Watershed Sciences – Puget Sound Lidar Consortium
Lidar Survey Specifications

Data acquisition	*Survey Design*	*Minimum requirements*[1]
Laser pulse rate	Up to 116,000 pulses per second	
Returns per pulse	Up to 4	First and last (up to 2)
On-ground laser beam diameter	approx 25 cm	Between 10 cm and 100 cm
Scan angle	±13 degrees	≤ ±20 degrees
Aircraft altitude	800 m above ground	
Aircraft speed	105 knots	
Ground swath width	<500 meters	
Swath overlap	50% sidelap (100% overlap)	No voids between swaths. No voids because of cloud cover or instrument failure. <20% no-overlap area per project. No arbitrary 1 km x 1 km square with >50% no-overlap area
Aggregate pulse density	>8/m^2	Barring non-reflective areas (e.g., open water, wet asphalt): • ≥85% design pulse density for entire project area. • Within areas of swath overlap, no 30m x 30m area with <50% design pulse density
Flight line direction	Opposing	
GPS base-line length	≤24 km	
GPS PDOP	≤3.0, ≥6 satellites in view	≤3.5, ≥6 satellites in view
Survey conditions		Leaf-off and no significant snow cover at discretion of Puget Sound Lidar Consortium
Accuracy	*Survey Design*	*Minimum requirements*
Absolute accuracy	<13 cm vertical, <10 cm horizontal (RMSE)[2]	≤20 cm vertical (RMSE)[3]

1 Local relief, turbulence, inability to maintain an exact flying height, and aircraft and instrument availability routinely lead to departures from the survey design. *Minimum requirements* listed here are the minimum acceptable under this contract. PSLC routinely evaluates delivered data to ensure compliance with minimum swath overlap and aggregate pulse density.

2 Watershed Sciences survey practices are optimized to achieve this absolute accuracy. Performance is verified by vendor-established ground control using hundreds of points per project.

3 Routinely evaluated by PSLC using available ground control points (GCPs). Number of available GCPs in a survey area is commonly small thus required RMSE is calculated using the formula

$$RMSE \leq 20\text{ cm} * (((n-1) - 2.326 * (n-1)^{1/2}) / n)^{1/2}$$

where **n** is the number of GCPs.

Between-swath reproducibility[4]		≤15 cm vertical on horizontal surfaces (RMSE)
Reproducibility of range measurements[5]		≤5 cm (RMSE)
Spatial reference framework		
Vertical Datum	NAVD88, Geoid03 (unless otherwise specified)	
Horizontal Datum	NAD83	
Projection	UTM, State Plane, Oregon Lambert (as requested)	
Units	Meters (UTM) or survey/international feet (State Plane, Oregon Lambert)	
Deliverables		
Report of Survey	Text report that describes survey methods; results; vendor's accuracy assessments, including internal consistency and absolute accuracy; and metadata *.pdf, .doc, or .odt format*	
Aircraft trajectories (SBET files)	Aircraft position (easting, northing, elevation) and attitude (heading, pitch, roll) and GPS time recorded at regular intervals of 1 second or less. May include additional attributes. *ASCII text or shapefile format*	
All-return point cloud	List of all valid returns. For each return: GPS week, GPS second, easting, northing, elevation, intensity, return#, return classification. May include additional attributes. No duplicate entries. *ASCII text and LAS version 1.1 format* *1/64th USGS 7.5-minute quadrangle (0.9375 minute by 0.9375 minute) tiles*	
Ground point list	List of X,Y,Z coordinates of all identified ground points. *ASCII text.* *1/4th USGS 7.5-minute quadrangle (0.375 minute by 0.375 minute) tiles*	
Ground surface model	Raster of ground surface, interpolated via triangulated irregular network from identified ground points. No unavoidable point misclassification[6] *ESRI floating point grid, 6 ft or 3 ft (2m or 1m) cell size, snapped to (0,0), 1/4th USGS 7.5-minute quadrangle (0.375 minute by 0.375*	

4 Extensive swath overlap allows for robust estimation of intra-survey reproducibility. Intra-survey measurement errors on flat ground are commonly 4-6 cm $RMSE_Z$, with an increase in Z errors as local slope increases. PSLC routinely analyzes samples of delivered data for conformance with this specification.

Because errors related to dense forest cover are outside the vendor's control, this contract includes no specification for the accuracy of bare-earth DEMs. The error of a bare-earth DEM includes errors in classifying points as ground and errors introduced by interpolation from scattered ground points to a continuous surface, as well as measurement errors. Analyses of swath-to-swath reproducibility suggest that, barring wholesale vertical shifts, errors of bare-earth DEMs produced by Watershed Sciences surveys of western Washington and northwest Oregon are circa 15 cm ($RMSE_Z$) or less.

5 Evaluated by measuring departures from planarity of returns from planar surfaces (e.g., building roofs)

6 PSLC evaluates conformance by visual inspection of large-scale shaded-relief images. Tiling artifacts and measurement errors may also be identified during this inspection

	minute) tiles
First-return (highest-hit) surface model	Raster of first-return surface, cell heights are highest recorded value within that cell, voids may be filled with ground surface model *ESRI floating point grid, 6 ft or 3 ft (2m or 1m) cell size, snapped to (0,0), 1/4th USGS 7.5-minute quadrangle (0.375 minute by 0.375 minute) tiles*
Surface models shall have no tiling artifacts and no gaps at tile boundaries. Areas outside survey boundary shall be coded as NoData. Internal voids (e.g., open water areas, shadowed areas in first-return surface) may be coded as NoData.	
Intensity image	*GeoTIFF, 3 ft (1m) pixel size, 1/4th USGS 7.5-minute quadrangle (0.375 minute by 0.375 minute) tiles*
Contours ***OPTIONAL*** (add 10% to total cost)	2-ft contours *AutoCAD .dxf or ESRI shapefile format* *1/64th USGS 7.5-minute quadrangle (0.9375 minute by 0.9375 minute) tiles*
Files shall conform to a consistent naming scheme. Files shall have consistent internal formats.	