ICSM QA SPECIFICATION G71
ROAD CONSTRUCTION SURVEYS

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This QA Specification G71 *Road Construction Surveys* 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.*

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QA SPECIFICATION G71

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ROAD CONSTRUCTION SURVEYS

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CLAUSE PAGE

FOREWORD

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REVISIONS TO EDITION 1

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

All 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~~.

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 or 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.

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 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.

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.

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.

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.

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.

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.

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).

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).

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.

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.

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.

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.

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 system 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 Quality System 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.

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.

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).

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.

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

ICSM NG71 contains 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).

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).

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.

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.

(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.

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 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.

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.

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

Pavement Surface (a)	Orders of Accuracy		Check Measurements to Survey Control Mark		Common Points Difference (e)	Sampling Plan Chainage Difference (f)	Specification Reference (g)
	Horizontal (b)	Vertical (c)	Horizontal (d)	Vertical (d)			
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

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.

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
$W \leq 1.5$ m	1
$1.5 \text{ m} < W \leq 6.0$ m	2
$6.0 \text{ m} < W \leq 11.0$ m	3
$11.0 \text{ m} < W \leq 16.0$ 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.

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.

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

Activity	Orders of Accuracy		Survey Checks to Survey Control Marks	
	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.

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	

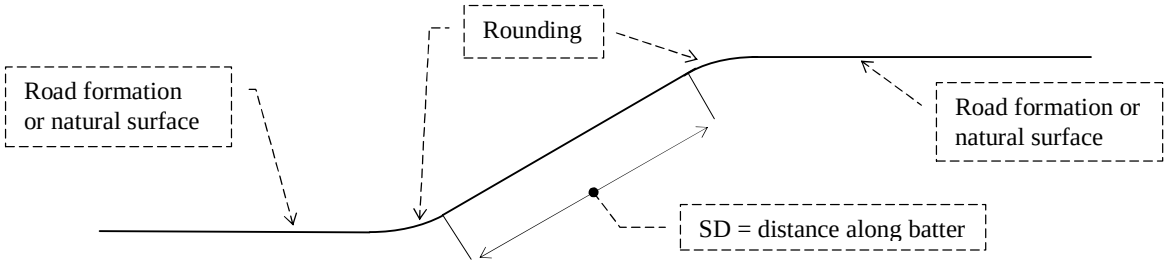

Figure G71.1 – Showing rounding on batter planes for cuts and fills

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.

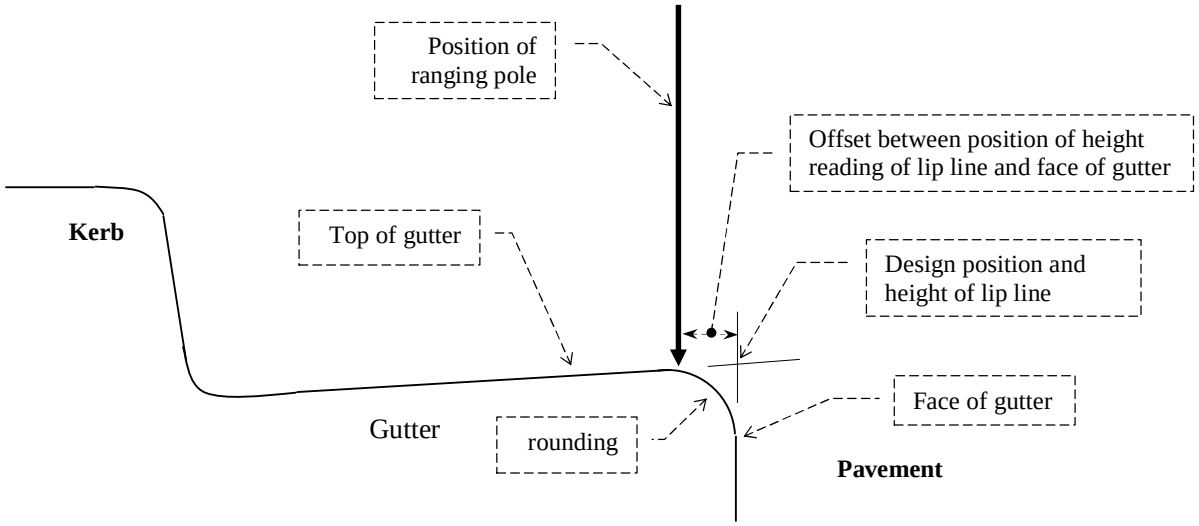

Figure G71.2 – Allowance for Lip Rounding when Determining Constructed Position of Lip Line

5.5 BRIDGES

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.

