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LAND SURVEYORS BOARD DIRECTIVES ON LAND SURVEY AND GEOMATICS PRACTICES

LAND SURVEYORS BOARD SINGAPORE

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Revision History

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Contents

10. GAZETTE SURVEY

Acknowledgements

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- SLA Survey and Geomatics Division
- SISV (Land Survey Division)
- Mr Loi Hwee Yong
- Mr Chua Keng Guan
- Mr Pang Choon Chew
- Mr Andrew Yap Chee Ming
- Mr Geoffrey Morris

Disclaimers

While every effort has been made to ensure the accuracy and quality of information contained in this publication, the Land Surveyors Board, its employees, agents or industry partners can take no responsibility for the subsequent use of this information, nor for any errors or omissions that it may contain.

The techniques, methods and equipment listed herein are not exhaustive. These directives do not preclude the use of any new technique or technology that may emerge. The Registered Surveyor shall be accountable for its achievable accuracy and in meeting stipulated specifications.

While these directives attempt to cover all of land survey practices that are under the purview of the Land Surveyors Board, it cannot cover every detail. Directives, standards and specifications published by other Authorities are also relevant to the land survey practices as follows:

Publication	Compliance by Registered Surveyor
Statutory Directives	To be complied with relevant statutory Acts Examples: • *Boundaries and Survey Maps Act (Cap.25)* • *The Land Titles Act (Cap.157)* • *The Planning Act (Cap.232)*
Other Directives	To be complied if relevant but LSB Directives on the same matter shall take precedence if available or where there is a conflict
Guidelines	To be complied with if specified or being referred to in a contract or any valid instruction

Standard and Specifications	To be adopted: (i) If specified or referred to in a contract or (ii) If the *Land Surveyors Board Directives on Land Survey and Geomatics Practices* has been referred to in a contract (iii) Survey directives issued by Authorities , Agencies and/or Employer. Examples: • *Standard and Specifications for 3D Topographic Surveying (Mapping) in Singapore* [Published by SLA] • *Standard and Specifications for Utility Survey in Singapore* [Published by SLA] • *General Specifications For The Conduct Of Hydrographic Survey* [Published by MPA]

1. INTRODUCTION

1.1 Introduction

These Directives cover all categories of land surveying except the cadastral surveys with respect to prevailing statutory provisions.

No attempt is made to detail how such surveys are to be carried out as different situations or requirements may require different solutions. The Registered Surveyors have to determine the use of appropriate equipment and methodology to satisfy their clients' specifications. The Directives shall cover the standard and essential specifications of survey practices demanded of a registered surveyor.

1.2 Precedence

The Directives are not intended to substitute the technical specifications stipulated by the Clients of registered surveyors regardless of the technical specifications being of higher or lower order. Contractual agreements on specifications entered into between the Registered Surveyor and his client shall take precedence over the directives in the event of disputes.

However, there may be specifications in the Directives that if the Client provides for a lower standard or non-compliance with authorities' requirement, the Registered Surveyor shall document that he had advised the Client on the inadequacy. The contractual engagement of Registered Surveyors shall not contravene the *Land Surveyors Act (Chapter 156)*.

The Directives are by no means exhaustive as new technologies and methods will continue to emerge. The Directives will be periodically reviewed to embrace and to leverage on these developments to respond to the changing business needs.

1.3 Registered Surveyors, Surveyors and Assistant Surveyors

1.3.1 Registration of Surveyors

As provided for in the *Land Surveyors Act (Chapter 156)*, a registered surveyor shall only practice if he (or she) has in force a valid practising certificate issued by the Land Surveyors Board.

1.3.2 Licensing of Corporations

In addition, for surveyors providing survey services under a corporate or partnership, a corporate licence granted by the Land Surveyors Board is required.

1.3.3 Competence Levels of Surveyors and Assistant Surveyors

Surveyors and Assistant Surveyors shall comprise those employed for field work and also those in the office for processing of data, computation and preparation of plans. For benchmarking the various competence level, the following are the categories of surveyors and assistant surveyors:

(a) Member and Probationer Member of Singapore Institute of Surveyors and Valuers (SISV):

    (i) Surveyors with academic qualifications acceptable by Land Surveyors Board for the Board's examinations and being a member or probationer member of SISV.

(b) Technical Member of SISV with:

    (i) *Diploma in Land Surveying* (Singapore Polytechnic)

    (ii) *Diploma in Geospatial Information & Technology* (BCA Academy)

    (iii) Land surveying degrees or diploma awarded by overseas institutions academically acceptable for Technical Membership and having passed prescribed courses conducted by SISV

(c) Surveyors who are registered as Authorised Assistants with Singapore Land Authority

(d) Surveyors who are an undergraduate in a degree in Land Surveying or Geomatics programme acceptable by the Land Surveyors Board for its examinations

(e) Assistant Surveyors with *Certificate in Basic Land Surveying* awarded by SISV

(f) Assistant Surveyors without formal academic training

Those with no formal training in land surveying but have been employed for land surveying works are encouraged to take up a relevant land surveying course. As it is difficult to assess the relevant experience and skill level for grading based on time spent in surveying, the academic qualification will be more equitable in view of the examinations for knowledge levels.

1.3.4 Competence and Direct Supervision of Surveyors and Assistant Surveyors

The Registered Surveyor shall be responsible for the competence and direct supervision of the Surveyors and Assistant Surveyors under his employment and/or under his management. The responsibility also includes their conduct relating to the survey works.

1.3.5 Qualifications for Assistant Surveyors

For Assistant Surveyors without formal academic training, the supervising Registered Surveyor is advised to ensure that he completes courses in Land Surveying relevant to the survey tasks assigned to him. The available courses are:

	Current Courses	**Recommendation**
1	Continuing Training Modules: CTM(1), CTM(2) and CTM(3) inclusive By SISV	For new employees without formal training in Land Surveying
2	Diploma in Geospatial Information & Technology By BCA Academy	For employees who are already practising surveying
3	Land Surveying modular courses leading to a Diploma – by SISV	For employees who are already practising surveying

Discontinued courses that are accredited for employment as Assistant Surveyors are:

(a) *Certificate in Cadastral Surveying* awarded by Singapore Institute of Surveyors and Valuers

(b) *Certificate in Basic Land Surveying* awarded by Singapore Institute of Surveyors and Valuers (Last completed run in 26th Aug 2015)

(c) *Certificate in Engineering Surveying* awarded by Singapore Institute of Surveyors and Valuers (Last completed in 17th Sept 2015).

Current available courses acceptable for employment as Assistant Surveyors are:

(a) Continuing Training Modules (CTM) 1, 2 and 3 (inclusive), or

(b) Cadastral Surveying I
(Note: Cadastral Surveying II is required for registration as Authorised Assistant with Singapore Land Authority)

(c) Diploma in Geospatial Information & Technology

(d) Land surveying modular courses run by SISV and credited towards a Diploma awarded by SISV.

1.3.6 Project Resident Surveyors

Where the requirement for a Project Resident Surveyor (PRS) for a major project is specified, the following rules shall apply:

(a) The Project Resident Surveyor shall be a Technical Member of SISV and has in force a valid PRS card issued by SISV

(b) For the same purpose, a member or a probationer member of SISV shall also qualify as a PRS

(c) These qualifications do not override the required relevant experience stipulated in the contract

(d) Where an employee of a registered surveyor is deployed as the PRS for a project, the employing contractor shall undertake the liability for the work done by the PRS. The extent of support by the Registered Surveyor shall be based on their agreed terms

(e) Any person engaged as a PRS for a project can only be the PRS of only one project at any one time unless exempted by the relevant authority

(f) The appointment of the PRS shall cease when he/she leaves the project.

1.3.7 Registration of Project Resident Surveyors

(a) Project Resident Surveyors shall be registered with the SISV for a specific project site.

(b) The PRS shall be issued an annually renewable identification card.

(c) Each PRS shall only be issued with only one identification card for one project at any one time.

(d) A PRS shall conduct his duties to his employer with complete fidelity.

(e) The registration and identification card can be revoked by the SISV upon any misconduct or fraudulent acts or breaches of the rules prescribed by SISV.

2. GENERAL DIRECTIVES ON SURVEY PRACTICES

2.1 Horizontal Datum – SVY21

The projected coordinate system, SVY21 Datum shall be adopted for the horizontal datum and be based on the Integrated Survey Network (ISN) in compliance with the *CS Directive on Cadastral Survey Practices*.

2.2 Vertical Datum – SHD

The Singapore Height Datum (SHD) shall be adopted for the vertical height measurements in Singapore.

Vertical height measurements based on SHD shall be derived from the Vertical Control Points administered by Singapore Land Authority. Vertical height measurements using GNSS shall be based on SGeoid09 model. The Registered Surveyor shall consider the accuracy requirements before adopting GNSS and SGeoid09 model. Extracts of SGeoid09 details are shown below:

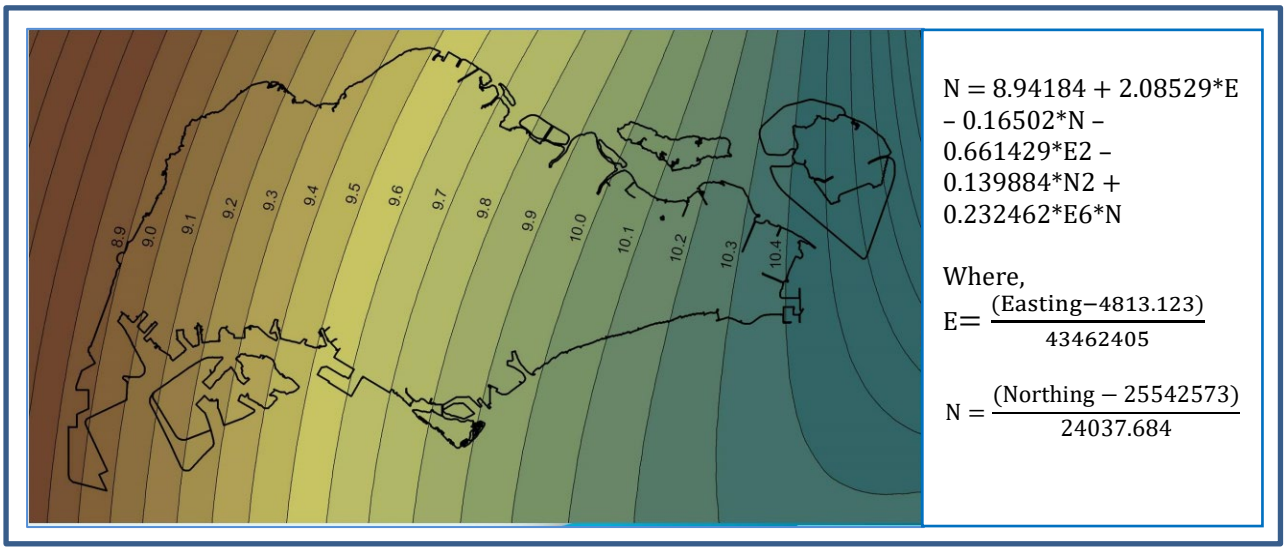

Figure 2-1: Details extracted from https://fig.net/resources/proceedings/2015/2015_07_vrfp_comm5/5A_Khoo_Singapore_Height_Datum.pdf

2.3 Chart Datum – CD

The Chart Datum (CD) established by the MPA Hydrographical Division shall be adopted as the datum for hydrographical surveys where applicable.

2.4 Accuracy of Survey Instruments

2.4.1 General Rule

The instrument to be used shall be of adequate accuracy for the intended task. However, the accuracy of survey observations, over and above the instrument's accuracy, shall be the basic criteria for acceptance of the accuracy of the survey.

2.4.2 Total Stations

The total station for general use shall have the following minimum manufacturer specified accuracy:

Distance	± 3mm + 3ppm	With prism or reflectorless.
Angular	± 5"	Regardless of display resolution

The above shall not apply where the Client has specified instruments of different accuracies.

