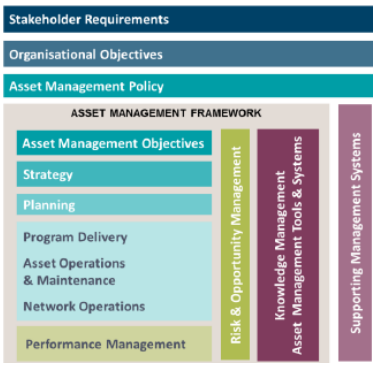
Transmission Overhead Line and Underground Cable Survey

Design Standard (Technical Specification)



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Western Power's Engineering and Design Function is responsible for this document

CONTACT

Western Power welcomes your comments, questions, and feedback on this document, which can be emailed to standards.excellence@westernpower.com.au

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Revision Details

Version	Date	Summary of change	Section
0	05/03/2019	Initial release	
1	16/02/2022	Reconfirmed	
2	05/03/2024	AMS format change	

1. Introduction

This technical specification details the survey requirements to facilitate the design of overhead transmission line and underground transmission cable.

1.1 Purpose and scope

The purpose of this specification is to ensure uniformity in the way line survey is conducted, recorded and presented.

This specification categorises the survey types required for overhead transmission line and underground transmission cable design.

1.2 Acronyms

Acronym	Definition
ASPRS	American Society for Photogrammetry and Remote Sensing is a scientific association
DXF	Drawing Exchange Format is a CAD data file format developed by Autodesk (AutoCAD) to enable data interoperability between AutoCAD and other programs.
ECW	Enhanced Compression Wavelet is a proprietary wavelet compression image format optimized for aerial and satellite imagery.
GDA	Geocentric Datum of Australia
GIS	Geographic Information Systems.
GPS	Global Positioning System is a space-based satellite navigation system that provides location and time information in all weather conditions.
LAS	LASer Exchange Format. The LAS file format is a public file format for the interchange of 3-dimensional point cloud data between users. The LAS file format is a binary file format that maintains information specific to the LiDAR nature of the data while not being overly complex (refer ASPRS).
MGA	Map Grid of Australia – the current Universal Traverse Mercator projection, which is based on the Geocentric Datum of Australia (currently GDA 94). It is the basis of the horizontal system of Eastings and Northings
LiDAR	Light Detection and Ranging
PLS-CADD	Power Line Systems – Computer Aided Design and Drafting. Line design program that includes all the terrain, sag-tension, loads, clearances and drafting functions necessary for the design of an entire powerline.
TNSP	Transmission Network Service Provider

1.3 Definitions

Term	Definition
Accuracy	The degree of conformity of a measured or calculated value compared to the actual value. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained (ASPRS Guidelines for Procurement of Commercial Geospatial Mapping Products).
Attachment Point	A Point on a structure where the conductor is attached to. Usually insulator.

Datum	Parameter or set of parameters that define the position of the origin, the scale, and the orientation of a coordinate system
Orthophoto	An aerial photograph that is geometrically corrected ("ortho-rectified") such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, orthophoto can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief, lens distortion, and camera tilt
Point classification	Assignment of a target identity classification to a particular LiDAR point or group of points.
Raw point cloud	After initial processing, the range and orientation associated with each laser pulse is converted to a position in a three dimensional frame of reference and this spatially coherent cloud of points is the base for further processing and analysis. The raw point cloud typically includes first, last, and intermediate returns for each emitted laser pulse. In addition to spatial information, LiDAR intensity returns provide texture or colour information.

1.4 References

References which support implementation of this document

Table 1.1 References

Reference No.	Title

2. Coordinate and Level Datum

The Horizontal Datum for the survey is GDA94 with coordinates expressed in MGA in zone 50.

The Vertical Datum – orthometric – is the Australian Height Datum (AHD) – as determined by the published heights of local survey control marks within or adjacent to the survey area. The most recent ICSM-approved Geoid model shall be used to derive orthometric heights from ellipsoidal data. The current Geoid model is AUSGeoid09.

3. Survey Equipment

The Contractor is responsible for ensuring all equipment is calibrated/verified and checked prior to use and maintained as such throughout the period of survey works, as well as ensuring it is fit for the survey purpose required.

4. Ground Based Line Survey

4.1 Overview

Survey data shall be described by 3D coordinate position collected by the surveyor. The surveyor shall capture the coordinate of the features as necessary to define the area.

All lines require the recording of weather data. The air temperature, solar conditions, date/time, measured wind speed and the direction shall be recorded. These measurements shall be recorded for the duration of the survey.

The method of acquisition shall be ground survey with total station and data recorder that produce horizontal and vertical positions with codes to describe different survey points.

4.2 Survey Points

The survey must include, as a minimum, the following details for new line routes:

- Natural surface levels
- Change in surface levels
- Location of property boundaries
- Location, depth and size of underground services, including manholes and pits
- Position, diameter and height of vegetation and trees
- Top of bank and toe of bank for rivers, creeks, gullies etc
- Edges and centerlines of roads, highway, freeways, tracks etc
- Above ground structures such as street lights, signs, fence/wall, buildings, bridges etc
- Railways and pipelines
- Proposed powerline crossing with a minimum of 3 measurements per span for each conductor, including the poles' details

For existing lines/as built surveys, in addition to the above requirements, the following items in Table 4.1 shall also be captured:

4.1: Existing lines/as built surveys

Item	Component	Point Description	Comment
Wood Pole	Pole base Pole top	Left transverse axis of the pole circumference at groundline and at the pole top. Right transverse axis of the pole circumference at groundline and at the pole top. Centreline of the pole at groundline and at the pole top.	Offset or calculated centreline points to be added to the datasheet. All poles of multipole structure including the stay pole to be included.
	Aerial Stay Ground Stay	Bow shackle to eye attachment points.	
Ground Anchor	Rod Eye-nut/Eye	Centreline of the rod at groundline. Rope thimble to eye nut/eye attachment point closet to the groundline.	
Steel Pole	Pole base Pole top Concrete Upstand	Left transverse axis of the pole circumference at groundline, upstand and at the pole top.	Offset or calculated centreline points to be added to the datasheet.