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.

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 & Spatial Information Act

A1.4 Additional Survey Requirements for Survey Equipment Control:

Example NSW 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 NSW 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	GPO Box 15	Phone:	(02) 8258 7500
Sydney NSW 2000	Sydney NSW 2001	Fax:	(02) 8258 7555

BATHURST

Survey Services			
Panorama Avenue	PO Box 143	Phone:	(02) 6332 8224
Bathurst NSW 2795	Bathurst NSW 2795	Fax:	(02) 6332 8230

LISMORE

c/- Department of Commerce			
Dalley Street, East Lismore	PO Box 73	Phone:	(02) 6626 5632
Lismore NSW 2480	Lismore NSW 2480	Fax:	(02) 6626 5666

COFFS HARBOUR

c/- Department of Commerce			
359 High Street	PO Box 291J	Phone:	(02) 6651 2507
Coffs Harbour Jetty NSW 2450	Coffs Harbour Jetty NSW 2450	Fax:	(02) 6651 1001

NOWRA

c/- Shoalhaven Shire Council			
Bridge Street	PO Box 42	Phone:	(02) 4429 3279
Nowra NSW 2541	Nowra NSW 2541	Fax:	(02) 4422 1816

NEWCASTLE

Land & Property Information			
NSW, State Government Building			
117 Bull Street	PO Box 488G	Phone:	(02) 4925 9999
Newcastle NSW 2300	Newcastle NSW 2300	Fax:	(02) 4929 2969

PORT MACQUARIE

c/- Hastings Municipal Council			
Cnr Lord Street & Burrawan Street	PO Box 84	Phone:	(02) 6581 8638
Port Macquarie NSW 2444	Port Macquarie NSW 2444	Fax:	(02) 6581 8620

WYONG

c/- Wyong Shire Council			
16 Hely Street	PO Box 20	Phone:	(02) 4350 5324
Wyong NSW 2259	Wyong NSW 2259	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		Cert-ificate	Joint survey
						Horiz.	Vert.		
Piles									
Driven reinforced concrete piles Driven prestressed concrete piles Driven H section steel piles Driven tubular steel piles Driven cast-in-place concrete piles Permanently cased cast-in-place reinforced concrete piles Bored cast-in-place reinforced concrete piles (without permanent casing) Driven composite piles	**Position:** (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.	AS 2159 Cl. 7.2	(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	Yes	No
	(b) For a pile installed from land, with a cut-off level at or more than 2 m below piling platform level		(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		
	(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		
	Cut-off levels:		± 25 mm			N.A.	5V		
Supply of pretensioned precast concrete members	**Conformity of dimensions of concrete members:**	Nil	Table B110.1					Yes	No
			Piles	**Planks**	**Girders**				
	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:								
	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			Yes, certificate for levels and alignment of side guides for first three segments and then every third segment.	No
	(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		
	- 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			No	No
	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		
	(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 erected 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 Profile of installed steelwork	 AS 4100	Consult formwok design and bridge plans **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. (b) 6 mm centre-to-centre of adjacent anchor bolt groups (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. (d) 6 mm from the centre of any anchor bolt group to the established column line through that Group. **Column Base** Position: ± 6 mm along either axis Level: ± 10 mm of the underside of steel base	 1H 1H 1H 1H 1H N.A.	 N.A. N.A. N.A. N.A. N.A. 3V	Yes Yes	No No

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**					Yes, set out diagram.	No
	Railings		3 mm deviation from line	2H	4V		
	Lighting columns		N.A.	3H	5V		
	Conformity reports						
	Railings			2H	4V		
	Light columns			3H	5V		
Installation of bridge bearings	**Bearings**		Clause 5.2			Certificate to verify set out position and certificate to verify the final position of the bearings	Yes
	(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		
	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 (over)

(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