2.4.3 Levels

The level, whether digital or optical, for general use shall have the following minimum manufacturer specified accuracy:

Engineering Works	± 2mm per sight up to 60m and 10mm per km
Precision Levelling	± 1mm per sight up to 60m and 3 mm per km

For First Order Levelling or where precise levelling is specified, precise level and invar staff(s) shall be used.

2.4.4 GNSS Receivers

The GNSS receiver shall be of survey grade with the following minimum performance specification for the respective application:

Real Time Kinematics (RTK)	Horizontal: 10 mm + 1 ppm RMS Vertical: 20mm + 1 ppm RMS Initialization time: < 15s
Post Processing Static	Horizontal: 5 mm + 1 ppm RMS Vertical: 8 mm + 1 ppm RMS

All GNSS receivers shall be tested and calibrated in compliance with the Chief Surveyor's *Specifications for GNSS Surveys of ISN Markers*.

2.4.5 Laser Scanners / LiDAR

The Laser scanning equipment shall be of survey grade with the following minimum range performance specification for the respective application

Engineering Works	Horizontal: 3 mm + 15 ppm Vertical: 3 mm + 15 ppm
Precision Works	Horizontal: 2 mm + 10 ppm Vertical: 2 mm + 10 ppm

Validation of field scanners shall be done in accordance with Section 8: Terrestrial Laser Scanning (TLS).

2.5 Compliance with Contract Specifications

Clients have the prerogative to stipulate specifications other than those specified in these directives.

Where the Client-stipulated specification does not comply with the intended submission requirement, the Registered Surveyor shall advise the Client of the inadequacy. If the Client chooses to continue with his specification, his instruction is to be documented that he has been advised.

2.6 Calibration of Distance Measuring Instruments

All total stations and distance measuring instruments shall be calibrated based on Chief Surveyor's standards using the calibration baseline at Lower Peirce Reservoir.

Each instrument shall be calibrated:
(a) Before being brought into use when new or after repair
(b) At intervals of not more than one year.

Contracts specifying calibration by vendors shall be deemed as an additional requirement over and above calibration specified in this Directive.

The permissible scale and constant errors and their treatment shall be in accordance with the *CS Directive on Cadastral Survey Practices*. This includes the permissible standard deviation of directional measurements.

Calibration certificates shall be filed and presented or submitted upon demand.

2.7 Testing and Calibration of GNSS Instruments

Each GNSS instrument used for surveys shall be tested:

(a) Before being brought into use when new or after repair

(b) At intervals of not more than one year.

The test shall comply with the "*Guidelines and Specifications for GNSS Surveys of ISN Markers"* published by the Chief Surveyor of Singapore Land Authority.

2.8 Field Checks of Instruments

2.8.1 Total Stations

When the Total Station in use shows persistent deviations in collimation of 3 times more than the vendor's specification for either horizontal or vertical angles, the instrument shall be adjusted for collimation.

The centring of the optical or laser plummet of the total station shall not exceed 1mm.

The instruments are to be checked periodically and before the commencement of any control surveys.

2.8.2 Levels

Each level shall be checked for its accuracy per sight through the two-peg test:

(a) Before being brought into use when new or after repair

(b) At intervals of not more than once every six months if only used intermittently

(c) Before the commencement of a vertical survey control network for a major project and immediately after the completion of the levelling exercise

The required performance accuracy shall be as provided in paragraph 2.4.3 above.

2.9 Method of Survey

2.9.1 Where the Method is Not Specified

Where the method of survey is not specified by the Client or in these Directives, the Registered Surveyor shall adopt or devise a method of survey that produces results complying with the accuracy and details required by the relevant Authority for which the survey results are to be submitted.

Where submission is not to be made to any Authority as advised by the Client, then the provisions in these Directives shall be complied with.

2.9.2 Where the Method is Specified in These Directives

Where the method is not specified by the Client but has been specified in these Directives, the method specified in the Directives shall be adopted unless the Registered Surveyor can show that his alternative method can provide equal or better results.

2.10 Field Survey Record

2.10.1 Permanence of Field Survey Record

(a) The Registered Surveyor shall maintain a record of the field survey data for a minimum of 5 years. This can be for inspection whenever required or for checks in case of queries in future.

(b) All written entries are to be made in ink for permanence. Inking over pencilled entries or transcribing from other records is expressly forbidden.

(c) Incorrect entries shall be cancelled by one stroke through all figures; i.e. the cancelled entry is to remain legible after the cancellation.

(d) The corrected entry shall be written above the cancelled entry. No figure shall be altered, erased or obliterated.

(e) Electronic data entries used in the survey are to be properly documented and archived.

2.11 Survey Computation

(a) Least squares errors adjustment shall be used for adjustment of survey control networks or for the distribution of random errors.

(b) Areas of lots and plots shall be computed and entered to the nearest tenth of a square metre (0.1 sq m).

(c) Scaled areas are to be distinguished by the abbreviation “Sc.” after the respective areas.

2.12 Boundary Data

2.12.1 SVY21 coordinates to be used

Unless instructed otherwise by the Client, all boundary data are to be in SVY21 Datum and refined by SLA.

2.12.2 Certifying SVY21 Coordinates Used

Notes shall be made of:

(a) The source of finalised SVY21 coordinates (e.g. Certified Plan)

(b) The date the SVY21 coordinates was refined or the date the Registered Surveyor checked that it has been refined

(c) The date the SVY21 coordinates has been verified by the Registered Surveyor with no refinement required. Records of the survey and computed data are to be kept as evidence of verifications.

2.13 Preparation of Pre-Computation Plan

(a) The pre-computation of the design layout is made to assist the Client and/or its’ appointed Consultant(s) to define the exact positions of features for setting out and to check for inconsistencies such as clearances.

(b) Salient locations shall be co-ordinated and reflected in the Pre-Computation Plan to firm up the feature’s or building’s position definitively.

(c) Where resulting clearances differ from the dimensions stated in the design or approved plans, they are to be highlighted.

(d) For development involving, adjoining or near property boundaries, the Registered Surveyor is required to verify and refine the boundaries on the ground prior to the preparation of the Pre-Computation Plan for setting out and construction.

2.14 Preparation of Survey Plan

2.14.1 Details

The details to be shown in a Survey Plan shall be in accordance to its required purpose and to the relevant Authority's requirement.

2.14.2 Plan Format

For plans that are landscape-oriented, the title block shall be on the right or at the bottom.

For portrait-oriented plans, generally, the title block shall be at the bottom.

2.15 Certification by Registered Surveyor

All submitted survey documents shall be certified by the Registered Surveyor.

The Registered Surveyor shall be responsible for all documents (digital and hardcopies), models and digital deliverables purportedly made by him or under his direct supervision.

For hardcopy deliverables, the certification shall include a declaration that the survey information presented has been done under his direct supervision and that the works are in compliance to industry standards.

For digital deliverables, the data shall be accompanied by a cover letter or survey report detailing the method of survey, calibration methods and accuracy achieved. The survey report shall be certified by the Registered Surveyor.

3. CONTROL SURVEY

3.1 Horizontal Control (At Surface Level) – General Rules

The horizontal control network in SVY21 Datum is to be established for all survey project(s) and shall be in closed loop(s) unless specified otherwise by the Client/Employer.

The horizontal control network shall consist of at least 4 good ISN markers and in compliance with *CS Directive on Cadastral Survey Practices*. In the event that there are insufficient ISN markers, new ISN markers shall be installed and surveyed as described in *Specifications for GNSS Surveys of ISN Markers* and being accepted by SLA.

The horizontal control network shall enclose the project site. Where ground conditions do not permit the enclosure of the site, the acceptable configurations listed in *CS Directive on Cadastral Survey Practices* shall apply.

'Cassini Datum' or Boundary Datum and boundary markers shall not be used for horizontal survey control.

RTK established controls, although in SVY21 Datum, shall not be used for horizontal survey control in view of their inherent accuracy level which does not comply with the requirement stipulated in the *CS Directive on Cadastral Survey Practices*.

Traverse networks can also be established with other methods such as triangulation or brace quadrilaterals subject to the site constraints or specific requirements.

3.2 Horizontal Control (At Surface Level) – Accuracies

There are varying accuracy standards designed for different project purposes. Some projects like underground tunnel will require 1st order standards whereas for other projects like volumetric survey, a 3rd order standard will suffice.

1st Order Traverse

For 1st Order horizontal control, a minimum of 4 sets of observations in four quadrants with a standard deviation of 1mm or less shall be made to obtain the mean.

The readings shall be recorded electronically to 1mm or better according to the resolution of the instrument used.

The instruments and tribrachs shall be checked for centring errors periodically or before commencement of major projects.

Atmospheric conditions such as temperature and pressure and their correction therefrom of measured distances shall be according to contract specifications.

The traverse network, inclusive of all sub-loops, shall be adjusted simultaneously by the Least Square Errors method. The residual in the adjustment at any station shall not exceed 0.010m. The error ellipse of any traverse station shall not exceed 0.010m.

2nd Order and 3rd Order Traverses

For 2nd order horizontal control, one set of observation in both faces shall be made to obtain the mean.

The readings shall be recorded electronically according to the resolution of the instrument used.

The instruments and tribrachs shall be checked for centring errors periodically or before commencement of major projects.

Atmospheric conditions such as temperature and pressure and their correction therefrom of measured distances shall be according to contract specifications.

3.2.1 Unless specified in the contract, the following table shall provide the general accuracies:

No.	Standard	Horizontal Accuracy tolerances		General type of survey works / Equipment
		Angular Closure	Linear Closure	
1	1st Order	Better than 1" per station	1:50,000	Tunnelling works, superstructures, etc.
2	2nd Order	Better than 3" per station	1:30,000	Road works, topographic, piling and various engineering survey works
3	3rd Order	Better than 5" per station	1:20,000	General earthworks, feasibility studies, etc

3.3 Vertical Control (At Surface Level) – Accuracies

A localised network of stable benchmarks shall be established for every project requiring vertical heights.

The vertical datum established from a Vertical Control Point (VCP) shall be derived from at least one VCP unless the contract specifies otherwise.

The verification shall comprise a minimum of 2 Witness Marks found to be consistent relative to the VCP.

Unless specified in the contract, the table below shall provide the general accuracy.

No.	Type of standard	Vertical Accuracy
1	Topographic	5 √ k
2	Earthworks	10 √ k
3	Road Works	3 √ k
4	Piling Works	5 √ k
5	Bore Hole Survey	5 √ k
6	Lidar Surveys	5 √ k
7	3D Monitoring / Settlement Monitoring	2 √ k
8	Tunnelling Works	2 √ k

Note: k = Distance in km

The vertical datum when established from SGeoid09 model using GNSS, shall be gross error checked against the local vertical controls before and after works daily. The allowable tolerance during the check shall be less than 50mm.

3.4 Levelling Standards

3.4.1 First Order Standards

(a) 1st order levelling survey shall be executed with a precise levelling procedure in double runs with equidistance between backsight and foresight. A precise level and invar staff(s) shall be used. Base plates shall be used for change points.

(b) When two invar staves are used for precise levelling, the difference of staff's index errors is to be accounted for. The index error difference can be nullified by having an even number of levelling setups between two benchmarks. In the double runs, the same levelling staff will occupy both the same benchmark it has occupied earlier.

(c) A minimum of 3 recorded observations with a standard deviation less than 1.0 mm shall be taken to obtain a mean observation. The readings shall be recorded electronically to 0.1 mm or better according to the instrument used.

(d) The vertical network, inclusive of all sub-loops, shall be adjusted simultaneously by the Least Square Errors method only.

3.4.2 Second Order Standards

Equidistance between backsight and foresight shall also be adhered to for 2nd Order levelling.