		Right transverse axis of the pole circumference at groundline, upstand and at the pole top. Centreline of the pole at groundline and at the pole top.	
Tower	K-points Concrete Upstand Foundation	K-point on the transverse and longitudinal face at each leg. Left transverse axis of the tower foundation circumference at groundline and top of upstand. Right transverse axis of the tower foundation circumference at groundline and top of upstand. Centre point of the tower at groundline, top of each upstand and top of tower.	Offset or calculated centreline points to be added to the datasheet.
Wire	Conductor Earthwire/OPGW Marker Balls Bird diverters	Wire attachment points, quarter span points and the ground points directly under the wire. Outline of marker ball/bird diverter and centre point.	Ground points as a minimum to be at every 25m or where the change in ground level gradient is greater than 300mm. Offset or calculated centreline points to be added to the datasheet. Undercrossing and overcrossing wires and stays to be included. The extent of survey to be 1 span beyond the battery limit.

4.3 Accuracy

The horizontal and vertical accuracy of the data shall be at least plus or minus 300mm.

4.4 Survey Data

The Contractor shall provide the survey data in an ASCII text or Microsoft Excel file (or files) with one data point per record (line/row) in the file.

The survey data file shall be in a comma delimited text format. The typical record format, space or comma delimited (preferred) is as follows:

Des,X-coord,Y-coord,Z-coord,FeatureCode,Comment

For each terrain point, there shall be one record that includes the following six (6) data fields:

1. Des - Alphanumeric point descriptor or point number of the terrain point. This can be any reference number as determined by the Contractor, and will only be used for future reference when further information regarding a specific point is requested.

2. X-coordinate (East-West) in meters.
3. Y-coordinate (North-South) in meters.
4. Z-coordinate (Elevation) in meters. This is the true elevation of the surveyed point, even if it is an aerial obstacle.
5. Feature Code (Integer),
6. Comment - Optional note to appear on all profile views. No commas are to be included within the optional note. Comments may be attached to the coordinate value to describe the particulars of the feature, or provide additional information about the location.

The Contractor must use the feature codes identified in *Western Power's PLS-CADD Feature Code*[1] to define the characteristic feature of the surveyed points. Feature codes shall be consistent for each point type or discreet feature. Alternate points, shall be approved by Western Power prior to commencement of the survey work.

4.5 CAD Drawings

Where requested, planimetric drawing of the required meter wide strip and alignments as nominated shall be submitted in DXF format as that is the only format PLS-CADD can read; however, the original DWG file used to create the DXF shall be submitted as well. The planimetric drawing shall be in the MGA Zone 50 GDA 94 coordinate system.

The planimetric CAD drawing shall be provided on Western Power's shared network platform or authorised alternatives.

4.6 Photography Requirements

For existing line survey, photographs with the following requirements are required as a minimum;

- One photo of the pole nameplate (showing pole number if visible)
- One profile photo for each pole
- One photo showing span/bay ahead (ie. from Pole 1 to Pole 2) showing conductor span
- One photo of the pole top

All photographs taken should be of high resolution, in focus and be able to show detail of the item being photographed. Photos shall be provided in JPEG format at full image capture resolution. The photos shall have a realistic appearance with appropriate brightness, white balancing and colour matching between adjacent or nearby objects. To achieve the quality of photos required, the cameras used must have at least 18 MP (Mega pixel) resolution with a 40 x optical zoom.

4.7 Deliverables

The deliverables will be on Western Power's shared network platform or authorised alternatives to be provided by the Contractor and approved by Western Power.

- Survey data
- CAD Drawings (if required)
- Photographs

[1] See Western Power's internal document

5. LiDAR

5.1 Data Acquisition

5.1.1 Overview

The Contractor must acquire LiDAR Data – including point cloud data, orthophotos and associated weather and atmospheric data – for overhead distribution and transmission assets within the portion of the survey area specified by Western Power. The Contractor must conduct the survey as a series of patrols utilising the most appropriate combination of aerial and ground-based platforms instrumented with suitable remote sensing equipment.

5.1.2 Point Cloud Acquisition

The Contractor must acquire point cloud data for all overhead assets as identified by Western Power. Minimum coverage relative to LiDAR-surveyed asset locations will be as specified in Table 5.1.

