USGS_IA_Western_2_2020_D21
Lidar 2020 Final Report

Report Produced for U.S. Geological Survey
Task Order: 140G0220F007
Report Date: 11/24/2021

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Contents

Overview

This task order is for a fall 2020/spring 2021 leaf-off lidar survey to be collected over a primary Defined Project Area (DPA) in the state of Iowa of approximately 12,233 square miles, including the counties of; Lyon, Sioux, O'Brien, Plymouth, Cherokee, Woodbury, Ida, Monona, Crawford, Harrison, Shelby, Audubon, Pottawattamie, Cass, Mills, Montgomery, Adams, Fremont, Page and Taylor. This project will support FEMA, NRCS, and the 3DEP mission. USGS_IA_WesternIA_2020_D21 was planned for the acquisition, processing, and derivative products of lidar data to be collected at an aggregate nominal pulse spacing (ANPS) of =0.71 meters (QL2). Approximately 4813 square miles of USGS_IA_WesternIA_2020_D21 referred to as USGS_IA_Western_2_2020_D21 was acquired in the late fall of 2020 and early spring 2021. USGS_IA_Western_2_2020_D21 project area consists of 12 Iowa counties; O'Brien, Cherokee, Ida, Crawford, Shelby, Audubon, and the eastern sections of Lyon, Sioux, Plymouth, Woodbury, Monona, and Harrison. The condition of the ground was good during the collection of the survey.

Acquisition of the USGS_IA_WesternIA_2020_D21 DPA was broken out to three subcontractors in the following manner.

Contractor	Number of Flight Days	Square Miles Flown
Aerial Services, Inc.	11	~3,371.70
Aerial Surveys International	5	~3,217.34
TAC	11	~5,616.31

Table 1: Prime Contractor and Subcontractor Days of Flight and Square Miles Flown

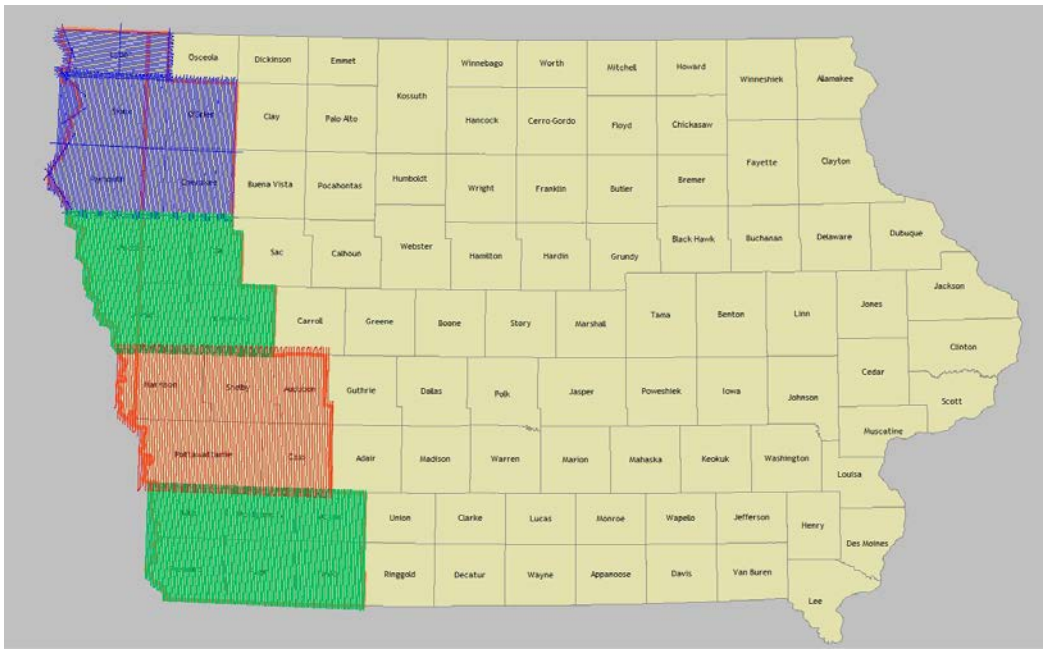

Figure 1: Western Iowa DPA Contractor and Subcontractor Breakout

The LiDAR data for USGS_IA_Western_2_2020_D21 project area was processed and classified according to project specifications. Detailed breaklines, bare earth Digital Elevation Models (DEMs), and Intensity Images were produced for the USGS_IA_Western_2_2020_D21 project area. Data was formatted into tiles with each tile covering an area of 1000 meters by 1000 meters. A total of 12,738 LAS files, 12,736 DEMs, and 12,738

Intensity Images were produced for the project, encompassing the USGS_IA_WESTERN_2_2020_D21 project area approximately 4831 square miles and formatted into 12,738 total tiles.

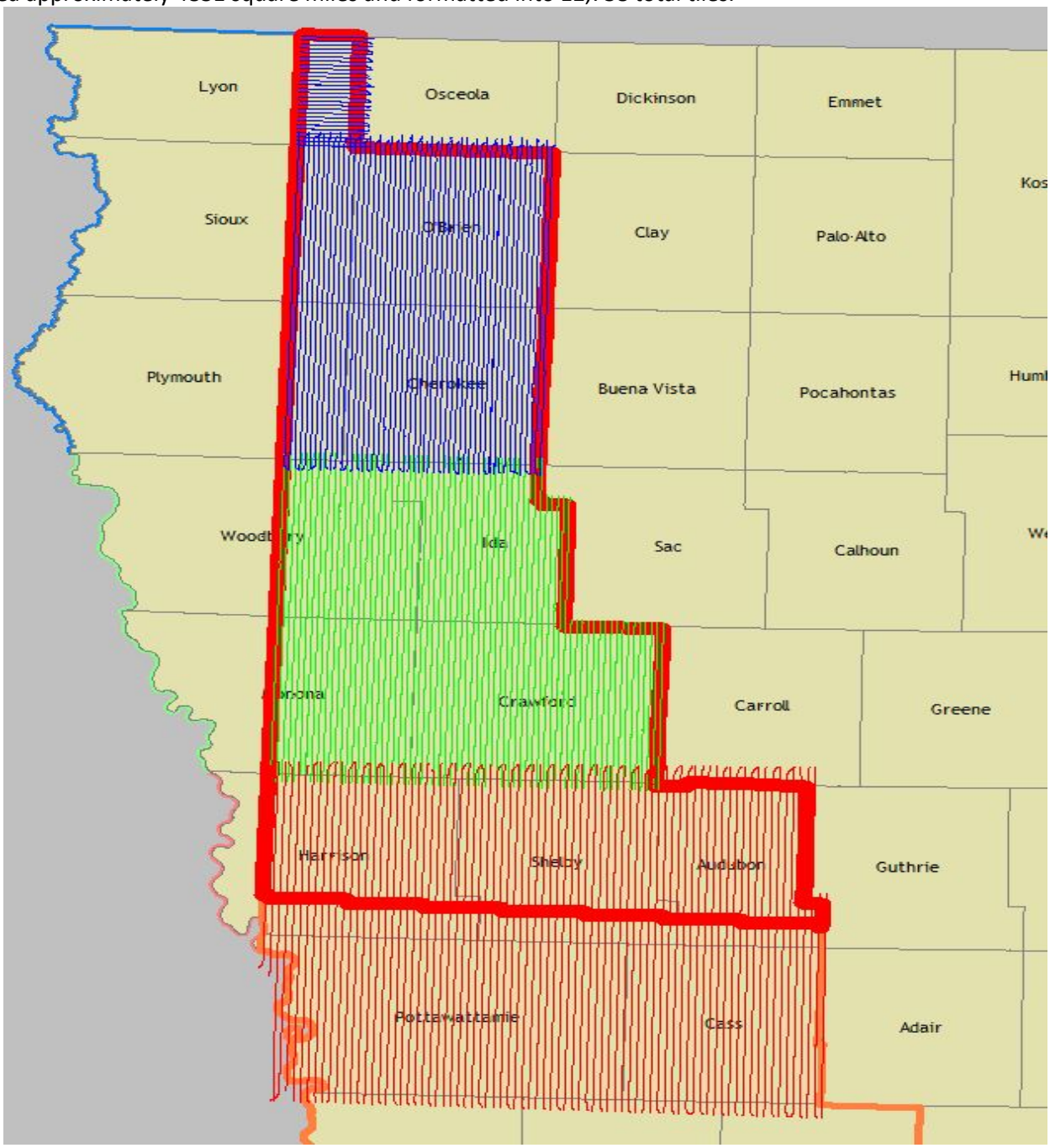

Figure 2: USGS_IA_Western_2_2020_D21 Breakout

Project team

Aerial Services, Inc. (ASI) served as the prime contractor for the project. In addition to project management, ASI was responsible for LIDAR acquisition and calibration of 1595.2 square miles of the northern section and ground filtration of this USGS_IA_Western_2_2020_D21 project area. ASI was responsible for bare earth cleanup of the entire USGS_IA_WesternIA_2020_D21 project. ASI produced the LiDAR products; Digital Elevation Model (DEM) production, Intensity Image production, and quality assurance for the entire project. Subcontractor: Aerial Surveys Incorporated, LLC was responsible for LiDAR acquisition and calibration of 1276.12square miles of the southern section of this USGS_IA_Western_2_2020_D21 project area. Subcontractor: Technical Applications and Consulting, LLC (TAC) was responsible for LiDAR acquisition and calibration of 1944.8 square miles of this USGS_IA_Western_2_2020_D21 project area. Subcontractor: Michael Backer International collected hydro for the entire USGS_IA_Western_2_2020_D21 project area. All follow-on processing was completed by the prime contractor.

Foth Infrastructure & Environment, LLC completed ground surveying for the project and delivered surveyed checkpoints. Foth Infrastructure & Environment, LLC was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the LiDAR-derived surface model. Please see SURVEY REPORT to view the separate Survey Report that was provided for this portion of the project.

Survey area

The project area addressed by this report falls wholly or partially within the USGS_IA_Western_2_2020_D21 project area consists of 12 Iowa counties; O'Brien, Cherokees, Ida, Crawford, Shelby, Audubon, and the eastern sections of Lyon, Sioux, Plymouth, Woodbury, Monona, and Harrison.

Date of survey

LiDAR acquisition for USGS_IA_Western_2_2020_D21 project area was conducted between the dates of November 27, 2020 to March 28, 2021.

Coordinate reference system

Data produced for the project was delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011)).

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88).

Coordinate System: Universal Transverse Mercator (UTM) Zone 15 North.

Units: Horizontal units are in meters, Vertical units are in meters.

Geoid Model: Geoid18

Lidar vertical accuracy

For the USGS_IA_Western_2_2020_D21 project area, the tested RMSEz of the classified LiDAR data for checkpoints in non-vegetated terrain equaled 0.041 meters compared with the 10 cm specification: The 95% confidence value of NVA of the classified LiDAR data computed using RMSEz x 1.96 and was found to equal 0.081 meters compared with the 0.196 meter specification.

For the USGS_IA_Western_2_2020_D21 project area project, the tested VVA of the classified LiDAR data computed using the 95th percentile was equal to 0.168meters, compared with the 0.294 meter specification.

This project must meet Non-vegetated Vertical Accuracy (NVA) ≤ 0.0196 meters (19.6 cm) at the 95% confidence level based on RMSEz ≤ 0.100 meters (10 cm) x 1.9600.

100 % of Totals	# of Points	RMSEz NVA (m)	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
NVA	96	0.041	0.081	-0.006	-0.004	0.393	0.041	-0.110	0.129	1.64

Table 2: Non-vegetated Vertica Accuracy (NVA) results

Additional accuracy information and statistics for the classified LiDAR data, raw swath data, and bare earth DEM data can be found in following sections of this report.

Project deliverables

The deliverables for the project are listed below.

- Classified Point Cloud Data (Tiled)
- Bare Earth Surface (Raster DEM – IMG format)
- Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
- Breakline Data (File GDB)
- Independent Survey Checkpoint Data (File GDB)
- Calibration Points (File GDB)
- Metadata
- Maximum surface height raster
- Swath separation Images
- Project Report (Acquisition, Processing, QC)
- Swaths Extents (File GDB)
- Tile Index (File GDB)
- DPA (File GDB)

Project tiling footprint

12,738 tiles, 12,738 LAS files, 12,736 DEM tiles, 12,738 Intensity Image tiles were delivered for the project. Each tile's extent is 1000 meter by 1000 meter. (See Appendix A for a complete listing of delivered tiles.) Two DEM tiles were excluded due to containing a small sliver tile <1 meter at it's widest.

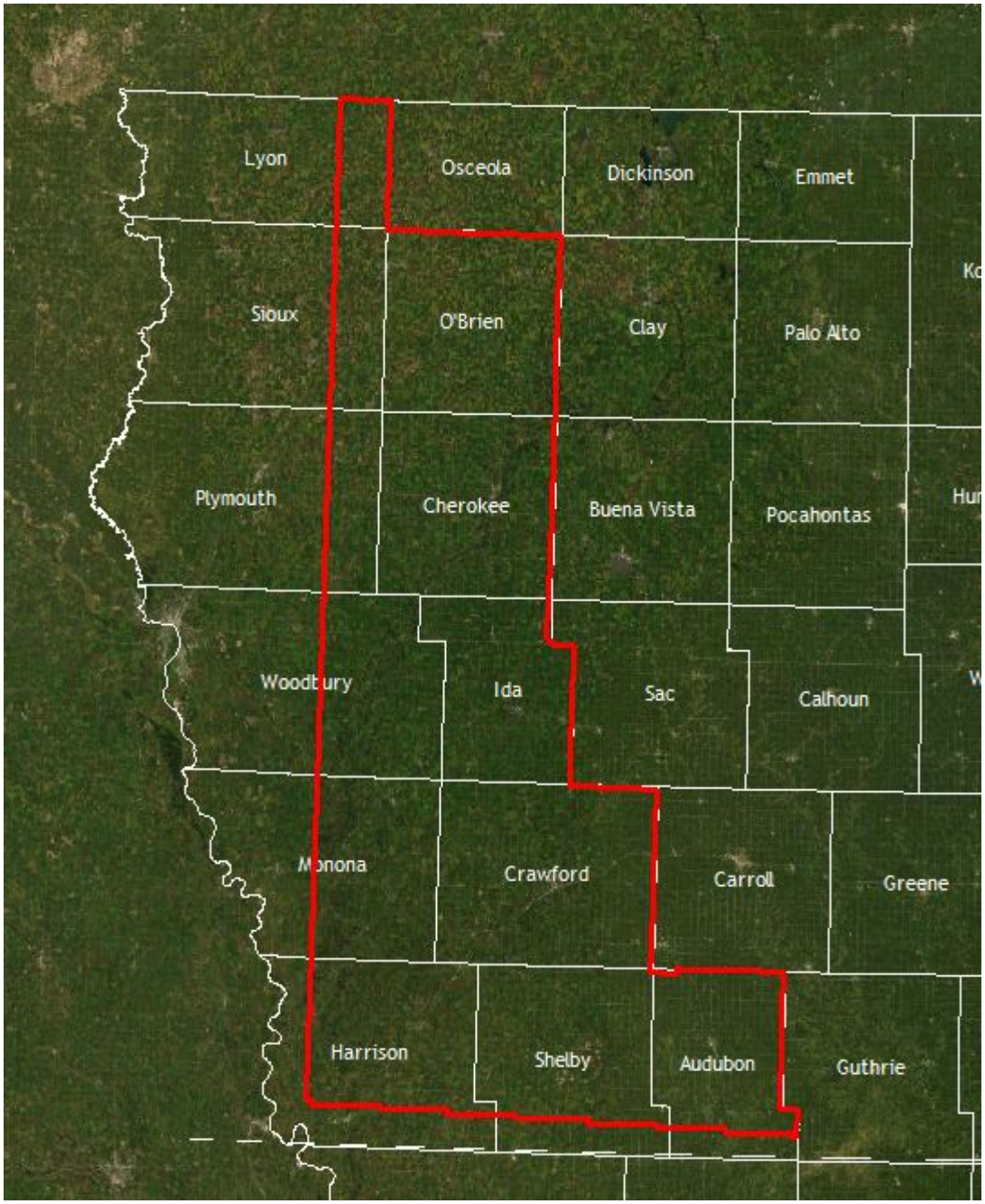

Figure 3: USGS_IA_Western_2_2020_D21 Area of Interest

Project Area Elevation Model

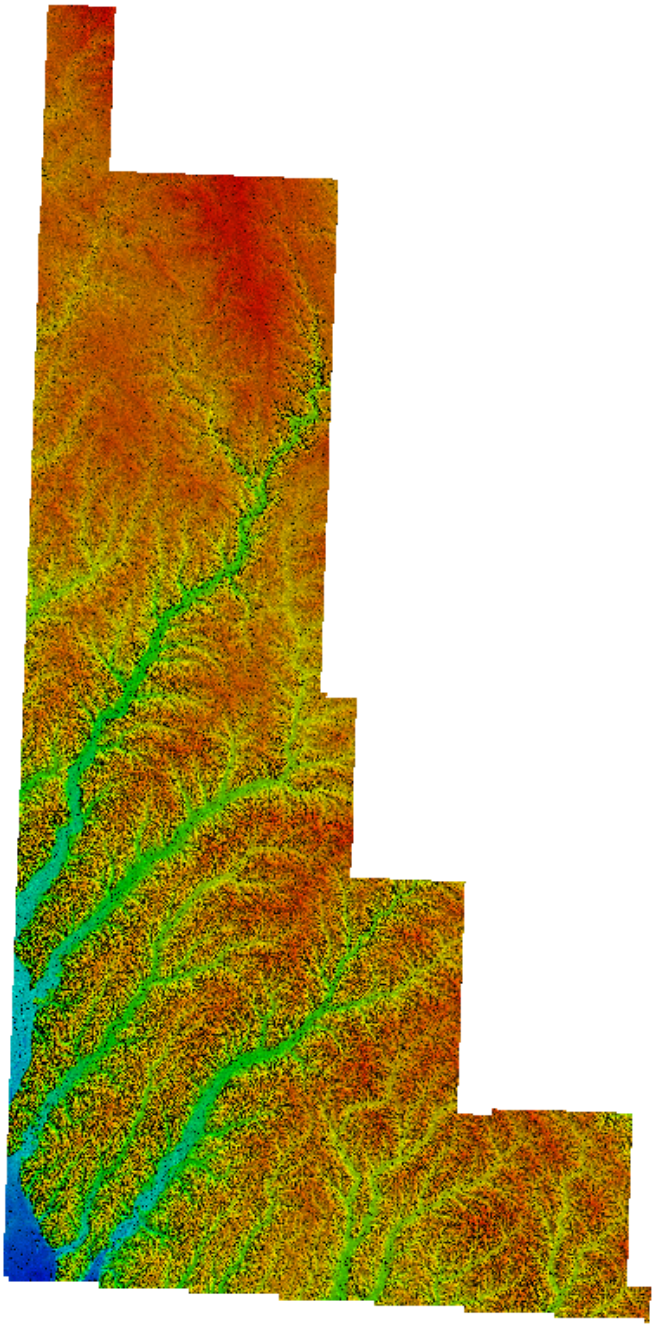

Figure 4: USGS_IA_Western_2_2020_D21 Elevation DEM

Aerial Services, Inc. LiDAR Acquisition Details and System parameters

Aerial Services, Inc. served as prime contractor for the USGS_IA_Western_2_2020_D21 project and preformed the LiDAR Acquisition and Calibration for Iowa counties; Lyon, Sioux, Plymouth, O'Brien and Cherokee.

The following image is of the Planned Flight Line Overview for the 5 counties of USGS_IA_Western_2_2020_D21 project area.

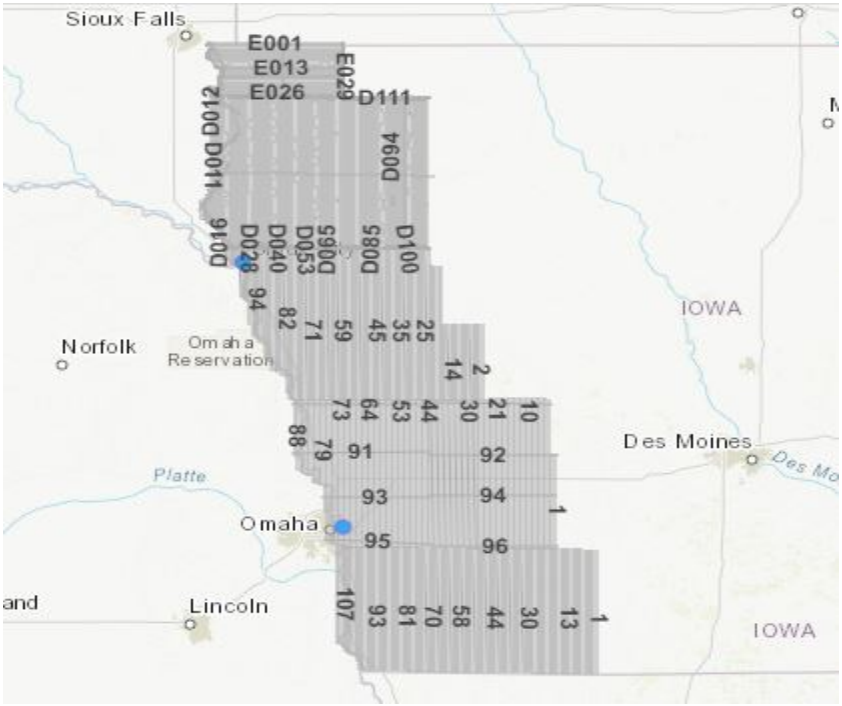

Figure 5: USGS_IA_WesternIA_2020_D21 project area planned flight line overview

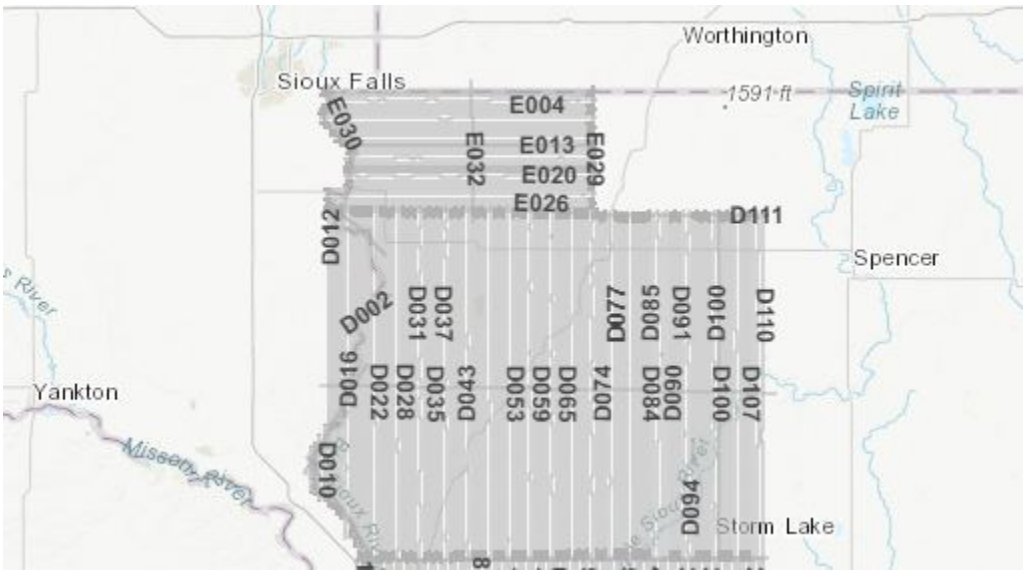

Figure 6: ASI planned flight line overview

Aerial Services, Inc. planned 164 passes for USGS_IA_WesternIA_2020_D21 and a series of cross flightlines for quality control. Of the 164 passes, 81 full or partial passes covered the USGS_IA_Western_2_2020_D21 project area.

In order to reduce any margin for error in the flight plan, Aerial Services, Inc. followed FEMA's Appendix A guidelines for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track'Air or Leica Mission Pro Flight Management Suite flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

Lidar System parameters

Aerial Services, Inc. operated a Cessna (Tail # N78AS) outfitted with a LEICA ALS70-HP lidar system during the collection of the study area. The following table illustrates Aerial Services, Inc. system parameters for lidar acquisition on this project. Data was acquired between 27 November 2020 and 07 December 2020.

Item	Parameter
System	Leica ALS-70 HP
Maximum Number of Returns per Pulse	4
Nominal Pulse Spacing (single swath), (m)	0.5
Nominal Pulse Density (single swath) (ppsm), (m)	4
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.5
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	4
Altitude (AGL meters)	1200
Approx. Flight Speed (knots)	125
Total Sensor Scan Angle (degrees)	50
Scan Rate (hz)	47
Scanner Pulse Rate (kHz)	212
Did the Sensor Operate with Multiple Pulses in The Air? (MPiA) (yes/no)	Yes
Nominal Swath Width on the Ground (m)	1119
Swath Overlap (%)	30
Max. Point Spacing Along Track (m)	1.37
Max. Point Spacing Across Track (m)	0.72

Table 3: Aerial Services, Inc. Lidar System Parameters

Calibration Report

Acquisition Control

Aerial Services, Inc. utilized known Iowa RTN base stations to control the lidar acquisition for the USGS_IA_Western_2_2020_D21 project area. The coordinates of the base stations are provided in the table below.