The vertical network shall be adjusted using Least Square Errors adjustment methods however linear error distribution methods may also be adopted.

3.4.3 Third Order Standards

For 3rd Order levelling where the height accuracy is +/-0.05m, the following shall apply:

(a) Fast Static RTK methods using the "SGeoid09" geoid model to obtain the SHD height may be adopted.
    (i) Examples of 3rd Order application are earthwork, soil investigation, utility mapping and hydrographical surveys.

(b) A minimum of 180 epochs shall be used to determine the solution.

3.5 Minimum Closure Standards for Control Surveys

The minimum closure standards for horizontal and vertical controls are summarised below:

	1st Order	2nd Order	3rd Order
Standard deviation of observations	≤ 1mm	≤ 1.5mm	≤ 5mm
Angular deviation of mean	≤ 1”	≤ 3”	≤ 5”
Centring error of tribrach	≤ 1mm	≤ 1.5mm	≤ 1.5mm
Centring error of Total Station / prism	≤ 1mm	≤ 1mm	≤ 1mm
Linear Closure	1:50,000	1:30,000	1:20,000
Angular Closure	3 √ N	5 √ N	10 √ N
Vertical Closure	2 √ K	5 √ K	10 √ K

Where: N = Number of angle stations and K = Distance in kilometres

3.6 Horizontal Control Survey (Underground)

The underground control survey refers to the survey works in a confined space during underground construction where the survey datum is to be transferred from the surface to the subterranean space. Examples are drive shaft and receiving shaft for tunnelling, open trench tunnels, pipe-jacking, etc.

The procedure for transfer differs according to the varying site constraints, construction methods (tunnel boring, pipe-jacking, excavation) and accuracy requirements.

The following are the typical sequence or order involved in the establishment and maintenance of underground control surveys (horizontal and vertical):

(a) Establishment of primary horizontal and vertical control network at surface level and enclosing the entire project area

(b) Establishment of secondary horizontal and vertical control networks to surround the shafts

(c) Transfer of horizontal control points to the subterranean space

(d) Transfer of vertical datum to the subterranean space

(e) Establishment of horizontal control survey in the subterranean space

(f) Maintenance and resurvey of subterranean horizontal and vertical control network periodically thereafter

3.7 Transfer of Horizontal Control Points from Surface level to Subterranean Space

This is the process after the secondary horizontal and vertical control networks surrounding the shafts are completed. Three (3) numbers of horizontal control points and the vertical datum are to be transferred from the surface level down to the subterranean space.

The following are some common methods for transferring survey controls:

(a) Zig-Zag Configuration in Traverse

(i) Where the diameter of the shaft provides sufficient space, the datum can be traversed down the shaft in a zig-zag configuration. 15m is the recommended minimum diameter for this procedure.

(ii) A minimum of 4 sets of observations in 4 quadrants shall be made for each leg of the traverse.

(iii) The vertical elevation that has been transferred down to the subterranean space by any suitable method shall be checked using an electronic distance measurement instrument pointing vertically. Measurements are to be made from both ends. Alternatively, a steel tape may be used. The mean obtained shall not differ from the survey results by more than 3mm/25m of vertical distance.

(b) Nadir Plummet System (NPS) or Zenith Plummet System (ZPS)

(i) This method involves two prism brackets with forced centring screws installed at the surface level over the shaft. Their positions are established from the secondary control network. They are then transferred down vertically using high precision optical or laser plummets.

(ii) The accuracy of the optical plummet used shall be in the order of 1:50,000 or better. A laser plummet of similar quality may be used, provided it has a laser footprint of <3mm in diameter.

(iii) The plummet observations are to be carried out in 4 quadrants and the mean position is to be adopted. The spread shall not exceed 4mm.

(iv) The transferred control point at the subterranean space shall not differ from the surface level control point by more than 2mm.

(v) The vertical elevations that have been transferred shall be checked using an electronic distance measurement instrument pointing vertically and measured from both ends. Alternatively, a steel tape may be used. The mean

obtained shall not differ from the survey results by more than 3mm/25m of vertical distance.

(c) Any Other Suitable Method

(i) Apart from the above common methods, the Registered Surveyor may develop or adopt any other suitable method to transfer the horizontal and vertical controls from the surface level down to the subterranean space below. The Registered Surveyor shall ensure that all accuracy requirements are met, and that all adequate checks are made.

3.8 Subterranean Control Standards

3.8.1 Datum transfer from surface to subterranean

Transfer of controls to subterranean sites shall be conducted using contract specified methods or any suitable methods provided that they meet the error budget of the project. The Registered Surveyor is to show and compute that the survey accuracy meets the error budget tolerance.

Transfer accuracy shall generally comply with the table:

	Precision in Horizontal	Precision in Vertical	Typical Projects
Depth < 30m	± 2mm	± 2mm	Utilities, Railway tunnels, vehicular tunnels
Depth > 30m	± 5mm	± 5mm	Railway tunnels, vehicular tunnels Rock Caverns, Subterranean space, Common Services Tunnel, etc…

3.8.2 Maintenance of underground control network

The underground work site may often be subjected to movements from heavy earthworks that may affect the stability of the control network points. The control network is recommended to be checked regularly at a frequency not more than 3 months apart.

4. CONSTRUCTION SURVEY

4.1 Datum and Boundary Adopted for Construction Survey

The SVY21 Datum is to be adopted for all construction projects. If any other datum is used as instructed by the Client or authority, the transformation/datum parameters are to be clearly stated.

The Singapore Height Datum (SHD) is to be adopted. If other datum is adopted, the co-relation to SHD is to be clearly stated.

For lot boundaries not surveyed in SVY21 Datum, the SVY21 coordinates obtained from SLA are to be verified and to be refined if it applies. The date of verification or refinement is to be stated.

Lot boundaries shall not be adopted from Road Line Plans, Cadastral Plan or any such plans not approved by Chief Surveyor for definition of boundaries.

Boundary marks shall not be adopted as base lines for setting out.

If any encroachment is found in the course of construction survey, the Client is to be alerted.

4.2 Pre-Computation and Setting Out Plan

Pre-computation and setting out plans are to be prepared in SVY21 coordinates. If project or local datum is adopted, the transformation parameters shall be indicated unless otherwise instructed by the Client.

Where applicable or relevant, Road Reserve Lines, Drainage Reserve Lines, Railway Protection Zones and Reserve Lines are to be incorporated. The Railway Protection Lines are to be verified before being incorporated.

Relevant setbacks and clearances are to be indicated on the plans. Any significant deviation is to be highlighted to the Client or Consultants.

This pre-computation plan should be reviewed and shall have the consent of the relevant QP / Authority prior to setting out surveys on-site.

4.3 Horizontal and Vertical Controls in Construction Survey

The SVY21 Datum and the Singapore Height Datum are to be adopted as specified in Chapter 3 of these Directives.

The Registered Surveyor shall be aware of the accuracy requirement and to adopt the appropriate method to meet the specifications of the contract or where there is none, then the relevant specifications in these Directives shall apply.

The control network for construction projects shall be checked in accordance with the contract's specifications or at quarterly intervals when not specified. In cases of possible adverse ground movements, the survey interval shall be shortened accordingly.

Survey Datum established by Realtime Kinetic (RTK) GNSS survey shall not be adopted for 1st and 2nd order survey control.

Unless specified otherwise in contracts, the following table provides the general requirement on accuracy:

	1st order	2nd order	3rd order
General Building	✓		
Infrastructures	✓		
General Foundations		✓	
Utilities		✓	
Earthwork/ bore hole			✓

4.4 Setting Out Survey

As different construction works require different solutions, the Registered Surveyor shall adopt the appropriate method to achieve the required accuracy and to facilitate the intended construction method.

All salient points are to be set out unless instructed by the Client otherwise.

The Registered Surveyor shall ascertain the reliability of the survey control points to be used before their adoption for setting out.

Less accurate methods of setting out (e.g. chain, tape) shall not be used if they do not meet the expected standard of accuracy.

Setting out boundary marks or adoption of boundaries shall comply with the *Land Surveyors Board Circular 1/2018*, apart from compliance with the Chief Surveyors Directive for Cadastral Practices.

Setting out using Realtime Kinetic (RTK) GNSS survey shall not be adopted for salient points such as grid lines, boundaries or any such point where accuracy is important.

All setting out points shall be clearly indicated on a setting out plan and checked against the design plan for correctness.

4.5 Setting Out Using GNSS Survey

The GNSS survey can be used in construction surveys and shall meet the specification stated in the *Specifications for GNSS Surveys for ISN Markers* published by Singapore Land Authority.

The “SGeoid09” geoid model shall be used to convert the GNSS ellipsoidal heights to SHD. The Registered Surveyor is to consider the accuracy of the geoid model, GNSS survey precision and ensure that it satisfies the requirements of the contract specification(s) before adopting the elevation values.

The GNSS shall be gross error checked daily against a known point established by a Registered Surveyor before and after the works. The deviation shall be less than or equal to 30mm for Northing and Easting components.

4.6 Underground Constructions

Underground construction is defined as any work below the natural ground level and being in an enclosed space such as road tunnel, MRT tunnel, deep tunnel sewer system, district cooling system, pipe jacking, basement, cavern, etc. Survey works are needed to facilitate their respective constructions.

4.6.1 Registered Surveyor's general roles in pre-underground construction include:

(a) Evaluate and approve the survey procedures submitted by the Project Resident Surveyor.
(b) Acquisition and collation of available underground utility services data
(c) Conduct geometric survey for existing tunnels/service for construction activities within the tunnel safety zones
(d) Pre-computation and setting out trial trenches/pits for location of existing underground utility lines
(e) Mapping existing or as-built positions and levels of utility lines
(f) Preparation of drawings or digital positions of the surveyed utility lines, pipes and tunnels.
(g) Establishing deformation monitoring system and conducting initial observations.

4.6.2 Registered Surveyor's general roles in underground construction include:

(a) Establishing horizontal survey control networks in SVY21 Datum and vertical survey control networks in Singapore Height Datum (SHD) in compliance with relevant specifications as reference control stations
(b) Pre-computation and setting out of manholes and shaft positions
(c) Transfer of datums down to the underground level in conformance to specified accuracies
(d) Progressive checking of alignments of tunnel guidance system, tunnel segment rings and determining the deviations
(e) Progressively provide survey support to ensure that the underground construction activities are within survey tolerance
(f) Progressive monitoring of any deformation of the surrounding environment resulting from the underground construction activities
(g) Progressive convergence monitoring of any deformation in the tunnel segment rings
(h) Conducting as-built surveys upon completion of construction and to prepare an as-built report
(i) Conduct an as-constructed geometric survey for newly constructed tunnel(s), when applicable.

4.7 Utilities and Services Construction

Utilities and services are usually buried from 1m to 3m deep. Services may include but are not limited to sewers, water pipes, power ducts and drainage. Much of the construction process falls under “Open-Cut” or “Pipe Jacking” methods.

4.7.1 Registered Surveyor’s general roles in utilities construction include:

(a) Evaluate and approve the survey procedures
(b) Acquisition and collation of available underground utility services data
(c) Conduct geometric survey for existing tunnels/service for constructions activities within the tunnel safety zones
(d) Pre-computation and setting out trial trenches/pits for location of existing underground utility lines
(e) Mapping existing or as-built positions and levels of utility lines
(f) Preparation of drawings or digital positions of the surveyed utility lines, pipes and tunnels
(g) Establishing a system where the field surveyor is available to conduct an as-laid survey of the services before it is covered.

4.7.2 As-built survey

The current practice for the as-built survey involves surveying of the manhole access top and the inverts. The pipes are then assumed between the manholes and the gradients are computed to be shown in the longitudinal section. At times, the construction records are inserted as required to supplement the as-built drawings. Much of the as-constructed services are not surveyed and may potentially not be accurately captured.

