey report submitted to the Principal must include a computer file of the observed surface strings using string labels contained in the current standard string codes specified in Annexure G71/A1.1. It must also be suitable for input into the specified software and capable of producing an accurate surface model of the surveyed surface using the software specified in Annexure G71/A1.1.

The survey model should include a three dimensional string, sometimes called a boundary string, that defines the limit of the quantity being measured.

Where the surveyed surface includes input from more than one survey, submit one digital model that is compiled from the individual surveys. Interrogate the compiled model to ensure its integrity and that it is free from anomalies and errors before submitting it to the Principal. Gather natural surface features using the stringline technique in accordance with accepted practice. Do not use strings with discontinuities.

The Principal may require access to the Contractor's survey measurements and/or computer models to resolve any survey discrepancies. When requested, this data must be in a format that is suitable for creating accurate models using the Principal's current CADD software.

5.3 EARTHWORKS SURVEYS

5.3.1 Survey Techniques

Where possible the Principal will provide you with Model Drawings showing the position of the batter profiles in relation to the design batter planes in cuts and embankments. Batter stakes, where placed, must be marked with their chainage, offset and slope distance to the hinge point.

Comply with the Orders of Accuracy for the earthworks activities contained in Table G71.8. Where EDM tacheometry survey procedures are used, comply also with the survey checks in Table G71.8. (Columns 4 and 5 contain the allowable horizontal and height differences from survey control marks when using EDM trigonometrical heighting techniques for each activity.)

Table G71.8 – Orders of Accuracy for Earthworks

	Orders of Accuracy		Survey Checks to Survey Control Marks	
Activity	**Horizontal**	**Vertical**	**Horizontal Difference**	**Height Difference**
Clearing & Grubbing	5H	6V	100 mm	100 mm
Batter Planes	4H	5V	30 mm	20 mm
Benches in Cut	5H	6V	100mm	100mm
Transitions Cut to Fill	4H	5V	30 mm	20 mm
Cut Floor Excavation	3H	5V	20 mm	20 mm
Cut Floor Surface	See Table G71.6 under column (a)			
Underside of Selected Material Zone	See Table G71.6 under column (a)			
Top of Formation	See Table G71.6 under column (a)			

5.3.2 Earthworks Verifications

5.3.2.1 Clearing and Grubbing

Provide evidence of the verification of the plan position of the intersection of the batter plane with the natural surface when carrying out a conformity and set out survey for clearing and grubbing.

5.3.2.2 Batter Planes

Provide evidence of the verification of the plan position of the intersection of the batter plane with the natural surface when carrying out conformity verification and set out surveys of batter planes. Unless otherwise specified, apply this Clause to other earthworks surfaces with designed levels, such as medians.

The position of the intersection of the batter plane with the natural surface varies with changes in the natural surface height. As construction activities may affect the natural surface before setting out the batter plane has commenced, it is possible that the offset distance of the intersection shown on the Drawings may have changed. Therefore, when setting out batters and clearing lines, which are offset to the intersection line, the natural surface height should be measured and the correct offset of the intersection line calculated.

Surveys to verify conformity of the batter plane must sample the batter plane in a defined grid pattern. Define the grid by selecting points along strings (cross sections) that run approximately normal to the edge of formation of the road. The distance between the cross sections must be between 10 and 15 metres.

On each cross section, select points at least one metre from the top and one metre from the bottom of the batter plane to negate the effects of rounding. Where the slope distance between rounding at the top and bottom of the batter is less than 5 metres, one point on the cross section is sufficient. Where there is more than 5 metres between the rounding at the top and bottom of the batter plane, adopt the number of points for each cross-section as shown in Table G71.9 and Figure G71.1 for sampling batter planes.

Table G71.9 – Sampling Plane for Surveying Batter Planes

Chainage Interval for Cross-Sections	Slope Distance (SD)	Number of Sampling Points for Each Cross-Section
10 to 15 m	SD < 5m	1
10 to 15 m	5m ≤ SD < 10m	2
10 to 15 m	10m ≤ SD < 15m	3
10 to 15 m	15m ≤ SD < 20m	4
10 to 15 m	Add an extra point for each additional 5 m in SD	

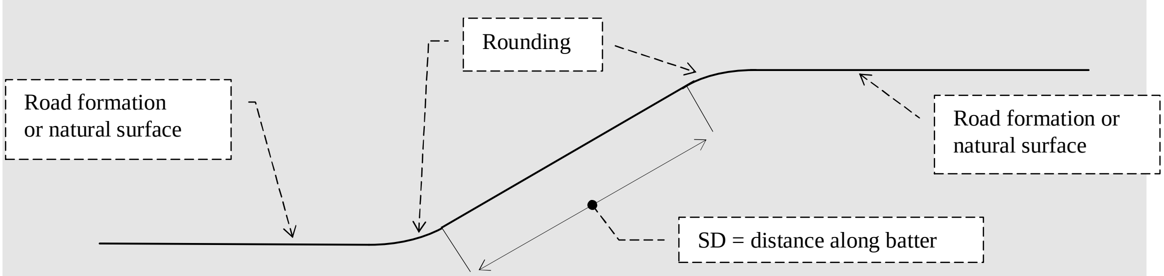


Figure G71.1 – Showing rounding on batter planes for cuts and fills

Sampling must ensure that only points that accurately represent the batter plane with due regard to anomalies are selected. The survey report must show the distance between specified and actual positions measured perpendicularly to the design batter plane unless otherwise specified.

5.4 Stormwater Drainage Systems

Comply with the Orders of Accuracy for the stormwater drainage structures contained in Table G71.10. Where EDM tacheometry survey procedures are used, also comply with the survey checks in Table G71.10 columns 4 and 5.

Table G71.10 – Orders of Accuracy for Drainage Structures Surveys

Activity	Orders of Accuracy		Survey Checks to Survey Control Mark	
	Horizontal	Vertical	Horizontal	Height
Kerb & Gutter	3H	4V	20 mm	5 mm
Concrete pipes, box culverts, headwalls and wing walls, energy dissipators, inlet and outlet structures	3H	5V	20 mm	10 mm
Gully pits and junction boxes	3H	5V	20 mm	10 mm
Lintel, covers and gratings when adjoining:				
Kerb & gutter	3H	4V	20 mm	5 mm
Concrete pavement	3H	2V	20 mm	4 mm
Asphalt pavement	3H	4V	20 mm	5 mm
Precast concrete box culverts	3H	4V	20 mm	10 mm
Open drains	4H	6V	50 mm	30 mm

5.4.1 Kerb and Gutters

Surveys to set out kerb lines must be with reference to the design height and horizontal position of the lip line in preference to any other feature of kerb and gutters unless otherwise directed by the Principal.

The conformity verification surveys must report the actual position of the lip line in relation to its design position. Survey methods must make allowance for the rounding of the constructed product when determining the horizontal position and height of the lip line (refer Figure G71.2).

Where possible the Principal will provide you with Model Drawings showing standard kerb and gutter profiles indicating where exposed edges are rounded.

Sample the kerb and gutter at 10 m intervals for conformity verification surveys.