Name	NAD83(2011) DD.MM.SS.SSSSS		Ellipsoid Ht (WGS84, m)
	Easting X	Northing Y	
IARR	43° 26' 00.58447"	-96° 08' 55.47162"	405.9089
IARV	43° 12' 02.87827"'	-96° 25' 56.02407"	379.1871
IAAS	43° 18' 20.16909"	-95° 46' 44.57517"	430.5744
IASL	43° 25' 15.18222'	-95° 08' 09.07761"	414.5607
IASP	43° 07' 41.67611"	-95° 09' 41.81994"	381.8388
IAAK	42° 48' 41.00926"	-96° 32' 54.06877"	369.2826
IASX	42° 33' 00.13888"	-96° 20' 54.47531"	329.1062
IALM	42° 47' 53.00359"	-96° 08' 55.35654"	365.9100
IACK	42° 46' 06.07977"'	-95° 32' 31.86168"	362.3723
IACV	42° 28' 52.77137"	-95° 46' 24.68982"	325.5023
IASP	43° 07' 41.67611"	-95° 09' 41.81994"	381.8388
IASM	42° 38' 53.58626"	-95° 12' 58.68742"	418.849

Table 4: Control base stations used for ASI ABGPS processing

Airborne GPS Kinematic

Aerial Services, Inc. conducted the survey using Novatel, Inc.'s Inertial Explorer Version 8.80.2305 software for processing the GPS/IMU data. All flights were flown with PDOP less than or equal to 3.0 and with at least 6 satellites in common view of both a stationary reference receiver and the airborne GPS. For all flights, the GPS data can be classified as excellent, with GPS residuals no larger than 10 cm being recorded.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using CloudPro, initially with default values from CloudPro or the last calibration mission flew with the sensor. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch, and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable point density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

Figure 7: ASI Lidar swath coverage

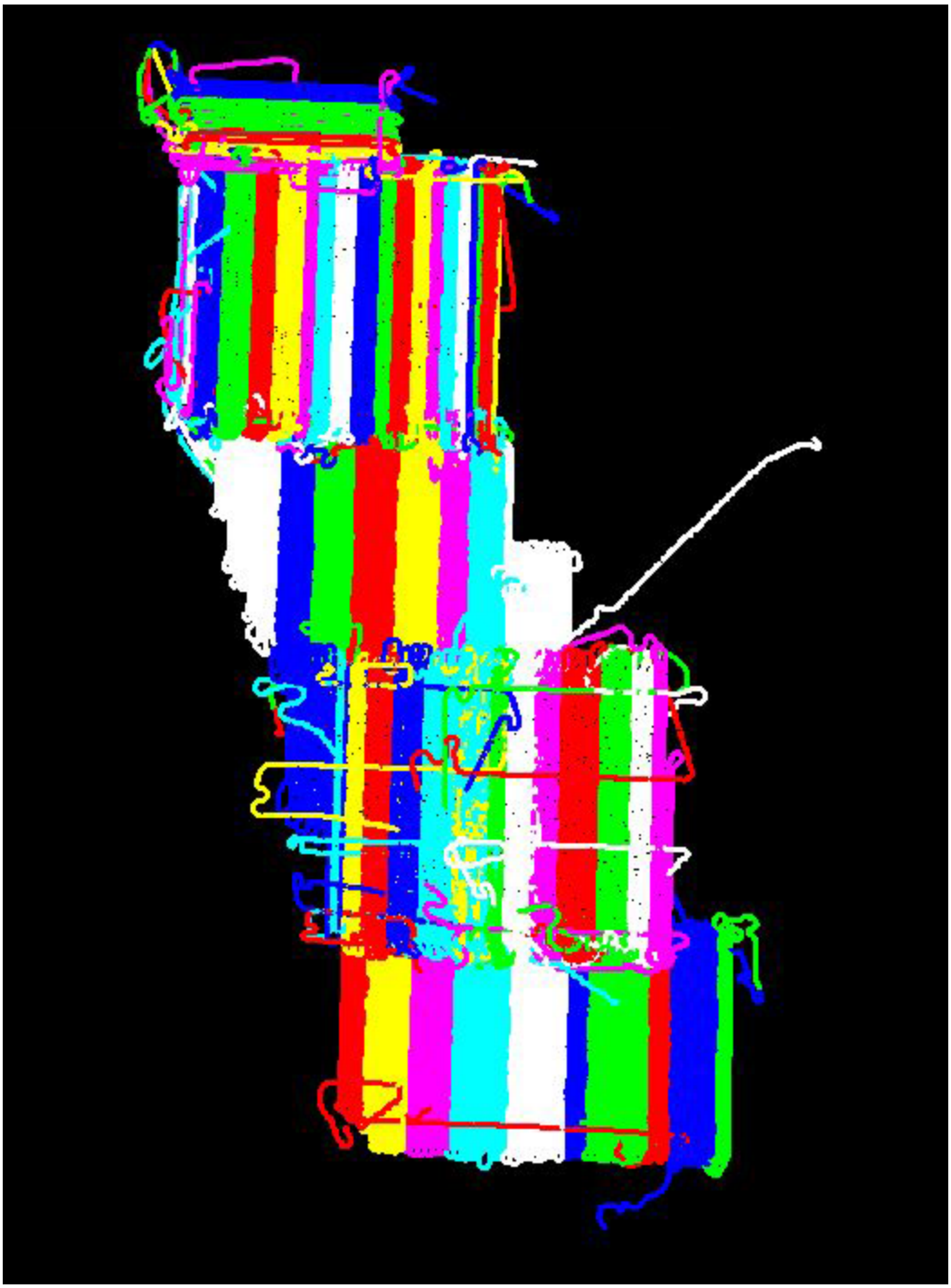

Figure 8: ASI's Combined project SBET

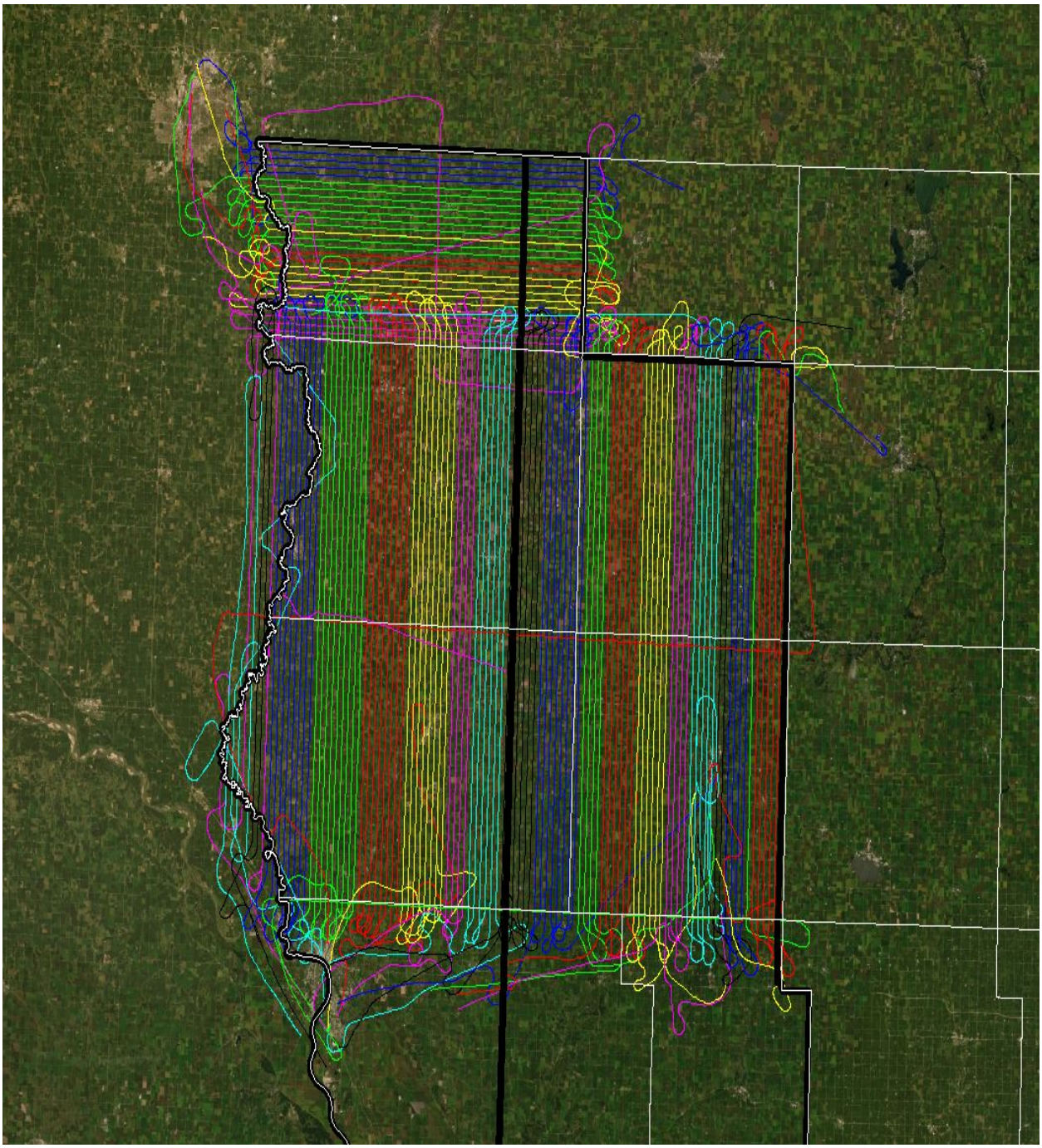

Figure 9: shows the combined trajectory of the flightlines ASI flew by mission over the USGS_IA_Western_2_2020_D21 project area

Boresight and Relative Accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers, or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch, and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project, the specifications used are as follows (derived from LiDAR base specifications for QL2): Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm RMSDz between adjacent and overlapping swaths.

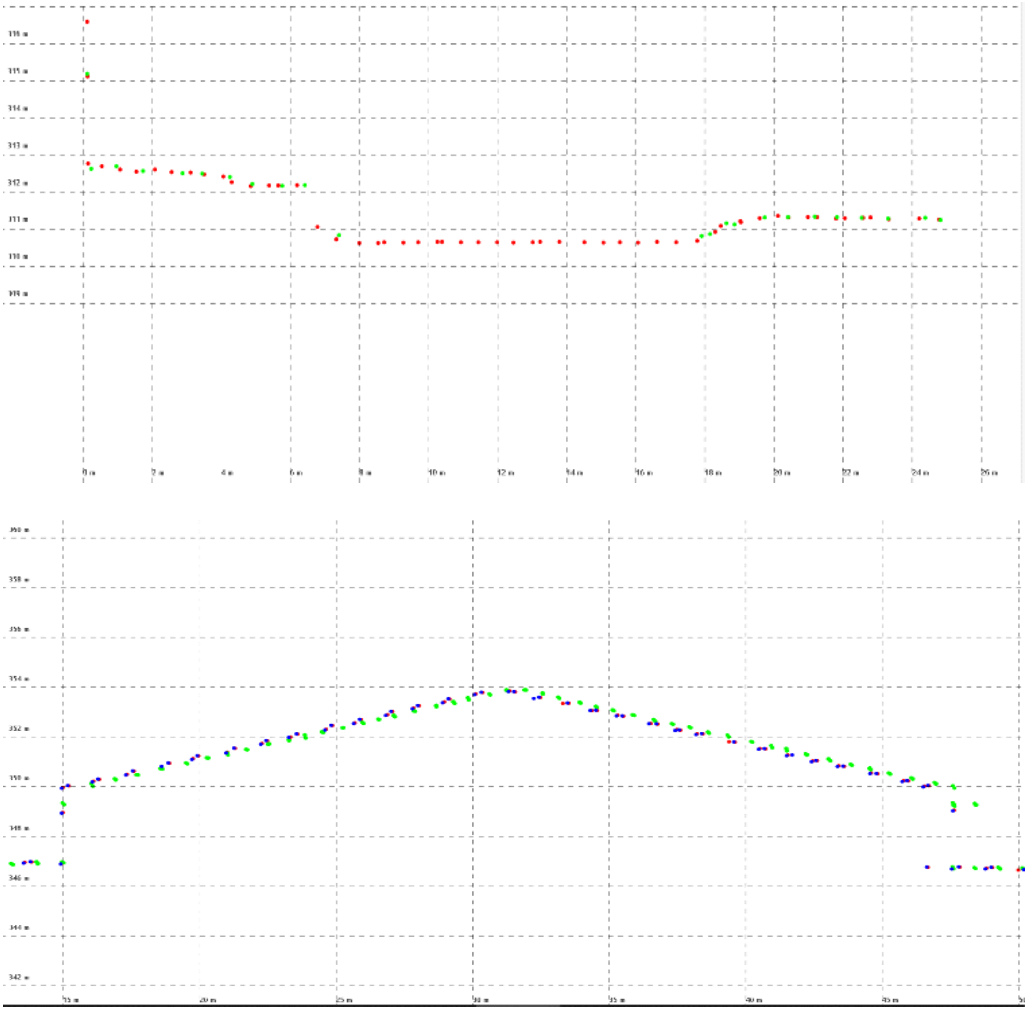

Figure 10: Profile views showing correct roll and pitch adjustments

Aerial Surveys International, LLC LiDAR Acquisition Details and System Parameters for the Western IA 2020 D21 project

Aerial Surveys International, LLC planned 171 passes for the USGS_IA_WesternIA_2020_D21 project and a series of cross flightlines for quality control. Of the 171 passes, 81 full or partial passes covered the USGS_IA_Western_2_2020_D21 project area.

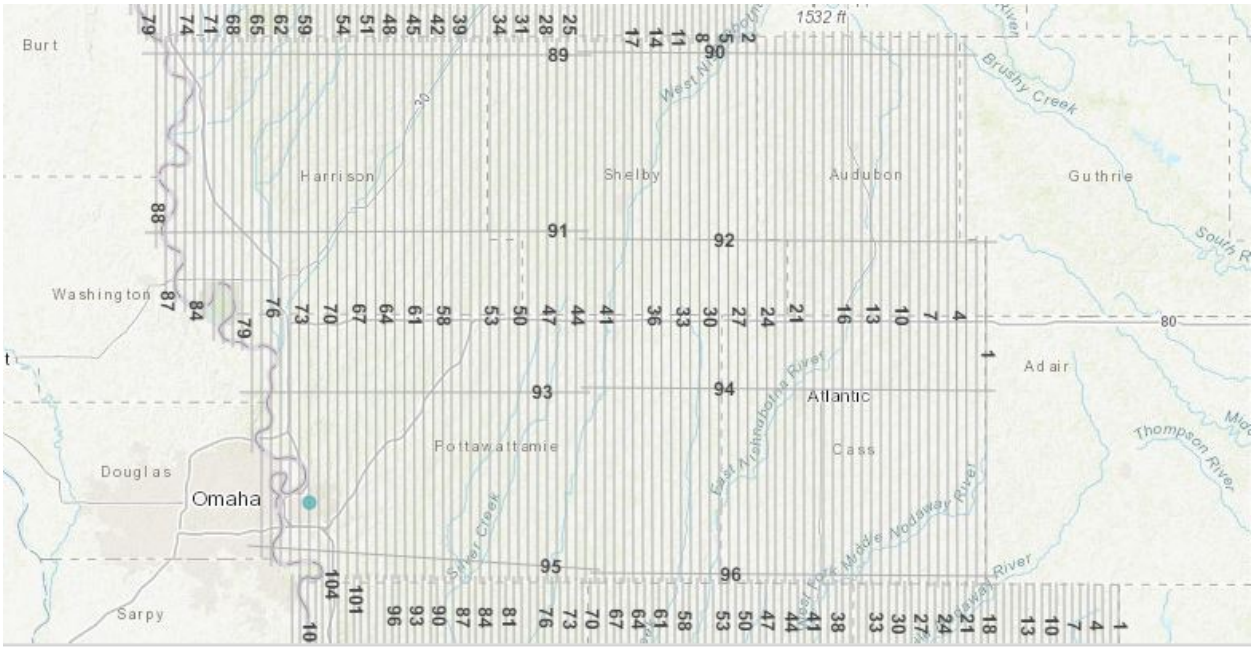

Figure11: Aerial Surveys International, LLC planned flight line overview

In order to reduce any margin for error in the flight plan, AERIAL SURVEYS INTERNATIONAL, LLC followed FEMA's Appendix A guidelines for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Topoflight flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

AERIAL SURVEYS INTERNATIONAL, LLC operated a Cessna 310 (Registration N7516Q) and a Cessna 402 (registration N2JJ) each equipped with an Optech T2000 Lidar system during the collection of this task order. Data was acquired between December 10, 2020 and March 19, 2021.

Item	Parameter
System	Optech T2000
Maximum Number of Returns per Pulse	8
Nominal Pulse Spacing (single swath), (m)	0.67
Nominal Pulse Density (single swath) (ppsm), (m)	2.49
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.67
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2.21
Altitude (AGL meters)	2300
Approx. Flight Speed (knots)	160
Total Sensor Scan Angle (degrees)	46
Scan Rate (hz)	61
Scanner Pulse Rate (kHz)	400
Did the Sensor Operate with Multiple Pulses in The Air? (MPiA) (yes/no)	Yes
Beam Divergence (mRADs)	0.16
Nominal Swath Width on the Ground (m)	1953
Swath Overlap (%)	30
Computed Down Track spacing (m) per beam	0.67
Computed Cross Track Spacing (m) per beam	0.67

Table 5: AERIAL SURVEYS INTERNATIONAL, LLC LiDAR system parameters

Calibration Report

Acquisition Control

AERIAL SURVEYS INTERNATIONAL, LLC, utilized POSPac PP-RTX to control the lidar acquisition for the USGS_IA_WesternIA_2020_D21 project. POSPac PP-RTX is a cloud based global GNSS correction service which utilizes Trimble's RTX technology to provide cm level post-processed positioning accuracy without base stations.

Airborne GPS Kinematic

Airborne GPS data was processed using PosPac MMS software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded. GPS processing reports for each mission are included in Appendix A.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Optech's LiDAR Mapping Suite (LMS), initially with default values from Optech's LiDAR Mapping Suite or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within our MARS 8 software for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch, and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable point density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

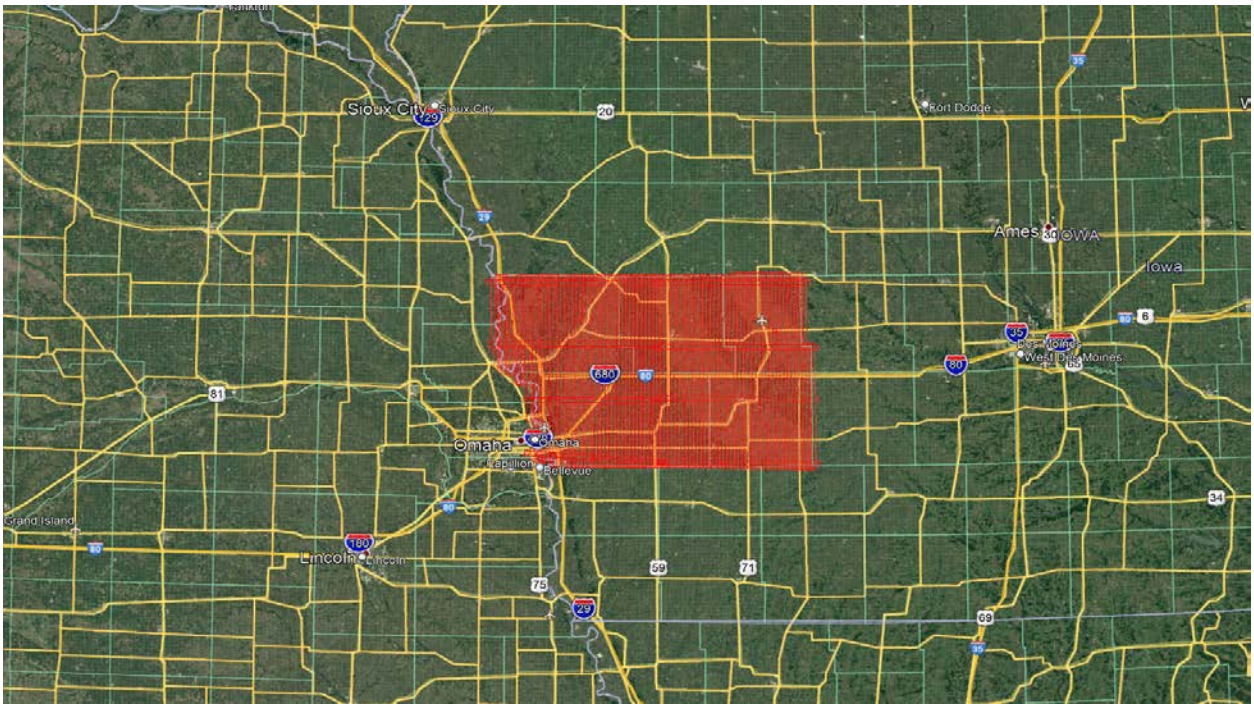

Figure 11: LiDAR swath output showing complete coverage

Boresight and Relative Accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers, or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch, and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project, the specifications used are as follows (derived from LiDAR base specifications for QL2): Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm $RMSD_z$ between adjacent and overlapping swaths.

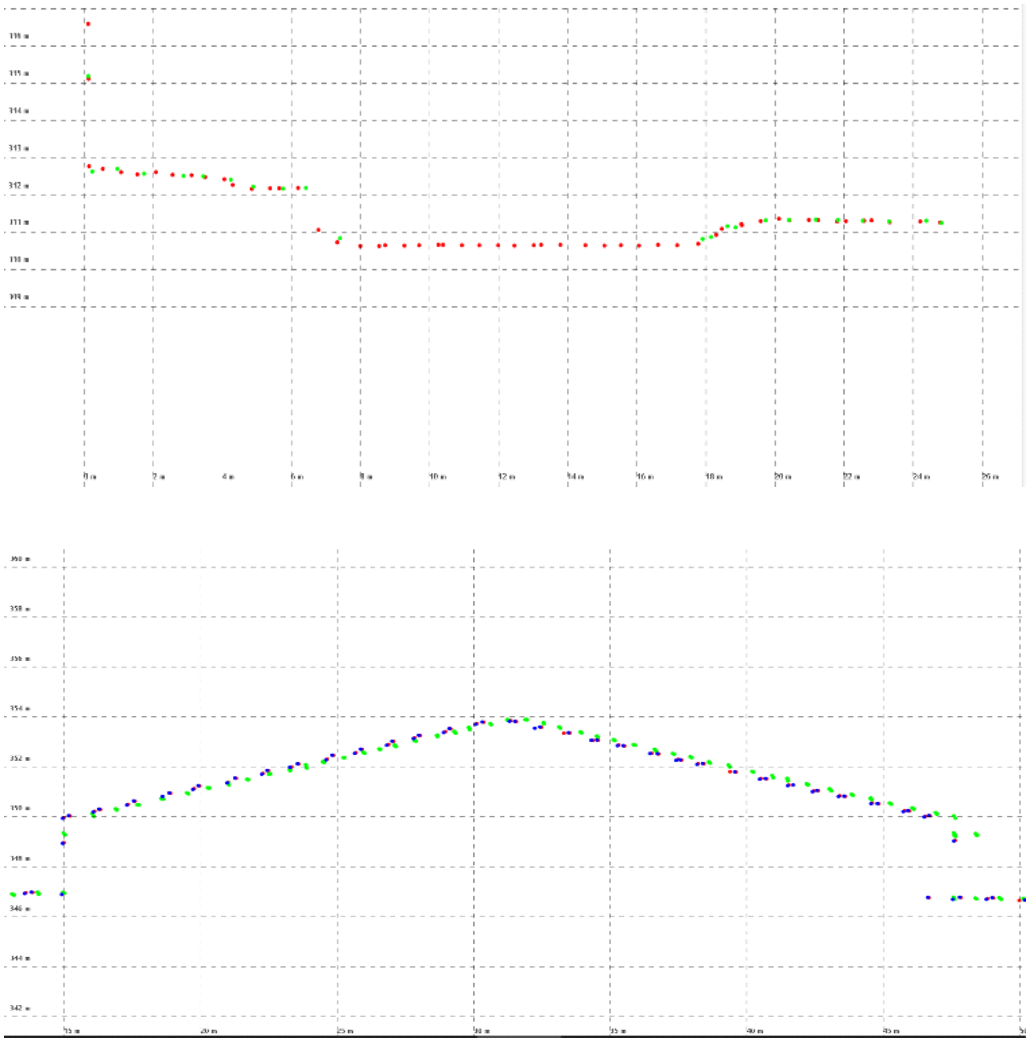

Figure 12: Profile views showing correct roll and pitch adjustments

Technical Applications & Consulting, LLC (TAC) LiDAR Acquisition Details and System Parameters - IA_WesternIA_2020_D21

Technical Applications & Consulting, LLC (TAC) planned 221 passes for the USGS_IA_WesternIA_2020_D21 project as well as a series of cross flight lines for quality control. Of the 221 passes, 72 full or partial passes covered the USGS_IA_Western_2_2020_D21 project area.