Where applicable, the survey methods shall meet the requirements stipulated in the contract and/or the Utility Survey Standards specifications issued by SLA. Where no requirements are stipulated, the below methods serve as a best practice:

Elements	Construction Methods	
	Open Cut trenching method	Pipe Jacking Method
Manhole	To survey the manhole top and invert of the manhole	To survey the manhole top and invert of the manhole
Pipes	To progressively survey the pipe top before closure of the trench as stipulated in the contract. In cases where this is not done, the RS shall clearly state so.	Where applicable and accessible, the as-built of the pipe shall be surveyed as stipulated in the contract. In cases where this is not done, the RS shall clearly state so.
Gradient Computation	To compute from the invert of the manhole	To compute from the invert of the manhole

4.8 GNSS Assisted Machine Control

Modern construction equipment (Machine) are increasingly remotely operated or robotic in nature. GNSS antennas are commonly installed onboard the Machine to assist in positional accuracy. The GNSS systems are to be tested for gross error. For practical reasons, antennas deployed should be of the same model.

The geometrical relationship between the antennas, machine critical part and the Machine Centre Reference Position shall be carefully measured using a precise total station and the offset(s) entered into the onboard acquisition computer. See Figure 4-1 below as an example.

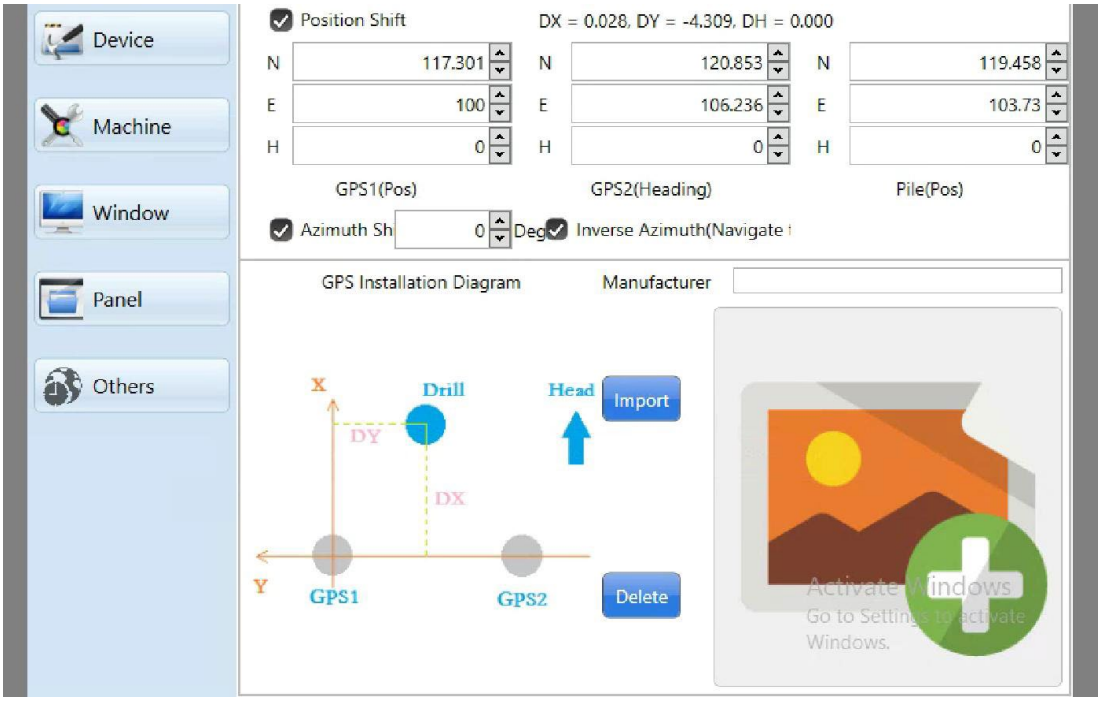

Figure 4-1: Details extracted from onboard survey system for GNSS assisted piling rig.

Where direction/heading of the machine is crucial to the operations, the machine heading shall be validated against a minimum of 4 independent observations. The residual difference between the machine heading and control heading should not exceed contract specifications requirements.

The offset correctness for the machine “desired centre” (auger centre, etc.) shall be validated against a known point or by way of an independent observation. The residual difference between the machine “desired point” and the known point shall not exceed the contract specifications requirements.

For each new activity at different sites, the above procedures are to be repeated.

A gross error check shall be carried out daily to ensure the functionality of the GNSS assisted positioning system.

5. MONITORING DURING CONSTRUCTION

The purpose of monitoring is to:

a) mitigate the impact of construction on the surrounding environment
b) provide early warning on adverse ground/structural conditions
c) identify the movement trend in support for geo-technical analysis and/or
d) track/detect structural behaviours and deformation over time or stress.

In general, the accuracies to achieve for the survey are as stipulated by the contract's specifications. The Registered Surveyor is to consider the accuracies requirements before designing and proposing the survey standards and methodology.

5.1 Standards of Controls

Monitoring surveys may be presented in relative or absolute positioning and may not require the implementation of SVY21 and SHD datums. For projects that require authority submission, it is recommended that the horizontal results are projected onto SVY21 Datum and vertical results are based on SHD.

The standards of controls implemented in relative or absolute positioning shall be of 1st order standards (refer to Section 3: Controls Survey and the method to carry out the works).

The reference control stations used for monitoring shall be outside the influence zone.

5.1.1 Methods of installation

Installation consideration shall generally take into account:

a) the stability of the feature/ground/structure
b) the monitoring target types
c) the accuracy requirements, and
d) the design provided by the Geo-Technical QP.

5.1.2 The stability of feature/ground/structure over time and weather has to be considered.

5.1.3 Monitoring target types

Monitoring target types cover 1D (Elevation Z only), 2D (Horizontal XY positions) or 3D (Horizontal and vertical positions XYZ)

1D target types

(a) A stainless bolt with a round head embedded perpendicularly into vertical structure. (Refer to Figure 5-1)

Figure 5-1: Stainless steel bolt with a round head embedded into a vertical structure (circled in red)

(b) A cross-head nail protected by a plastic sleeve embedded onto the horizontal concrete surface. The cross-head nail shall protrude slightly above the plastic sleeve and shall be secured with a non-shrink grout or a self-anchoring system. (Refer to figure 5-2)

Figure 5-2: (left) Cross-head nail and plastic sleeve; (right) A cross-head nail protected by a plastic sleeve embedded onto the horizontal concrete surface

(c) A digital level barcode strip provided by vendors printed on waterproof materials shall be installed onto the vertical structure and secured using epoxy or high bond adhesive tape. Paper photocopies of the digital barcode is not recommended due to photocopying scaling problems and expansion/shrinkage from weather. (Refer to Figure 5-3)

Figure 5-3: A vendor-provided digital level barcode strip printed on a waterproof material

2D target types

(a) A prism target shall be installed onto the surface of the structure. The prism shall be secured using screw, bolts or epoxy. (Refer to Figure 5-4)

Figure 5-4: Prism target

(b) A reflective sticker target shall be secured onto the surface of the structure out of reach of the general public. The use of the reflective sticker target is generally only

recommended on structures that restrict destructive installations. *Note* The reflective sticker target generally has a lower accuracy compared to a prism target.*

3D target types

(a) A prism target shall be installed onto the surface of the structure. The prism shall be secured using screw, bolts or epoxy. (Refer to Figure 5-4)

(b) A target reflective sticker secured using epoxy or high bond adhesive shall be installed onto the surface of the structure. The use of the target reflective sticker is generally only recommended on structures that restrict destructive installations.

5.2 Methods of Monitoring Survey

Monitoring of structural deformation movement is usually done via manual survey, either by 3D survey with a total station, or by 1D vertical levelling for settlement of the ground.

In certain site conditions where it becomes a challenge on manpower deployment, where high monitoring frequency or when the structure/ground to be surveyed is within restricted zones, the use of automated monitoring may be more suitable.

The adoption of survey methods varies widely and the Registered Surveyor is to consider the instrument accuracy, methods of survey and the contract's requirements.

5.2.1 Vertical (1D) Manual Monitoring

Vertical monitoring equipment shall have precision better than the accuracy required for the survey (Example: a 2mm accuracy requirement shall be surveyed using an equipment with precision better than 0.67mm)

All levelling equipment shall be checked using two peg test before the start of a monitoring cycle. Records of such test shall be appended as part of the vertical monitoring report.

For high precision monitoring survey (tunnelling related, etc), an Invar level staff shall be used.

Photocopied Barcode stickers shall not be used due to inherent scale error and distortions.

Total stations shall not be used solely for vertical monitoring.

For the purpose of monitoring, it may be necessary to have temporary points for observation of monitoring targets. The temporary points shall be established from staff placed on stable ground/change plates and at equal distances for the backsight and foresight observations.

Observations from the level equipment shall be no more than 50m away.

All levelling runs shall be closed (looped or closed against another primary controls) and within 50% of the accuracy required (Example: 3mm accuracy requirement shall have a misclosure no more than $1.5\sqrt{k}$, where k = the distance in kilometres.

The level misclosure shall be adjusted before computation of the 1-D monitoring targets.

5.2.2 Lateral (2D) and 3-Dimensional Manual Monitoring

2D and 3D monitoring equipment shall have a precision of one third of the accuracy required for the survey (Example: a 3mm accuracy requirement shall be surveyed using an equipment with precision better than 1mm)

For the purpose of monitoring, the use of a total station is generally accepted. The Registered Surveyor shall compute the error budget taking into account the centring errors, the distance to prism targets, the precision of the equipment and the changes in atmospheric pressure and temperature before conducting the survey.

Traverses, if any, used for monitoring shall be closed (looped or closed against another primary controls) and observations to prism targets shall not exceed the baseline distance.

The linear misclosure shall be least square adjusted before computing the positions of the 2D or 3D targets.

5.2.3 Real Time Automated Monitoring System

In an automated monitoring system deployment, the system would be set up to monitor a specific area for structural deformation movement in 3D (X, Y and Z). The system, when operational, shall operate fully automated 24/7 continuously at specified monitoring frequencies to survey the structure or specific area via 3D surveys.

The system shall have sufficient fixed references at stable locations, with glass prisms affixed to the structure to be monitored (acting as the monitored points), to be installed at strategic locations, so as to effectively monitor the structure, and with adequate line-of-sight from the Total Station.

The system shall comprise the following to allow for fully automated, sensible monitoring:

(a) 1”, 1mm + 2ppm motorized Total Station
(b) Sufficient references at non-influence zone
(c) Glass (monitoring) prisms
(d) Steady power supply
(e) Telecommunication capabilities (for data transfer)
(f) Total Station to be setup on stable foundation
(g) Able to perform under inclement weather conditions

When operational, the system shall be capable of:

(a) Taking survey measurements at specified times / frequencies throughout the day, with a minimum of 4 cycles per day
(b) Auto survey adjustment of the raw survey measurements
(c) Auto dissemination monitoring results in 3D, within minutes from end of a monitoring cycle
(d) Allowing retrieval of results either via an online interface or through Client's email
(e) Sending SMS alerts if monitoring readings exceed specified tolerances.

In the case of automated monitoring for Viaduct columns or similar, the following shall also be followed:

(a) At least 2 no's of glass prisms shall be installed securely on the column, at minimum of 2m apart

(b) Establishment of initial (base) readings shall be observed from the position of the AMS sensor and sufficient sets of surveyed data (with outliers removed) shall be averaged to determine the initial coordinates

(c) Manual survey of the same monitored prisms on a monthly basis, as an added verification that the system is performing to standards, and that the automated monitoring results are robust and reliable.

5.2.4 Accuracy Tables for Monitoring Survey

The surveying methods shall be designed by the Registered Surveyor to meet the accuracy requirements of the contract specifications. In general, the accuracy and methods of survey should be computed to meet the 95% confidence level of the stipulated requirements.