Kerb and gutter specifications for road projects reference Australian Standard AS 2876-2000, "Concrete kerbs and channels (gutters) – manually or machine placed", for controlling kerb and gutter construction. This includes survey tolerances for the horizontal position of the finished surface, which not all specifications will include. Clause 9 (b) of AS 2876 states:

> *"The finished concrete shall not vary from horizontal alignment or level by more than 10 mm at any point. The finished work shall not deviate at any point more than 5 mm under a straightedge 3 m long. Deviation on vertical curves shall not exceed 5 mm from the true vertical curve."*

In addition, surveyors should examine technical specifications for kerb and gutters to determine if there are any additional survey requiremnents. For example, NSW Roads & Traffic Authority kerb and gutter specifications require the finished gutter lip shall not be higher than the adjoining pavement or more than 10 mm lower. The finished height of the lip line is designed at the same height *as the adjoining pavement. Their preference is not to have the lip line constructed higher than the pavement surface, but it should be constructed slightly lower (than the pavement surface).*

Appendix 2.1 is MD.R15.A01.A.1, which is an example of an RTA Model Drawing for kerb and gutters. It shows standard kerb and gutter types and the location of set out points.

Sample the kerb and gutter at 10 m intervals for conformity verification surveys.

Where the rounding is consistent, a constant offset may apply, but where irregularities in the rounding exist, the surveyor may have to measure the offset for each height determination point.

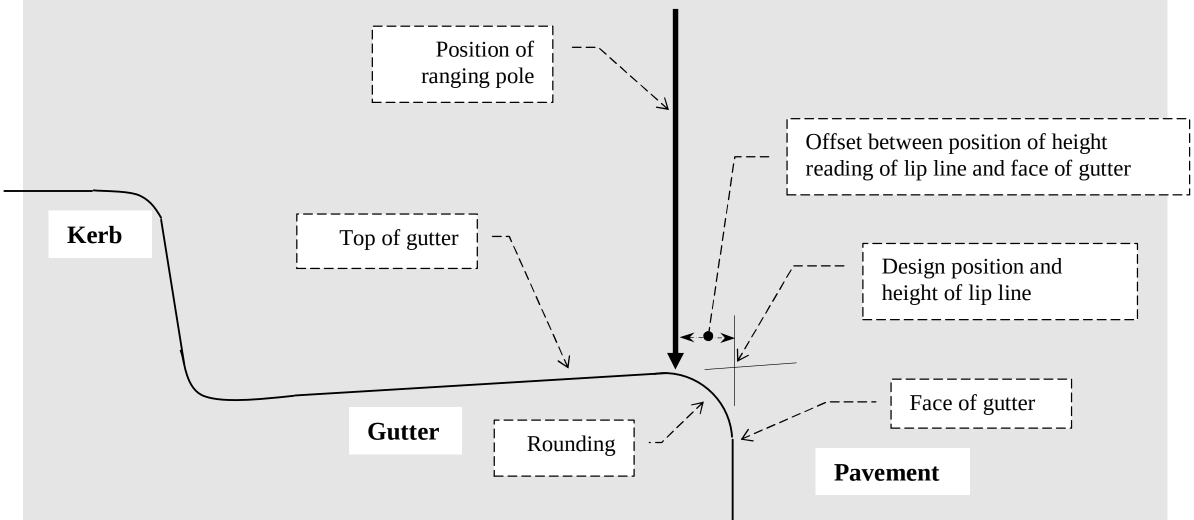


Figure G71.2 – Allowance for Lip Rounding when Determining Constructed Position of Lip Line

Stormwater Structures:

Drainage structures are defined as:

"Devices to control stormwater flowing into and through a stormwater drainage system including culverts, inlets and outlet structures, junction boxes, gully pits, drop structures, headwalls, wingwalls, energy dissipators, and ancillary hardware such as grates, frames and step irons, as well as subsurface drainage pipes at pits."

A stormwater drainage system is one or more drainage structure and/or open drain arranged to collect and convey surface runoff water.

In addition to the structures contained in the definition, kerbs and gutters also form part of the stormwater drainage system but may be treated in a separate specification.

Open drains are controlled by batter lines and are generally located at least 2.5 metres from tops of cuttings or toes of embankments, unless otherwise shown in the drawings.

Setting Out Point:

The Principal may provide supplementary drawings to aid set out of drainage structures, including position of set out points and the location of invert levels of the structure. If not provided then seek advise from the Principal's representative on setting out requirements. Appendix 2.2, is an example of a supplementary drawing issued by the NSW RTA for the set out details of a gully pit in a SA type kerb for concrete pipes up to 450 mm in diameter.

5.5 BRIDGES

Annexures NG71/M and NG71/N contain diagrams showing some of the common terms of components used in bridge specifications.

5.5.1 The Bridge Survey Control

Calculate the coordinates of survey control marks used for bridge surveys using ground distances and not grid distances as applied to road works. In addition, use ground distances when measuring from survey control marks for all survey work on bridges.

This is because road designs are placed on a datum plane, which requires reducing ground distances to grid distances. However, bridge components have specific engineering spatial requirements that can not be adjusted to fit to a reference datum plane. Therefore the survey control network must not affect component measurements during set out surveys. To address this issue, only ground distances must be used to calculate coordinates of marks defining the survey control network for the bridge construction.

The survey control network for the bridge is known as the Bridge Survey Control. It must be separate to the main Survey Control Network. Most marks will have different two-dimensional coordinates to the main Survey Control Network due to the different distances used to calculate coordinates for the controls.

Bridge Survey Control must be on the same azimuth as the main Survey Control Network and adopt the coordinates of one of the survey control marks from the main Survey Control Network. It must include at least three survey control marks for each bridge.

Submit details of the Bridge Survey Control prior to commencing survey work for the bridge.

The Bridge Survey Control must change only the horizontal coordinates and must adopt the heights of the survey control marks used from the main Survey Control Network. Submit a separate Bridge Survey Control Mark Schedule for each Bridge Control in accordance with Clause 2.4.

HOLD POINT

Process Held:	Use of the Bridge Survey Control for setting out the bridge works.
Submission Details:	Plan of the Bridge Survey Control plus coordinates, measurements and calculations used to determine coordinates.
Release of Hold Point:	The Principal will consider the submitted documents and may inspect the survey control marks and calculations prior to authorising the release of the Hold Point.

Procedures for determining coordinates of the Bridge Survey Control must comply with Clause 2.2.

5.5.2 Survey Tolerances on Bridges

Survey records must track estimated allowances for deflection of concrete formwork before and during concreting on bridges.

Where Annexure G71/A states that Annexure G71/F is applicable, comply with Table G71.11, which lists the tolerances and survey Orders of Accuracy for concrete components of bridges for setting out concrete formwork and verifying conformity of the finished concrete.

Where Annexure G71/A states that Annexure G71/G is applicable comply with Table G71.12, which lists the tolerances and survey Orders of Accuracy for other bridge components and verifying conformity of other bridge components.

Regardless of G71/F and G71/G being applicable, maintain records for the checking and verification of formwork for concrete cast in-situ as follows:

(a) as planned:

- (i) the designed characteristic (level, dimension, position) at that point on the structure as shown in the Drawings;
- (ii) the calculated or estimated deflection/settlement of the formwork prior to and during concreting;
- (iii) the target characteristic for the formwork (allowing for deflection/settlement); and
- (iv) the specified tolerance on final location of the structure at that point.