Table 5.1: Minimum Coverage Width Requirements

Circuit Type	Minimum Coverage Width Required
< 66kV	15m either side of widest point on any structure (i.e. minimum 30m coverage)
66 kV & 132 kV Metro	15m either side of widest point on any structure (i.e. minimum 30m coverage)
66 kV & 132 kV Country	20m either side of widest point on any structure (i.e. minimum 40m coverage)
220kV and 330 kV	50m either side of widest point on any structure (i.e. minimum 100m coverage)
Zone & Terminal Substations	The full extent of a substation yard and the property boundary plus a 100m buffer as defined by Western Power's GIS polygonal feature class

5.1.3 LiDAR Point Density Requirements

A survey required to deliver LiDAR Engineering deliverables must adhere to the following technical requirements:

- The LiDAR returns must characterise key features of the network assets such that it may consistently and reliably produce both a simple network baseline model and, when required, a detailed PLS-CADD model.
- The data must be of a sufficient quality to enable the accurate identification and modelling of pole top points, pole ground points, stay attachment points, stay ground points, insulators, cross arms, conductors, conductor attachment points, buildings, roads, tracks, vegetation, railways and fences.
- A minimum point density of 20 points per square metre (PPM) is required. This PPM definition equates to the typical density that would be observed on an area of mostly bare and reasonably reflective (i.e. not dark tarmac) ground at any location within the delivery corridor (i.e. a grass field, a footpath). This equates to first return only and this measurement may only include returns from a single flight swath (i.e. not inclusive of overlaps for two swaths).

- The spatial distribution of geometrically usable points is expected to be uniform and free from clustering in order to ensure consistent data densities throughout the project area. A minimum of 90% of 1x1m grid cells measured within the corridor (and being of the bare flat ground described above) shall contain at least 20 LiDAR points.
- Every span of the surveyed line must have sufficient points on each conductor phase to enable accurate modelling of the span, regardless of conductor type. This is described as measuring at least six evenly spaced points reflected off each conductor phase for each catenary. Synthetically generated points are not permitted.
- Provide clear edge definition of buildings and other man-made structures such that any subsequent clearance checks are reliable and accurate.
- The point density of the LiDAR points cloud is to be sufficient enough to allow accurate modelling of the survey area as outlined in Section 6.

5.1.4 LiDAR Accuracy and Check Points

The absolute accuracy of the LiDAR data compared to the datum defined by the WA survey network must comply with the following requirements. Note that Accuracy is reported as a confidence interval at 95% confidence or two times RMSE – i.e. if one were to check accuracy in a large number of locations, then 95% of those locations would fall within the accuracy bounds stated.

Table 5.2: Absolute Accuracy Requirements

Survey type	Vertical accuracy 95% confidence	Horizontal accuracy 95% confidence	Number of check points
Engineering surveys	+/- 0.15 m	+/- 0.20 m	12 per capture area, evenly distributed

Vertical accuracy is proved through a comparison to a series of check points which are of a higher order of accuracy. The Contractor is required to prove accuracy through the independent collection of sufficient height check points in areas of bare flat ground per the table above such that a suitable sample size is created to give a meaningful statistical result. This height validation will be presented in the survey report as an accuracy assessment statement including the methods used to create the check points and the statistical results from the accuracy check.

Horizontal accuracy is proved by collecting topographic points or strings on linear features which are visible in the LiDAR intensity image and recording the difference as a scalar (i.e. non-directional) vector. Sufficient numbers of such points in the number of locations defined by the table above will validate horizontal accuracy is being achieved. Note that these check points may not be used in any adjustments to the LiDAR data during processing and that Western Power reserves the right to carry out external accuracy validation checks at any location on the network.

Relative accuracy describes the difference in height between successive points on a hard, flat surface which is assumed to be completely level and thus the points should in theory have the same elevation value. The result is described by measuring the difference on a series of points to produce a statistical distribution. The relative accuracy between successive survey points must comply with the following requirements:

Table 5.3: Relative Accuracy Requirements

Survey type	Relative accuracy 95% confidence
Engineering surveys	+/- 0.05 m

Where the specified accuracies are difficult to achieve or at significantly higher cost than elsewhere on the network, the Contractor should advise Western Power and propose an alternative approach for achieving a suitable level of accuracy. Approval must be obtained from Western Power prior to implementing this approach.

5.1.5 Orthophoto Acquisition

The Contractor must capture downward looking aerial imagery during LiDAR Data acquisition flights suitable for post-processing into orthophotos. Aerial imagery must meet the following requirements:

- Images shall be suitable for production of orthophotos at a resolution of 15cm or better.
- Image acquisition for the area being flown shall occur no less than 30 minutes after sunrise and no less than 30 minutes before sunset on the day of acquisition for the area being flown.
- Images shall be free from blur, smoke, haze and cloud in more than 99% of tiles and shall have sufficient radiometric resolution to enable the deliverable product to be analysed without the use of enhancement tools.
- Images shall be suitable for production of orthophotos that form a seamless mosaic providing a continuous view of the survey area with the minimum coverage width specified in Table 5.1.
- Images shall be suitable for production of orthophotos that have a realistic appearance with appropriate brightness, white balancing and colour matching between adjacent or nearby photos.

5.1.6 Weather and Atmospheric Data Acquisition

The ambient air temperature, wind speed and direction, shall be gathered using an instrument(s) or from other data sources of sufficient accuracy to ensure that the conductor temperature, and therefore position, is identifiable to this required accuracy within a span and/or strain section. The methodology for data acquisition must be provided to Western Power for approval.

Wind speeds below 0.5m/s are of particular interest; hence the Contractor shall ensure that any wind measuring device and calculation methodology is appropriate for the intended use at all operational wind speeds. Wind speed should be measured as a scalar, whereas wind direction should be measured as a vector average over the same time period. All Contractor weather measurements shall be recorded on an instantaneous basis, averaged in 1 minute intervals or better.