The general precision for monitoring works shall be as follows:

	Horizontal monitoring requirements	Vertical monitoring requirements	Typical work
1st Order Monitoring Standards	+/-2mm	+/-2mm	Deep excavation, tunnelling works
2nd Order Monitoring standards	+/-3 to 5mm	+/-3 to 5mm	Shallow excavation Road side works
3rd Order Monitoring	+/-5mm	+/-10mm	General earthworks, in-filling, subgrade works, etc…

5.2.5 Deliverables for Monitoring Survey

Deliverables should include:

(a) Numerical results (adjusted using statistical methods, i.e. least square)
(b) Trend plots
(c) Temporal changes from the control monitoring
(d) Registered surveyor certification on monitoring report

6. AS-BUILT AND TOPOGRAPHICAL SURVEYS

6.1 Horizontal Datum

SVY21 Datum is to be used in the conduct of the survey.

6.2 Vertical Datum

The Singapore Height Datum (SHD) shall be used for the vertical datum.

Reduced levels are to be established from SLA's Vertical Control Point (VCP).

Unless specified otherwise, one VCP shall be adequate for the purpose of Topographical Survey provided at least 2 witness marks are found to be consistent with the VCP.

In the event this condition for the witness marks is not satisfied, another VCP is to be used subject to the same condition.

Alternatively, if 2 VCPs are found to be consistent with each other within tolerance for precise surveys, they can be adopted for the Topographical Survey.

Where Benchmarks (TBMs) established in another survey are re-used, at least 3 TBMs are to be verified for consistency. The onus shall be on the surveyor to verify an adequate number of TBMs.

Where the levels are established by other means, such as Real-Time Kinetic (RTK) with SiRent or Integrated Survey Network, the measured levels shall be acceptable only if the allowable height accuracy is 5cm or more. If the requirement is better than 5cm, such means to establish levels cannot be adopted unless the surveyor can prove the specified higher accuracy is complied with.

6.3 Accuracy Standard of Traverses

The minimum accuracy and methods for horizontal control and vertical survey shall comply with the 2nd order of standards.

6.4 Positional Uncertainties

Unless specified by the Client to be otherwise, the horizontal positional error tolerances shall be no more than 50mm. The error tolerances shall be based on total cumulative errors inclusive of those from the control surveys and not just the inherent errors of the survey technique and instrument used.

Unless specified otherwise, vertical height tolerance shall be no more than 50mm and being the measure of cumulative errors inclusive of the levelling from VCPs.

Where an open traverse line is extended from a traverse survey station for the survey of topographical details, the probable error propagation is to be included in the cumulative error computation.

For critical dimensions such as those relating to the boundary, the *CS Directive on Cadastral Survey Practices* is to be complied with.

The onus of positional accuracy to satisfy the contracted specification is on the Registered Surveyor regardless of the methods adopted for the works.

6.5 Details to be Surveyed

All visible details shall be surveyed.

Saplings and trees where required shall be surveyed. Generally, trees with a girth of 300mm and above, measured at 1m above ground level, are surveyed. The trees shall be surveyed to their centres.

For sewer manholes and inspection chambers the covers (or top levels) shall be surveyed. Access to the inverts is restricted and subject to regulatory requirements.

For open concrete drains, invert levels and copings (or top levels) shall be surveyed generally at 20m intervals unless specified otherwise. For covered drains, the invert levels accessible from openings or gratings shall be surveyed instead unless specified otherwise. Where siltation has taken place, the inverts to the concrete base shall be taken. Where it is not possible, the siltation shall be correctly annotated on plan.

OG boxes, lamp/cable posts with numbers, exposed/overhead cables, etc. shall be surveyed.

Road names and house/block numbers shall be picked up and shown.

Edges of pond shall be surveyed.

Where reflectorless measurements (total station or laser scanning) are made, the correct ground level is the measurement made to the ground and not the grass, shrubs

or movable objects. If a feature is tilted (e.g. a tilted pole), the correct position of that feature is the measurement at ground level.

Generally, the specified accuracy of topographical surveys does not comply with cadastral standard. Any encroachment shown in a topographical survey plan can only be indicative and cannot be definitive. Where encroachment is of issue, the Registered Surveyor is to advise their clients that an encroachment survey of a cadastral standard in compliance with the Chief Surveyor Directives will be required.

Boundaries shall be shown on topographical survey plans and shall be based on SVY21 coordinates. Generally, they shall be refined coordinates unless boundaries are not of concern or relevance for the works.

6.6 Survey Techniques

The Registered Surveyor shall decide on the most appropriate technique to meet or exceed the required quality.

The onus shall be on the Registered Surveyor to substantiate having met the quality and accuracies for his works.

The following is a list of techniques commonly used:

(a) Total Station
- (i) All equipment must be calibrated at least once every 12 months or after any services / repair.
- (ii) Leased equipment shall be calibrated before use.
- (iii) Traverse control to be established around the project area. Network to encompass the whole site.
- (iv) Secondary control to be established for detail topographical survey.
- (v) All visible details to be surveyed.
- (vi) Bearings, angles and distances shall be recorded.
- (vii) Topographical plan shall be prepared by suitable software with geo-referencing.
- (viii) Output format shall follow contract specification.

(b) Real Time GNSS Kinematic (RTK)
- (i) SVY21 and SGeoid09 datum must be used for projection.
- (ii) All RTK equipment must be tested at least once every 12 months or after any services / repair.
- (iii) Leased receiver must be tested before use.
- (iv) Differential correction for RTK shall be from SLA Virtual Reference Station (VRS-RTK) or a base station (Base-rover) established by a Registered Surveyor. Data correction shall be at every second.
- (v) The distance between the base station and the roving unit shall not be greater than 5km (ideally less than 2 km).
- (vi) Correct height of the antenna's phase centre must be measured, recorded, and stored into the roving receiver.

(vii) The GNSS antenna used as a rover unit shall carry out a gross error validation on known control points established by conventional method before and after each day of survey. At least two points have to be within ±30mm horizontally and +/-50mm vertically.

(viii) During the survey, the following parameters are to be adhered to:
   a) GDOP values ≤ 4
   b) Elevation angle setting ≥ 15 degrees
   c) Minimum number of satellite ≥ 6

(ix) Results of validation must be recorded and appended as part of the survey report.

(c) Post-Processed GNSS

In general, post processing GNSS survey methods are similar to Real time GNSS kinematic survey except for the following:

(i) The corrections are applied post-survey.

(ii) Differential correction for post-processing GNSS survey shall be from SLA physical base stations. Base station data shall be downloaded at every 1-second interval.

(iii) A minimum of 1 base station shall be used to correct the GNSS observations.

(d) Static Terrestrial Laser Scanning

Topographical/as-built survey of the site can be conducted using Terrestrial Laser Scanning subject to the following:

(i) Vegetation impact on data collection

(ii) Attention to registration

(iii) Compliance with directives listed in Chapter 8

(iv) Missing areas are to be measured using conventional methods

(v) Care in digitisation of features and extractions of geo-spatial information.

(e) UAS Aerial Survey

Topographical/as-built survey of the site can be conducted using UAS Aerial Survey subject to the following:

(i) Care has to be noted that CAAS approval is required for all survey flights

(ii) Valid operator license and pilot license are required for all survey flights

(iii) Vegetation impact on data collection

(iv) Compliance with directives listed in Chapter 7

(v) Missing areas are to be measured using conventional methods

(vi) Care in digitisation of features and extractions of geo-spatial information.

(f) Photogrammetry

Photogrammetric survey, in these Directives, covers mapping survey and certification of 3D measurements of land, buildings or objects and includes the interior details if it applies.

Photogrammetric methods include using aerial cameras to capture stereopairs or oblique photos from aircraft or UAS, and terrestrial cameras for obtaining stereopairs or convergent works on the ground.

As achievable accuracy varies significantly, the Client's specification or contract specification shall take precedence. In the absence of such specifications, the Registered Surveyor shall advise the Client on accuracy before commencing the survey.

The Registered Surveyor shall be responsible for:

(i) Planning the execution e.g. flight path, adequate coverage, etc.
(ii) Provision of accurately measured control stations e.g. ground control points, targets, etc. for accuracy and validation of accuracies
(iii) Provision of geo-spatial references to statutory compliances
(iv) Establishing accurate survey controls in 3D to meet the required accuracy specifications
(v) Calibration of cameras and lenses at frequency suitable for his purpose.

6.6.1 Certifiable Accuracy

The Registered Surveyor shall be able to:
Account for the achieved accuracy and reliability of both collected and processed data
Report on the validation results if executed or the error analysis being in compliance with specifications.

As achievable accuracies of each technique differ, registered surveyors are to adopt only the techniques that meet the required quality.

The measure of accuracy shall not be attributed only to the technique adopted but also to the cumulative errors of the control network and practical errors; e.g. verticality of a prism pole.

The listed techniques are not exhaustive. These directives do not preclude the use of any new technique that may emerge but the Registered Surveyor shall be accountable for its achievable accuracy.

The publication *Standard and Specifications for 3D Topographic Surveying (Mapping) in Singapore* by Singapore Land Authority shall be referred to for more details on the techniques.

6.7 Treatment of Cadastral Data in Topographical Surveys

In general, all boundaries shown in a Topographical Survey Plan shall be in SVY21 coordinates. Where existing lots are not in SVY21 coordinates as per their Certified Plans, the coordinates will have to be verified and/or refined in SVY21 coordinates.

Exceptions from the requirement for verification and/or refinement are only permitted where the boundaries shown in the plan are immaterial to the survey intent. Examples are:

(a) Survey of a small plot within a big lot in a large military training ground where the boundary is immaterial

(b) Survey of a small plot in a condominium and away from the boundaries for an A and A works where the setback from the boundaries is immaterial.

The topographical survey shall not be used for the purpose of an encroachment report or the resolution of encroachment due to its inherent inaccuracies. For issues on encroachment, an Encroachment Survey complying with *CS Directives on Cadastral Survey Practices* is to be adopted.

6.8 Unacceptable Practices

The following are unacceptable practices by virtue of their inherent inaccuracies.

6.8.1 Use of Real Time Kinetic (RTK) Survey for Control Station

The use of RTK survey to establish control stations for any topographical survey or any engineering surveys relating to land lot boundaries (e.g. setting out for the construction of perimeter wall) is unacceptable by virtue of its inherent inaccuracies.

6.8.2 Boundary Datum (Cassini Datum)

In the event the subject lot boundary is in the 'Cassini' datum and its coordinates are yet to be refined in SVY21 Datum, the Registered Surveyor shall advise the Client on the need and rationale to modernise the survey in the SVY21 Datum including the need for refinement.

In any proposal to the Client for topographical survey, the Registered Surveyor is to include the scope for the verification and refinement of the SVY21 coordinates.

Cassini Datum is strictly not to be adopted for any works.

6.8.3 Use of Cadastral Map or Road Line Plan for Boundary Data

The Cadastral Map or the cadastral information in the Road Line Plan shall not be used in lieu of the SVY21 coordinates where the boundary is of significance. The SVY21 coordinates must be obtained from SLA, and where applicable, they are to be verified in compliance with *CS Directives for Cadastral Survey Practices*.

6.8.4 Registered Surveyor to bear full responsibilities for survey plans/reports

If a registered surveyor certifies a survey plan, a map or a survey report, he is deemed to have certified the correctness and accuracy of the geo-spatial information contained within the document and not just a part of it. This applies to any document that satisfies any one of the following conditions:

(a) A document stipulated in any statutes to be certified by a registered surveyor
(b) A document specified by a contract to be certified by a registered surveyor
(c) A document required an authority to be certified by a registered surveyor
(d) A document intended to be authoritative on survey accuracy and details.