(b) as measured:

- (i) the characteristic as set out;
- (ii) the characteristic as verified;
- (iii) the difference between the verified value and the target value; and
- (iv) the magnitude of any out of tolerance measurement (i.e. the amount by which the measured difference exceeds the specified tolerances).

Specifications for incrementally launched concrete bridge girders require a survey certificate for the reference point with a stability of ± 0.5 mm. The certificate must show the physical structure of the reference mark and how you will control its stability to the required accuracy.

All fitments and embedments must be located with sufficient accuracy to prevent any misfit or misalignment between mating components.

.

For the transfer of heights of millimetre accuracy over distances greater than 100 metres the following non-simultaneous reciprocal EDM trigonometrical heighting procedure is suggested.

For sight distances between 100 and 200 metres adopt the mean of three readings of height differences on both faces from each end of the line. For distances greater than 200 metres adopt the mean of five readings of height differences on both faces from each end of the line. For all distances dial the atmospheric readings into the instrument. The height differences from both ends of the line must be observed in less than 30 minutes to minimise the effect of refraction. Use the same ranging pole without adjusting its length for measuring all height differences.

(Reciprocal trigonometrical heighting requires measuring the height difference from both ends of the line simultaneously to eliminate the effect of refraction. Non-simultaneous reciprocal trigonometrical heighting means that there may be a time difference between measurements at either end. However, the procedure limits the time difference to 30 minutes.)

For precise work sight distances for radiation procedure 1H may extend to 130 metres as described in Clause NG B 2.3. For sight distances greater than 130 metres use at least two Specialised Construction Activity survey control marks that subtend an angle of at least 15 degrees to verify the bearings

Annexure G71/A – Details of Work

A1 PROJECT SPECIFIC REQUIREMENTS

A1.1 CADD Software

The software applicable to this Contract is:

Insert details of applicable CADD software here. If not applicable, then delete this comment and change the heading of A1.1 to "NOT USED".

The standard Survey Pick Up Codes for this contract is:

Insert details of standard Survey Pick Up Codes here. If not applicable, then delete this comment and change the heading of A1.1 to "NOT USED".

A1.2 The Surveying Board With Jurisdiction Over Surveyors to be Engaged for Work Under Specified Clause of this Contract

Example : NSW Board of Surveying and Spatial Information

A1.3 The Surveying Regulation Established by the Relevant Surveying Board

Example : NSW Surveying Act

A1.4 Additional Survey Requirements for Survey Equipment Control:

Example Surveyor General's Directions No 5 and No 9

A1.5 Name Of The State Geodetic Survey:

Example The NSW State Control Survey

A1.6 Additional Survey Requirements for Protection of Survey Infrastructure

Example Surveyor General's Direction No 11 "Preservation of Survey Infrastructure"

A1.7 Relevant Land Titles Office

Example NSW Land and Property Management Authority

A1.8 Occupational Health and Safety Specifications Applicable to the Contract

Example RTA G23/24 Occupational Health and Safety

A1.9 Application of Bridge Tolerances and Orders of Accuracy

Concrete Bridge Surfaces (Clause 5.5.2) application of Table G71.11 in Annexure G71/F **Yes/No**

Other Bridge Components (Clause 5.5.2) application of Table G71.12 in annexure G71/G **Yes/No**

ANNEXURE G71/B – MEASUREMENT AND PAYMENT

The costs for all activities associated with planning and implementation of survey activities as detailed in this Specification must be included in the rates or prices generally in the Contract;

Or

As nominated below.

Delete the option that is not applicable

ANNEXURE G71/C – SCHEDULES OF HOLD POINTS AND IDENTIFIED RECORDS

C1 SCHEDULE OF HOLD POINTS

Clause	Description
2.1	Survey Report verifying survey control marks
2.3	Survey measurement to re-establish the survey infrastructure
3.2	Notification of Joint Survey details
3.2	Report of Joint Survey including calculations of quantities
3.3	Covering up of work subject to a conformity survey
4.1	The work process survey
5.5.1	Use of the Bridge Survey Control

C2 SCHEDULE OF QUALITY RECORDS AND IDENTIFIED RECORDS

Clause	Description
2.1	Survey Report verifying survey control marks
2.3	Plans, locality sketches and diagrams of new permanent marks
2.3	Plan of Survey to relocate the cadastre
2.4	Survey Control Mark Schedule
3.2	Method of Joint Survey
3.3	Survey Report verifying conformity
4.1	Alternative survey procedures
5.5	Details of the Bridge Survey Control

ANNEXURE G71/D – PLANNING DOCUMENTS

Refer to Clause 1.2.3.

The following documents are a summary of documents that must be included in the Quality System documentation. Review the requirements of this Specification and others included in the Contract to determine additional documentation requirements.

Clause	Description
1.4.1	Procedures to set out, verify conformity and measure quantities
1.4.1	Responsibilities of the qualified surveyors
2.4	Management of the Survey Control Marks Register
3.1	Pavement software
3.1	Quantities software
5.1.3	Sampling plan for pavements

ANNEXURE G71/E – THE BODY RESPONSIBLE FOR THE STATE OR TERRITORY GEODETIC SURVEY

Insert name of relevant body and if available, details of offices of the body throughout the state or territory.

Example

OFFICE LOCATIONS FOR NSW LAND AND PROPERTY MANAGEMENT AUTHORITY

NSW Land and Property Management Authority information centres for survey marks and the protection of survey marks. Opening hours are Monday to Friday, 8.30 am to 4.30 pm.

SYDNEY		
Survey Services 2nd Floor, 1 Prince Albert Road Queens Square Building Sydney NSW 2000	GPO Box 15 Sydney NSW 2001	Phone: (02) 8258 7500 Fax: (02) 8258 7555
BATHURST		
Survey Services Panorama Avenue Bathurst NSW 2795	PO Box 143 Bathurst NSW 2795	Phone: (02) 6332 8224 Fax: (02) 6332 8230
LISMORE		
c/- Department of Commerce Dalley Street, East Lismore Lismore NSW 2480	PO Box 73 Lismore NSW 2480	Phone: (02) 6626 5632 Fax: (02) 6626 5666
COFFS HARBOUR		
c/- Department of Commerce 359 High Street Coffs Harbour Jetty NSW 2450	PO Box 291J Coffs Harbour Jetty NSW 2450	Phone: (02) 6651 2507 Fax: (02) 6651 1001
NOWRA		
c/- Shoalhaven Shire Council Bridge Street Nowra NSW 2541	PO Box 42 Nowra NSW 2541	Phone: (02) 4429 3279 Fax: (02) 4422 1816
NEWCASTLE		
Land & Property Information NSW, State Government Building 117 Bull Street Newcastle NSW 2300	PO Box 488G Newcastle NSW 2300	Phone: (02) 4925 9999 Fax: (02) 4929 2969

PORT MACQUARIE		
c/- Hastings Municipal Council Cnr Lord Street & Burrawan Street Port Macquarie NSW 2444	PO Box 84 Port Macquarie NSW 2444	Phone: (02) 6581 8638 Fax: (02) 6581 8620
WYONG		
c/- Wyong Shire Council 16 Hely Street Wyong NSW 2259	PO Box 20 Wyong NSW 2259	Phone: (02) 4350 5324 Fax: (02) 4350 5324