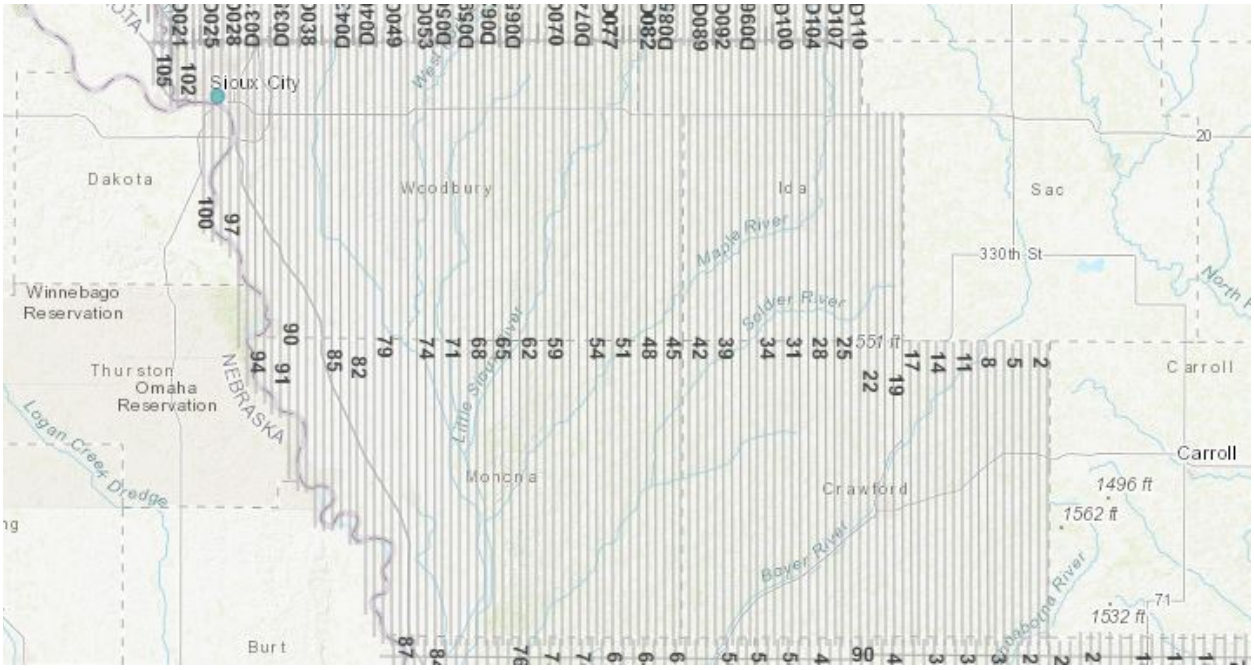

Figure 13: Technical Applications & Consulting, LLC planned flight line overview

To reduce any margin for error in the flight plan, TAC followed FEMA's Appendix A guidelines for flight planning that included the following criteria:

- A digital flight line layout using Optech AMM Software flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

TAC operated a Cessna Turbo Utility 206 (Registration N8647Q) equipped with an Optech Galaxy LiDAR system during the collection of this project. Data was acquired between 03/19/2021 and 03/28/2021. TAC experienced acquisition delays due to inclement weather in the specified area of interest. Once the snow melted TAC collected any necessary refights.

Item	Parameter
System	Optech Galaxy T500
Maximum Number of Returns per Pulse	6
Nominal Pulse Spacing (single swath), (m)	0.43
Nominal Pulse Density (single swath) (ppsm), (m)	5
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.43
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	5
Altitude (AGL meters)	1485
Approx. Flight Speed (knots)	120
Total Sensor Scan Angle (degrees)	50
Scan Rate (hz)	70
Scanner Pulse Rate (kHz)	500
Did the Sensor Operate with Multiple Pulses in The Air? (MPiA) (yes/no)	Yes
Beam Divergence (mRADs)	0.25
Nominal Swath Width on the Ground (m)	1385
Swath Overlap (%)	20
Computed Down Track spacing (m) per beam	0.44
Computed Cross Track Spacing (m) per beam	0.44

Table 6: TAC LiDAR system parameters

Calibration Report

Airborne GPS Kinematic

Airborne GPS data was processed using POSPac MMS 8.6 GNSS-aided inertial post-processing software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 40 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded. GPS processing reports for each mission are included in Appendix A.

Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

The mission point .LAS is output using LMS Pro with default values or the last boresight for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch, and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable point density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

Figure 14: LiDAR swath output showing complete coverage

Boresight and Relative Accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers, or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch, and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project, the specifications used are as follows (derived from LiDAR base specifications for QL2): Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm RMSDz between adjacent and overlapping swaths.

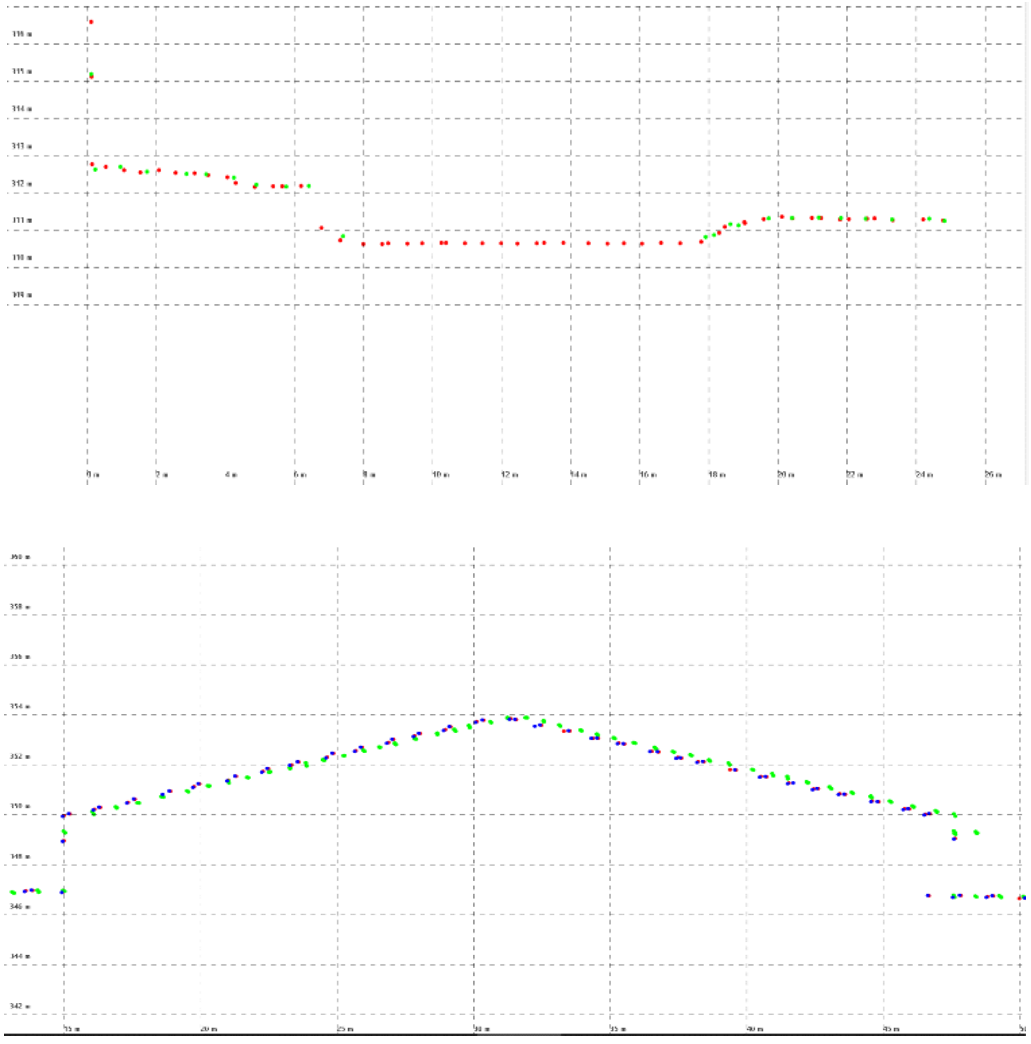

Figure 15: Profile views showing correct roll and pitch adjustments

The following table is a listing of Flight lines and corresponding, Lift_ID, Date, Point Source ID, Scanner, and adjusted GPS Start and End times.

Name	Lift_ID	Date	PT Source ID	Scanner	Start Time	End Time
201127_163628	20201127A	11/27/2020	1	ALS_70	290530176	290531406
201127_170208	20201127A	11/27/2020	2	ALS_70	290531717	290532658
201127_172035	20201127A	11/27/2020	3	ALS_70	290532823	290534040
201127_174241	20201127A	11/27/2020	4	ALS_70	290534149	290535077
201127_180053	20201127A	11/27/2020	5	ALS_70	290535242	290536479
201127_192859	20201127A	11/27/2020	6	ALS_70	290540528	290541470
201127_194654	20201127A	11/27/2020	7	ALS_70	290541602	290542833
201127_200918	20201127B	11/27/2020	8	ALS_70	290542947	290543888
201127_202813	20201127B	11/27/2020	9	ALS_70	290544082	290545291
201127_205123	20201127B	11/27/2020	10	ALS_70	290545471	290546378
201127_210824	20201127B	11/27/2020	11	ALS_70	290546492	290547633
201127_212952	20201127B	11/27/2020	12	ALS_70	290547781	290548681
201127_220758	20201127B	11/27/2020	14	ALS_70	290550067	290550905
201127_222434	20201127B	11/27/2020	15	ALS_70	290551063	290552121
201127_235823	20201127C	11/27/2020	16	ALS_70	290556693	290557545
201128_001522	20201127C	11/27/2020	17	ALS_70	290557711	290558796
201128_154011	20201128A	11/28/2020	20	ALS_70	290613200	290614073
201128_155754	20201128A	11/28/2020	21	ALS_70	290614264	290615453
201128_161948	20201128A	11/28/2020	22	ALS_70	290615578	290616443
201128_163657	20201128A	11/28/2020	23	ALS_70	290616607	290617816
201128_165842	20201128A	11/28/2020	24	ALS_70	290617911	290618770
201128_194119	20201128B	11/28/2020	27	ALS_70	290627668	290628603
201128_195919	20201128B	11/28/2020	28	ALS_70	290628748	290629937
201128_202115	20201128B	11/28/2020	29	ALS_70	290630065	290630992
201128_203914	20201128B	11/28/2020	30	ALS_70	290631144	290632312
201128_210025	20201128B	11/28/2020	31	ALS_70	290632414	290633334

201128_211857	20201128B	11/28/2020	32	ALS_70	290633525	290634673
201202_224529	20201202B	12/02/2020	91	ALS_70	290984319	290985611
201202_230926	20201202B	12/02/2020	92	ALS_70	290985755	290987013
201202_233642	20201202B	12/02/2020	94	ALS_70	290987391	290988704
201203_000045	20201202B	12/02/2020	95	ALS_70	290988835	290990093
201203_002423	20201202B	12/02/2020	96	ALS_70	290990253	290991538
201203_004743	20201202B	12/02/2020	97	ALS_70	290991653	290992842
201203_194341	20201203A	12/03/2020	98	ALS_70	291059811	291061179
201203_200857	20201203A	12/03/2020	99	ALS_70	291061327	291062571
201203_203117	20201203A	12/03/2020	100	ALS_70	291062667	291064007
201203_210511	20201203A	12/03/2020	102	ALS_70	291064701	291065979
201203_212904	20201203A	12/03/2020	103	ALS_70	291066134	291067536
201203_215419	20201203A	12/03/2020	104	ALS_70	291067648	291068879
201203_221619	20201203A	12/03/2020	105	ALS_70	291068969	291070344
201203_224113	20201203A	12/03/2020	106	ALS_70	291070463	291071652
201203_234952	20201203B	12/03/2020	107	ALS_70	291074581	291075955
201204_001456	20201203B	12/03/2020	108	ALS_70	291076086	291077282
201204_003808	20201203B	12/03/2020	109	ALS_70	291077478	291078853
201204_010305	20201203B	12/03/2020	110	ALS_70	291078974	291080163
201204_150531	20201204A	12/04/2020	111	ALS_70	291129521	291130978
201204_153224	20201204A	12/04/2020	112	ALS_70	291131134	291132316
201204_155449	20201204A	12/04/2020	113	ALS_70	291132480	291133882
201204_162017	20201204A	12/04/2020	114	ALS_70	291134007	291135182
201204_164215	20201204A	12/04/2020	115	ALS_70	291135325	291136796
201204_170825	20201204A	12/04/2020	116	ALS_70	291136895	291138070
201204_195854	20201204B	12/04/2020	117	ALS_70	291147125	291148658
201204_202601	20201204B	12/04/2020	118	ALS_70	291148752	291149934
201204_204845	20201204B	12/04/2020	119	ALS_70	291150115	291151675
201204_212029	20201204B	12/04/2020	120	ALS_70	291152019	291153229
201204_214340	20201204B	12/04/2020	121	ALS_70	291153411	291154944

201204_221058	20201204B	12/04/2020	122	ALS_70	291155048	291156237
201204_233247	20201204C	12/04/2020	123	ALS_70	291159957	291161400
201204_235835	20201204C	12/04/2020	124	ALS_70	291161504	291162742
201205_002237	20201204C	12/04/2020	125	ALS_70	291162947	291164328
201205_004759	20201204C	12/04/2020	126	ALS_70	291164468	291165657
201205_160400	20201205A	12/05/2020	131	ALS_70	291219428	291220624
201205_162649	20201205A	12/05/2020	132	ALS_70	291220798	291221326
201205_164213	20201205A	12/05/2020	134	ALS_70	291221721	291222814
201205_170250	20201205A	12/05/2020	135	ALS_70	291222958	291224140
201205_172549	20201205A	12/05/2020	136	ALS_70	291224337	291225836
201205_175256	20201205A	12/05/2020	137	ALS_70	291225964	291227167
201205_193433	20201205B	12/05/2020	138	ALS_70	291232062	291233670
201205_200322	20201205B	12/05/2020	139	ALS_70	291233791	291234973
201205_212110	20201205C	12/05/2020	141	ALS_70	291238458	291239640
201205_214431	20201205C	12/05/2020	142	ALS_70	291239859	291241488
201205_221807	20201205C	12/05/2020	143	ALS_70	291241875	291243029
201205_224210	20201205C	12/05/2020	144	ALS_70	291243318	291244975
201205_235348	20201205D	12/05/2020	145	ALS_70	291247617	291248806
201207_172237	20201207A	12/07/2020	148	ALS_70	291396946	291398149
201207_174545	20201207A	12/07/2020	149	ALS_70	291398333	291399818
201207_181249	20201207A	12/07/2020	150	ALS_70	291399958	291401147
201207_183537	20201207A	12/07/2020	151	ALS_70	291401326	291402797
201207_190227	20201207A	12/07/2020	152	ALS_70	291402937	291404188
201207_210756	20201207B	12/07/2020	153	ALS_70	291410466	291412026
201207_215452	20201207B	12/07/2020	155	ALS_70	291413281	291414284
20210319_165157	210319_386A	03/19/2021	3002	Optech	300207917	300209060
20210319_171356	210319_386A	03/19/2021	3003	Optech	300209236	300210315
20210319_173447	210319_386A	03/19/2021	3004	Optech	300210487	300211664
20210319_175654	210319_386A	03/19/2021	3005	Optech	300211814	300212891
20210319_181801	210319_386A	03/19/2021	3006	Optech	300213081	300214264

20210319_213247	210319_386B	03/19/2021	3008	Optech	300224767	300225943
20210319_215449	210319_386B	03/19/2021	3009	Optech	300226089	300227174
20210319_221642	210319_386B	03/19/2021	3010	Optech	300227402	300228566
20210319_223837	210319_386B	03/19/2021	3011	Optech	300228717	300229777
20210319_225846	210319_386B	03/19/2021	3012	Optech	300229926	300231088
20210319_232054	210319_386B	03/19/2021	3013	Optech	300231254	300232365
20210319_234306	210319_386B	03/19/2021	3014	Optech	300232586	300233731
20210320_145442	210320_386A	03/20/2021	3016	Optech	300287282	300288520
20210320_151759	210320_386A	03/20/2021	3017	Optech	300288679	300289742
20210320_153950	210320_386A	03/20/2021	3018	Optech	300289990	300291240
20210320_160324	210320_386A	03/20/2021	3019	Optech	300291404	300292470
20210320_162357	210320_386A	03/20/2021	3020	Optech	300292637	300293888
20210320_164744	210320_386A	03/20/2021	3021	Optech	300294064	300295174
20210320_170909	210320_386A	03/20/2021	3022	Optech	300295349	300296603
20210320_173325	210320_386A	03/20/2021	3023	Optech	300296805	300297903
20210320_175457	210320_386A	03/20/2021	3024	Optech	300298097	300299352
20210320_205615	210320_386B	03/20/2021	3026	Optech	300308975	300310060
20210320_211715	210320_386B	03/20/2021	3027	Optech	300310235	300311477
20210320_214124	210320_386B	03/20/2021	3028	Optech	300311684	300312769
20210320_220200	210320_386B	03/20/2021	3029	Optech	300312920	300314118
20210321_145730	210321_386	03/21/2021	3033	Optech	300373850	300374914
20210321_151913	210321_386	03/21/2021	3034	Optech	300375153	300376457
20210321_154514	210321_386	03/21/2021	3035	Optech	300376714	300377785
20210321_160704	210321_386	03/21/2021	3036	Optech	300378024	300379301
20210321_163112	210321_386	03/21/2021	3037	Optech	300379472	300380541
20210321_165146	210321_386	03/21/2021	3038	Optech	300380706	300382019
20210321_171638	210321_386	03/21/2021	3039	Optech	300382198	300383255
20210321_173830	210321_386	03/21/2021	3040	Optech	300383510	300384835
20210328_152113	210328_386	03/28/2021	3042	Optech	300980073	300981239
20210328_154336	210328_386	03/28/2021	3043	Optech	300981416	300982488

20210328_160520	210328_386	03/28/2021	3044	Optech	300982720	300983857
20210328_162717	210328_386	03/28/2021	3045	Optech	300984037	300985111
20201210_201929	201210_448	12/10/2020	4002	Optech	291666769	291667483
20201210_203422	201210_448	12/10/2020	4003	Optech	291667662	291668376
20201210_204843	201210_448	12/10/2020	4004	Optech	291668523	291669635
20201210_211058	201210_448	12/10/2020	4005	Optech	291669858	291670949
20201210_213157	201210_448	12/10/2020	4006	Optech	291671117	291672231
20210319_155827	210319_448A	03/19/2021	4008	Optech	300204707	300205778
20210319_161840	210319_448A	03/19/2021	4009	Optech	300205920	300206968
20210319_205442	210319_448B	03/19/2021	4018	Optech	300222482	300223131
20210319_210826	210319_448B	03/19/2021	4019	Optech	300223306	300223978
20210319_212130	210319_448B	03/19/2021	4020	Optech	300224090	300224763
20210319_213550	210319_448B	03/19/2021	4021	Optech	300224950	300226038
20210319_215527	210319_448B	03/19/2021	4022	Optech	300226127	300227187
20210320_145540	210320_448A	03/20/2021	4024	Optech	300287340	300288509
20210320_151814	210320_448A	03/20/2021	4025	Optech	300288694	300289761
20210320_153844	210320_448A	03/20/2021	4026	Optech	300289924	300291084
20210320_160044	210320_448A	03/20/2021	4027	Optech	300291244	300292303
20210320_162053	210320_448A	03/20/2021	4028	Optech	300292453	300293607
20210320_164317	210320_448A	03/20/2021	4029	Optech	300293797	300294858
20210320_170357	210320_448A	03/20/2021	4030	Optech	300295037	300296196
20210320_172539	210320_448A	03/20/2021	4031	Optech	300296339	300297404
20210320_204627	210320_448B	03/20/2021	4033	Optech	300308387	300309476
20210320_210707	210320_448B	03/20/2021	4034	Optech	300309627	300310757
20210320_212823	210320_448B	03/20/2021	4035	Optech	300310903	300311985
20210320_214902	210320_448B	03/20/2021	4036	Optech	300312142	300313273
20210320_221054	210320_448B	03/20/2021	4037	Optech	300313454	300314545
20210320_223118	210320_448B	03/20/2021	4038	Optech	300314678	300315785
20210320_225232	210320_448B	03/20/2021	4039	Optech	300315952	300317038
20210321_145244	210321_448	03/21/2021	4041	Optech	300373564	300374648

20210321_151421	210321_448	03/21/2021	4042	Optech	300374861	300376138
20210321_153852	210321_448	03/21/2021	4043	Optech	300376332	300377408
20210321_160008	210321_448	03/21/2021	4044	Optech	300377608	300378828
20210321_162257	210321_448	03/21/2021	4045	Optech	300378977	300380035
20210321_164347	210321_448	03/21/2021	4046	Optech	300380227	300381534
20210321_170815	210321_448	03/21/2021	4047	Optech	300381695	300382739
20210328_150947	210328_448A	03/28/2021	4050	Optech	300979387	300980552
20210328_153118	210328_448A	03/28/2021	4051	Optech	300980678	300981772
20210328_155242	210328_448A	03/28/2021	4052	Optech	300981962	300983100
20210328_161342	210328_448A	03/28/2021	4053	Optech	300983222	300984299
20210328_163448	210328_448A	03/28/2021	4054	Optech	300984488	300985630
20210328_165548	210328_448A	03/28/2021	4055	Optech	300985748	300986817
20210328_221832	210328_448B	03/28/2021	4056	Optech	301005112	301006204
20210328_223931	210328_448B	03/28/2021	4057	Optech	301006371	301007470
20210328_225959	210328_448B	03/28/2021	4058	Optech	301007599	301008697
20210328_232049	210328_448B	03/28/2021	4059	Optech	301008849	301009939
20210329_162926	329_1_z14	03/29/2021	7291	Optech	301070566	301072174
20210329_165844	329_1_z15	03/29/2021	7292	Optech	301072325	301073620
20210329_172235	329_1_z15	03/29/2021	7293	Optech	301073755	301075377
20210329_175315	329_1_z15	03/29/2021	7294	Optech	301075595	301076869
20210329_181718	329_1_z15	03/29/2021	7295	Optech	301077039	301078625
20210329_184615	329_1_z15	03/29/2021	7296	Optech	301078775	301080056
20210329_191004	329_1_z15	03/29/2021	7297	Optech	301080204	301081663
20210329_211232	329_2	03/29/2021	7299	Optech	301087552	301088858
20210329_213629	329_2	03/29/2021	7300	Optech	301088990	301090453
20210329_220549	329_2	03/29/2021	7301	Optech	301090749	301090929
20210329_221054	329_2	03/29/2021	7302	Optech	301091055	301092382
20210329_223446	329_2	03/29/2021	7303	Optech	301092487	301092749
20210329_224255	329_2	03/29/2021	7304	Optech	301092975	301094237
20210329_230602	329_2	03/29/2021	7305	Optech	301094362	301095653

20210329_232910	329_2	03/29/2021	7306	Optech	301095750	301097192
20210329_235527	329_2	03/29/2021	7307	Optech	301097328	301098628
20210330_001848	329_2	03/29/2021	7308	Optech	301098729	301100228
20210330_004609	329_2	03/29/2021	7309	Optech	301100370	301101666
20210330_010929	329_2	03/29/2021	7310	Optech	301101770	301103323
20210330_013821	329_2	03/29/2021	7311	Optech	301103501	301104812
20210330_020347	329_2	03/29/2021	7312	Optech	301105028	301106527
20210330_142008	330_1	03/30/2021	7314	Optech	301149209	301150641
20210330_144626	330_1	03/30/2021	7315	Optech	301150786	301152090
20210330_151144	330_1	03/30/2021	7316	Optech	301152304	301153739
20210330_153830	330_1	03/30/2021	7317	Optech	301153910	301155214
20210330_160301	330_1	03/30/2021	7318	Optech	301155382	301156863
20210330_163017	330_1	03/30/2021	7319	Optech	301157017	301158329
20210330_165447	330_1	03/30/2021	7320	Optech	301158487	301159997
20210330_172225	330_1	03/30/2021	7321	Optech	301160146	301161456
20210330_174719	330_1	03/30/2021	7322	Optech	301161639	301163113
20210330_181436	330_1	03/30/2021	7323	Optech	301163277	301164603
20210330_184008	330_1	03/30/2021	7324	Optech	301164809	301166272
20210330_190747	330_1	03/30/2021	7325	Optech	301166468	301167779
20210330_211002	330_2	03/30/2021	7327	Optech	301173802	301175283
20210330_213716	330_2	03/30/2021	7328	Optech	301175436	301176753
20210330_220201	330_2	03/30/2021	7329	Optech	301176921	301178489
20210330_223018	330_2	03/30/2021	7330	Optech	301178618	301179945
20210330_225524	330_2	03/30/2021	7331	Optech	301180125	301181732
20210330_232436	330_2	03/30/2021	7332	Optech	301181876	301183207
20210330_234933	330_2	03/30/2021	7333	Optech	301183374	301184860
20210331_001612	330_2	03/30/2021	7334	Optech	301184972	301186298
20210331_121349	331_1	03/31/2021	7336	Optech	301228029	301229735
20210331_124520	331_1	03/31/2021	7337	Optech	301229920	301231262
20210331_131216	331_1	03/31/2021	7338	Optech	301231536	301233255

20210331_134350	331_1	03/31/2021	7339	Optech	301233430	301234764
20210331_141107	331_1	03/31/2021	7340	Optech	301235067	301236815
20210331_144245	331_1	03/31/2021	7341	Optech	301236965	301238308
20210331_150906	331_1	03/31/2021	7342	Optech	301238547	301240330
20210331_154225	331_1	03/31/2021	7343	Optech	301240546	301241736
20210331_160619	331_1	03/31/2021	7344	Optech	301241980	301243472
20210331_163325	331_1	03/31/2021	7345	Optech	301243606	301244841
20210331_165742	331_1	03/31/2021	7346	Optech	301245062	301245754
20210331_191920	331_2	03/31/2021	7348	Optech	301253561	301254449
20210331_193639	331_2	03/31/2021	7349	Optech	301254600	301255772
20210331_195902	331_2	03/31/2021	7350	Optech	301255943	301256675
20210331_201328	331_2	03/31/2021	7351	Optech	301256808	301257477
20210331_202635	331_2	03/31/2021	7352	Optech	301257595	301258328
20210331_204054	331_2	03/31/2021	7353	Optech	301258454	301259123
20210331_205347	331_2	03/31/2021	7354	Optech	301259227	301260007
20210331_210853	331_2	03/31/2021	7355	Optech	301260133	301260801
20210331_212221	331_2	03/31/2021	7356	Optech	301260941	301261702
20210331_213735	331_2	03/31/2021	7357	Optech	301261855	301262524
20210331_215034	331_2	03/31/2021	7358	Optech	301262634	301263399
20210331_220534	331_2	03/31/2021	7359	Optech	301263534	301264217
20210331_221838	331_2	03/31/2021	7360	Optech	301264318	301265044
20210331_223311	331_2	03/31/2021	7361	Optech	301265192	301265868
20210331_224607	331_2	03/31/2021	7362	Optech	301265967	301266709
20210331_230036	331_2	03/31/2021	7363	Optech	301266836	301267510
20210331_231340	331_2	03/31/2021	7364	Optech	301267621	301268353
20210331_232811	331_2	03/31/2021	7365	Optech	301268492	301269172
20210331_234106	331_2	03/31/2021	7366	Optech	301269266	301269988
20210401_000440	331_2	03/31/2021	7368	Optech	301270680	301271052

Table5: USGS_IA_Western_2_2020_D21 Project Area Flight lines by Mission

Final Calibration Verification

Foth Infrastructure & Environment, LLC conducted the survey throughout the area of interest. 167 ground control points (GCPs) were used to test the accuracy of the calibrated swath data. Of these 167 GCPs 68 were use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in the figure below. Surveyed ground control points (GCPs) and the accuracy results from testing the calibrated swath data against the GCPs is provided in the following tables. Ground control points (GCPs) vertical accuracy results no further adjustments to the swath data were required based on the accuracy results of the GCPs.