Even where the Registered Surveyor had conducted only a part of a survey job, but certifies the resulting document, he is deemed to have checked all the surveyed data in the document.

The survey data and/or geo-spatial information are broadly defined as mapping, surveying, geo-referencing, digital twin (as-built BIM or as-built point clouds), cadastral information or any such geo-spatial information in digital and/or hardcopy media.

Example:

(i) A registered surveyor has been appointed to conduct the ground controls for a large mapping (mobile, aerial, scanning, etc) project. The Registered Surveyor proceeds to certify the eventual maps but claims to be only liable for the "control" component only.

This is not an acceptable practice. The Registered Surveyor will be liable for the whole document (hardcopy and/or softcopy) and any negligence may be subjected to a complaint where it will be investigated by the Land Surveyors Board.

The exception is where the Registered Surveyor is required to endorse a drawing that is also endorsed by a Professional Engineer or Architect in which he is responsible for the survey information contained therein (i.e. piling plan).

6.8.5 Graffiti and Vandalism

The Registered Surveyor is to be mindful of the public property while marking/demarcating survey monuments. The marks made shall be discreet and pose no risk to the public. Label markings painted shall be kept aesthetic.

Examples:

(i) When monuments on pavement surfaces are marked by nails which protrude 5mm and not hammered flush to the ground causing a trip hazard to the public.
(ii) When these nails are spray painted with large triangular symbols and then labelled with spray paint causing an eye-sore to the public.

In these cases, the Registered Surveyor should install proper nails surrounded by a sloping plastic sleeve that mitigates a tripping accident. The labels shall be discreetly marked with a paint marker.

7. Unmanned Aerial System Survey

7.1 Introduction

Unmanned Aerial System (UAS) Survey refers to the application of survey methods using a LiDAR or photogrammetry system mounted on an Unmanned Aerial System. The UAS may be fixed wing or rotary based but it is recommended that a rotary based system be used in the restricted air space of Singapore.

Survey methodology (equipment selection, data acquisition, survey standards and deliverables) are to comply with SLA issued UAS Survey Standards.

7.2 Registered Surveyors and CAAS Approved Pilots

7.2.1 Employment of CAAS Drone Pilots

Surveyors and Assistant Surveyors flying a UAS shall be certified by CAAS and cleared to fly the platform with the relevant drone permit in place. The terms and conditions within the permit are to be strictly adhered to.

The Registered Surveyor shall be responsible for the safety, competence and direct supervision of the drone pilots in his employ or under his management.

7.2.2 Registration of Surveyors

As provided for in the *Land Surveyors Act (Chapter 156)*, a registered surveyor shall only certify to the accuracy of the survey if he (or she) has in force a valid practising certificate issued by the Land Surveyors Board. Additional rules may apply and practitioners are advised to consult the Board before attempting a UAS survey.

The data acquisition is carried out by the drone pilots under the supervision of the Registered Surveyor. The Registered Surveyor shall be responsible for the flight mission design and the **entirety** of the data collected, processed and presented.

7.3 Flight Mission

In designing a flight mission, the Registered Surveyor should consider the following

(a) Safety of the public and site security
(b) Risk Assessment and mitigation
(c) Purpose of Survey and the accuracy standards required:
    (i) Equipment quality
    (ii) IMU quality
    (iii) GNSS positioning
    (iv) Ground control
    (v) Points density.
(d) Validation checks against ground control points

7.3.1 Safety and Site Security

The use of UAS follows the restrictions imposed by the Civil Aviation Authority of Singapore *(https://www.caas.gov.sg/public-passengers/unmanned-aircraft).* The Registered Surveyor is to be mindful of the operational zones and that the activity falls under Business/Non-recreational/Non-educational purposes and will require a UA Pilot License, Operator Permit and Class 1 Activity Permit.

7.3.2 Risk Assessment and mitigation

A risk assessment shall be conducted for each mission site. Risks to Health and Safety to the public shall be considered and an evacuation route shall be designed for each survey site. The Registered Surveyor shall maintain a workforce on ground with prominent safety vest donned to direct the public and assuage any uncertainties and worries.

7.3.3 Fit for Purpose Selection

The use of a UAS covers a wide range of applications. Generally, the UAS should not be used for Cadastral Surveys and works involving cadastral boundaries. As a guide, the types of equipment, survey line intervals, positioning standards, ground control points density and points density are variables to be considered in achieving the Client's required accuracy. The Registered Surveyor is to consider all these factors while designing the flight mission.

Extracts from SLA guideline on UAS Survey Standards are extracted here for reference.

(a) Survey Standards

No.	Type of Standards	Absolute Accuracy (In RMSEσ1)		Minimum NPD (pts/m^2)	Maximum NPS (pts/m^2)	Applications
		Horizontal Tolerance	Vertical Tolerance			
1	1st order survey	0.026m	0.026m	24	0.20	Topographical survey (as-built, preconstruction), volume certification, etc.
2	2nd order survey	0.051m	0.051m	12	0.30	Construction progress survey, earthworks, etc.
3	3rd order survey	0.102m	0.102m	4	0.50	Feasibility studies, environmental studies, etc.

Table 7-1 : Extracted from *SLA UAS Survey Standards*

*NPD = Nominal Points Density (The minimum number of points per m^2)
*NPS = Nominal Points Spacing (Maximum distance allowed between points)
*Tolerance values listed are in absolute positioning at sigma 1 (68% confidence level)

(b) Equipment Selection

A high-grade LiDAR sensor with a range precision better than 20mm at 50m shall be used.
Cameras mounted on the UAS shall have a resolution of 24 megapixels or better.

(c) Survey Line Intervals and Data Acquisition

The survey line interval should overlap with each other by 40% or more. A higher survey standard will require greater overlaps. Before and after each flight mission, the UAS shall conduct a calibration flight. The calibration flight consists of a combination of “figure of 8” flights and “straight line” flights to allow trajectory post-processing / calibrations.

(d) Positioning Standards

The use of GNSS with direct geo-referencing shall be adopted. The weightage between IMU accuracy and GNSS accuracy shall be post-processed from the calibration flight and corrections assigned to the trajectory file.

The projected vertical height measurements can be based on ground controls points (levels based on VCPs) or from SGeoid09 projections with a base station mounted over a known control point.

(e) Ground Control Points

The ground control points (GCPs) shall be rigid, at least 1m wide x 1m length and visually obvious (with contrasting quadrants colours) from the height of data acquisition. The ground control points shall adequately surround the survey site and coordinated from Vertical Control Points (VCPs) or a SiRENT linked GNSS. The Registered Surveyor is to consider the accuracy requirements before determining which methods is to be adopted.

(f) Validation checks

At least 4 numbers of Ground control points established shall be used to validate the survey results. These GCPs are known as Validation Control Points (VGCPs). The VGCPs are **not** to be incorporated into the flight processing and act as an independent quality check.

The flight coordinates (X, Y and Z) over the VGCPs are compared against the corresponding VGCPs coordinates (X_1, Y_1 and Z_1) to derived the individual difference, mean difference and RMSE. The computed RMSE shall be within sigma one of the survey accuracies required. Refer to figure 7-2 as an example.

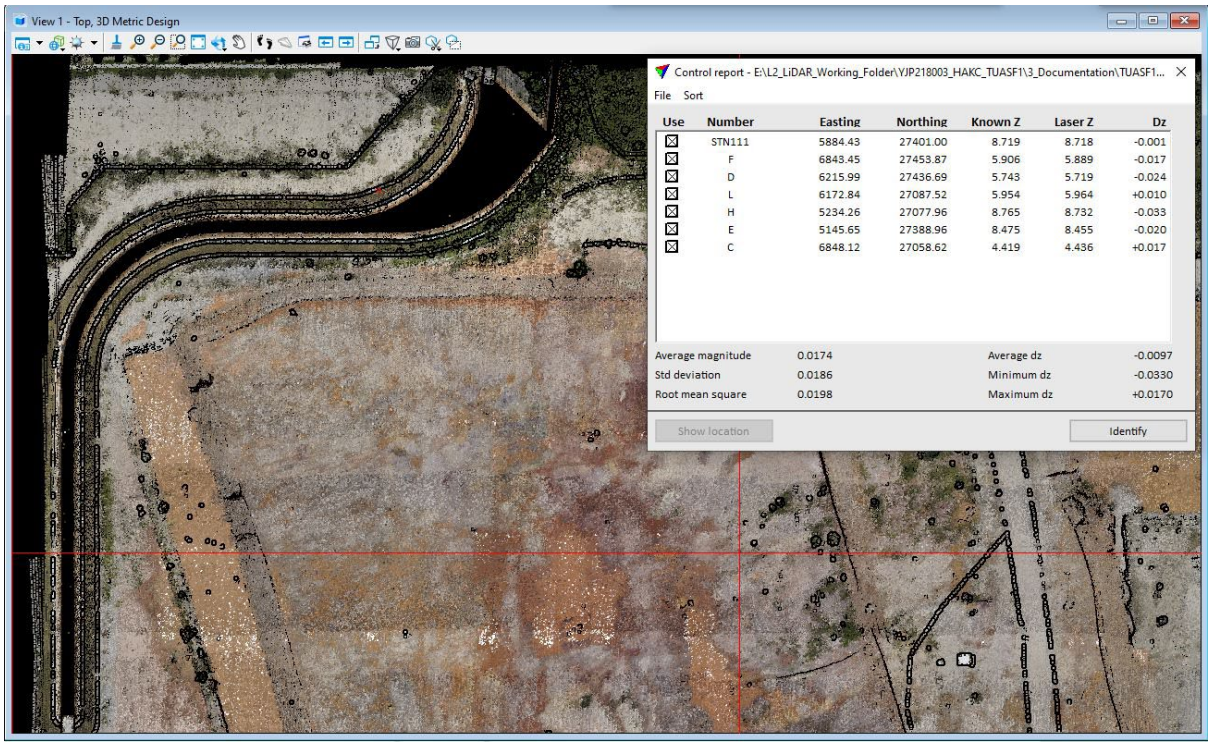

Figure 7-2 : Example of incorporating VGCPs for QA/QC (Extracted from *SLA UAS Survey Standards*)

7.4 UAS deliverables

The data collected via UAS LiDAR or photogrammetry are increasingly adopted for progress monitoring, volumetric computation, feasibility studies and general purpose topographic survey. Techniques, specifications, equipment and methods demanded are continuously being refined and will change from time to time.

UAS survey specifications stipulated in the contract shall be complied with. Should the contract's requirements be inappropriately excessive or inadequate for the purpose of survey, the Registered Surveyor is to recommend the appropriate methods with consideration to the guidelines provided in the LSB directive and *SLA UAS Survey Standards*.

Point clouds, models and relevant documents are to be geo-referenced and accompanied by a survey report certifying the accuracy achieved, the validation done and the methods undertaken.

Dataset extracted from 3D point clouds should meet the topographic standards stipulated under Section 6. As-Built and Topographic Survey.

7.5 Making Proper Statements

Registered surveyors are to be mindful when making statements on performance of the UAS survey precision. To this end, the statements must be fair and do not result in unreasonable accuracies and erroneous perceptions. Example of erroneous perceptions are:

(a) Quoting the camera resolution (in mm) as the survey precision in photogrammetry

(b) Quoting the LiDAR range precision as the survey accuracy without considering the GNSS, IMU and various other influences.

The recommendation and guidelines above are not exhaustive. Technologies and methodologies for UAS are expected to evolve over time and the guidelines provided do not disavow the Registered Surveyor from his professional duties to the Client. The Registered Surveyor will need to demonstrate that the proposed methods meet the tolerance accuracy of the project.

8. Terrestrial Laser Scanning (TLS)

Terrestrial laser scanning (TLS) refers to the use of a laser scanner mounted on a static platform, typically on a tripod, for survey measurements from ground level. The following specifications apply to TLS that are done for geo-referenced measurements or certified geo-spatial accuracy.