ANNEXURE G71/F – TOLERANCES FOR CONCRETE BRIDGE SURFACES

Table G71.11 - Dimensional Tolerances for Concrete Bridge Surfaces and Survey Orders of Accuracy

Item		Tolerance in mm Unless Shown Otherwise	Orders of Accuracy	
			Horizontal	Vertical
(i)	Footings:			
	• Plan dimensions for formed footings and pile caps	– 10 to + 50	3H	N.A.
	• Plan dimensions for unformed footings	0 to + 150	3H	N.A.
	• Thickness < 300 mm	– 5 to + 25	N.A.	4V
	• Thickness ≥ 300 mm	– 10 to + 50	N.A.	5V
	• Top of footing or pile cap reduced level	– 25 to + 25	N.A.	5V
	• Departure from the plan position in any direction	50	3H	N.A.
(ii)	Variation in cross section of columns, piers, headstocks, slabs, walls, beams and similar parts (excluding deck slabs and end posts):			
	• < 3 m	– 5 to + 15	Tape (1)	N.A.
	• ≥ 3 m	– 10 to + 25	Tape (1)	N.A.
(iii)	Variation of cross section of end posts	– 5 to + 5	Tape (1)	N.A.
(iv)	Variation in thickness of deck slabs (excluding allowance for correction of camber or hog)	– 5 to + 15	N.A.	4V
(v)	Deck joints:			
	• Width of slot	– 3 to + 3	1H	N.A.
(vi)	Variation from vertical of specified batter of columns, piers, walls and barriers:			
	• Unexposed concrete	12 mm in 3 m (1/250)	2H	4V
	• Exposed concrete	6 mm in 3 m (1/500)	1H	4V
(vii)	Variation from grades shown in the Drawings for kerbs and barriers	3 mm in 3 m (1/1000)	2H	4V
(viii)	Reduced level of tops of headstocks and piers:			
	• With pedestals	– 10 to + 10	N.A.	4V
	• Without pedestals	– 5 to + 5	N.A.	4V
	• Difference in level across width of headstocks	5	N.A.	4V (2)
(ix)	Bearing pads and pedestals:			
	• Reduced level	– 2.5 to + 2.5	N.A.	3V
	• Variation from grade across the width of individual pads and pedestals must not exceed	1 in 200	N.A.	4V (3)
	• Deviation from flat surface	–1.0 to + 1.0	Straight edge & tape	N.A.

Item	Tolerance in mm Unless Shown Otherwise	Orders of Accuracy	
		Horizontal	Vertical
(x) Departure from plan position at any level:			
• Columns, piers, walls, headstocks, beams, slabs, kerbs and other similar components	25	1H	N.A.
• Relative displacement of adjoining components must not exceed	10	Tape (1)	N.A.
• Centreline of bearings	5	1H	N.A.
(xi) Departure from alignment :			
• Rows of columns, faces of piers or walls	10	1H	N.A.
• Handrails, faces of hand rail posts, kerbs	5	1H	N.A.
(xii) Maximum allowance for irregularities in exposed concrete surfaces:			
• Sections less than 1 m in dimension when measured with a straight edge across the dimension of the section	2.5	Straight edge & tape	N.A.
• Sections greater than 1 m in dimension when measured with a straight edge across the dimension of the section, except that when sections are greater than 3 m in dimension, a 3 m straight edge must be used	5	Straight edge & tape	N.A.
• Deviation from design kerb dimensions	– 2.5 to + 2.5	Tape	N.A.
(xiii) Flatness of front face of barriers	3 mm in 3 m	Straight edge & tape	
(xiv) Flatness of top surface of bridge deck in any direction.	5 mm in 3 m	Straight edge & tape	
(xv) Slip formed barriers:			
• Deviation from a 3 m straight edge held longitudinally on all surfaces	6	Straight edge & tape	
• Vertical and horizontal alignment between adjacent barrier segments	6	Straight edge & tape	

Legend for Table G71.11

(1) Careful use of a calibrated steel tape provides sufficient accuracy.

(2) May use differential levelling procedure where measurement of the relative height difference across the headstock is required and not AHD values.

(3) May use a builder’s spirit level or differential levelling procedure.

N.A.: Not applicable

Note: where Table G71.11 is applicable then a survey certificate is required on all formwork prior to placing concrete.

Annexure G71/G – Dimensional Tolerances and Orders of Accuracy for Some Bridge Components

Table G71.12 lists survey tolerances and survey input for some bridge components, along with the required survey Orders of Accuracy as defined in Clause 4.

Table G71.12 – Dimensional Tolerances and Orders of Accuracy for Some Bridge Components (continued over page)

Specification Covering	Work Activity	Refer. or Std.	Tolerance [(2)]	Orders of Accuracy Horiz.	Orders of Accuracy Vert.	Cert-ificate	Joint survey
Piles							
Driven reinforced concrete piles	**Position:**						
Driven prestressed concrete piles Driven H section steel piles Driven tubular steel piles	(a) For a pile installed from land, with a cut-off level no more than 2 m below piling platform level Note: Where a pile projects above the ground, a tighter inclination tolerance may be required.		(a) ± 75 mm horz. + 4% of the specified incl. for piles raked up to 1:5, and 7% for piles raked > 1:5.	3H	5V		
Driven cast-in-place concrete piles Permanently cased cast-in-place reinforced concrete piles	(b) For a pile installed from land, with a cut-off level at or more than 2 m below piling platform level	AS 2159 Cl. 7.2	(b) ± 75 + 20 (h - 2) mm horz. + 4% of the specified incl. for piles raked up to 1:5, and 7% for piles raked > 1:5, where h is the depth to cut-off in metres.	3H	5V	Yes	No
Bored cast-in-place reinforced concrete piles (without permanent casing)	(c) For a pile installed from a floating plant		(c) ± 150 mm horz. + within 4% of the specified incl. for piles raked up to 1:5, and 7% for piles raked > 1:5.	4H	6V		
Driven composite piles	**Cut-off levels:**		± 25 mm	N.A.	5V		

Specification Covering	Work Activity	Refer. or Std.	Tolerance: Piles	Tolerance: Planks	Tolerance: Girders	Horiz.	Vert.	Cert-ificate	Joint survey
Supply of pretensioned precast concrete members	**Conformity of dimensions of concrete members:**		Table B110.1					Yes	No
	Linear dimensions:								
	Cross sections < 2 m		± 4 mm	± 4 mm	± 4 mm	Tape [(1)]	N.A.		
	Cross sections > 2 m		N.A.	N.A.	± 7 mm	Tape [(1)]	N.A.		
	Length		± 20 mm	Greater of 0.06% L or ± 10 mm		2H (Piles), 1H (Girders)	N.A.		
	Core hole opening:	Nil							
	Location		N.A.	± 7 mm		1H	N.A.		
	Diameter or side dimensions		N.A.	± 4 mm		Tape [(1)]	N.A.		

Specification Covering	Work Activity	Refer. or Std.	Tolerance (2)		Orders of Accuracy		Cert-ificate	Joint survey
					Horiz.	Vert.		
	Diagonal twist:							
	Up to 2 m on shorter side		± 7 mm	± 4 mm	1H or Tape (1)	N.A.		
	Over 2 m and less than 4 m		± 7 mm	± 5 mm	1H or Tape (1)	N.A.		
	Over 4 m		± 7 mm	± 7 mm	1H or Tape (1)	N.A.		
	Twist (angular rotation)		0.5° over length of member		1H or Tape (1)	N.A.		