The Contractor shall record site parameters for each bay, (at a given representative time of measurement for each bay) including but not limited to the following parameters:

- Bay/Span identification (structure numbers)
- Representative time of measurement for that bay (local time and date)
- Details of the relevant meteorological station/s
- Ambient air temperature accurate within +/-1.0°C
- Solar radiation

- Electrical loading (where provided by Western Power)
- Wind speed at meteorological station/s accurate within +/-0.1m/s
- Wind angle to conductors in degrees and accurate to +/-0.1°

5.1.7 Provision of Equipment for LiDAR Survey

The Contractor must provide appropriate equipment for acquisition of LiDAR Data, including vehicular platforms, LiDAR sensors, orthophoto cameras, weather stations and other equipment required.

As a minimum, any LiDAR sensor used must be capable of:

- Reliably measuring features including terrain, vegetation, earth wires and all conductors;
- Achieving the minimum required point density;
- Achieving the specified accuracy;
- Detecting multiple discrete returns, with a minimum of four (4) potential returns for each outbound laser pulse for the purposes of vegetation canopy penetration; and
- Recording the intensity of each return with sufficient sensitivity and dynamic range that intensity can be used to visually interrogate the LiDAR point cloud.

5.2 LiDAR Data Processing

5.2.1 Overview

The Contractor must process the LiDAR Data acquired during a survey according to the requirements of this section.

5.2.2 Point Cloud Processing

Point Cloud Tiling

The Contractor must apply tiling to the point cloud. Point Cloud Tiling shall meet the following requirements:

- The classified point cloud (simple and full classification) will be delivered to Western Power in 500 x 500 m non-overlapping tiles.
- The origin of the bottom left of the tile must align exactly to the MGA system on a 1000 m increment, i.e. the coordinate of the corner of a tile will always have two zeroes in whole metre X and Y values

All deliverables should contain a reference to the relevant Tile.

Classified Point Cloud LAS and ASCII XYZ

The Contractor must develop classified point clouds for the defined corridor widths, fully calibrated and adjusted to AHD and classified per the appropriate schema. These must be produced as both:

- Fully compliant LAS v1.4, Format 3 point record format with all standard attributes including:
  - Intensity values (native radiometric resolution)
  - Return number
  - Georeferencing information in all LAS file headers

  - GPS times recorded as adjusted GPS time, at a precision sufficient to allow unique timestamps for each pulse.
  - Classification scheme to be applied as per Section 5.2.3.
  - Tiled delivery, as per Section 5.2.2.

- Classified Point cloud in ASCII XYZ CSV (comma separated values) format containing points for each classification of each line or area (column 1 as the survey point number; column 2 is the MGA easting of the point; column 3 is the MGA northing of the point; column 4 is the AHD height; column 5 is the survey classification code; column 6 is for adjusted GPS adjusted date; column 7 GPS adjusted time).
  - Example: Nr,easting,northing,height,classification-code,date,time,comments
  - '1,190291.80,6519689.28,420.17,40,2015-07-03,13:34:08,'

Digital Elevation Model (DEM)

The Contractor must derive a DEM from classified ground points.

The DEM must be developed in the following manner;

- 1m grid bare earth Digital Elevation Model (DEM)
- The DEM should be generated from the LiDAR mass point data classified as "Ground" only, so that it defines the "bare earth" ground surface.
- The DEM generation should employ a Point to TIN and TIN to Raster process with Natural Nearest Neighbour interpolation – there shall be no gaps within the boundary of the corridor
- Void areas (i.e., areas outside the project boundary but within any tiling scheme) shall be coded using a unique "NODATA" value
- ESRI floating point GRID format
- Tiled delivery, as per Section 5.2.2.

5.2.3 Engineering Classification Scheme

The point cloud used to produce LiDAR Engineering deliverables must be classified as outlined in

Table 5.4 and the following quality requirements are to be achieved by the Contractor:

- Point classification is to be consistent across the entire project and facilitate reliable modelling and analysis without further data correction being required by Western Power or another subcontractor.
- Classification accuracy is defined on a per-span basis, such that only a percentage of spans may contain classification errors, i.e. 98% classification accuracy means that if 100 spans were checked, only two would contain a classification error for those classes. This will be subject to systematic spot-checks on delivery.
- For powerline features (inclusive of poles, conductors, stays, etc.) the acceptable error rate is 1% of spans, such that there may be no misclassification of terrain or vegetation into these classes. If not specified as a separate class, any features associated with the pole (i.e. a stay or insulator) may be grouped together in the structure class.
- Classification of buildings, vegetation and other temporary features above 2.0m in height are subject to an acceptable error rate of 3% of spans, restricted to misclassifications within these classes, i.e. a building classified as a tree.