8.1 TLS Selection

The laser scanner to be adopted shall comply with the contracted specification for its performance. For each job, the following are the key parameters considered:

(a) Accuracy
(b) Nominal points density
(c) Sampling points interval or sampling interval
(d) Range
(e) Data acquisition speed

8.1.1 Accuracy

The types of accuracy to be considered within a job are:

(a) Range accuracy – linear measurement accuracy

(b) Relative accuracy (in 2-dimensions or 3-dimensions)

(c) Absolute accuracy (geo-referenced accuracy in SVY21 coordinates)

The required accuracy shall be according to contract specification. If the Directives are being referred to, the standards in Section 8.3 shall apply for both range accuracy and 3D Accuracy. However, geo-referenced accuracy shall depend on contract specifications or statutory standards set by the Authorities.

8.1.2 Nominal Points Density (NPD)

NPD refers to the number of scanned points within a one m^2 area. For any pre-set angular interval, the NPD value is inversely proportional to the distance measured (the longer the range, the lower the number of scanned points in a one m^2 area). Both the angular step width and the distances measured from the laser scanner are to be considered to ensure the specified density of scanned points are achieved. Unless specified in the contract, the standards in Section 8.3 of these Directives shall be complied with.

8.1.3 Sampling Points Interval

Sampling points interval refers to the linear allowable space between scan points in a single set of measurement from a TLS station. This has a direct impact on the NPD and the level of detail/resolution achievable.

8.1.4 Range

As the accuracy of a measurement degrades with the distance measured, the limit for the measured distance is to be set on the laser scanner to comply with the required density and accuracies. Alternatively, all points exceeding the measured distance limit are to be discarded after post-processing.

When stating an effective range for a laser scanner, the Registered Surveyor shall specify the reflectance of the natural target that the stated range was based on.

8.1.5 Data acquisition speed

Unless specified in the contract, data acquisition speed is not a pre-requisite as point density and accuracy take precedence. However, the Registered Surveyor shall clarify his stated data acquisition speed by inclusion of the range for the stated effective measurement rate.

8.2 Validation of Laser Scanner

8.2.1 Validation Purpose

The purpose of validation is a field check to determine the scanner accuracy and precision, the standards it can achieve and whether the scanner is at a quality deemed fit for use in the contract.

If the manufacturer's technical specifications have been adopted in the contract, the laser scanner shall be validated against the manufacturer's technical specifications.

8.2.2 Frequency of Validation

The validation of the laser scanner shall be executed before it is used in the job.

Where the job exceeds 6 months, the validation exercise shall be conducted every 6 months. Where the scanning interval exceeds 6 months, the validation exercise may be conducted before the subsequent scan instead of 6 months.

8.2.3 Parameters to be Validated

Unless more parameters are stated in the contract specification, the subject laser scanner's accuracy in 3D over required distances is to be validated.

The validation is to envelop the intended range of the distances to be measured in the job. Where the validation is against the manufacturer's technical specifications, the measured distances shall cover the distance stated by the manufacturer for the stated accuracy.

In view of degradation of signal quality over distances, accuracy for longer distances shall not be extrapolated from shorter ones. E.g. if statement is 5mm over 50m, the distance validated should cover at least 50m.

8.2.4 Setup of Targets

The number of targets to set up shall be no less than 4.

Their relative positions shall satisfy the following criteria:

(a) The distances apart shall be adequate for the positioning of the scanner to cover both the minimum and maximum ranges of the intended job's measured distances (from scanner to object)

(b) If the validation is against the manufacturer's technical specification, at least one distance (laser scanner to target) shall exceed the distance stated for the accuracy;
   (i) E.g. 'One sigma @ 100m range' will require at least one measured distance to be >100m. Extrapolation from shorter distances is not acceptable.

(c) The arrangement of the targets is such that:
   (i) the horizontal angles covered by the targets from the laser scanner must be at least 180° in at least one of the scan positions

   (ii) the vertical angle between the most inclined line and least inclined line shall be at least 45° from among the scans.

8.2.5 Validation Procedure

The procedure spelt herein shall serve as the minimum requirement.

The location can be:

(a) Within a large enclosed space – use of walls, floor, ceiling, floor or stable objects for the placement of targets

(b) Outdoor – use of rigid stable objects for the placement of targets.

The relative 3D positions of the targets are measured using a total station from one location to provide the control coordinates. As the accuracy of these measurements will affect the results of the subsequent validation, a high precision total station should be used to minimise the probable errors. Multiple sets of observations are also recommended to acquire more accurate results.

The targets are then scanned using the subject laser scanner. There shall be at least 3 scans from distinct positions that satisfy the range and angular requirements. All scanned targets are to be clear of obstructions in all the scans.

8.2.6 Survey Range

The shortest and longest distances between any scanner position to the targets are to be highlighted in the report. This information shall serve as the upper and lower bounds of scanning distances.

8.2.7 Evaluation of Data

The control coordinates (need not be geo-referenced) obtained using the total station can be computed and thereafter tabulated:

Control Coordinates of Targets

Target No.	Northing (m)	Easting (m)	Elevation (m)
1			
2			
3			
4			
5			

Additional columns to reflect the error ellipses may also be incorporated for detailed analysis but they are not required in this simplified validation procedure.

The distances between the targets are computed from the control coordinates and also from each set of scan results. The data can be tabulated below for comparison:

Comparison of Control Distances and Scanned Distances

Targets		Distances (m)				Mean	Residual	Accuracy
From	To	Control	Scan 1	Scan 2	Scan 3	Diff (mm)	RMS (mm)	(mm/50m)
1	2							
		Diff (mm)						
1	3							
		Diff (mm)						
1	4							
		Diff (mm)						
1	5							
		Diff (mm)						
2	3							
		Diff (mm)						
2	4							
		Diff (mm)						
2	5							
		Diff (mm)						
2	6							
		Diff (mm)						
3	4							
		Diff (mm)						
3	5							
		Diff (mm)						
3	6							
		Diff (mm)						
4	5							
		Diff (mm)						
4	6							
		Diff (mm)						
5	6							
		Diff (mm)						

The accuracy shall be interpolated (but not extrapolated) to the specified distance. The default (standardised) distance is 50m. The computation for the accuracy shall be:

$$\frac{\text{Mean Difference (mm)}}{\text{Control Distance (m)}} \times 50 \text{ (m)}$$

All the accuracies established in the validation must satisfy the specified accuracy. The accuracy for the subject laser scanner shall be the lowest accuracy listed in the results.

No target within the whole validation exercise can be discarded or omitted in the evaluation. Only the complete data set from a scan position can be discarded. The number of scans used shall not be less than 3.

8.2.8 Alternative Validation Method

The validation method as described herein is simplified (ignoring the differences between measurements made from the laser scanner to target(s)) and compares computed distances between scanned targets. The simplification also excludes the error ellipses in the error analysis. The Registered Surveyor may propose other validation methods that provide better analyses but he shall be required to prove his method and results if called to do so.

8.2.9 Certifying a Laser Scanner being ‘Fit for Use’:

The criteria to certify that a subject laser scanner is validated to be fit for use are:

(a) Validation exercise being conducted by, or under the supervision of, a registered surveyor

(b) The validation report duly signed by the Registered Surveyor

(c) Report showing the results to be in compliance with the contract specifications, or the manufacturer’s technical specifications if adopted, and/or the standards stated in Section 8.3 if it is referred to in a contract.

8.3 Standards of TLS Surveys

The TLS survey standards, if not specifically referred to in a contract, are as follows:

No	Type	Sampling Interval	Range	Range Accuracy	3D Accuracy
1	For high definition projects such as heritage buildings, sculptures, plants, cables, where resolution is needed at 5mm or less	5mm at every 50m interval	No more than 50m scan range	1.5mm + 10ppm	3mm at 50m
2	For projects such as as-built of structures, buildings, vessel, topography, BIM LOD 300, etc... where resolution is needed at every 50mm or less	10mm at every 50m interval	No more than 75m scan range	2.0mm + 15ppm	8mm at 50m
3	For earthworks, feasibility studies and general-purpose projects like volumetric computation, etc... where resolution is needed at every 1m or less.	20mm at every 50m interval	As required	2.0mm + 15ppm	15mm at 50m

The Range Accuracy refers to the accuracy stated by manufacturers which in the validation exercise is simplified by adopting the accuracy in the validation results.

The 3D accuracy refers particularly to the accuracy stated the validation results.

Specifications in a contract shall take precedence over the standards stated above.

8.4 Geo-References

8.4.1 Where a geo-reference is specified or used, the SVY21 Datum and Singapore Height Datum are to be adopted. Survey controls are to be established such that the scanned data are geo-referenced to the required accuracy.

8.4.2 Horizontal Datum

The SVY21 Datum shall be adopted for the horizontal datum and which shall be based on the Integrated Survey Network (ISN) in compliance with the *CS Directive on Cadastral Survey Practices*.

The use of Real Time Kinematic (RTK) is not recommended in view of its inherent lower level of accuracy that may not meet the specified standard. Where the cadastral boundary is related or referred to in the survey, RTK shall not be adopted.

8.4.3 Vertical Datum

The Singapore Height Datum (SHD) shall be adopted for the vertical datum.

The establishment of elevations shall be by the method and standard using level and staff prescribed in these Directives in Section 3 on Control Survey.

Reduction of Ellipsoidal heights for SHD using the SGeoid09 model or by established ground control points (GCPs) can be acceptable if their accuracies can comply with the specifications. It should be noted that the SGeoid09 model has an uncertainty of approximately +/-4cm in height (95% confidence level accordingly). Registered surveyors are to consider this before reducing elevations from Ellipsoid to SHD.

8.5 Point Cloud Registration

Point cloud registration is the process of aligning multiple, overlapping 3D point clouds of the same scene to form a detailed and accurate representation of the surveyed area.

The appropriate registration process to be performed will depend on the type of survey and intended accuracy. The residuals of the registration process must be equal to or better than the geometric precision required by the end deliverable.

The precision of any parameters derived in the registration process for each scan along with the residuals of the registration should be included in the survey report.

8.6 TLS Deliverables

Laser scanning technologies are being increasingly adopted for progress monitoring, as-built scanning and scan to BIM solutions for building construction projects. Techniques, specifications, equipment and methods demanded are continuously being refined and will change from time to time.

TLS survey specifications stipulated in the contract shall be complied with. Should the contract's requirements be inappropriately excessive or inadequate for the purpose of survey, the Registered Surveyor is to recommend the appropriate methods with consideration to the guidelines provided in the LSB directive.

Point clouds, models and relevant documents are to be geo-referenced and accompanied by a survey report certifying the accuracy achieved, the validation done and the methods undertaken.

8.7 Making Proper Statements

Registered surveyors are to be mindful when making statements on performance of a laser scanner. To this end, the statements must be fair and do not result in erroneous perceptions or comparisons. When referring to manufacturer's technical specifications:

(a) It must state the reflectance of the natural target for which the measurable range was based on

(b) For accuracy, it must include the range for which the stated accuracy applies

(c) For data acquisition speed, it must include the range for the stated effective measurement rate

Where the manufacturer's technical specification is not used, the performance parameters from the validation exercise can be used.

9. HYDROGRAPHIC SURVEY

9.1 Land Surveyors (Exemption) (No.2) Order 2004

The Land Surveyors (Exemption) (No.2) Order 2004 was published vide GN No. S79/2004 in the Government e-Gazette on 26 February 2004. The Exemption Order states:

> "Section 10 of the Act shall not apply to any person who carries out or causes to be carried out any hydrographic or hydrologic survey or other study of the waters and sea-bed within the territorial limits of Singapore for navigational purposes or studies of marine science and ecology."