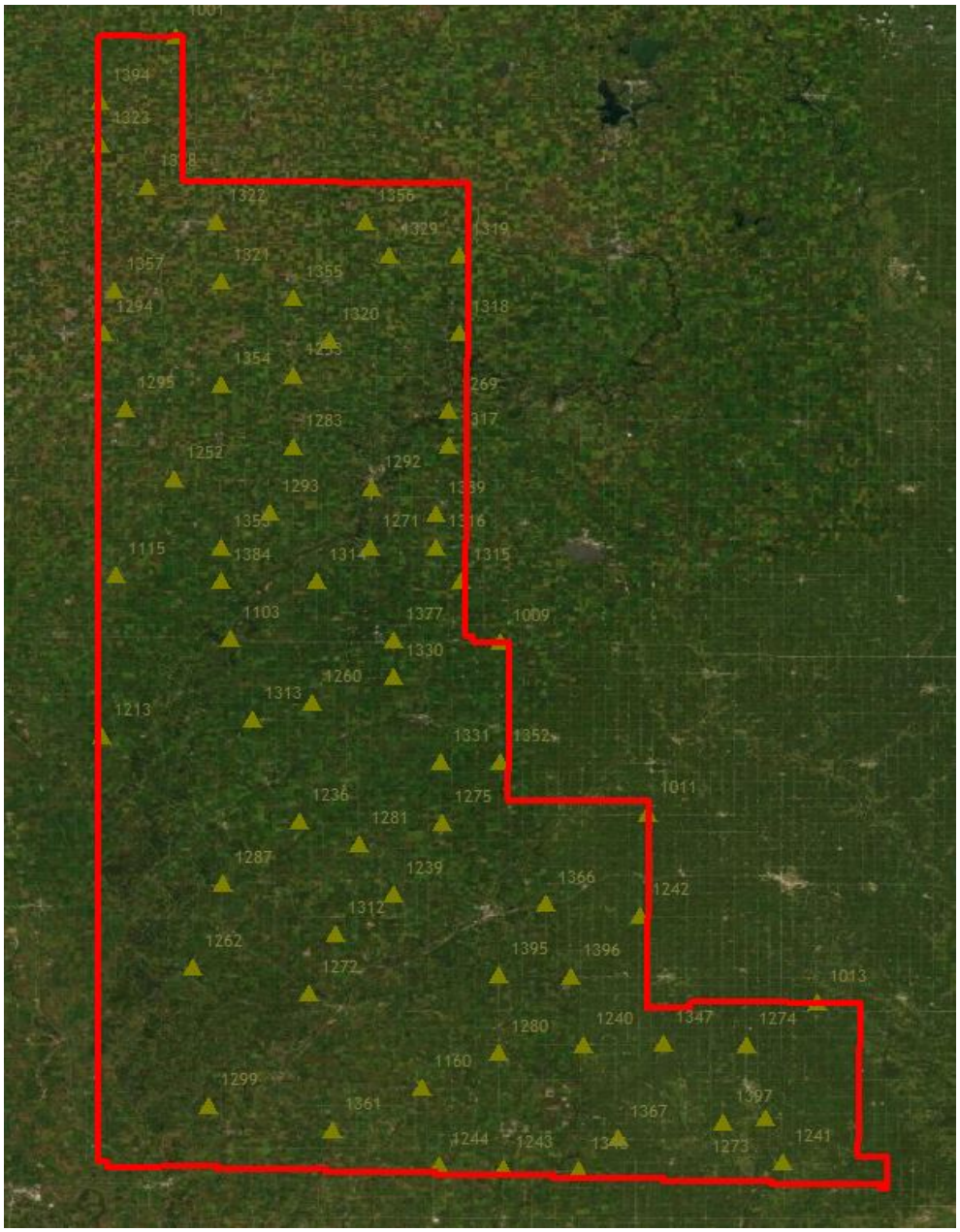

Figure 16: Surveyed Ground Control Point Locations in UTM 15 N Block 2 project area.

Point ID	NAD83 (2011 adj) UTM Zone 15 N		NAVD88 (Geoid 12B)		
	Easting X (M)	Northing Y (M)	Z-Survey (M)	Z-LiDAR (M)	Dz (M)
GCP1009	307489.311	4704955.164	424.397	424.430	0.033
GCP1394	257161.725	4808418.863	445.151	445.220	0.069
GCP1357	257607.551	4772862.199	437.022	436.980	-0.042
GCP1328	262779.380	4792051.794	432.205	432.270	0.065
GCP1323	256810.501	4800322.636	428.672	428.690	0.018
GCP1313	273563.456	4691386.212	438.443	438.380	-0.063
GCP1295	258417.910	4750266.925	431.869	431.860	-0.009
GCP1294	255849.398	4764882.290	404.715	404.700	-0.015
GCP1252	264345.873	4737053.303	425.412	425.380	-0.032
GCP1115	255934.008	4719222.575	378.835	378.800	-0.035
GCP1103	271011.726	4706600.231	344.303	344.370	0.067
GCP1001	267609.717	4820431.432	477.681	477.680	-0.001
GCP1397	335448.593	4613647.907	448.585	448.580	-0.005
GCP1396	315401.395	4641860.420	410.974	411.010	0.036
GCP1395	305584.574	4642194.945	429.895	429.890	-0.005
GCP1389	299569.103	4729223.376	428.420	428.410	-0.010
GCP1384	270184.368	4717449.426	389.081	389.080	-0.001
GCP1377	293107.250	4705555.090	426.116	426.100	-0.016
GCP1367	320979.919	4611310.644	415.333	415.360	0.027
GCP1366	312402.102	4655639.832	372.199	372.150	-0.049
GCP1361	282091.896	4613781.577	385.015	385.020	0.005
GCP1356	291566.844	4784591.650	464.471	464.420	-0.051
GCP1355	281461.233	4770438.459	428.574	428.580	0.006

GCP1354	271393.165	4754577.699	444.119	444.090	-0.029
GCP1353	270414.587	4723895.490	430.734	430.720	-0.014
GCP1352	306797.969	4682245.255	450.977	451.020	0.043
GCP1347	327736.877	4628705.115	438.327	438.330	0.003
GCP1346	315532.962	4605312.212	408.336	408.300	-0.036
GCP1331	298821.389	4682500.545	426.783	426.790	0.007
GCP1330	292885.760	4698810.443	423.972	423.980	0.008
GCP1329	294570.860	4778134.222	466.214	466.150	-0.064
GCP1322	271658.724	4785239.719	438.225	438.230	0.005
GCP1321	271966.484	4773947.937	425.410	425.380	-0.030
GCP1320	286055.055	4762264.098	434.997	435.020	0.023
GCP1319	304156.994	4777809.289	441.812	441.880	0.068
GCP1318	303680.306	4763225.874	433.558	433.540	-0.018
GCP1317	301554.255	4742199.741	429.480	429.460	-0.020
GCP1316	299361.552	4723093.928	403.966	403.950	-0.016
GCP1315	302408.476	4716572.601	417.708	417.690	-0.018
GCP1314	283123.929	4717099.302	417.891	417.910	0.019
GCP1312	283439.489	4650712.711	405.368	405.310	-0.058
GCP1299	265136.837	4618935.243	350.471	350.470	-0.001
GCP1293	277130.749	4730185.020	422.675	422.670	-0.005
GCP1292	290934.230	4734400.892	370.735	370.710	-0.025
GCP1287	268504.090	4660570.530	409.686	409.690	0.004
GCP1283	280764.572	4742466.965	444.285	444.220	-0.065
GCP1281	287178.823	4667418.147	410.012	409.950	-0.062

GCP1280	305136.996	4627721.447	424.897	424.880	-0.017
GCP1275	298678.893	4671129.615	461.045	461.040	-0.005
GCP1274	339018.216	4628397.202	439.792	439.800	0.008
GCP1273	341412.643	4614533.823	383.875	383.880	0.005
GCP1272	279586.756	4639668.115	405.268	405.230	-0.038
GCP1271	290472.634	4723322.442	397.082	397.070	-0.012
GCP1269	301696.377	4748696.422	425.983	425.970	-0.013
GCP1262	263900.190	4644998.513	337.756	337.770	0.014
GCP1260	281678.399	4694337.392	403.073	402.990	-0.083
GCP1253	281047.036	4755938.217	416.997	417.000	0.003
GCP1244	296436.897	4606724.193	416.813	416.800	-0.013
GCP1243	305211.736	4605875.484	363.770	363.760	-0.010
GCP1242	325164.659	4652879.622	440.319	440.370	0.051
GCP1241	343459.365	4606099.825	380.784	380.770	-0.014
GCP1240	316694.601	4628867.885	391.459	391.470	0.011
GCP1239	291646.257	4657911.162	426.343	426.410	0.067
GCP1236	279383.491	4671869.120	413.963	413.970	0.007
GCP1213	253018.451	4688890.668	345.490	345.550	0.060
GCP1160	294509.491	4621442.341	380.012	380.030	0.018
GCP1013	348767.568	4636142.469	425.290	425.300	0.010
GCP1011	326521.412	4672087.834	447.766	447.810	0.044

Table 7: USGS_IA_Western_2_2020_D21 surveyed ground control points (GCPs).

This project meets Ground Control Vertical Accuracy ≤ 19.6 cm at the 95% confidence level based on RMSEz ≤ 10 cm x 1.9600.

100 % of Totals	# of Points	RMSEz NVA (m)	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
GCP	68	0.035	0.068	-0.003	-0.005	0.17	0.035	-0.083	0.069	0.000

Table 8: USGS_IA_Western_2_2020_D21 Ground Control Vertical Accuracy (GCP) results

NVA was run on the unclassified point cloud which met the Non-Vegetated Accuracy (NVA) of ≤ 19.6 cm at the 95% confidence level based on RMSEz ≤ 10 cm x 1.9600.

100 % of Totals	# of Points	RMSEz NVA (m)	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
NVA	96	0.041	0.081	-0.006	-0.004	0.393	0.041	-0.110	0.129	1.640

Table 9: USGS_IA_Western_2_2020_D21 Vertical Accuracy NVA results

Between Swath Relative Accuracy (DZ Orthos)

Inter-swath relative accuracy passes specification. All pixels colored green are areas where overlapping flight lines are within 8 cm of each other. Areas colored red are where differences greater than 16 cm exist (this is expected in vegetated and sloped areas).

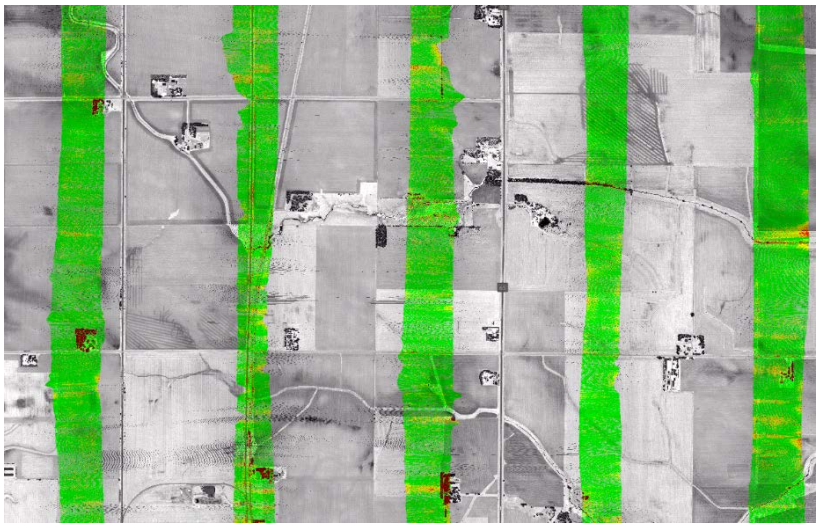

Figure 17: DZ Ortho of inter-swath

Within Swath Relative Accuracy (Intraswath)

Intra-swath relative accuracy was reviewed and passes specification. All flight lines were reviewed to confirm intra-swath within 6 cm (green) of each on flat plainer surfaces. Areas colored red are where differences greater than 6 cm exist. Red areas are expected in vegetated and sloped areas as this is an assessment only of hard surface repeatability.

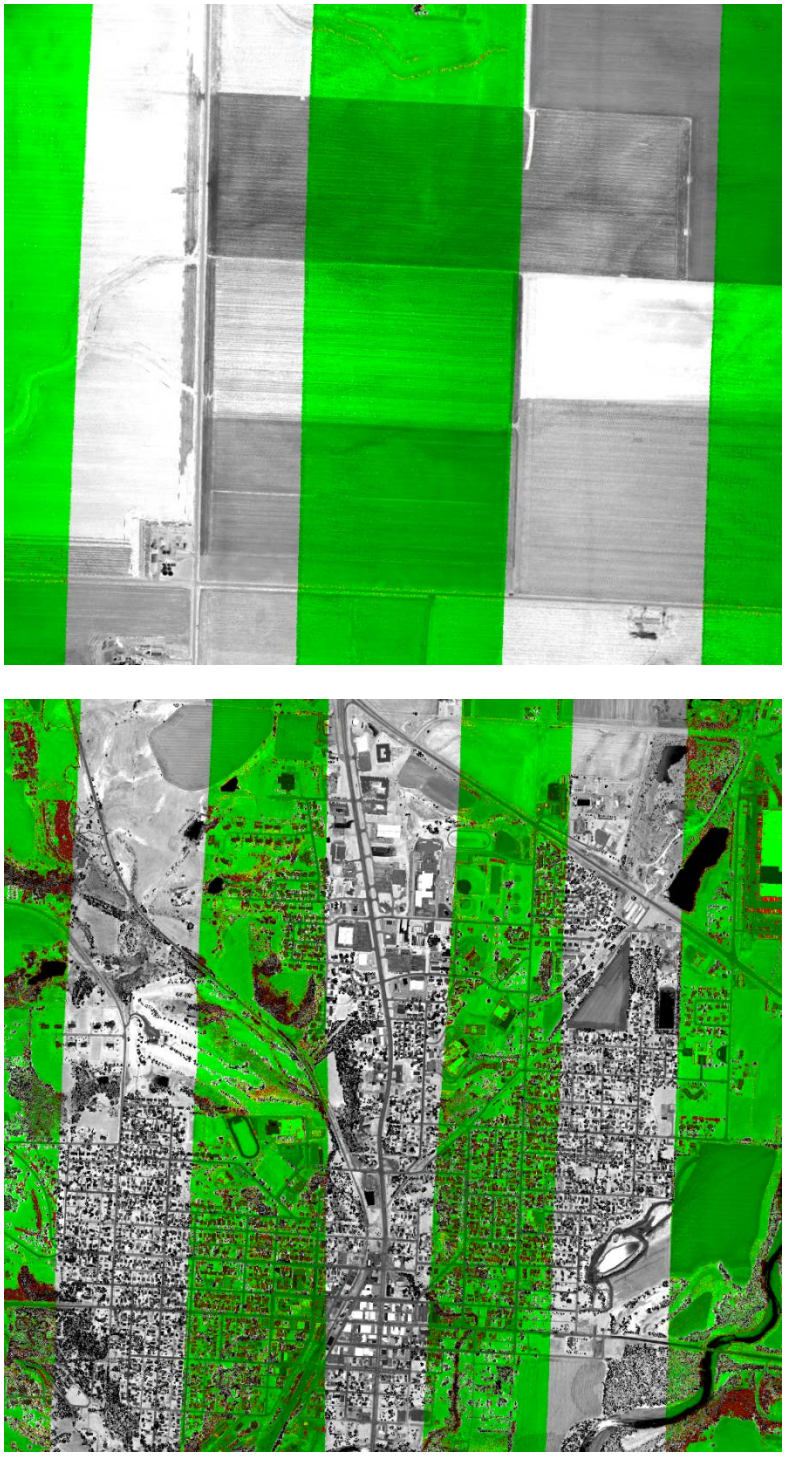

Figure 18: Intra-swath DZ ortho

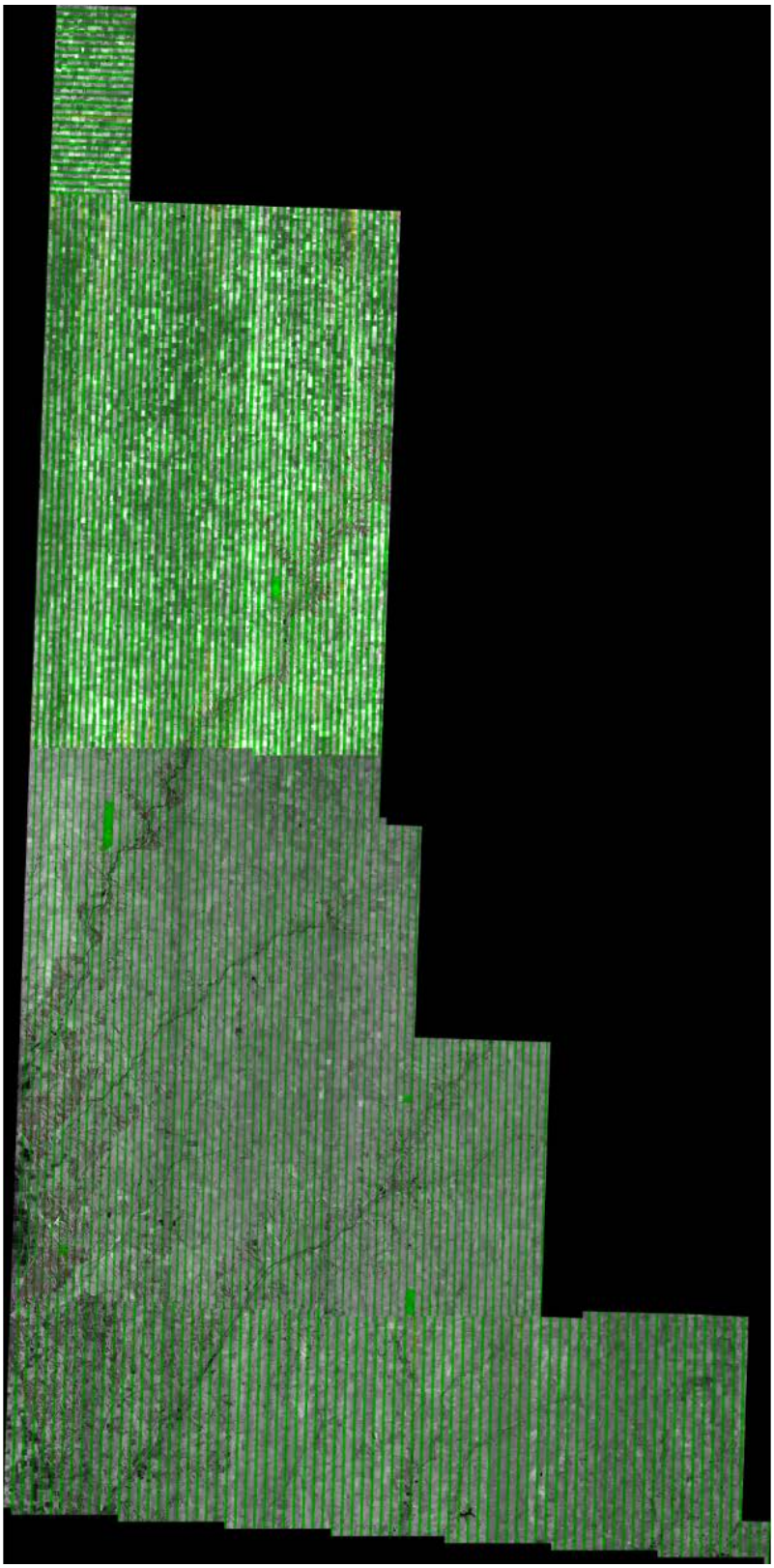

Figure 19: USGS_IA_Western_2_2020_D21 Project Area Delta-z raster image.

Horizontal Alignment/Calibration Check (Rooftops/Planar Surface Profiles)

The profiles show lidar points colored by flight line. The overlapping flight lines match and there is no horizontal (or vertical) offset between the flight lines.

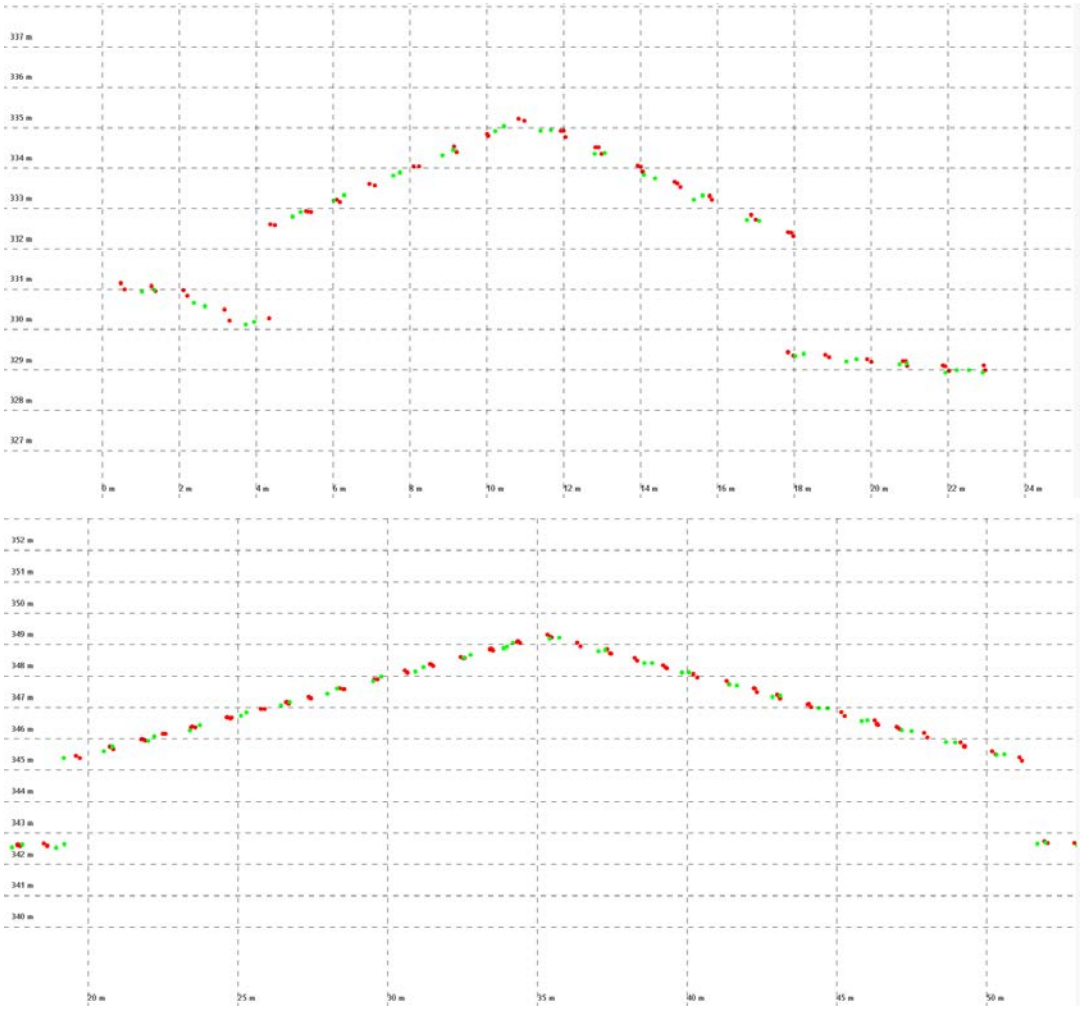

Figure 20: Profile views showing alignment checks

See Appendix B: For Aerial Services, Inc. GPS and IMU Processing Reports

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data were confirmed, ASI utilized TerraScan software for data processing. The acquired 3D laser point clouds, in LAS binary format, were imported into the project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model. This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

In TerraScan surface models for each tile was created to examine the ground classification. ASI analysts visually reviewed the ground surface model for artifacts left in the ground classification. Theses artifacts consist of vegetation, buildings, and bridges that were still present in the ground after initial processing. ASI analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that errant points are removed from the ground classification. Bridge decks are manually classified to class 17. After the ground classification had been completed, the dataset was processed through a water classification routine that utilized breaklines compiled by the Prime and Subcontractor to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, ground points that are within 2x NPS or less of the hydrographic features are moved to class 20 ignored ground, due to breakline proximity. Overage points are then identified in TerraScan and used to set the overlap bit for those points. The withheld points identified during the classification routine are used to set the withheld bit. The LiDAR tiles were classified to the following classification schema:

- Class 1 – Default, Processed, but unclassified
- Class 2 – Ground, Bare-earth
- Class 7 – Low Noise (low and manually identified)
- Class 9 – Water
- Class 17 – Bridge Decks
- Class 18 – High Noise (high, manually identified)
- Class 20 – Ignored Ground (Breakline Proximity)

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, the LAS files were then bitset finalized to LAS v1.4 using TerraScan software to flag the overlap bit and withheld bit. An LP360 64 bit was used to deduce the Well Known Text (WKT) and ASI proprietary software was used to format the LAS to the final LAS v1.4 Format 6 version. LAStools by rapidlasso GmbH, open source, lasInfo (open source LGPL) and ASI proprietary software was used to perform final analysis to checks on LAS header information, LAS point classes, and LAS timestamps.