Specification Covering	Work Activity	Refer. or Std.	Tolerance [2]			Orders of Accuracy		Cert-ificate	Joint survey
						Horiz.	Vert.		
Supply of pretensioned precast concrete members (cont'd)	Profile:		**Piles**	**Planks**	**Girders**				
	Vertical plane (hog)	Nil	N.A.	0.05 L	Greater of 35% of design value or ± 20 mm	1H or Tape [1]		Yes	No
	Horizontal plane (bow)		Greater of 0.06% L or ± 8 mm			1H or Tape [1]			
Precast concrete members (non-pretensioned)	**Conformity of dimensions of concrete members**		Table B115.1						
			Piles	**Girders & post-tensioned members**					
	Linear dimensions:								
	Cross sections < 2 m		± 4 mm	± 4 mm		Tape [1]	N.A.		
	Cross sections > 2 m		± 7 mm	± 7 mm		Tape [1]	N.A.		
	Length		± 20 mm	Greater of 0.06% L or ± 10 mm		2H (P), 1H (G)	N.A.		
	Core holes, openings:								
	Location		N.A.	± 7 mm		1H	N.A.		
	Diameter or side dimensions		N.A.	± 4 mm		Tape [1]	N.A.	Yes	No
	Diagonal dimensions:								
	Up to 2 m on shorter side		± 7 mm	± 4 mm		1H or Tape [1]	N.A.		
	Over 2 m and less than 4 m		± 7 mm	± 5 mm		1H or Tape [1]	N.A.		
	Over 4 m		± 7 mm	± 7 mm		1H or Tape [1]	N.A.		
	Twist		0.5° over length of member			1H or Tape [1]	N.A.		
	Profile:								
	Vertical plane (deviation from design profile)		Greater of 0.06% L or ± 8 mm			1H or Tape [1]	N.A.		
	Horizontal plane (bow)		Greater of 0.06% L or ± 8 mm			1H or Tape [1]	N.A.		
Erection of pretensioned precast concrete members	Pre-alignment underside member must marry with the bearings. G71 joint survey and conformance survey for girders.		Clause 4.3 Member bearings must comply with B284			See B284		Yes	Yes
	Profile Diagram before placing cast-in-situ concrete supported by member. G71 joint survey and conformance survey for girders.		Clause 6.4 Position 20 mm, deviation from plumb of 1/200 times distance between points or 10 mm, which ever is less.					Yes	Yes
Incrementally launched prestressed concrete girders	**Reference Point** Procedure for establishing, verifying and maintaining survey control and for certification of accuracy of control marks, plus set out from control marks.		Clause 6.1 ± 0.5 mm in position & height			Establish control with LU of 4mm and use 1H and 1V procedures from control marks		Yes	No

Specification Covering	Work Activity	Refer. or Std.	Tolerance (2)	Orders of Accuracy		Cert-ificate	Joint survey
				Horiz.	Vert.		
Incrementally launched prestressed concrete girders (cont'd)	**Installation of launching bearing:**		Clause 5.3				
	(a) Position:						
	(i) Measured in a direction parallel to bridge centreline		± 3 mm	1H	N.A.		
	(ii) Measured in a direction normal to bridge centreline		± 1.5 mm	1H	N.A.		
	(b) Level:						
	(i) Launching bearings within the casting bed						
	- Levels relative to the Reference Point		± 2 mm	N.A.	2V		
	- Levels relative to the soffit sliding surface adjacent to the launching bearing		± 0.5 mm	N.A.	1V		
	(ii) Launching bearings between the casting bed and the launching abutment and braking saddle plates						
	- Levels relative to the Reference Point		± 2 mm	N.A.	2V	Yes, certificate for levels and alignment of side guides for first three segments and then every third segment.	No
	- Levels relative to adjacent launching bearings or braking saddle plate		± 0.5 mm	N.A.	1V		
	- Levels relative to launching bearings or braking saddle plate located at the same cross section		± 0.5 mm	N.A.	1V		
	(iii) All other launching bearings						
	- Levels relative to launching bearings on adjacent piers or abutments		± 1.5 mm	N.A.	2V		
	- Levels relative to launching bearings located on the same pier or abutment		± 0.5 mm	N.A.	1V		
	(c) Deviation from specified plane:						
	Deviation from the specified plane, both longitudinally and transversely.		< 1 mm in 1000 mm	1H	2V		
	Sliding surfaces on casting yard		Clause 7.4				
	Soffit:						
	(a) Vertical tolerance (relative to Reference Point)		± 2 mm	N.A.	2V		
	(b) Vertical tolerance (relative to other soffit sliding surface).		± 1 mm	1H	1V	No	No
	(c) Slope tolerance (deviation from specified slope).		< 1 mm in 1000 mm	1H	2V		

Specification Covering	Work Activity	Refer. or Std.	Tolerance (2)	Orders of Accuracy		Cert-ificate	Joint survey
				Horiz.	Vert.		
Incrementally launched prestressed concrete girders (cont'd)	Lateral Sliding Surfaces: (a) Horizontal tolerance (relative to deck centreline). (b) Slope tolerance (deviation from specified slope).		1.5 mm < 1 mm in 1000 mm	1H 1H	N.A. 2V	No	No
	Installation of top attachment plates for permanent bearings						
	(a) Measured in a direction parallel to the bridge centreline. (b) Measured in a direction transverse to the bridge centreline		± 10 mm ± 3 mm	1H (2) 1H (2)	N.A. N.A.	No	No
Erection of precast concrete members (not pretensioned)	Pre-alignment of temporary and permanent supports on girder bridges		Clause 6.4 Compliance with B80, or Cl. 6.4 if B80 not applicable (a) deviation for position 20mm in any direction (b) deviation of point from a straight line < 1/250 times length or 10 mm, which ever is less (c) vertical members deviation from plumb < 1/250 times length or 10 mm, which ever is less	Consult bridge plans		Yes, profile of completed work where member is errected on girder bridges	No
Supply and installation of void former	Position of void		Clause 5.1 Position: 7 mm	1H	N.A.	No	No
Erection of structural steelwork	Profile of temporary formwork supporting steelwork		Consult formwok design and bridge plans			Yes	No
	Profile of installed steelwork	AS 4100	**Location of Anchor Bolts**				
			(a) 3 mm centre-to-centre of any two bolts within an anchor bolt group. An anchor bolt group is defined as the set of anchor bolts which receives a single fabricated steel member.	1H	N.A.	Yes	No
			(b) 6 mm centre-to-centre of adjacent anchor bolt groups	1H	N.A.		
			(c) Maximum accumulation of 6 mm per 30 000 mm along an established column line of multiple anchor bolt groups, but not to exceed a total of 25 mm.	1H	N.A.		
			(d) 6 mm from the centre of any anchor bolt group to the established column line through that Group.	1H	N.A.		
			Column Base				
			Position: ± 6 mm along either axis Level: ± 10 mm of the underside of steel base	1H N.A.	N.A. 3V		