- For the classification of ground points from the data below 2m in height above ground, the acceptable error rate for false points retained in ground (i.e. high or low) is 5% of spans.
- For spurious points (i.e. high and low points) these must not be retained in one of the target classes or default class described in the table in more than 5% of spans.
- Conductor voltage assignments must be 100% correct unless the source of the error is based upon incorrect source data supplied, in which case it can then be corrected.
- Noticeable variations in the character, texture and/or quality of the classification between tiles, swaths, lifts, or other non-natural divisions will be a cause for rejection of the entire deliverable

Table 5.4: Engineering Point Cloud Classification Scheme

Code	Classification Description	Colour	Red	Green	Blue
1	Point of Intersection (P.I.) synthetic points defining pole/structure centre on ground		255	51	0
2	Ground (not road surface)		201	93	9
3	Road surface		0	0	0
4	Above ground features greater than 2 metres. These features will include buildings, overpass bridges etc.		253	226	163
5	Vegetation greater than 2 metres		118	181	49
6	Vegetation ground to 2 metres		146	208	80
7	Building		253	226	163
8	Model key points		201	93	9
9	Conductors of the low voltage study power line attached (covered)		117	117	117
10	Conductors of the low voltage study power line attached (bare)		244	44	230
11	Conductors of the low voltage study power line attached crossing (ABC)		117	117	117
12	Conductors of the 6,600 volt study power line attached		202	122	245
13	Conductors of the 11,000 volt study power line attached		255	170	0
14	Conductors of the 12,700 volt single phase study power line attached		56	168	0
15	Conductors of the 19,100 volt single phase study power line attached		197	0	255
16	Conductors of the 22,000 volt study power line attached		0	197	255
17	Conductors of the 33,000 volt study power line attached		255	255	0
18	Conductors of the 66,000 volt study power line attached		115	76	0
19	Conductors of the 132,000 volt study power line attached		255	0	0
20	Conductors of the 220,000 volt study power line attached		153	0	204
21	Conductors of the 330,000 volt study power line attached		230	152	0

Code	Classification Description	Colour	Red	Green	Blue
22	Conductors of the Service Line (CUSA) study power line attached		255	0	0
23	Grid structure towers		0	0	0
24	Vegetation offset from the conductor beyond 6.5m		59	154	54
25	Telecommunication Infrastructure attached		0	0	0
26	Conductors of the low voltage study power line unattached (covered)		117	117	117
27	Conductors of the low voltage study power line unattached (bare)		244	44	230
28	Conductors of the low voltage study power line unattached crossing (ABC)		117	117	117
29	Conductors of the 6,600 volt study power line unattached crossing		202	122	245
30	Conductors of the 11,000 volt study power line unattached crossing		255	170	0
31	Conductors of the 12,700 volt single phase study power line unattached crossing		56	168	0
32	Conductors of the 19,100 volt single phase study power line unattached crossing		197	0	255
33	Conductors of the 22,000 volt study power line unattached crossing		0	197	255
34	Conductors of the 33,000 volt study power line unattached crossing		255	255	0
35	Conductors of the 66,000 volt study power line unattached crossing		115	76	0
36	Conductors of the 132,000 volt study power line unattached crossing		255	0	0
37	Conductors of the 220,000 volt study power line unattached crossing		153	0	204
38	Conductors of the 330,000 volt study power line unattached crossing		230	152	0
39	Unknown feature code – processed unclassified	White	255	255	255
40	Study conductor		117	117	117
41	Telecommunication Infrastructure unattached crossing		0	0	0
99	Default – all features (excluding spurious points) not included in the other classes	White	255	255	255

Codes 25 and 41 apply to telecommunication infrastructure such as Telstra and NBN. Western Power does not have spatial records of this data which is more prevalent in urban areas. With the exception of overhead (“running”) earth wires, poles will typically be structured with the highest voltage circuit at the top, and the lowest voltage circuit at the bottom. All streetlight circuits, Telstra, NBN or other communication conductors will be attached below the lowest voltage circuit.

5.2.4 Orthophoto Processing

The Contractor must ortho-rectify photos captured during LiDAR Data acquisition flights. The Orthophotos must be produced as geo-referenced, downward-looking and Ortho-corrected photos in compressed ECW format at a resolution of 15cm and meet the following requirements:

- Geo-referencing of the photos shall be to an accuracy of three pixels when comparing to photo control derived from targets or existing ground features.
- The ortho-correction of photos shall be carried out to the DTM based on use of “ground” points. Photos will be joined to form a seamless mosaic such that it forms a continuous view along the line corridor or of the survey area with the minimum coverage width specified in Table 5.1.
- The orthophotos shall have a realistic appearance with appropriate brightness, white balancing and colour matching between adjacent or nearby photos.
- The orthophotos shall be provided in the same tiling and numbering scheme as the LiDAR deliverables and named accordingly.
- The collars of the photos (where no photographic data exists) are to be transparent through a no data value which can be read by common GIS software.
- The ECW files shall be created with compression ratio of 5:1. Coordinate system reference must be embedded in the ECW file header such that common GIS platforms will automatically read this and position the image.

5.2.5 Weather and Atmospheric Data Processing

The Contractor must process weather and atmospheric data to determine the wind speed at the conductors at the time of the survey and, where requested by Western Power for the purposed of generating a PLS-CADD model, the conductor temperature. The methodology for calculating this information must be provided to Western Power for approval.

The Contractor shall record final adopted weather and atmospheric data for each bay/span, (at a given representative time of measurement) including but not limited to the following parameters:

- Wind speed for bay/span at representative conductor height
- Calculated conductor temperature (only if a PLS-CADD model is required)
- Average calculated conductor temperature for each tension section (only if a PLS-CADD model is required)
- Average ambient temperature for each strain section (only if a PLS-CADD model is required)

5.3 LiDAR Data Delivery

5.3.1 LiDAR Deliverables

The Contractor must deliver the LiDAR Data acquired during a survey according to the requirements of this section.

The deliverables outlined in this section will be provided in a staged manner in accordance with the relevant Contractor Program on Western Power’s shared network platform or authorised alternatives to be provided by the Contractor and approved by Western Power.