This project consists of 78,962,758,457 lidar points the table below shows the total number of points for every class.

Project Count by Class		
Class 1	Processed, unclassified	3828107671
Class 2	Bare-earth ground	50930959997
Class 7	Low Noise	2483853
Class 9	Water	63896699
Class 17	Bridge Decks	1926076
Class 18	High Noise	66498
Class 20	Ignored-Ground	3242609
Class Overlap 1	Overlap Processed, unclassified	6271478146
Class Overlap 2	Overlap Bare-earth ground	17709002738
Class Overlap 7	Overlap Low Noise	1022666
Class Overlap 9	Overlap Water	1002268
Class Overlap 17	Overlap Bridge Decks	839910
Class Overlap 18	Overlap High Noise	1046346
Class Overlap 20	Overlap Ignored-Ground	483809
Class Withheld 1	Withheld Processed, unclassified	867422
Class Withheld 2	Withheld Bare-earth ground	4405721
Class Withheld 7	Withheld Low Noise	269

Class Withheld 18	Withheld High Noise	132706507
Class Overlap Withheld 1	Overlap Withheld Processed, unclassified	4490421
Class Overlap Withheld 2	Overlap Withheld Bare-earth ground	4727845
Class Overlap Withheld 7	Overlap Withheld Low Noise	986
Class Overlap Withheld 18	Overlap Withheld High Noise	35106358
Project Total Count		78962758457

Table 10: By Class Point Count.

LiDAR Qualitative Assessment

ASI's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in LiDAR data and the results of the visual review USGS_IA_Western_2_2020_D21 project area.

Data Voids

Acceptable voids (areas with no LiDAR returns in the LAS files) that are present in the majority of LiDAR projects include voids caused by bodies of water. No unacceptable voids are present in the USGS_IA_Western_2_2020_D21 project area.

Bridge Removal Artifacts

The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to continue the surface beneath the bridge where no LiDAR data was acquired. Locations where bridges were removed will generally contain less detail in the bare-earth surface because these areas are interpolated. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are bridge deck (blue).

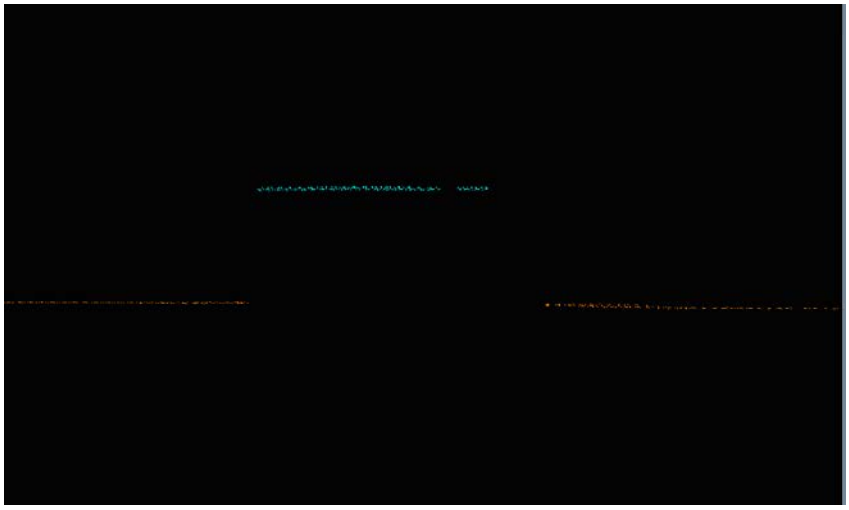

Figure 21: Profile view of a classified bridge deck (blue) and ground (orange).

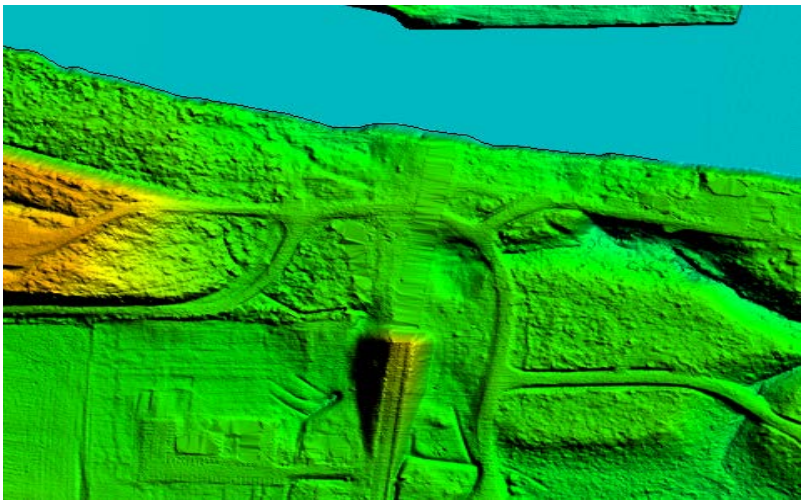

Figure 22: DEM with bridge removed from surface model.

Culverts

Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, ASI erred on assuming they would be culverts especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.

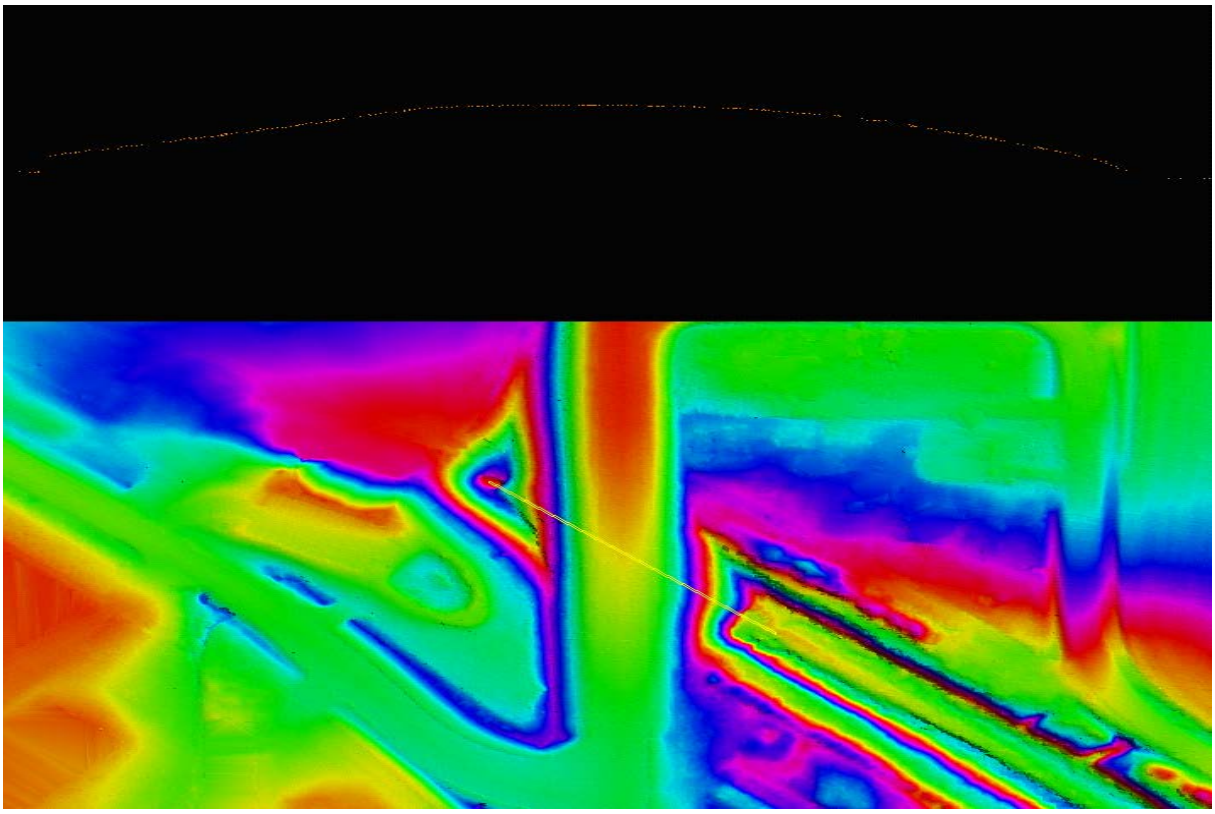

Figure 23: Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Hills and dirt mounds are present throughout the project area. These features are correctly included in the ground.

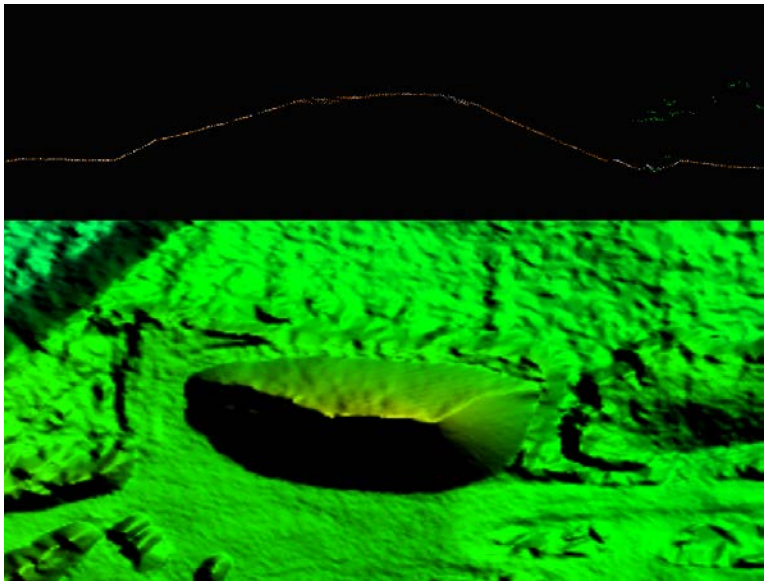

Figure 24: Profile with the points colored by class (unclassified points are white, ground points are orange) is shown on the right and a DEM of the surface is shown to the left. These features are correctly included in the ground classification.

Flightline Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flightline ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible flightline ridge that is within tolerance is shown below.

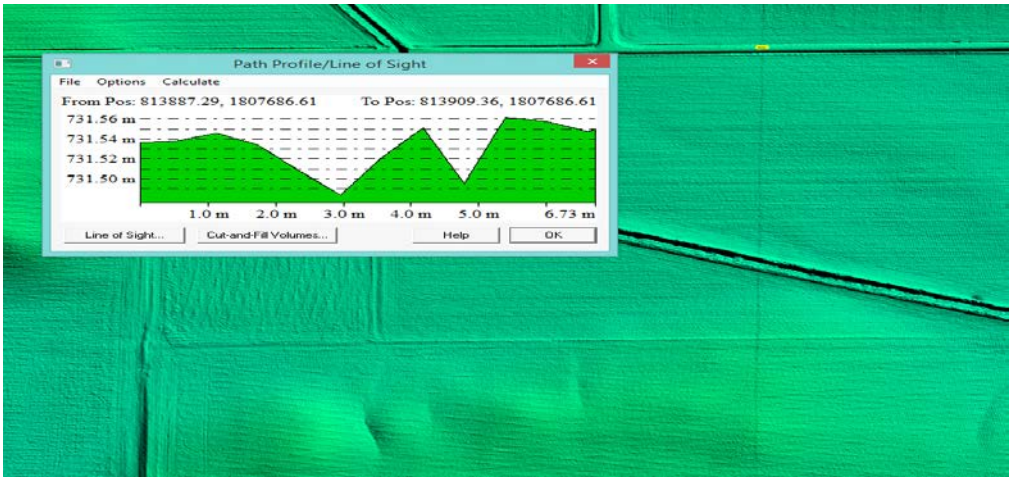

Figure 25: The flight line ridge is less than 8 cm. Overall; this projects data meets the project specifications for 8 cm RMSDz relative accuracy requirement.

Dam and Lock system

Irregularities in the natural water flow exist in sections of river affected by Lock and Dam systems. Series of locks enable vessels to “step” up or down a river or canal from one water level to another. There are no Lock systems in the USGS_IA_Western_2_2020_D21 project area.

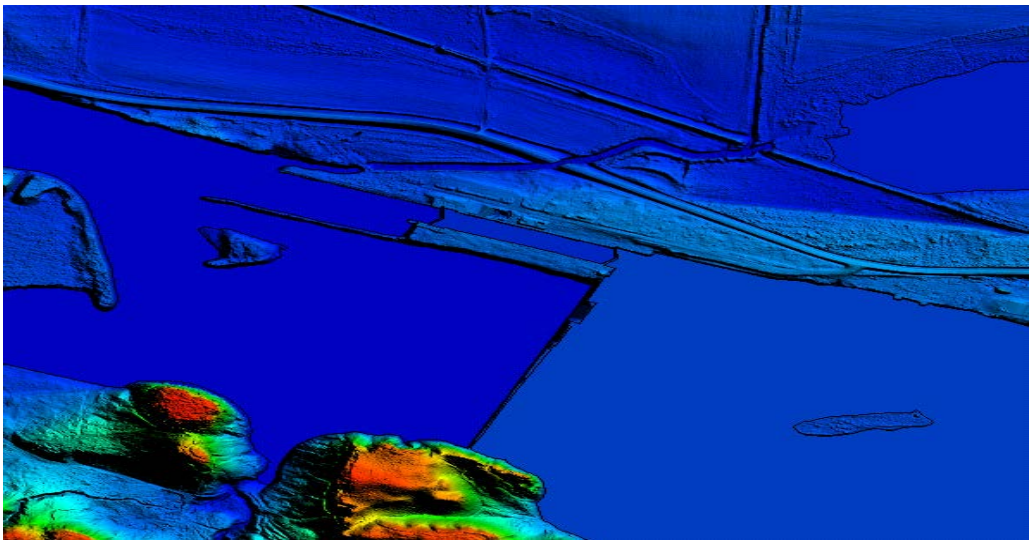

Figure 26: DEM shows Large Dam structure that disrupts natural monotonic river flow, coupled with a lock system.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all LiDAR files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using ASI proprietary tools. ASI routinely reviews for: proper LAS versions, Coordinate Reference System, Global Encoder Bit, Time Stamp, System ID, Multiple Returns, Intensity, Classification, Overlap and Withheld Points, Scan angle, XYZ Coordinates.

LiDAR Positional Accuracy

BACKGROUND

ASI quantitatively tested the dataset by testing the vertical accuracy of the LiDAR. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. The nature of lidar data makes it difficult to assess absolute horizontal accuracy as one would with imagery or compiled planimetric data. Guidance on how

absolute horizontal accuracy can be estimated and reported based on the error budget of the instrumentation and operational parameters can be found in ASPRS (2014). The horizontal accuracy of each lidar project shall be reported using the form specified by the ASPRS (2014).

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment of USGS_IA_Western_2_2020_D21 project area, ninety six check points were surveyed. All of those check points are located within bare earth/open terrain (96 NVA points). Please see provided survey report which details and validates how the survey was completed for this project. Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement. All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table.

Point ID	NAD83 (2011) UTM Zone 15 North Easting (M)	NAD83 (2011) UTM Zone 15 North Northing (M)	NAVD88 (Geoid12B) Elevation (M)
NVA1351	268541.120	4681918.810	405.524
NVA1229	260159.313	4707441.296	433.483
NVA1220	268465.108	4691570.951	405.800
NVA1212	258137.346	4679430.888	330.857
NVA1186	266357.896	4799937.914	438.499
NVA1184	257338.545	4813223.972	437.970
NVA1179	264533.645	4714305.022	395.494
NVA1168	260898.890	4730765.277	425.467
NVA1167	258183.764	4743735.352	422.027
NVA1135	275311.658	4694549.903	442.921
NVA1134	279920.370	4704822.212	400.878
NVA1132	265757.944	4780587.879	419.006
NVA1131	258127.861	4766506.755	402.577
NVA1128	264155.350	4696893.873	340.795
NVA1119	264976.622	4754745.792	433.941
NVA1108	264155.195	4772583.351	422.933

NVA1102	261313.198	4685612.448	335.996
NVA1046	266898.484	4814027.782	459.309
NVA1035	266716.853	4808031.018	454.472
NVA1518	270716.280	4787894.906	428.278
NVA1517	284204.277	4784846.483	473.415
NVA1463	254168.986	4656207.249	318.925
NVA1390	290690.140	4728122.394	396.002
NVA1369	306547.094	4621062.153	388.434
NVA1365	299778.892	4735806.929	422.397
NVA1364	277289.461	4736611.565	423.077
NVA1282A	263798.795	4724103.689	390.881
NVA1279	338963.722	4623369.343	403.123
NVA1270	297929.157	4784410.619	449.055
NVA1234	327604.640	4622046.478	401.390
NVA1233	328227.991	4606474.696	409.124
NVA1231	293948.524	4630768.197	442.833
NVA1230	305599.574	4643799.333	418.826
NVA1228	276059.647	4644512.593	379.108
NVA1226	299534.388	4627783.937	399.889
NVA1219	276026.282	4658895.825	379.883
NVA1195	339235.343	4636262.513	429.444
NVA1194	322850.166	4641659.838	431.338
NVA1193	315186.476	4672398.894	377.070
NVA1192	308441.175	4663126.960	362.898

NVA1191	306603.853	4689629.919	394.939
NVA1190	291873.016	4748375.471	413.586
NVA1189	297463.528	4769819.520	448.178
NVA1178	287476.536	4676443.868	394.806
NVA1177	254802.689	4650131.193	324.030
NVA1176	254772.305	4620506.459	322.648
NVA1165	291119.961	4716916.772	431.106
NVA1162	280936.823	4749476.621	423.792
NVA1161	283704.707	4736429.592	421.651
NVA1149	316050.917	4612749.431	376.412
NVA1143	339609.117	4619366.598	394.340
NVA1141	349983.214	4615174.654	400.536
NVA1140	317966.592	4658728.214	383.710
NVA1139	315097.370	4639953.093	424.446
NVA1138	326218.605	4660117.314	411.118
NVA1137	316187.069	4622367.147	419.289
NVA1136	293374.049	4645154.375	344.843
NVA1133	276961.976	4717256.749	350.595
NVA1126	259366.377	4662552.079	330.180
NVA1118	271085.052	4744544.972	445.981
NVA1116	270601.119	4730417.674	403.539
NVA1114	283373.423	4722961.375	362.216
NVA1113	285918.958	4688185.624	365.768
NVA1112	275674.047	4679445.229	353.775

NVA1100	269499.161	4672247.040	349.049
NVA1097	257023.968	4635501.722	324.696
NVA1096	269810.597	4651592.476	347.770
NVA1095	285609.769	4660881.674	375.376
NVA1094	283955.233	4636490.628	348.377
NVA1093	275292.789	4623937.910	326.870
NVA1092	290215.669	4613598.901	363.885
NVA1091	267521.611	4614307.375	340.152
NVA1090	305154.785	4613113.399	403.716
NVA1064	327338.789	4610604.937	392.299
NVA1063	305644.860	4632869.056	388.834
NVA1062	305257.028	4654301.229	387.264
NVA1061	298242.108	4663189.214	450.396
NVA1060	298697.044	4677673.491	425.854
NVA1059	296440.651	4691065.637	376.957
NVA1058	291530.476	4707097.275	438.795
NVA1057	291051.152	4738761.806	412.122
NVA1056	292399.547	4758002.821	438.603
NVA1055	296357.533	4760954.699	434.440
NVA1054	286161.418	4773847.517	464.781
NVA1052	285146.693	4784873.328	473.789
NVA1051	269526.624	4788417.317	431.968
NVA1039	302819.856	4731026.523	437.832
NVA1038	304298.689	4754799.029	422.248

NVA1037	303944.938	4771236.571	445.575
NVA1036	285333.196	4791291.040	468.720
NVA1012	327920.602	4635121.636	436.014
NVA1010	308164.202	4674123.402	404.719
NVA1008	303756.490	4705281.798	423.376
NVA1007	305483.781	4784056.243	421.663
NVA1006	301284.644	4790584.734	437.985
NVA1005	267613.387	4791882.518	439.559
VVA1535	257356.051	4813187.816	436.831
VVA1533	267605.394	4820418.184	476.902
VVA1532	266863.748	4813673.857	456.577
VVA1531	267049.971	4806402.669	451.752
VVA1530	258573.235	4802577.701	415.234
VVA1519	263253.318	4772529.805	410.207
VVA1505	263656.174	4754803.310	416.756
VVA1494	257690.038	4734078.924	422.803
VVA1493	256095.644	4719378.217	383.207
VVA1484	269942.992	4703659.954	344.340
VVA1476	262775.863	4690172.931	347.905
VVA1559	306710.638	4680654.260	453.498
VVA1558	323991.624	4668310.352	430.049
VVA1557	319776.436	4622233.106	381.600
VVA1549	277378.585	4694509.153	428.324

VVA1541	268396.576	4628011.838	363.825
VVA1525	256468.999	4793093.210	412.145
VVA1516	299044.129	4784208.731	440.836
VVA1514	304498.242	4790841.290	422.430
VVA1513	286484.200	4773390.170	460.383
VVA1512	301493.943	4768104.678	427.617
VVA1504	282669.985	4762414.731	420.123
VVA1503	296096.052	4760688.401	439.400
VVA1492	270766.345	4743328.477	441.687
VVA1491	291346.060	4735548.962	356.881
VVA1490	298429.090	4748729.723	376.550
VVA1489	300300.631	4731909.692	423.030
VVA1488	302991.551	4724524.493	425.158
VVA1487	283714.284	4723123.078	361.670
VVA1486	276966.043	4717566.539	345.628
VVA1485	301825.363	4708961.019	404.442
VVA1478	290871.625	4705690.931	428.485
VVA1477	294265.636	4622543.826	380.011
VVA1470	257032.027	4676238.575	325.842
VVA1469	268327.065	4671889.378	337.281
VVA1468	275999.021	4658328.524	354.579
VVA1467	285608.812	4683338.623	401.567
VVA1466	295644.009	4691641.622	370.820
VVA1465	299325.269	4670861.540	450.742

VVA1464	290052.885	4658088.784	402.128
VVA1462	268288.213	4656351.227	414.615
VVA1460	325788.273	4660182.273	420.222
VVA1459	293040.456	4644642.706	348.575
VVA1453	279745.021	4614376.345	371.850
VVA1452	315043.989	4639545.095	412.046
VVA1451	305966.571	4655449.597	407.264
VVA1450	284502.575	4637487.487	337.960
VVA1449	327611.801	4623819.934	389.066
VVA1448	256695.876	4635395.123	323.484
VVA1447	335307.912	4633869.095	413.902
VVA1446	305785.743	4633321.744	388.231
VVA1445	307346.546	4614672.811	371.363
VVA1444	350392.649	4635581.835	386.318
VVA1443	338914.538	4620378.414	394.906
VVA1442	328496.967	4606574.137	414.228
VVA1401	258737.913	4612781.074	311.137
VVA1400	281719.963	4623711.535	366.007
VVA1164	276618.648	4777266.864	448.245
VVA1163	271583.863	4762682.817	437.482
VVA1053	280860.222	4761905.726	428.434

Table 11: USGS_IA_Western_2_2020_D21 project area project LiDAR Validation Checkpoints

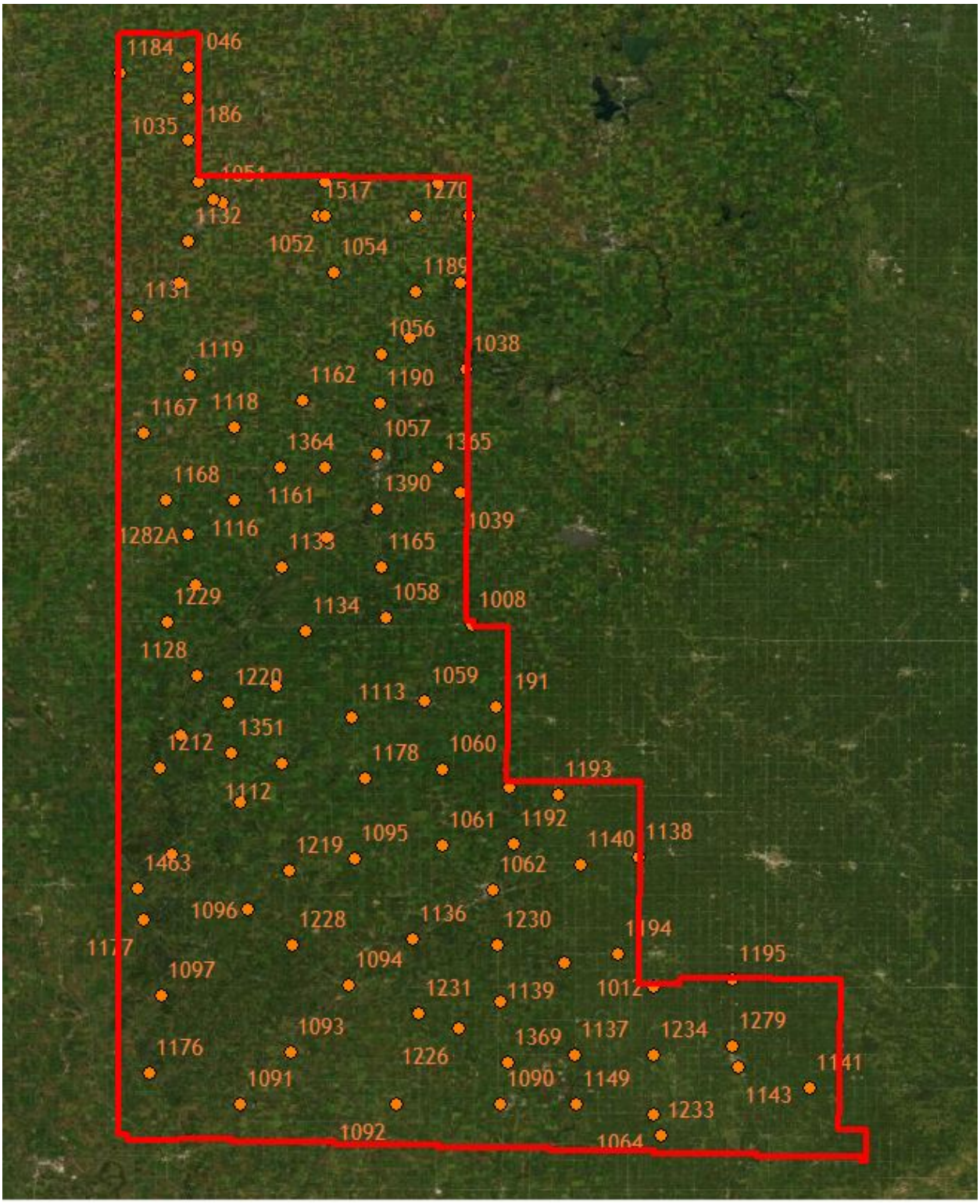

Figure 27: Location of USGS_IA_Western_2_2020_D21 project area LiDAR NVA Checkpoints