Specification Covering	Work Activity	Refer. or Std.	Tolerance (2)	Orders of Accuracy		Cert-ificate	Joint survey
				Horiz.	Vert.		
Erection of structural steelwork (cont'd)	Profile of installed steelwork (cont'd)	AS 4100	**Plumbing of compressed member**				
			Must not exceed height/500 or the lesser of:				
			Up to 60 m height: 25 mm	N.A.	4V		
			Above 60 m height: 25 mm + 1 mm per 1000 mm to max 50 mm	N.A.	4V	Yes	No
			Level & alignment of beam				
			Beam is within ± 10 mm for level	N.A.	3V		
			Within ± 3 mm of its horizontal to other members	1H	N.A.		
	Gap for expansion joints		Spans less than 50 m: 0, + 5 mm	1H	N.A.	Yes	No
			Spans greater than 50 m: 0, + 10 mm	1H	N.A.		
Erection of structural aluminium	Profile of temporary formwork supporting aluminium	See B260	See B260			Yes	No
	Profile of installed aluminium					Yes	No
Erection of barrier railing and minor components	**Setting out hold down bolts**						
	Railings		3 mm deviation from line	2H	4V		
	Lighting columns		N.A.	3H	5V	Yes, set out diagram.	No
	Conformity reports						
	Railings			2H	4V		
	Light columns			3H	5V		
Installation of bridge bearings	**Bearings**		Clause 5.2				
	(i) Position		3 mm	1H	N.A.		
	(ii) Level:						
	- For bridges with short girders		± 5 mm	N.A.	2V		
	- For bridges with continuous superstructure		0.0001 x *Length* or 5 mm, whichever is greater	N.A.	2V		
	- Bearing inclination		1/200	N.A.	2V	Certificate to verify set out position and certificate to verify the final position of the bearings	Yes
	Elastomeric bearings						
	(i) Level						
	- Elastomeric strips (*on headstock*):		± 2.5 mm	N.A.	2V		
	- Elastomeric pads (*usually on mortar pad*):		± 2.5 mm	N.A.	2V		
	- Difference in level between adjacent bearings		± 2.5 mm	N.A.	2V		
	(ii) Position						
	- Elastomeric strips		± 5 mm transversely and ± 15 mm longitudinally	1H	N.A.		
	- Elastomeric pads		± 3 mm transversely and ± 3 mm longitudinally	1H	N.A.		

Legend for Table G71.12

(1) Careful use of a calibrated steel tape provides sufficient accuracy.

(2) The tolerances shown in the referenced Specification may be subject to change. Where the tolerances shown in Table G71.12 are inconsistent with the tolerances shown in the referenced Specification, the latter has precedence.

G71/H TO G71/L – (NOT USED)

ANNEXURE G71/M – REFERENCED DOCUMENTS

(Example list of reference documents)

	NSW Government
	Surveying & Spatial Information Act 2002
	Surveying Regulation 2006
	Australian Standards
AS 2159	Piling – Design and Installation
AS 4100	Steel Structures
AS 2876	Concrete Kerbs and Channels (gutters)
	RTA Specifications
RTA Q	Quality Management System
RTA G2	General Requirements
RTA G21/G22	Occupational Health and Safety
RTA G40	Clearing and Grubbing
RTA R44	Earthworks
RTA B50	Driven Reinforced Concrete Piles
RTA B51	Driven Prestressed Concrete Piles
RTA B53	Driven H-Section Steel Piles
RTA B54	Driven Tubular Steel Piles
RTA B57	Driven Cast-in-Place Concrete Piles
RTA B58	Permanently Cased Cast-in-Place Concrete Piles
RTA B59	Bored Cast-in-Place Reinforced Concrete Piles (without Permanent Casing)
RTA B61	Driven Composite Piles
RTA B80	Concrete Work for Bridges
RTA B110	Supply of Pretensioned Precast Concrete Members
RTA B115	Precast Concrete Members (Not Pretensioned)
RTA B150	Erection of Pretensioned Precast Concrete Members
RTA B152	Incrementally Launched Prestressed Concrete Girders
RTA B153	Erection of Precast Concrete Members (Not Pretensioned)

RTA B170	Supply and Installation of Void Formers
RTA B260	Erection of Structural Steelwork
RTA B261	Erection of Structural Aluminium
RTA B264	Erection of Barrier Railings and Minor Components
RTA B284	Installation of Bridge Bearings

Surveying Standards and Guides

NSW Surveyor General's Directions for Survey Practice

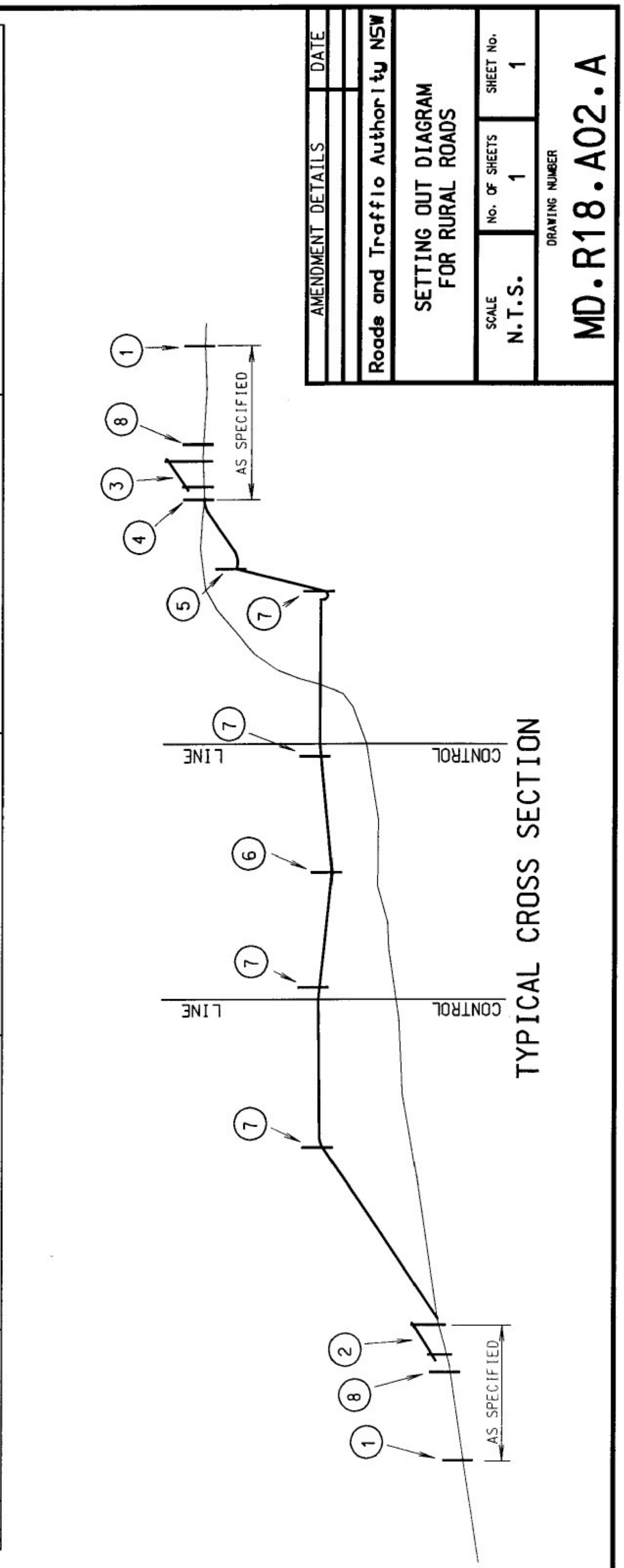
Inter-Governmental Committee on Surveying and Mapping (ICSM) Standards and Practices for Control Surveys (SP1)