Consistent naming convention will be strictly enforced in relation to all aspects of the reporting deliverables associated with the overall delivery of services. File naming convention for deliverables needs to be first approved by Western Power.

The Contractor must deliver one set of Common Deliverables as described in this section for each LiDAR Capture Area included within a survey. Common Deliverables are summarised in Table 5.5.

Table 5.5: Summary of LiDAR Common Deliverables

ITEM	Deliverables	Description/Function	Reference to Specifications	Format
C.1	Survey Report	Outlines survey control list survey marks/CORS stations, time date of each flights, illustrates achieved accuracy RMSE. Lists density and point distribution.	5.3.2	PDF
C.2	Aerial and Ground Track Files	Track of flight with local date and time stamp for each mission beginning and end.	5.3.3	SHP
C.3	Not Surveyed Areas File	Polygons where LIDAR Data was not acquired in relation to the WP network.	5.3.4	SHP
C.4	Poles and Structures Files	Lists of pole and structure positions matched with supplied asset record identifiers.	5.3.5	CSV, SHP
C.5	Unmatched Poles and Structures File	Lists of pole and structure positions that could not be matched with supplied asset record identifiers.	5.3.6	CSV, SHP
C.6	Conductors of all voltages file	Lists of conductors of all voltages (each voltage in a separate file) matched to supplied conductor data.	5.3.7	CSV, SHP
C.7	Unmatched conductors files	Lists of conductors of all voltages (each voltage in a separate file) that could not be matched with suppled conductor data.	5.3.8	CSV, SHP
C.8	Reference Tiles	Cross reference of deliverables to the tile reference system.	5.3.9	SHP

5.3.2 Survey Report

The Contractor must deliver a Survey Report for each LiDAR Capture Area that provides Western Power with information on the set of data being delivered for that LiDAR Capture Area. The Survey Report must also demonstrate that the required level of quality assurance has been carried out to ensure the survey has achieved full coverage, and that the data is fit for purpose and meets the stated accuracy requirement. A Survey Report must include the following:

- A list of aerial/ground patrols undertaken along with the appropriate reference to the aerial or ground track file
- Confirmation that each survey has been verified as meeting key specifications such as trajectory quality, density, spacing, coverage and noise along with accompanying notes where this has deviated from the norm or an issue with the data is explainable or will not impact the purpose
- Attributes for each survey including the specific and sensor used, any reference stations utilised for the trajectory processing and any other pertinent information about survey conditions or events
- A summary of the processing activities used to create the geodetically correct LAS files in that area including any control points used to correct heights beyond the ellipsoid to AHD correction via the Geoid model
- A summary of the accuracy assessment showing how the delivered data meets vertical, horizontal and relative accuracy requirements by way of the proof described earlier in the document

- A summary of the pole matching outcomes detailing the confidence interval for matched poles, the number of mismatched poles, found and not found poles
- A summary of the conductor matching outcomes detailing the confidence interval for matched conductors, the number of mismatched conductors, found and not found conductors
- All survey control coordinates, site ID and check point comparisons in both Excel spreadsheet and SHP file formats
- Any other information relevant to Western Power's understanding of how the data was acquired, processed, analysed and delivered.

5.3.3 Aerial and Ground Track Files

The Contractor must deliver track files of LIDAR acquisition flights as well as for ground captured data. This requires a point-based track with a new 3D shapefile point each five seconds with XY and Z (Ellipsoidal) values as an attribute. The attributes shall also include the start time and end time for the patrol. The files should be supplied in SHP format and Western Power requires the Contractor to provide copies of track files delivered in association with completed Survey Reports for each LiDAR Capture Area.

In addition to the individual track files, the Contractor must supply a single SHP file showing the available LiDAR coverage for that LiDAR Capture Area generated from the captured swaths with each swath being a separate feature. The swath shall be attributed with flight/ground reference and date of capture.

5.3.4 Not Surveyed Area

The Contractor must deliver a single SHP file for the entire LiDAR Capture Area showing areas where LiDAR data was NOT collected. This should correspond to the reporting described above to provide a reason for missing coverage.

5.3.5 Poles and Structures

The Contractor must provide a report detailing the location of poles and structures identified during the survey. This report must be provided in CSV and SHP format and include pole and structure positions at the centroid of the structure at ground level, derived from survey and matched with supplied asset record.

5.3.6 Unmatched Poles and Structures

For existing lines, the Contractor must provide a report detailing poles or structures identified via survey that are not matched to poles/structures that were supplied by Western Power's but not identified in the LiDAR survey. This report must be provided in CSV and SHP format.

5.3.7 Conductors

The Contractor must provide a report detailing conductors of all voltages (each voltage in a separate file) matched to supplied conductor data. This report must be provided in CSV and SHP format.

5.3.8 Unmatched Conductors

The Contractor must provide a report detailing conductors of all voltages (each voltage in a separate file) identified via survey that are not matched to supplied conductor data. This report must be provided in CSV and SHP format.

5.3.9 Reference Tiles

The Contractor must provide a tiling index for each LiDAR Capture Area in the form of a SHP file whereby a feature class contains a single polygon defining each tile. Attributes in the Tile Index file should contain: LASfile name, LiDAR Capture Area, Survey Company Name, year of acquisition.

6. PLS-CADD Modelling Requirements

6.1 Overview

Where requested, the Contractor must deliver a PLS-CADD model as specified by Western Power. Unless otherwise directed by Western Power, PLS-CADD modelling will only be performed on data that has been acquired and processed in accordance with the LiDAR requirements of this specification.