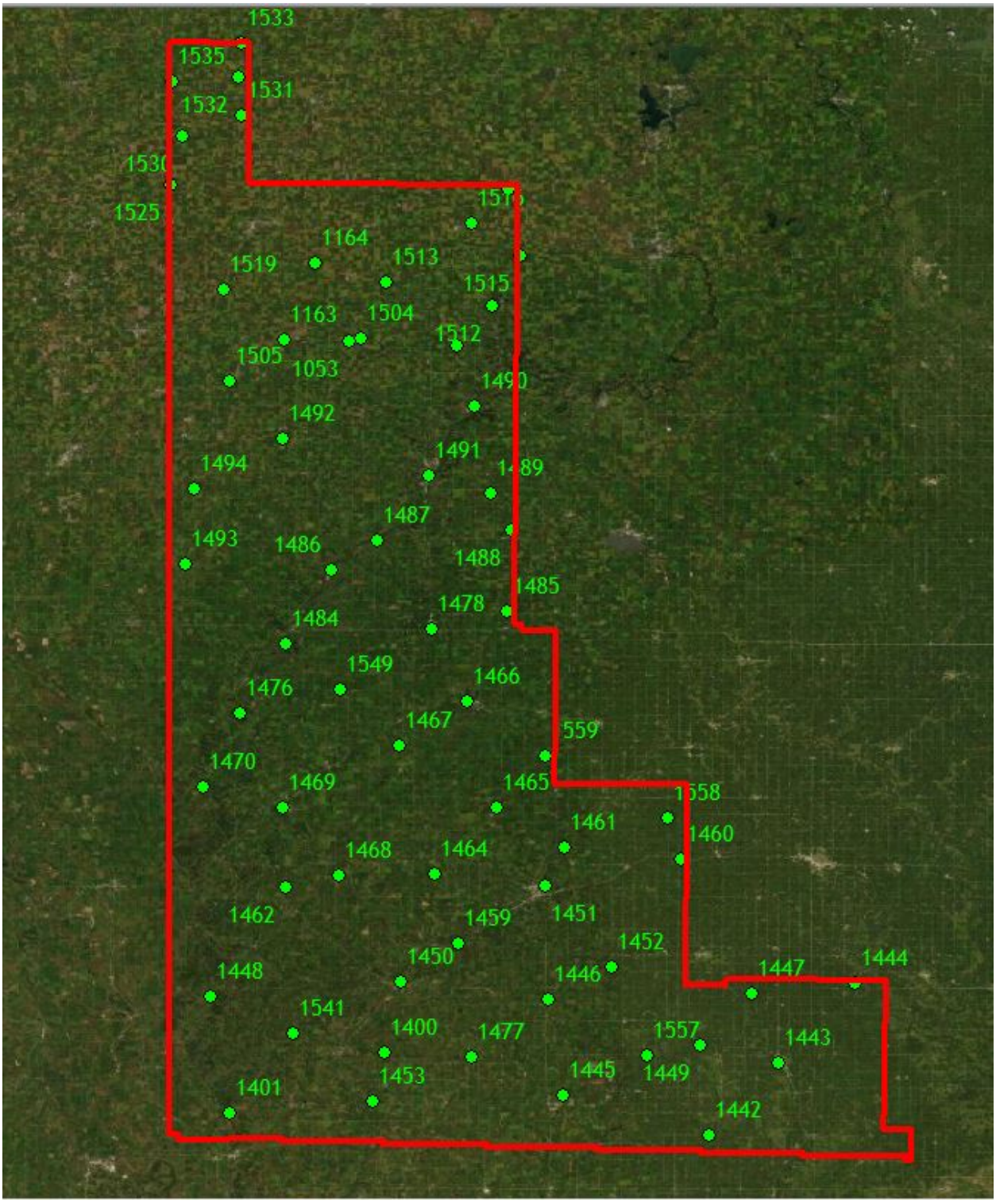

Figure 28: VVA Checkpoints were located in USGS_IA_Western_2_2020_D21

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in nonvegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated LiDAR sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the USGS_IA_Western_2_2020_D21 project area, vertical accuracy must be 19.6 cm (0.64 ft) or less based on an RMSEz of 10 cm (0.33 ft) x 1.9600. VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The USGS_IA_Western_2_2020_D21 project area VVA standard is 29.4 cm (0.96 ft) based on the 95th percentile.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using RMSEz *1.96	19.6 cm (based on RMSEz (10 cm)*1.96)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined and at the 95th Percentile error	29.4 cm (based on combined 95th percentile)

Table 12: Acceptance Criteria.

The primary QA/QC vertical accuracy testing steps used by ASI are summarized as follows:

1. Foth Infrastructure & Environment, LLC surveyed QA/QC vertical checkpoints in accordance with the project's specifications.

2. Next, ASI interpolated the bare-earth LiDAR DTM to provide the z-value for every checkpoint.

3. ASI then computed the associated z-value differences between the interpolated z-value from the LiDAR data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.

4. The data were analyzed by ASI to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

VERTICAL ACCURACY RESULTS

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified LiDAR LAS files.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (95% confidence)Spec = 0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) spec = 0.294 m
NVA	96	0.081	
VVA	60		0.168

Table 13: Tested NVA and VVA.

HORIZONTAL ACCURACY TEST PROCEDURES

The Optech Galaxy Prime data set was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 32.72 (cm) RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 64.13 cm at a 95% confidence level.

Breakline Production methodology

MicroStation, in conjunction with TerraSolid's TerraScan and TerraModeler was utilized for the collection of hydrologic breaklines, which occurred independently of manual edit. Collection was done using 2D information in the LAS format, intensity format, and ground surface. Breaklines are developed to the limit of the defined project boundary. Breaklines are in the same coordinate reference system and unit of measure as the LiDAR point delivery. Hydrologic water-surface edges are set at or just below the immediately surrounding terrain. Breaklines are developed to the limit of the project boundary.

Breakline Qualitative Assessment

Completeness and horizontal placement is verified through visual review against LiDAR intensity imagery, and bare earth surface. Breakline features are check for connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

Feature Definition

Inland Streams and Rivers

Streams and Rivers with a nominal width of 30 meters (100 feet), were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Streams and rivers do not break at bridges, but they are closed ended breaks at culvert locations. Steams and Rivers breaklines have been delivered in PolylineZ format in the final GDB.

Inland Ponds and Lakes

Inland ponds and lakes of 2 acres (86,111 square feet/ ~350'/~106 meter diameter for a round pond) or greater were collected. Inland pond and Lakes were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Inland pond and Lakes Breaklines have been delivered in PolygonZ format in the final GDB.

Islands

Permanent island 4000m² (1 acre) or larger were delineated within all water bodies. Breaklines have been delivered in PolygonZ format in the final GDB

Bridge Breaklines

Breaklines were placed across the bottom of the bridge embankment when triangulation occurred due to bridge deck classification. Breaklines have been delivered in PolylineZ format in the final GDB.

Intensity Imagery Production & Qualitative Assessment

INTENSITY PRODUCTION METHODOLOGY

ASI utilized MicroStation in conjunction with TerraSolid's TerraScan for Intensity production. Global Mapper was used to QC the products. ArcGIS was used finalize the Intensity's projection.

Intensity Images are created for each tile in the tiling schema. The Intensities are reviewed for any issues requiring corrections. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

INTENSITY QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the Intensity deliverables to ensure that all tiled Intensity products were delivered with the proper extents, and contained proper referencing information. Intensity bounding values were manually set in RiProcess to utilize the full range of values available. Subcontractor intensities were linearly scaled to match the intensity of ASI's collection. During some reprocessing to improve the calibration, some points received maximum value intensity; however these were corrected to the original output values prior to delivery.

Figure 29: Intensity Image example.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

ASI utilized MicroStation Connect in conjunction with TerraSolid's TerraScan and TerraModeler for DEM production. Global Mapper version 21.0 was used to format and QC the products. GDAL version 2.4.0 was used finalize the DEMs projection.

The final bare earth LiDAR points are used to create a terrain. The final 3D breaklines collected for the project are enforced in the terrain. The terrain is then converted to raster format using linear interpolation. DEMs are created for each tile in the tiling schema. The DEMs are reviewed for any issues requiring corrections, including remaining LiDAR ground misclassification, erroneous breakline elevations, poor hydro flattening, and processing artifacts. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

DEM QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained proper referencing information.

The image below shows an example of a bare earth DEM.

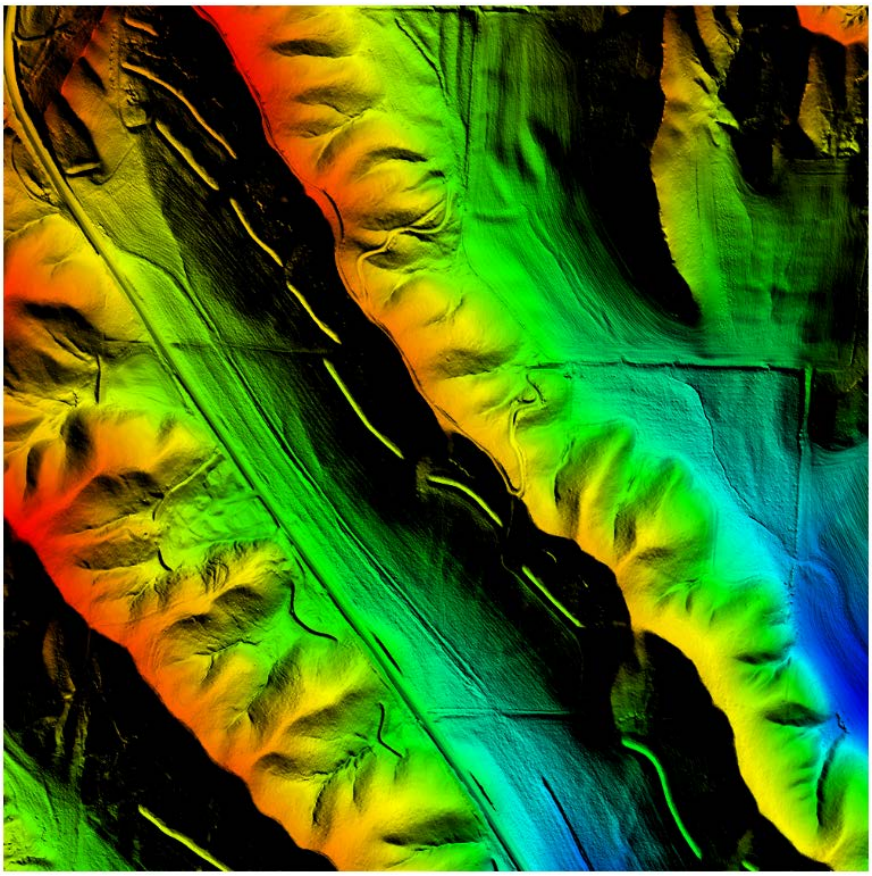

Figure 30: Bare Earth DEM example

DEM VERTICAL ACCURACY RESULTS

The same 156 checkpoints that were used to test the vertical accuracy of the LIDAR were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source LiDAR and final DEM deliverable. DEMs are created by averaging several LiDAR points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS. The DEM pixel does not average several LiDAR point's together, it interpolates (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the survey elevations.

The following table; summarizes the tested vertical accuracy result from a comparison of surveyed checkpoint to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSEz x 1.960)	VVA – Vegetated Vertical Accuracy (95th percentile)
NVA	96	0.079	
VVA	60		0.171

Table 14: DEM vertical accuracy summary

DEM datasets were tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 0.040 meters with a 0.079 meters accuracy at 95 % confidence level. Actual VVA accuracy tested 0.171 meters using checkpoints located in forested land cover categories at the 95th percentile, derived according to ASPRS guidelines, tested against the DEM. Based on the vertical accuracy testing conducted by ASI, the DEM dataset for the USGS_IA_Western_2_2020_D21 project area satisfies the project's pre-defined vertical accuracy criteria.

Appendix A: List of Delivered LAS File

w2490n4609
w2490n4610
w2490n4611
w2490n4612
w2490n4613
w2500n4609
w2500n4610
w2500n4611
w2500n4612
w2500n4613
w2500n4614
w2500n4615
w2500n4616
w2500n4617
w2500n4618
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w2530n4676
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w2530n4681
w2530n4682
w2530n4683
w2530n4684
w2530n4685
w2530n4686
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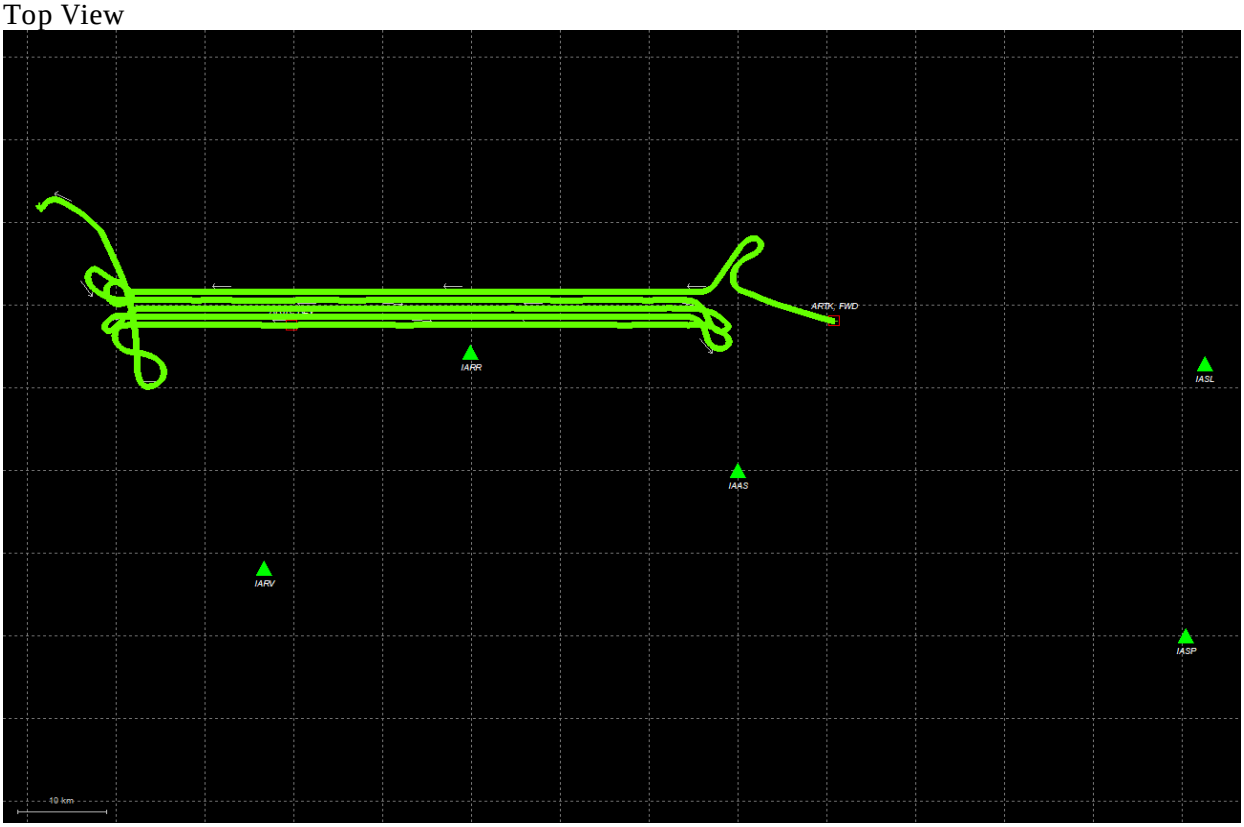
Appendix B: GPS and IMU Processing Report