Inter-Governmental Committee on Surveying and Mapping (ICSM) Guide to QA Specification G71 – Road Construction Surveys

NSW Department of Lands - Control Surveys and SCIMS

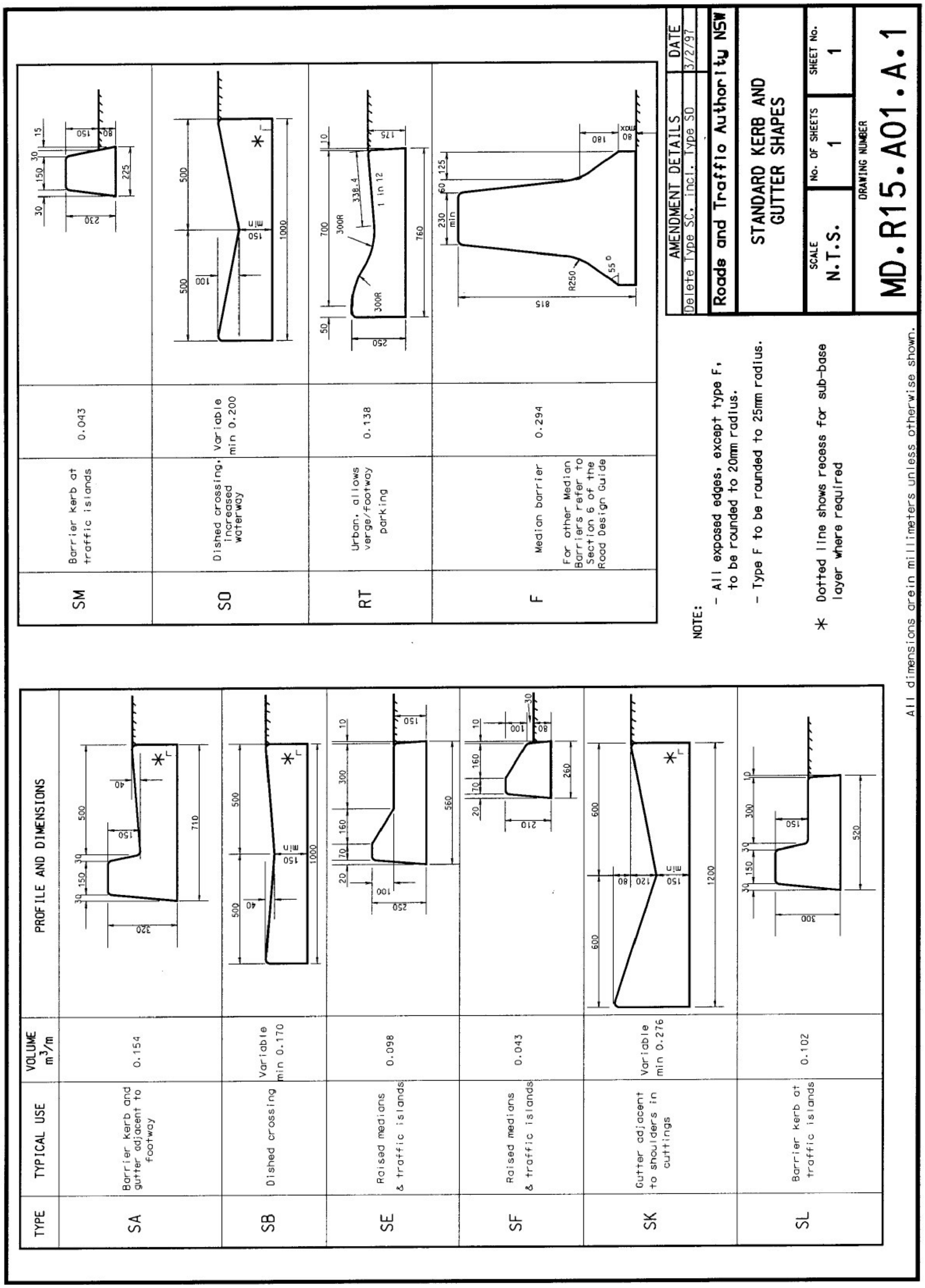
APPENDIX 1 – MODEL DRAWING SHOWING POSITION OF BATTER PROFILES IN RELATION TO DESIGN BATTER PLANE

No.	DESCRIPTION	LOCATION	TYPE OF MARK	COLOUR	REMARKS
1	Clearing Stake	Limit of clearing	25 x 25 stake	Top 600mm. – pink	
2	Fill Batter Profile	Toe of fill batter	50 x 50 posts with 75 x 25 rail parallel to batter	Orange	1000mm vertical above batter.
3	Cut Slope Profile	Adjacent to cut slope peg	50 x50 posts and 75 x 25 rail parallel to batter	Dark blue	300mm vertical above batter.
4	Cut Slope Peg	Edge of cut	50 x 50 peg	Dark blue	
5	Rock Slope peg	Edge of rock cut	50 x 50 peg or steel rod (12n)	Dark blue	Accurately locate for presplit drilling.
6	Median drain Peg	Invert of median drain	50 x 25 post	White with black line to indicate R.L. of drain invert	
7	Formation peg	900mm from edge of formation	50 x 50 post or steel rod (min. 20n)	Sub-grade level and selected sub-grade thickness-light green	Sufficient height to protect x-fall across total formation.
8	Recovery Mark and indicator	Immediately clear of earthworks.	Tack in 50 x 50 x 200 peg 50 x50 x 1500 post or star picket	White White and red	Peg driven flush with ground Chainage & offset written on stake.