All overhead conductors shall be modelled within the latest version of PLS-CADD and will have the following features:

- Feature coded point cloud
- Ortho-rectified image tiles linked to the model along with appropriate geo-referencing
- Structure image – Elevation view to be attached to model for QA purpose (this is useful for modelling custom timber configuration such as braced post/i-string)
- All cables strung in PLS-CADD
- All under and over crossings of distribution and transmission lines shall be modelled. A minimum of three spans shall be modelled at each crossing location (i.e. the crossing span, plus one span either side of the crossing).
- All major underlying modelling assumptions, rules and operations used to create the model shall be documented in the Criteria Notes. The intent is for the designer to provide an appropriate level of notation such that a designer not familiar with the model could review it and be able to re-create the design.

6.2 Feature Codes

The feature codes used shall be in accordance with *Western Power's PLS-CADD Feature Code*[2]. The contractor shall pay particular attention to the insulator, conductor and stay attachment points.

6.3 PLS-CADD Criteria

PLS-CADD load criteria shall be developed by the Contractor and submitted to Western Power for review.

6.4 Conductor Temperature Calculations

Determination of the conductor temperature at the time of survey using meteorological data and conductor loads at the time of survey is required. Calculation of conductor temperature is performed using TNSP 2009 methodology including solar heat gain at the time of survey.

The TNSP 2009 conductor ampacity rating method shall be used for all conductor temperature calculations, taking into account the ambient temperature, weather conditions and load flow parameters. In addition, solar loading at the time of survey shall be considered.

[2] See Western Power's internal document

Where no other information is available, the corresponding emissivity factor shall be taken as 0.5, with an absorptivity factor of 0.5.

The Contractor shall calculate the conductor temperature within each span and/or strain section to an accuracy of at least +/-1°C. This true temperature shall be used for matching the conductors in PLS-CADD.

6.5 Line Loading

Western Power will supply the line loading data (5 minutes interval) to the Contractor for use in the ampacity calculations. The Contractor will specify the required line names and the dates for which the loading data is required.

The data will be emailed to the Contractor as a Microsoft Excel spreadsheet, detailing time vs amperes.

6.6 Cable (Conductor) Modelling

Each type of phase conductor and earthwire used by Western Power shall have its independent PLS-CADD cable file. These files are the electronic representations of the physical wires, and the properties do not change for a given conductor type. Each conductor type may either be linear or non-linear in nature. Unless otherwise provided by Western Power, the Contractor shall only create and use linear cable files.

The Contractor shall model the cable files based on the applicable Australian or International standard for a specified conductor. Western Power will supply the conductor data (mechanical and electrical parameters) for those conductors that are not available to the Contractor in an Excel spreadsheet. The Contractor shall then generate linear cable files with these parameters.

Conductor data for each span shall be provided to the Contractor in a spreadsheet format as per the conductor voltages.

6.7 Structure Modelling

Western Power will determine the PLS-CADD method to be used for structure modelling.

All files shall be named in accordance with *Western Power's Structure Model Naming Convention*[3] and be individually labelled to match structure name.

The pin (or post) insulators attachment points can be directly modelled. Where disc insulators are used in the network (for instance, running disc angle locations), the string length shall be appropriately modelled to best fit the survey data. Note that this length of insulator string (for disc insulators) shall be used as the "length of free swing suspension insulator" for Conductor Clashing Reports.

Structure numbering shall be as per the Western Power pole label. Structures to be located at the catenary intersection points.

For "pi" (H-frame), gantry, tower, 5 pole cricket wicket structures, the point of inflection (PI point) shall be at the centreline of the structure. For 3 pole structures, the point of inflection (PI point) shall be at the base of the centre pole.

[3] See Western Power's internal document

6.8 Graphical Sagging

The cable files shall be sagged using Finite Element Analysis in PLS-CADD to match the points of the conductors at the calculated conductor temperature.

6.9 PLS-CADD Notes

PLS-CADD Notes shall be used to capture any deviation in modelling or any data limitation or discrepancy identified during the modelling.

6.10 Client Acceptance Review

Prior to compilation of reports, the completed PLS-CADD model shall be provided to Western Power for review and approval.

Western Power will complete an initial review of the submitted data within ten working days of receipt from the Contractor, and advise the Contractor of initial acceptance of the submitted PLS-CADD Model, or advice of issues requiring further attention before acceptance.

6.11 Structure Naming Conventions

Label each support with the number (nameplate ID) followed by the line abbreviation e.g. 112 KOJ-ALB 81 instead of KOJ-ALB 81 POLE 112.

The crossing distribution structure label shall be the pick id e.g. S102201

Unknown private pole could be labelled U1,U2…etc

6.12 Phase Naming Convention

Western Power's PLS-CADD Phase Naming Convention[4] shall be used.

6.13 Feature Symbols

The Contractor must propose a set of feature symbols for Western Power approval.

6.14 PLS-CADD Folder Layout

The Contractor must apply the folder layout in Figure 6.1 unless otherwise agreed with Western Power and supply all PLS-CADD deliverables in this folder layout.