20201127-162331.docx QC Report - 06/22/2021 09:07:25

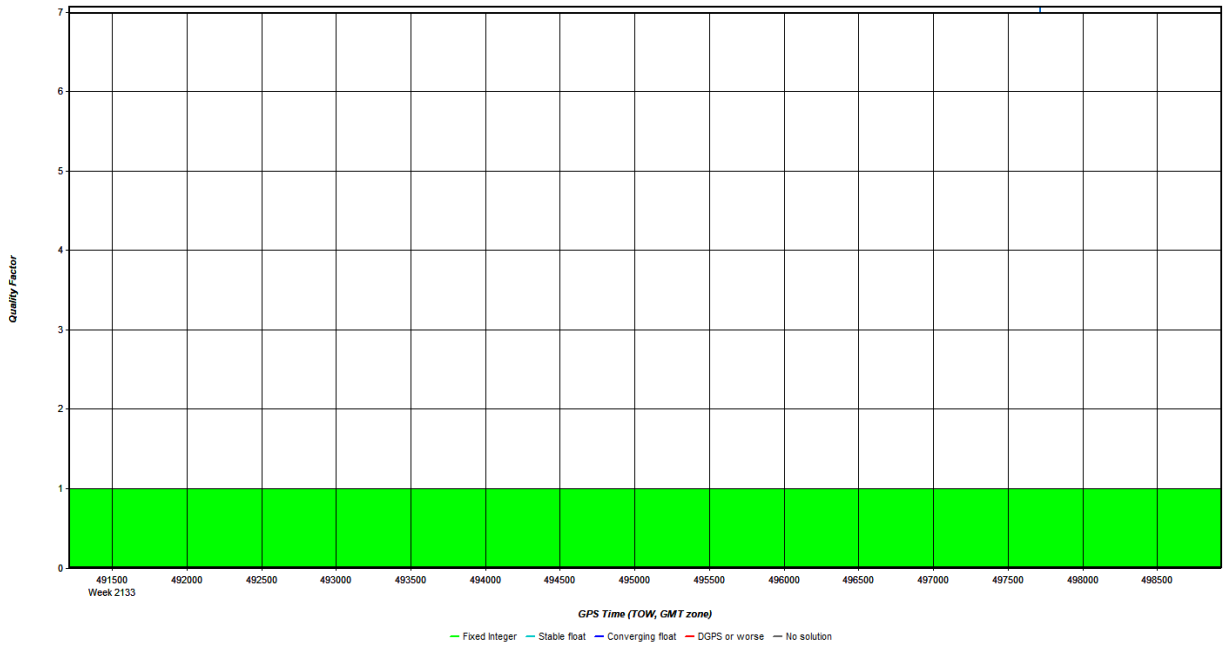
Smoothed Trajectory Information

Top View

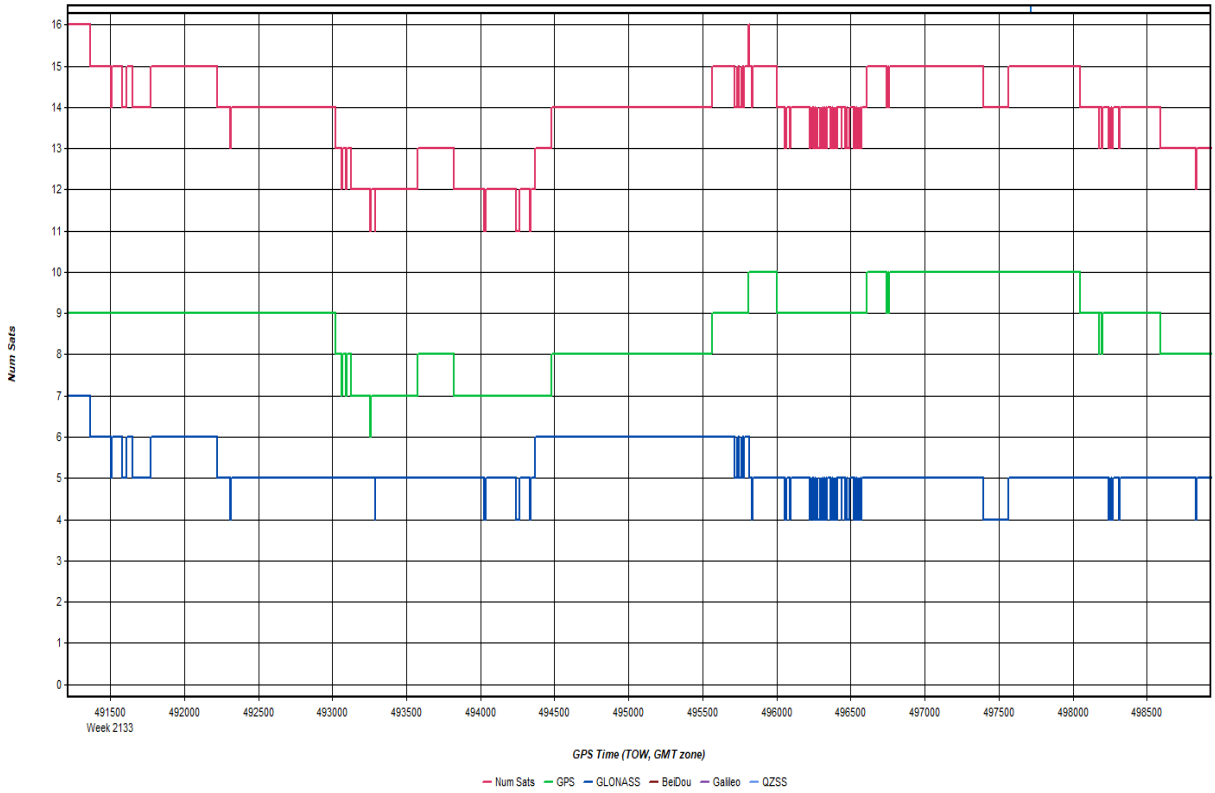


GNSS QC

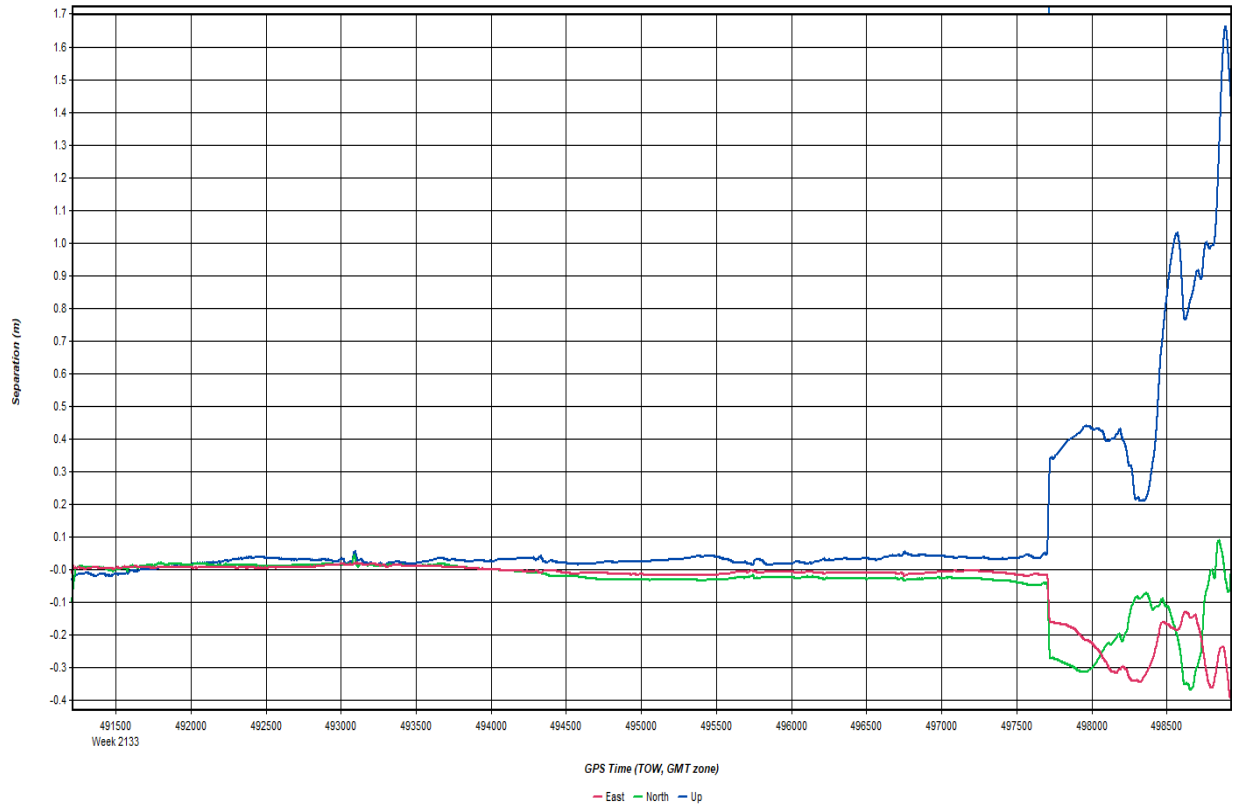
Quality Factor Plot



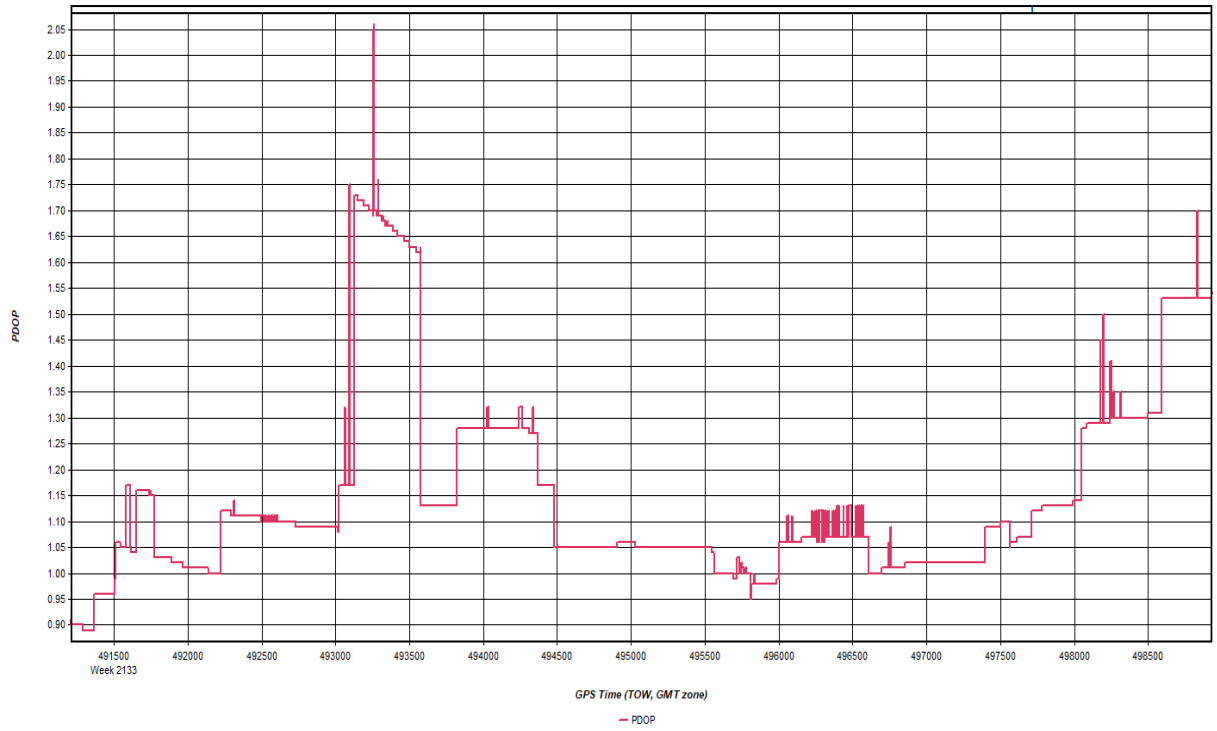
Number of Satellites Plot



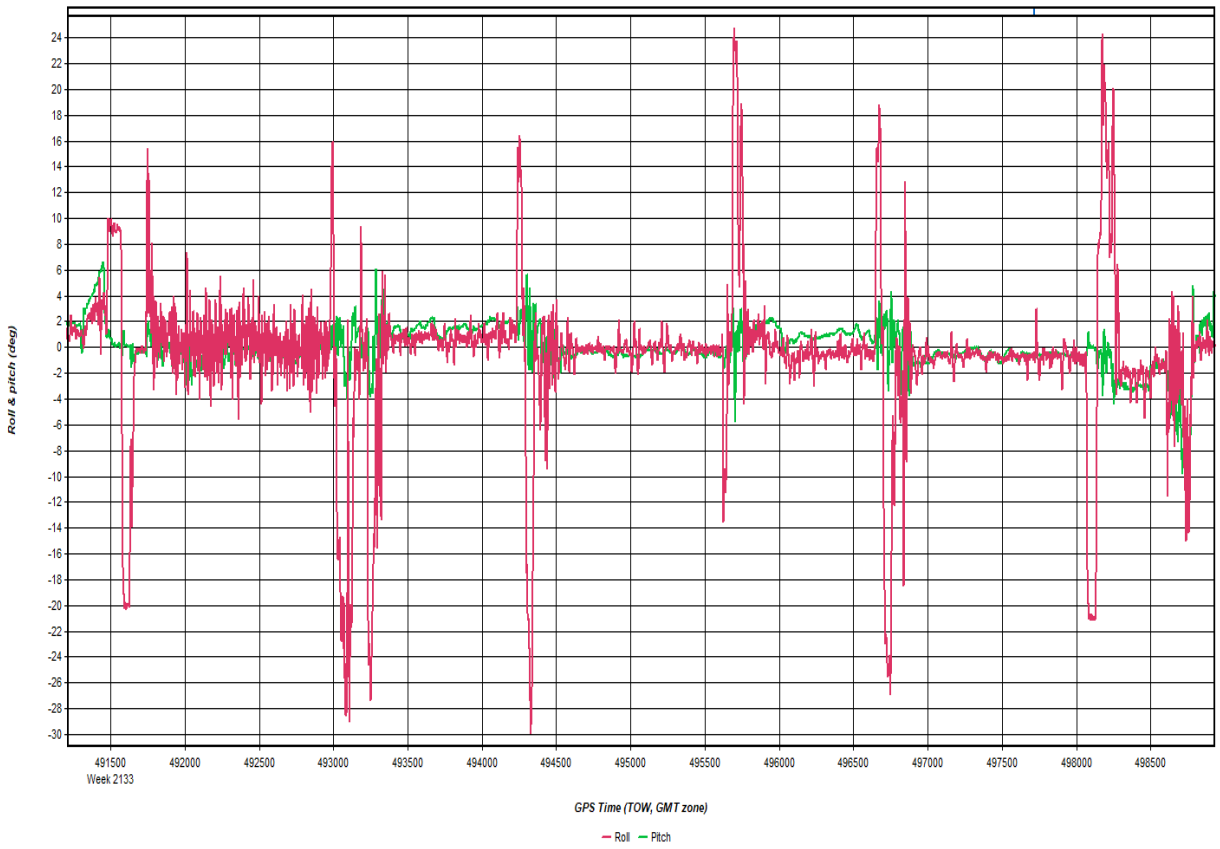
Forward/Reverse or Combined Separation Plot



PDOP Plot



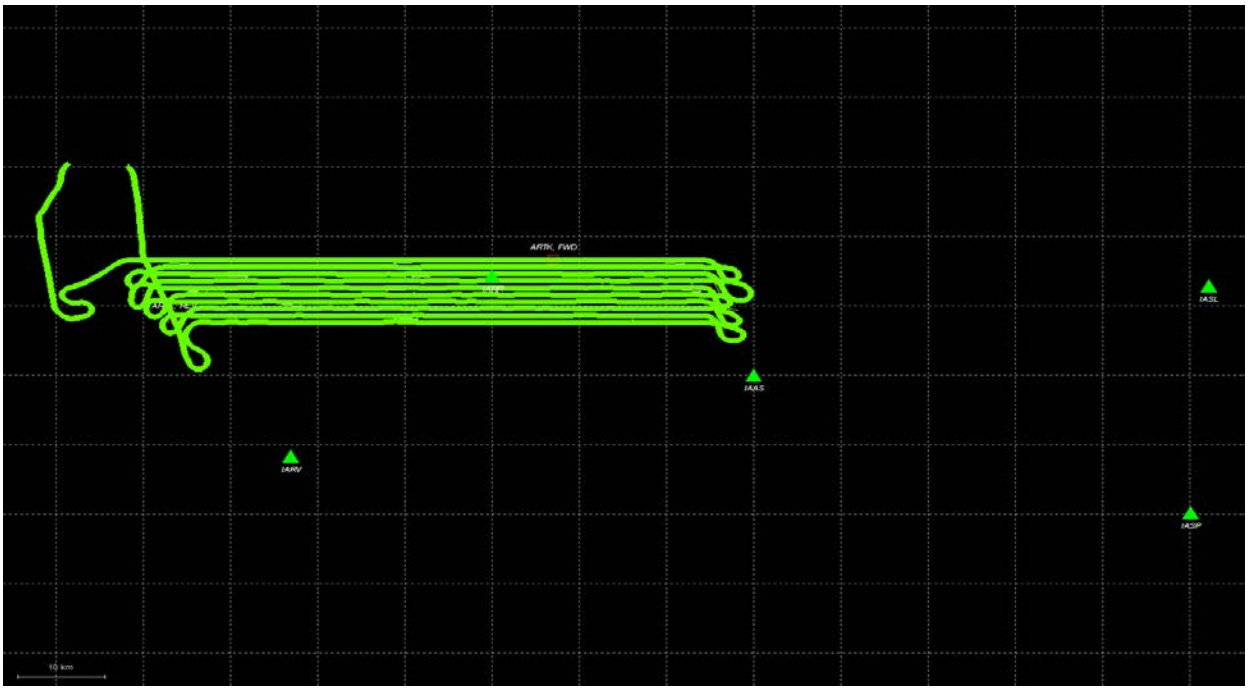
Roll & Pitch Plot



20201127-190707.docx QC Report - 06/22/2021 09:07:25

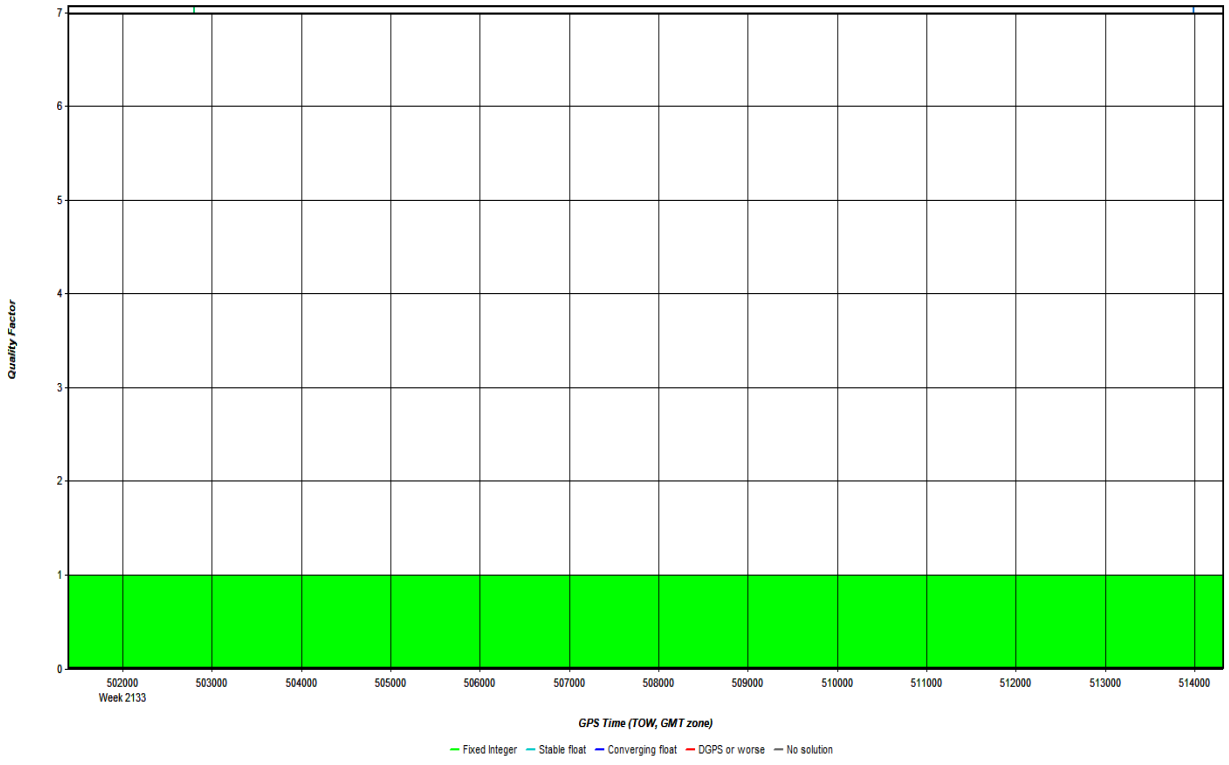
Smoothed Trajectory Information

Top View



GNSS QC

Quality Factor Plot



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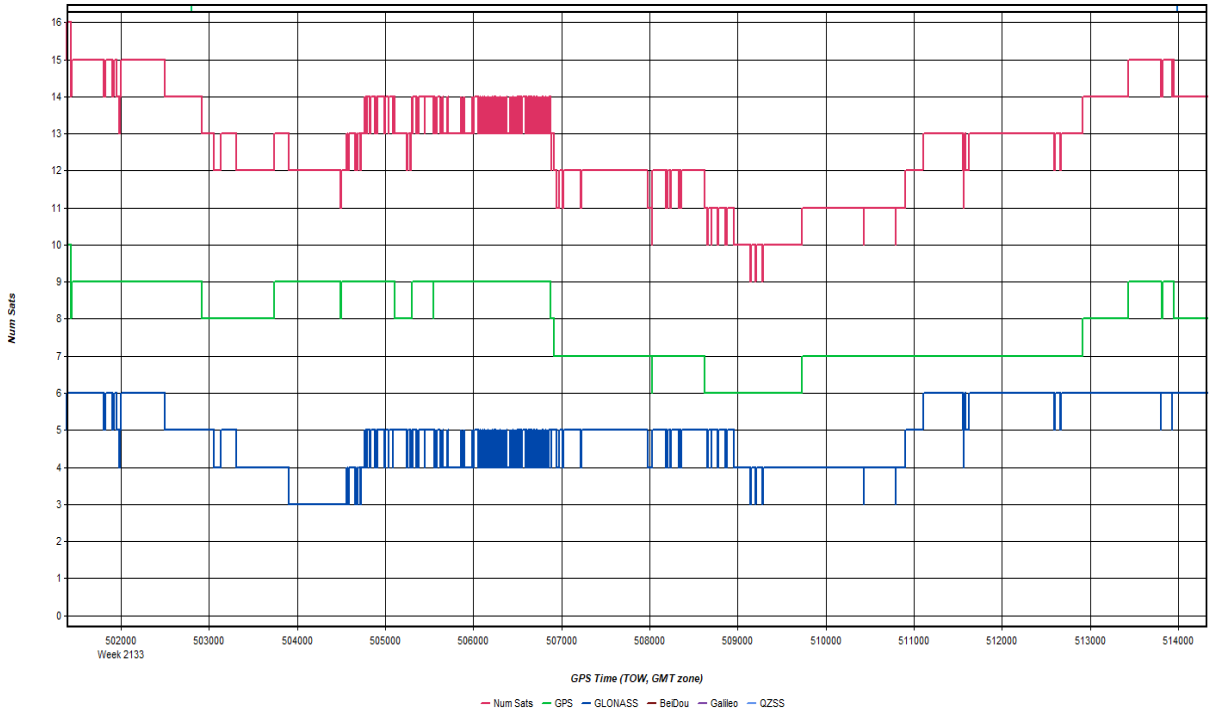
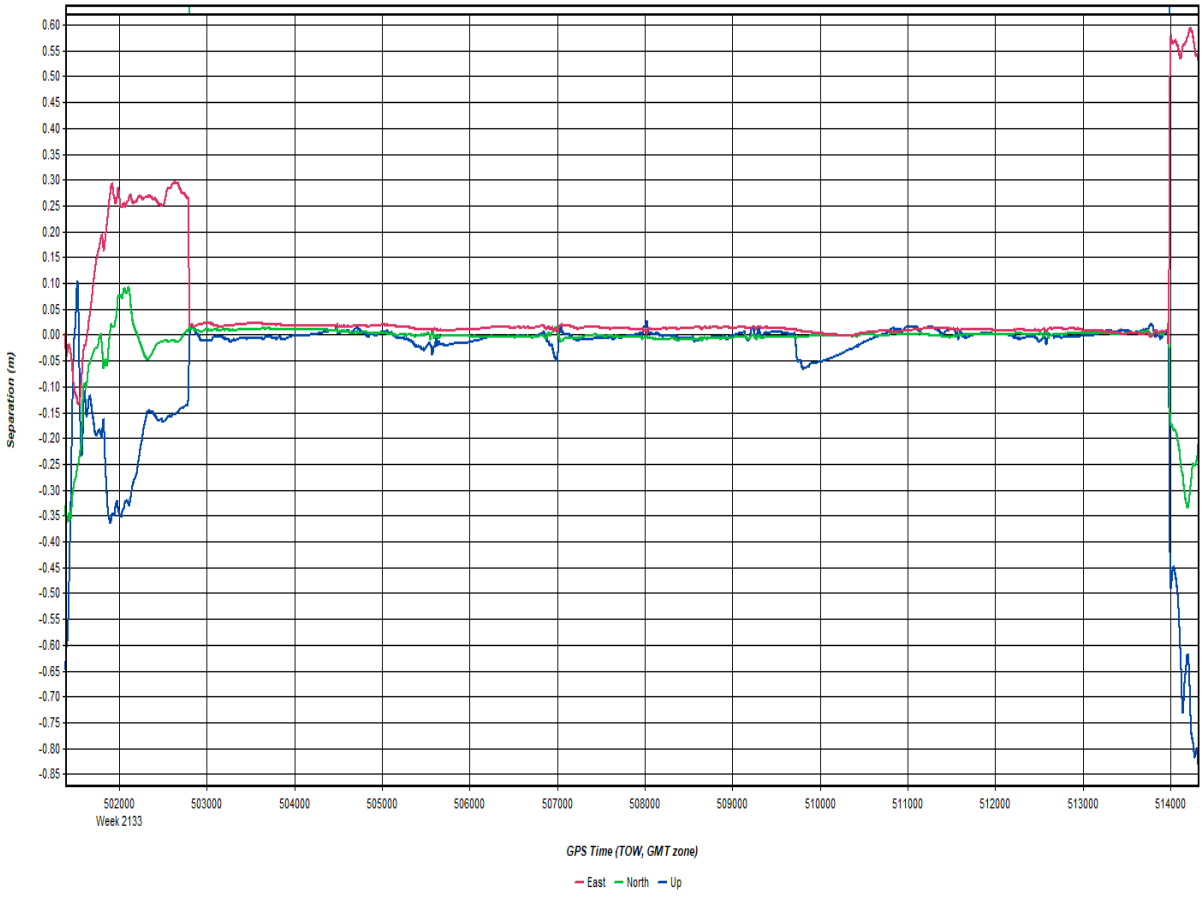


Forward/Reverse or Combined Separation Plot



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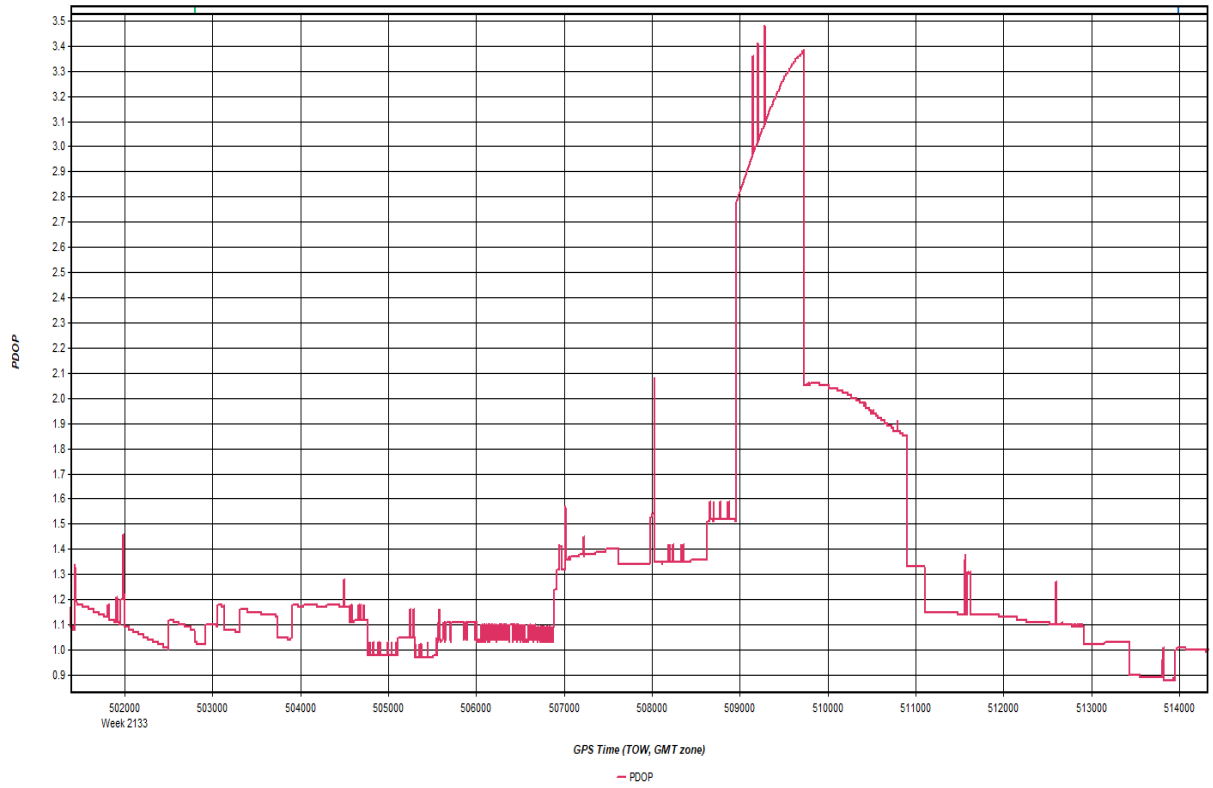
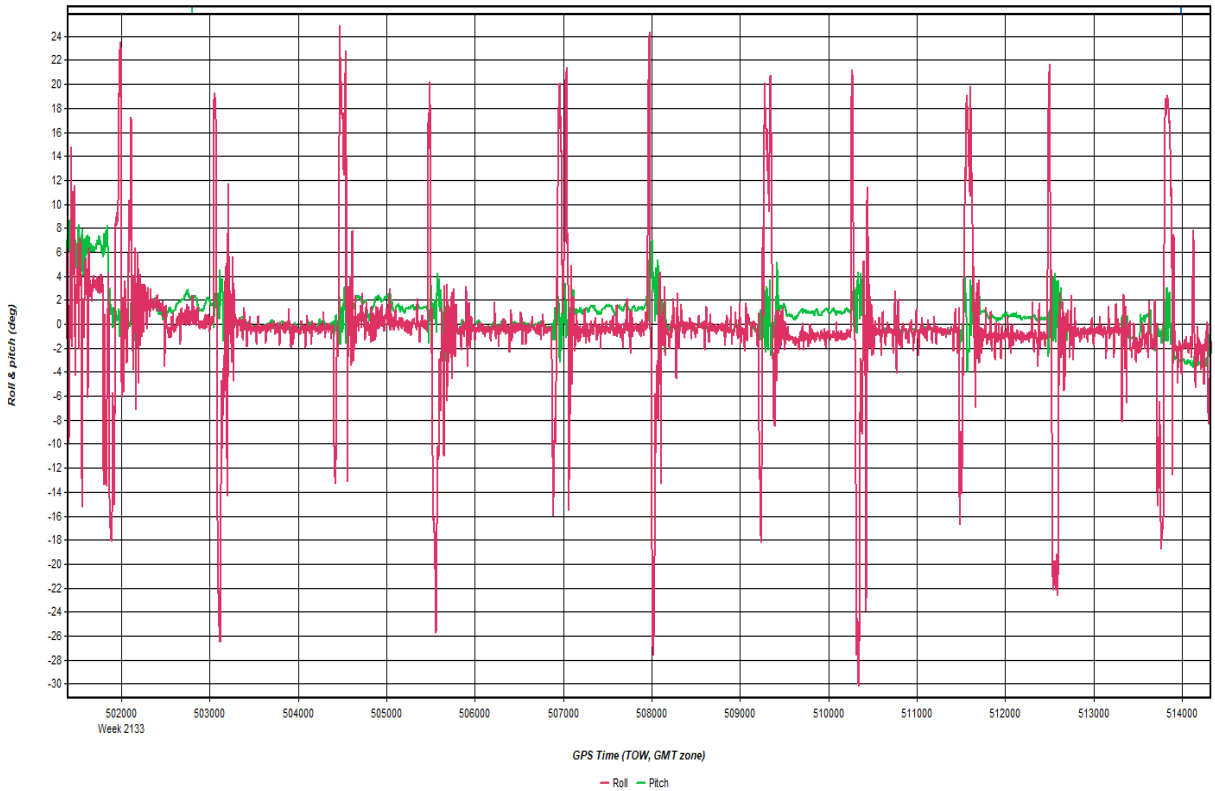