9.2 Hydrographic Survey

Pursuant to the Exemption Order, hydrographic or hydrologic survey or other study of the waters and sea-bed as stated in the Order shall not be within the purview of the *Land Surveyors Act (Chapter 156).* Such survey can only be carried out with the approval of the Maritime and Port Authority of Singapore under the *MPA Act (Chapter 170A)*.

A registered surveyor under the *Land Surveyors Act (Chapter 156)* is permitted to carry out the following hydrographic surveys and studies that are not relating to maritime navigation or require submissions to MPA:

(a) Inland waterways (reservoirs, canals, stream, lakes, pond, etc)
(b) Foreshore Construction in respect of land reclamation, shore protection works, bunds, retaining walls and outfall/intake structures
(c) Residential and commercial properties/facilities/structures located along the foreshore
(d) Soil investigation

The hydrographic surveys shall be carried out in accordance with the *General Specifications for the Conduct of Hydrographic Surveys* available on the MPA corporate website.

https://www.mpa.gov.sg/web/portal/home/port-of-singapore/services/charts-tidal-info-atons-and-hydrography/conducting-hydrographic-surveys

For surveys arising from all Committee for Marine Projects (COMET) applications, the works shall comply with the conditions as stipulated in the respective approval documents.

For surveys standards that are not defined by contract specifications or fall within *MPA Act (Chapter 170A)*, the following specifications may be adopted.

9.3 Method of Survey for General Purposes

Hydrographic survey shall be carried out using either a single beam echo sounder or a multibeam echo sounder. Multibeam survey is recommended for water depths greater than 3m Chart Datum (CD) and at areas (wharves, ports, jetty, etc.) where 100% insonification of the seabed is required as per IHO S.44 standards.

9.3.1 Positioning

In general, horizontal positioning is to be controlled by Differential Global Positioning System (DGNSS) with an accuracy ±1m or better. The DGNSS shall be checked against a known coordinated position before and after survey each day.

For surveys carried out on coastal development sites where precision and accuracy are required to be in the sub-metre range, the use of RTK with centimetre accuracy is recommended.

9.3.2 Sounding Datum

Vertical Datum shall be the datum used for soundings unless otherwise specified in the survey requirements. The Vertical Datum used shall be clearly stated on all survey plans. The relationship between Vertical Datum and Singapore Height Datum shall also be shown.

9.3.3 Tidal Corrections

Tidal Recordings for reduction of soundings may be taken from the nearest automatic tide gauge station if the tidal character in range and time are similar or from a tide gauge established by the surveyor and Vertical Datum on the gauge is related to official Benchmarks or VCPs.

9.3.4 Survey Grid

The survey results shall be plotted on the SVY21 grid in metres based on the Transverse Mercator Projection with false origin coordinates 38744.572N 28001.642E at Latitude 1° 22' 00" N Longitude 103° 50' 00" on WGS84 Spheroid, and Central Meridian scale factor of 1. (ISN)

9.4 Single Beam Method of Survey

9.4.1 Equipment

Depths shall be recorded with Dual Frequency Echo Sounder (about 30 kHz and 210 kHz). The echo sounder shall be calibrated by bar checks up to the maximum depth expected in the survey area before and after sounding each day. The records of such bar checks shall be marked on the same echo roll used for the particular day's sounding. Unless otherwise stated, the data from the higher frequency shall be used for the production of the cartographic chart.

9.4.2 Sounding Line Interval and Sounding Density

Sounding lines shall be spaced at intervals of 5m and at closer intervals where the seabed is irregular and high spots are detected. Soundings shall be recorded at 3m or less along each sounding line. Cross lines shall be run at 10 times the line interval of the sounding lines.

9.4.3 Interpretation of Soundings

High spots detected on the analogue trace unless conclusively proven to be a false echo shall be plotted on the survey plan.

9.4.4 Field Survey Records

The following records shall be presented:

(a) All depths and position data shall be recorded digitally in real time
(b) The raw data comprising date, time, x, y, z shall be presented in ASCII format
(c) On all echo traces the name of surveyor, bar check, date and time, fix numbers shall be annotated
(d) Record of field equipment calibration (bar checks)
(e) Tidal records.

9.5 Multibeam Method of Survey

9.5.1 Equipment

Depths shall be recorded with a multibeam echosounder (about 400 kHz). The echo sounder shall be validated by bar checks up to the maximum depth expected in the survey area or where practically allowed before and after sounding each day.

9.5.2 Survey Accuracy

In general, the standards of MBES shall be as follows:

(a) Seafloor coverage 100% with 0.5m grid cells
(b) Feature Detection $1m^3$
(c) Positioning Accuracy ±1m
(d) Maximum Allowable Total Vertical Uncertainty
(e) 95% Confidence Level $\pm \sqrt{[a^2+(b \times depth)^2]}$
(f) where a = 0.25m
b = 0.0075m
depth in metres

The MBES complete with Gyro/Motion Sensors and Sound Velocity Profiler, GNSS and Tide Gauges selected shall conform to the above standards.

9.5.3 Vessel Mobilisation Records

(a) Vessel/Sensor offsets shall be measured
(b) Squat table shall be established
(c) GNSS gross error checks
(d) Gyro field calibration checks
(e) PATCH test
(f) Sound Velocity Profile (SVP)

The relative positions and heights of the Multibeam Echo Sounder's Transducer, Gyro Compass, Heave, Roll and Pitch Sensors and GNSS Antenna are to be measured and the offsets from the survey vessel's axes are to be integrated in the software. In addition, the draft of the vessel fore and aft shall be measured for vessel with LOA 25m or larger. The vessel's squat and settlement at different survey speeds shall be determined.

Field calibration shall be based on the principle of repeatability in that the seafloor or objects ensonified shall appear the same in whatever the azimuth, at whatever the speed and whatever the motion history of the survey vessel. These field calibrations known as the patch tests shall be conducted prior to the commencement of the survey, daily, and at any significant component change.

Sound Velocity Profile shall be conducted prior to the patch tests.

9.5.4 PATCH Test

The patch tests shall be conducted daily to resolve the following biases:

(a) Latency - GNSS and Multibeam Echo Sounder using GNSS 1PPS
(b) Roll Offset - Swath Sounder
(c) Pitch Offset - Swath Sounder
(d) Yaw Offset - Swath Sounder.

When all calibrations are done the various offsets can be calculated and input into the acquisition computer. For accurate alignment of the sensors' offsets, a number of iterations have to be conducted to cancel out the influences of the different parameters.

9.5.5 Sounding Line Interval and Sounding Density

The swath to swath overlap shall attain 100% seafloor coverage. The full swath shall be logged. However, only the section of the swath that complied with the accuracy standards shall be utilised. The sounding tracks shall be maintained parallel and preferably parallel to the bathymetric contours. Cross lines shall be run perpendicular to the start and end of the main lines.

The ping rate of the MBES shall be set such that at the survey speed of the vessel the seabed is ensonified at least at every 0.5m interval along the sounding track.

The MBES shall be capable of detecting seabed features of 1m cube.

The software used shall be capable of logging the full swath return pings and coordinates both derived from GNSS and dead reckoning between GNSS measurements. The latency of the GNSS and the echo pings shall be set and applied from the 1PPS signal in real time.

The biases of latency, roll, pitch and yaw from the patch tests shall be corrected by the acquisition software prior to logging the data.

9.5.6 Interpretation of Soundings

Any high spots detected, unless conclusively proven to be false, shall be used in the gridding process. Unless otherwise stated, the shallowest point within each grid square shall be selected as the plotted chart depth.

9.5.7 Field Survey Records

a) Name of Cat.B or Cat.A Hydrographer
b) Raw and processed data
c) Daily PATCH test results
d) Daily GNSS gross error checks
e) GNSS fixes of the sounding boat
f) Daily SVP
g) Tidal records

9.6 Method of Survey for Coastal Protection

For hydrographic surveys in the support of coastal protection, the following standards are to be adhered to.

9.6.1 Survey Process

Hydrographic surveying is required at every chainage (generally 5m) perpendicular to the shore protection design during the following stages:

a) Final sand layer stage / before geo-fabric laying stage. The survey shall be conducted and the slope profile acceptable within 24hrs of the geo-fabric installation. Deployment of single beam or multibeam methods are both acceptable. The survey results shall cover from 20m away from toe to up to 1m above CD. The profile shall be supplemented with land survey above 1m CD.

b) Rock laying phases. The survey shall be conducted after each different types of rocks are installed (type A, C, etc..) and the slope profile acceptable to design standards before proceeding with the next type of rock laying activity. Single beam or multibeam are both acceptable to be deployed. The survey results shall cover from 20m away from toe to up to 1m above CD. The profile shall be supplemented with land survey above 1m CD.

c) Final rock protection phase. A profiling survey shall be conducted at every chainage using either single beam or multibeam from 20m away from toe to up to 1m above CD. The profile drawn shall be supplemented with land survey data above 1m CD. In addition to the profiling survey, the area between the chainage shall be accurately surveyed using multibeam.

9.6.2 Survey Method

The survey shall be conducted using a multibeam system with data set binned at 0.5m cell. Binning shall be done on average biasness to determine the slope profile against the design.

Submissions to MPA shall be on shoal biasness.

9.6.3 Positioning selection

The shore protection works require accuracy in the centimetre range and are to be done at various gradients. The hydrographer shall adopt RTK in the survey.

9.6.4 Tidal Corrections

Tidal reduction shall be obtained from MPA tide gauges or MPA approved temporary tide gauge installed on site. No tide pole shall be used for the reduction.

9.6.5 Profile Documentation

For each chainage/profile survey using single beam, the following information shall be presented clearly on the echo roll:

(a) Surveyor's name
(b) Opening and closing bar checks results
(c) Sounding display at a maximum of 2m interval along the survey line annotated with the:
    (i) Date / Time stamped
    (ii) Depth observed and
    (iii) Coordinates.

The tidal corrected dataset shall be checked and non-conformance to the survey tolerance shall be clearly identified for rectification works. The dataset shall be certified by the FIG IHO Cat.A Hydrographer.

9.7 Submission of Plans and Survey Records

Certification: The Surveyor shall certify all plans, field records, reports, data sheets, equipment calibration records, sounding plots, etc.

Survey Plans: The Surveyor shall submit 2 paper prints and report of the survey plans, bathymetric chart denoting the depth values, colour banded chart to MPA Chief Hydrographer apart from the requirement of the Registered Surveyor's Client (an MPA requirement for Hydrographic Survey in Singapore Territorial Waters).

Survey Reports: The Surveyor shall submit a comprehensive survey report giving details on the Outline of Operation, Field Operation, Methodology of Survey, Equipment used, Frequency used, Weather and Sea Condition, Tidal Corrections, Calibration of Sensors, Data Processing, Log Sheets, Findings and Results including 3-dimensional image of the survey results

10. GAZETTE SURVEY

10.1 Gazette Notification Surveys

The purpose of the gazette survey is to announce to the public the actions and decisions of the government with relation to the land lots and area identified in the gazette survey.

Where applicable, the gazette survey shall include the following information:

(a) The survey shall be carried out in SVY21 coordinates and salient points of the boundaries are to be described in terms of coordinates and shown on the plan. For clarity, the salient points should be indicated by running consecutive numbers. A tabulation which lists the salient point numbers and their respective coordinates are to be shown on the gazette plan.

(b) For airspace, subterranean or stratum gazettes where elevations are required, the lower bound levels and upper bound levels are to be provided in addition to the horizontal coordinates

(c) Features and structures that are relevant to the gazette shall be surveyed and its corresponding coordinates shown in the gazette plan

(d) The Lot parcel boundaries and the respective lot numbers may be overlaid and shown on plan

(e) The name and area in sq. m of the area/place to be gazetted are to be indicated in the plan

(f) North symbol to be included and grid lines are to be shown

(g) The Lot numbers, the total area in sq. m, coordinates commencing from an agreed position running in a clockwise manner shall be supplied to the Client in addition to the plan.