[4] See Western Power's internal document

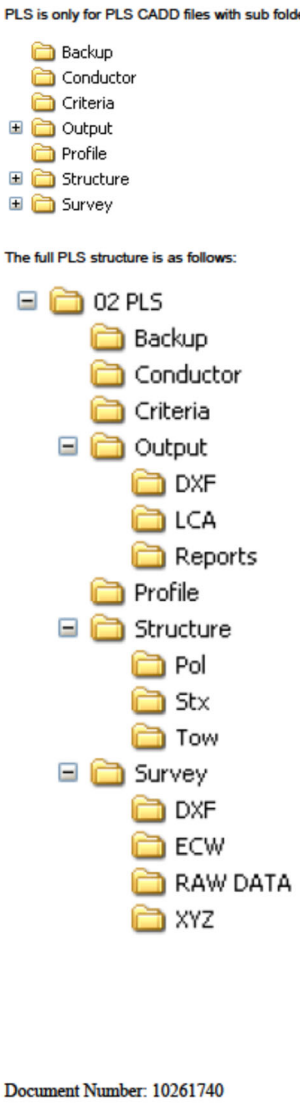

Figure 6.1: PLS-CADD Folder Structure

6.15 Deliverables

Where PLS-CADD modelling is required, the Contractor must undertake the required modelling and provide deliverables which includes:

- PLS-CADD Cable Files, one per conductor, providing an electronic representation of a physical wire;
- PLS-CADD Structure Files, providing an electronic representation of a physical structure;
- PLS-CADD Notes, providing a summary of model deviations, discrepancies or data limitations; and

- PLS-CADD Model, providing an integrated model of the required network section.

7. Underground Utility Survey

7.1 Overview

The Contractor shall perform the tasks required to provide the amount and accuracy of underground utility data as requested by Western Power. This applies to all existing (including redundant) and under-construction utility infrastructure.

7.2 Desktop Survey

The Contractor is required to collect utilities data from the service providers (eg. Dial Before You Dig). Cursory site inspection and anecdotal evidence may be used to complete the desktop survey.

7.3 Site Survey

For a site survey, a licensed surveyor is required to provide in three dimensions, as a minimum, the following details:

- Natural surface levels
- Change in surface levels
- Location of property boundaries
- Location, depth and size of underground services, including manholes and pits
- Position, diameter and height of vegetation and trees
- Edges and centerlines of roads, highway, freeways, tracks etc
- Above ground structures such as street lights, signs, fence/wall, buildings, bridges etc
- Railways and pipelines

The Contractor shall update the utilities locations obtained from supplied plans (desktop survey) to align with surveyed surface features to depict their location.

7.4 Detection Survey - Ground Penetration Survey (GPR)

Where requested, the Contractor shall undertake the GPR surveys to confirm the depth and alignment of the underground utility services within the selected alignment.

7.5 Verification Survey - Non-destructive Digging

Where requested, the Contractor shall carefully expose subsurface utility by pothole excavation using hand digging or sensitive vacuum techniques so that the utility service or its protective covering are not destroyed.

7.6 On Site Identification of Services

Services located are to be marked on site with crayon, paints or pegs with colours matching the standard line colour (refer section 7.8). Erroneous marks should be removed if possible or covered over.

- Paint markings shall be at less than 15m intervals on linear runs and at all changes in direction for all services.

- Indicative depths shall be painted at less than 30m intervals and at all changes in depth for all services.
- Services information shall be marked at start and finish of the service run and less than 50m intervals and include:
  - Services ownership e.g. Telstra, Optus, Amcom, Water Corp, Western Power.
  - Cable type and size e.g. Optic fibre, High Voltage, Main Cable, SSI cable, Communication cable or Signal Feed cable.
  - Pipe construction type and size shall be provided where information is available
  - Additional information regarding assets (i.e. HPGM high pressure gas main)

The Contractor shall ensure all markings are discrete and not outsized

The Contractor shall ensure buildings and properties are not damaged by paint markings.

For non-destructive digging, PVC pipe markers must be installed to identify the locations and include the following information:

- Date
- Location company
- Service type / size
- Depth to service
- Ribbon or paint colour to match service type (refer section 7.8)

7.7 Accuracy

The required level of accuracy for each type of underground utility survey activity is depicted in Table 7.1 .

Table 7.1: Underground Utility Survey Accuracy

Survey Type	Horizontal Accuracy	Vertical Accuracy
Desktop Survey	N/A	N/A
Site Survey	+/- 300mm	N/A
Detection Survey	+/- 150mm (less than 1.2m depth) +/-300mm (depths greater than 1.2m)	+/-500mm
Verification Survey	+/- 50mm	+/- 50mm

7.8 CAD Drawings

CAD drawings of the underground utility survey shall be submitted in MicroStation DGN format. The drawing shall be in the MGA Zone 50 GDA 94 coordinate system.

The line colour for each subsurface utility must be in accordance with Table 7.2.

Table 7.2: Line Colour for Underground Utility Survey

Utility Service	Colour
Cadastral boundaries	Black
Communication - copper	White
Communication – optic fibre	Purple
Drainage / stormwater	Green
Electricity – distribution (33kV and below)	Orange
Electricity – transmission (66kV and above)	Red
Gas	yellow
Sewer	brown
Unidentified services	pink
Water	blue

Other features not listed can be represented by any other colour as long as it is clearly indicated in the legend of plot.

The CAD drawing shall be provided on Western Power's shared network platform or authorised alternatives.

7.9 Deliverables

The deliverables will be on Western Power's shared network platform or authorised alternatives to be provided by the Contractor and approved by Western Power.

- Raw data obtained from service providers, including evidence of no services in area responses
- Survey data
- CAD Drawings