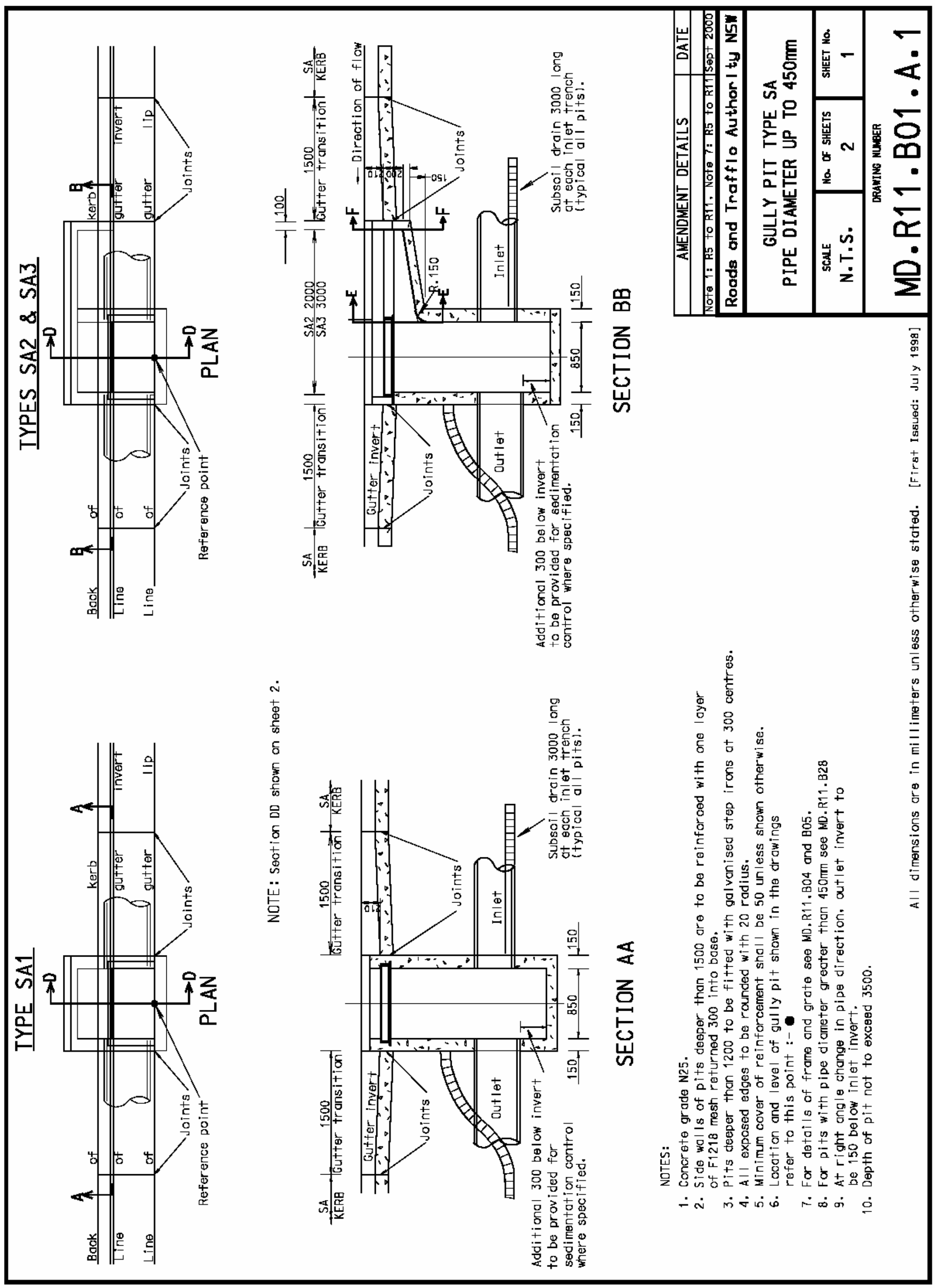


APPENDIX 2 – MODEL DRAWINGS DRAINAGE DRAWINGS

2.1 STANDARD KERB AND GUTTER SHAPES FOR RTA ROADS

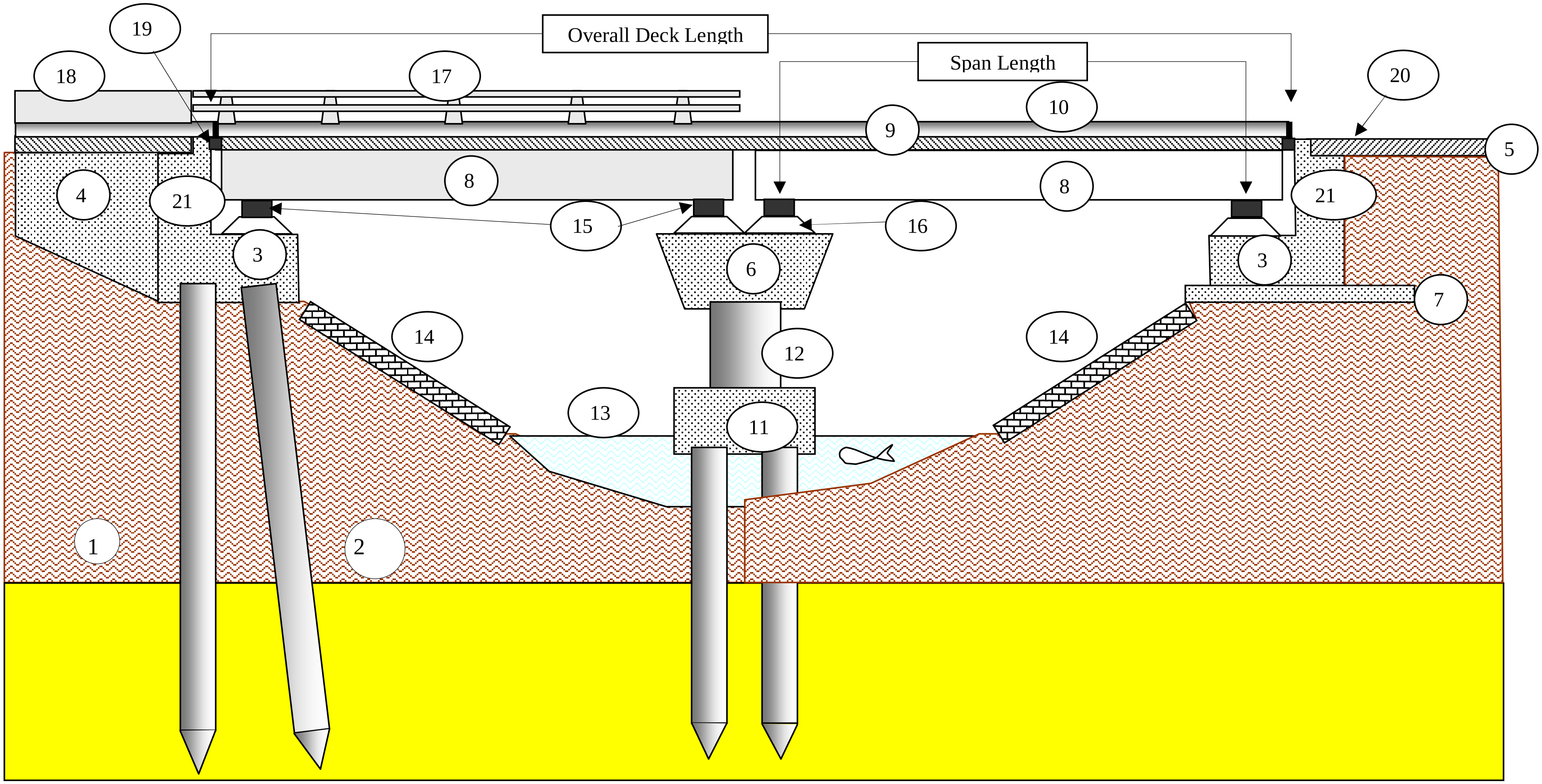


2.2 SET OUT POINTS FOR GULLY PITS TYPE SA



APPENDIX 3 – SCHEMATIC REPRESENTATION OF BRIDGE COMPONENTS

1. Vertical Piles	4. Wingwalls	7. Spread Footing	10. Kerb/Parapet	13. Waterway	16. Bearing Plinth	19. Expansion Joints
2. Raked Piles	5. Bridge Approach	8. Girders	11. Pile Cap	14. Batter Protection	17. Barrier Railing	20. Approach Slabs
3. Abutment Sill	6. Pier Headstock	9. Deck Slab	12. Pier Column	15. Bearings	18. Approach Barrier Transition	21. Abutment Dwarf Walls



TYPICAL BRIDGE ABUTMENT DETAIL