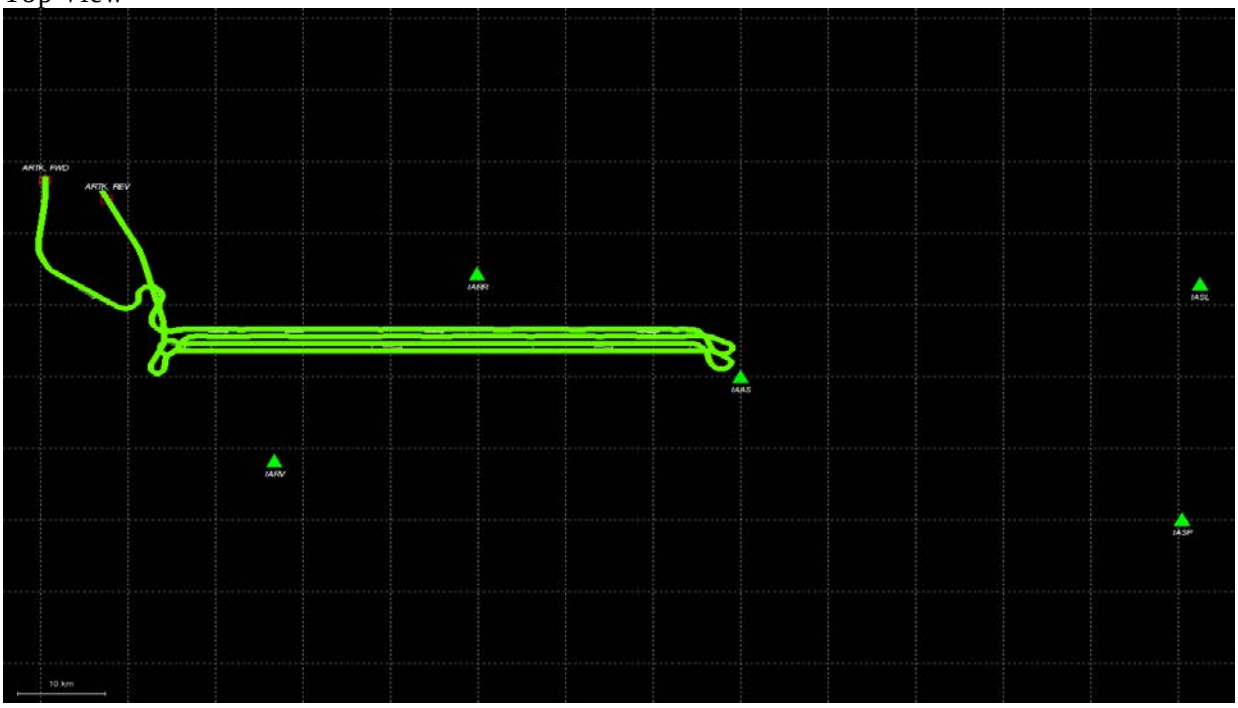
Roll & Pitch Plot



20201127-233917.docx QC Report - 06/22/2021 09:12:25

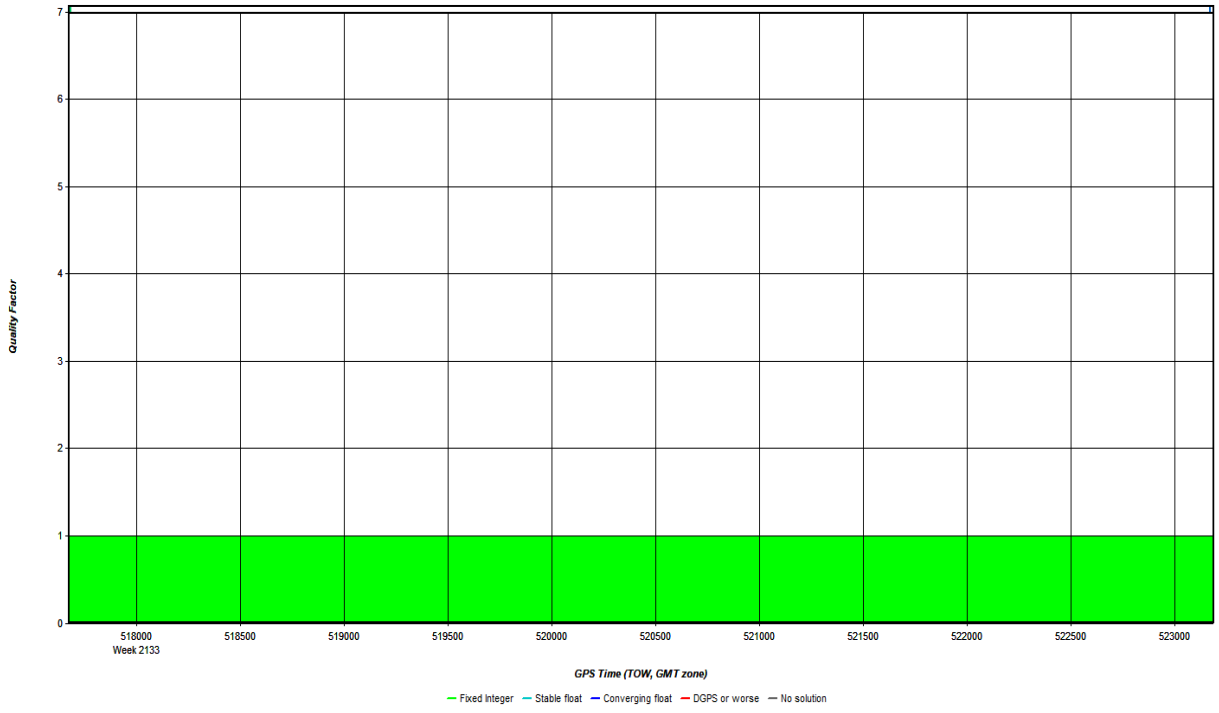
Smoothed Trajectory Information

Top View

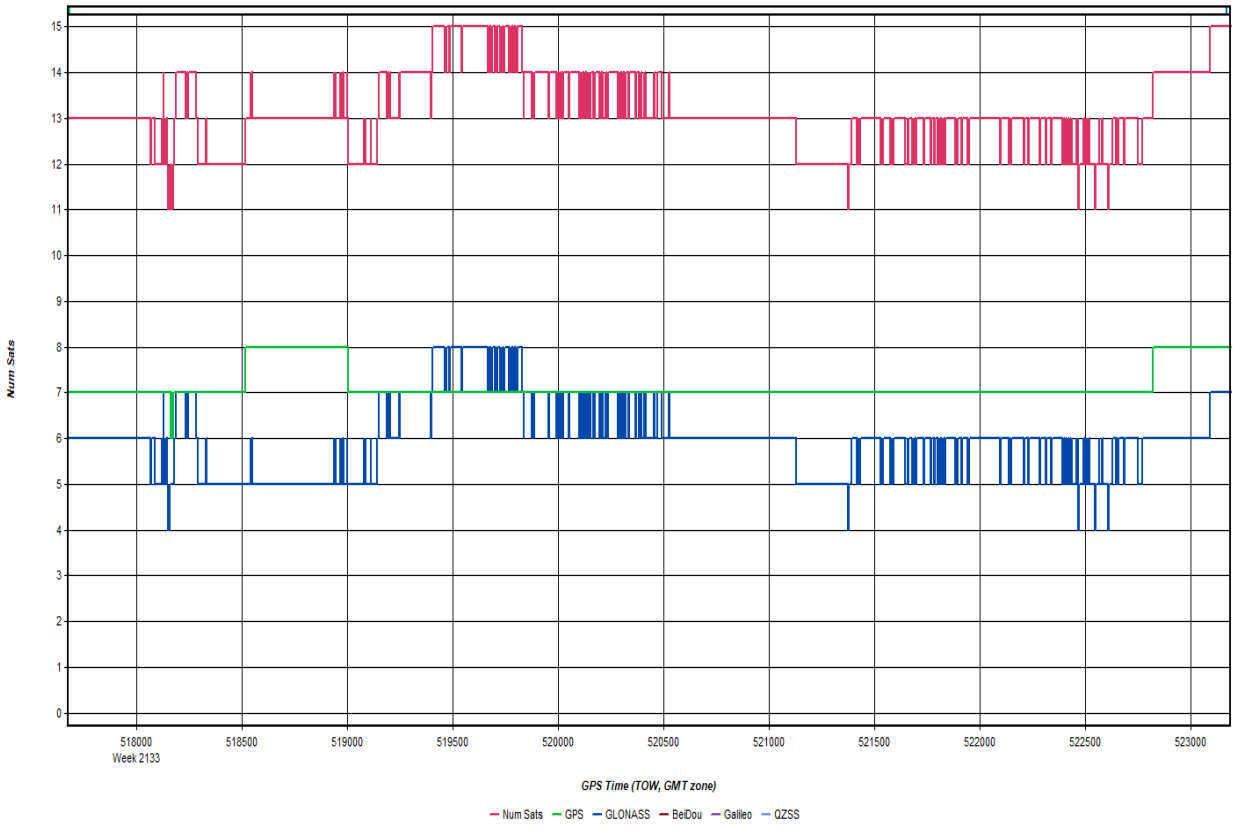


GNSS QC

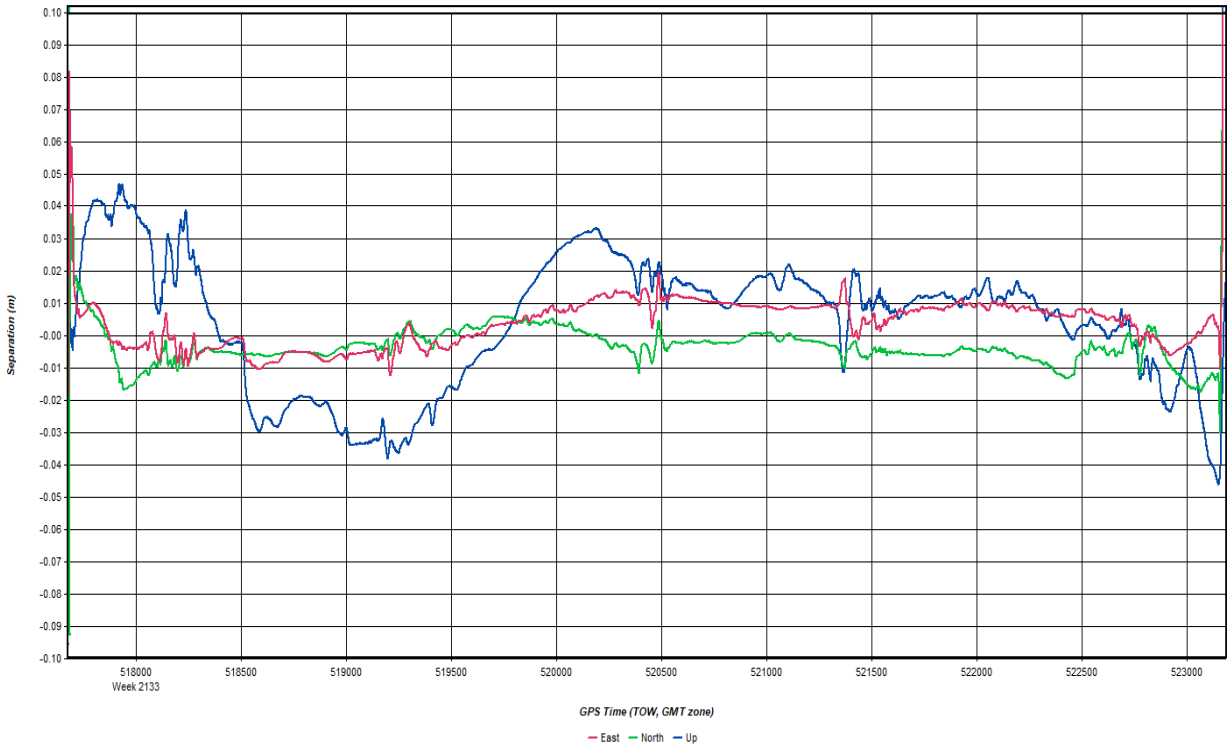
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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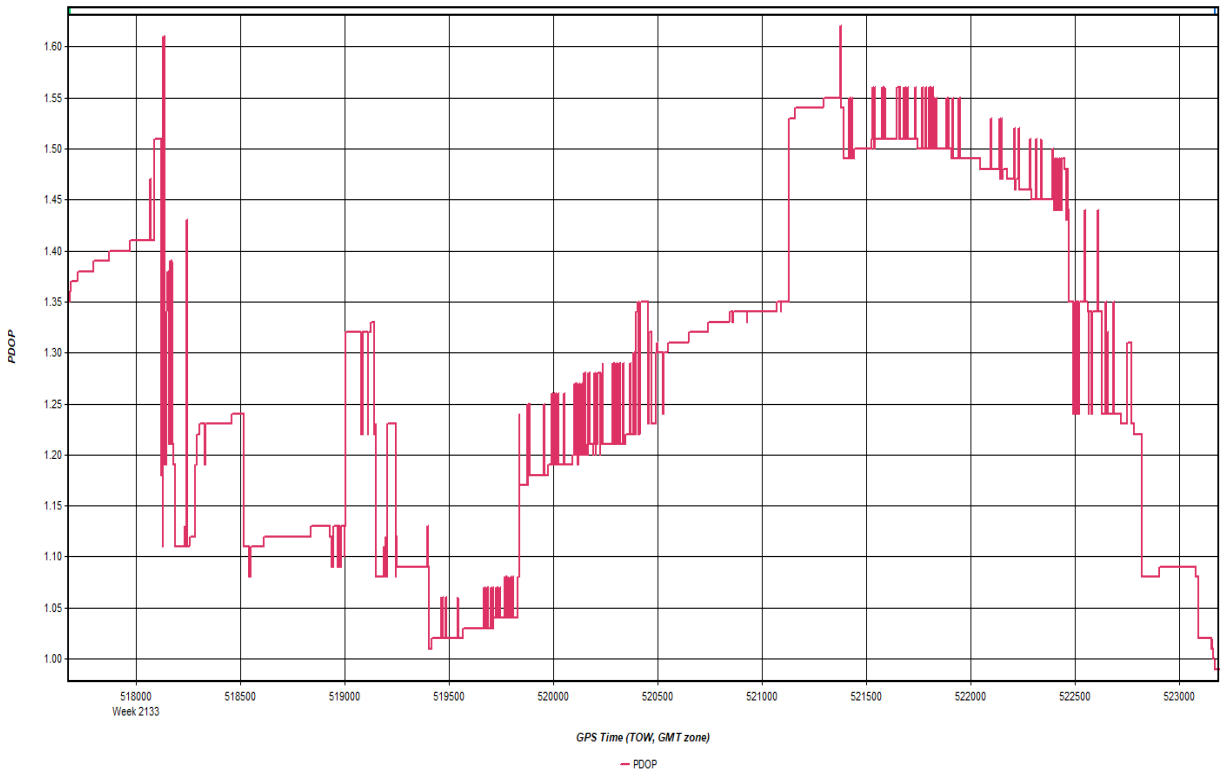
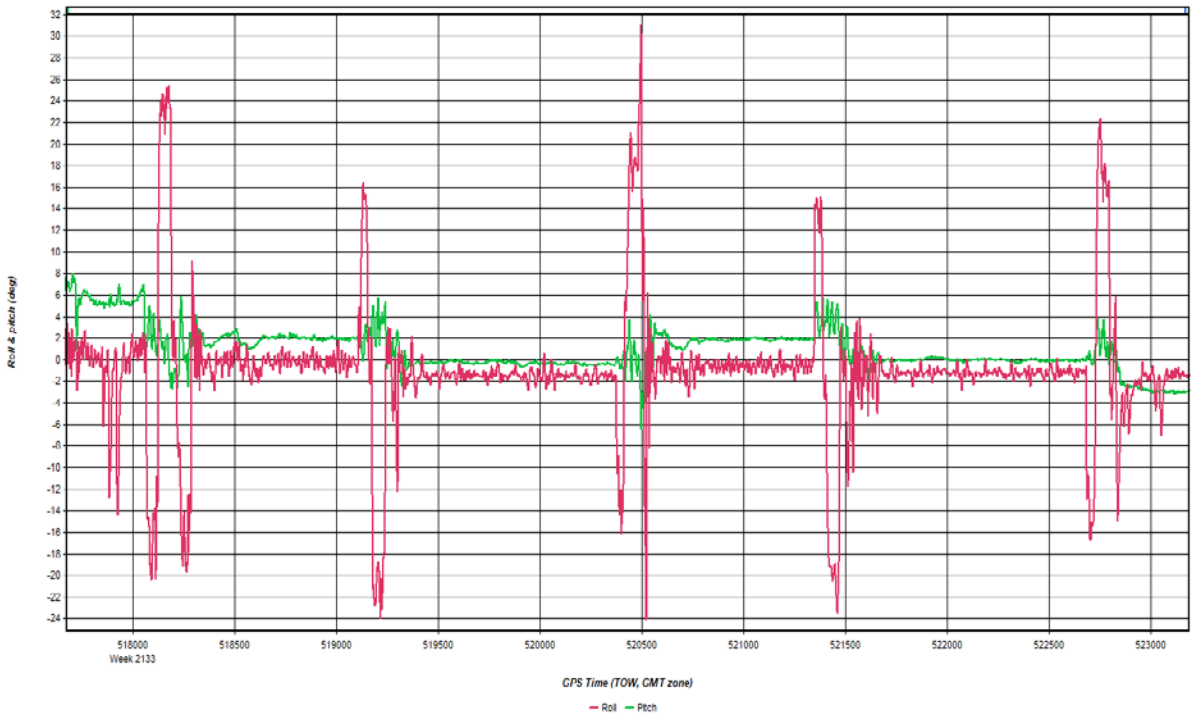


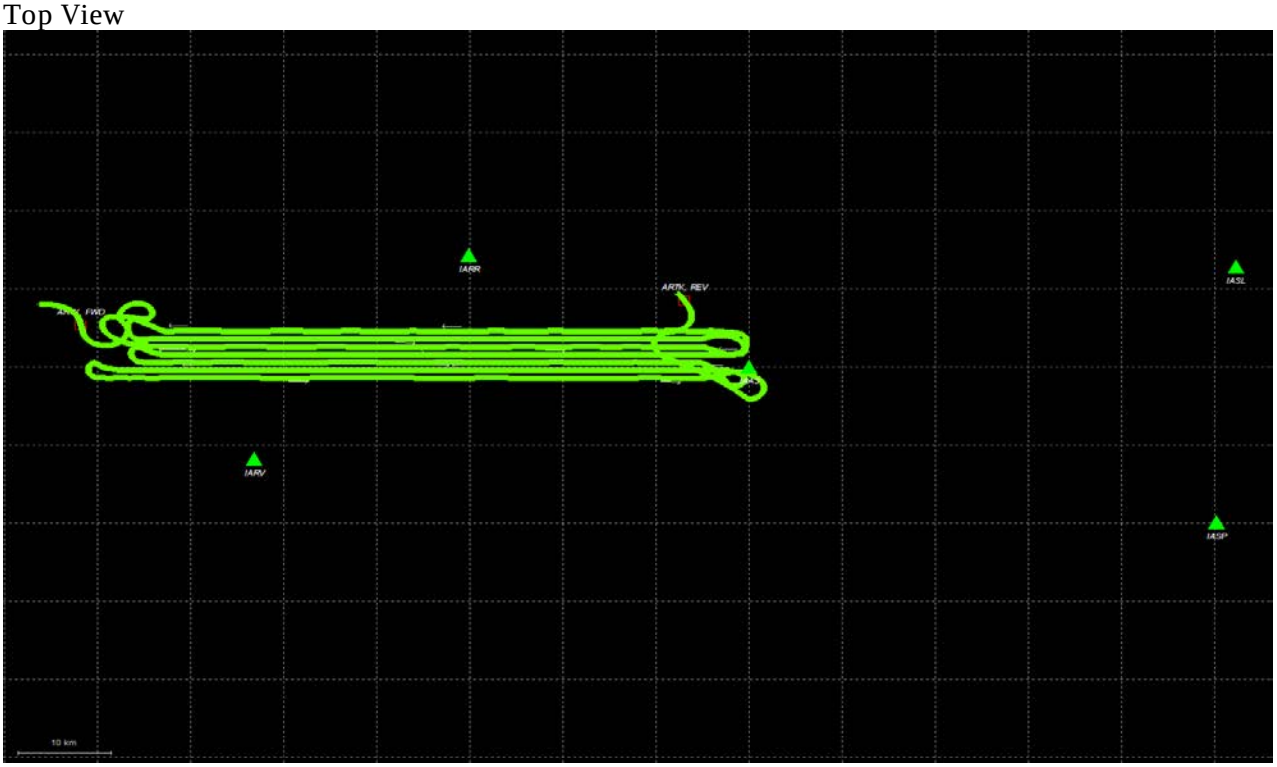
Roll & Pitch Plot



20201128-152926.docx QC Report - 06/22/2021 09:39:12

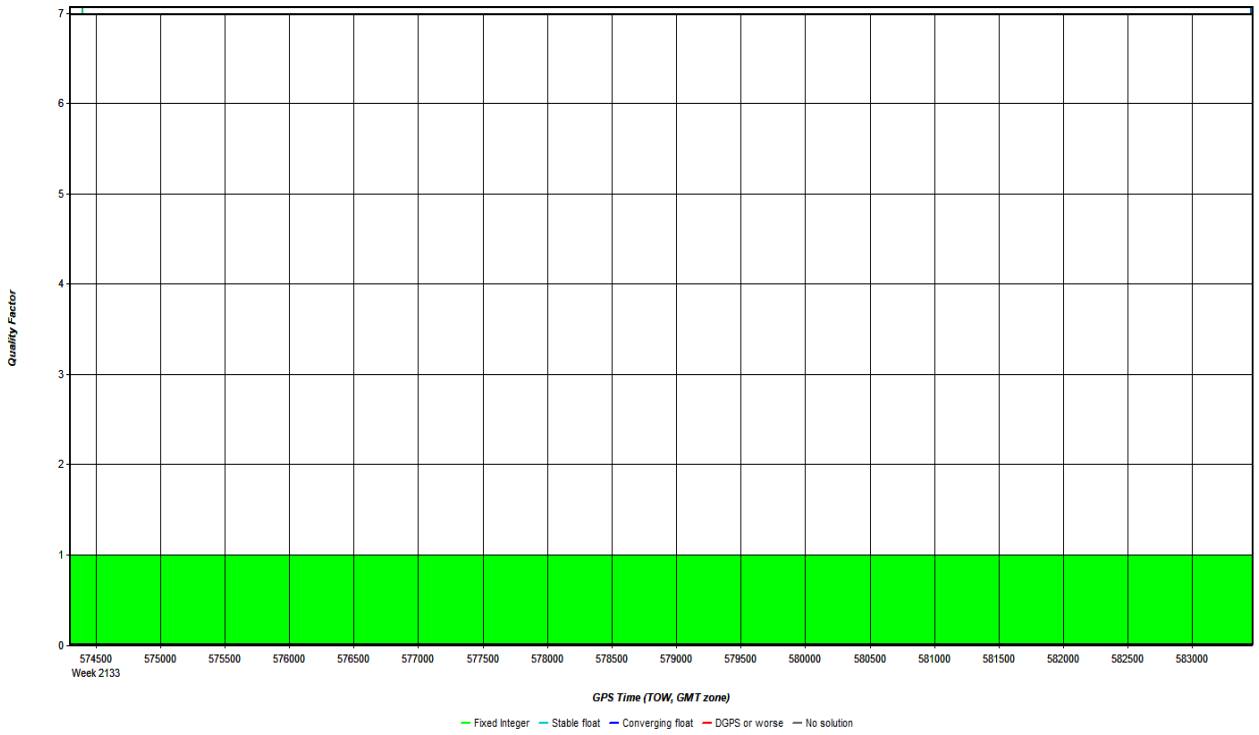
Smoothed Trajectory Information

Top View

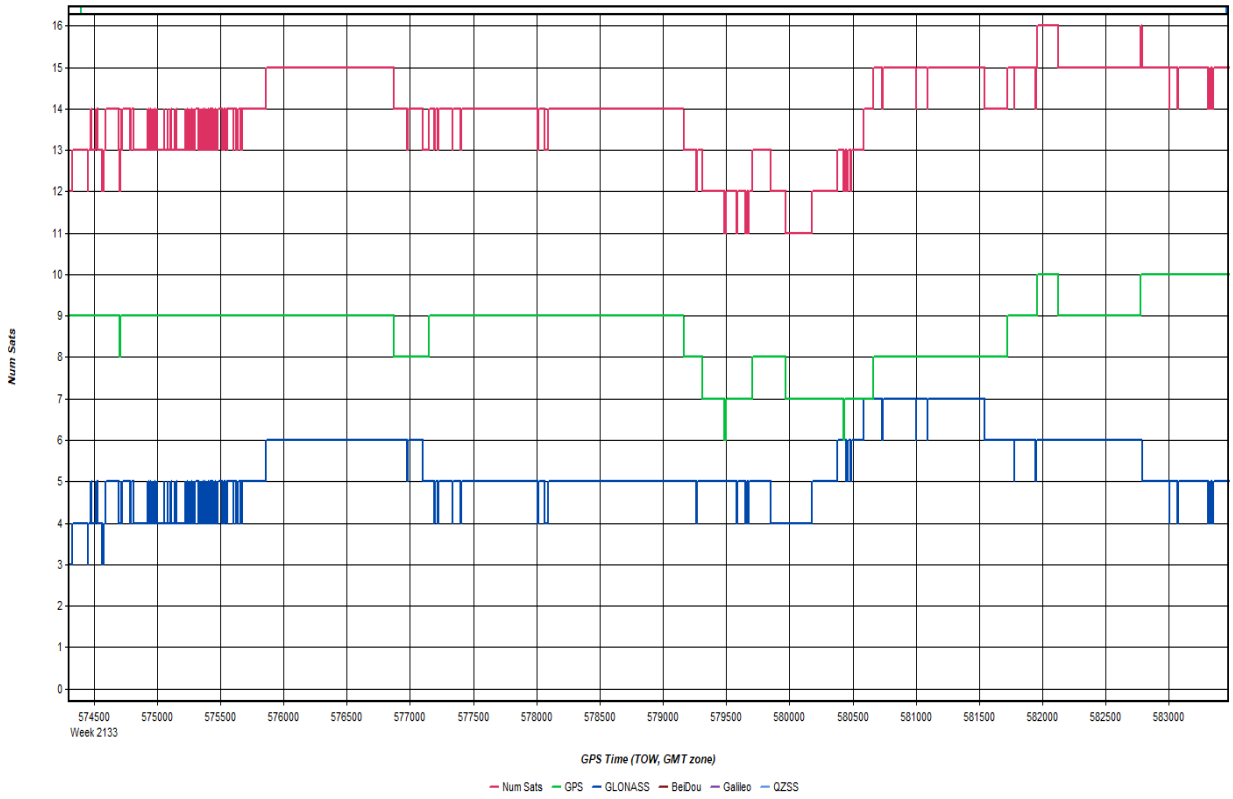


GNSS QC

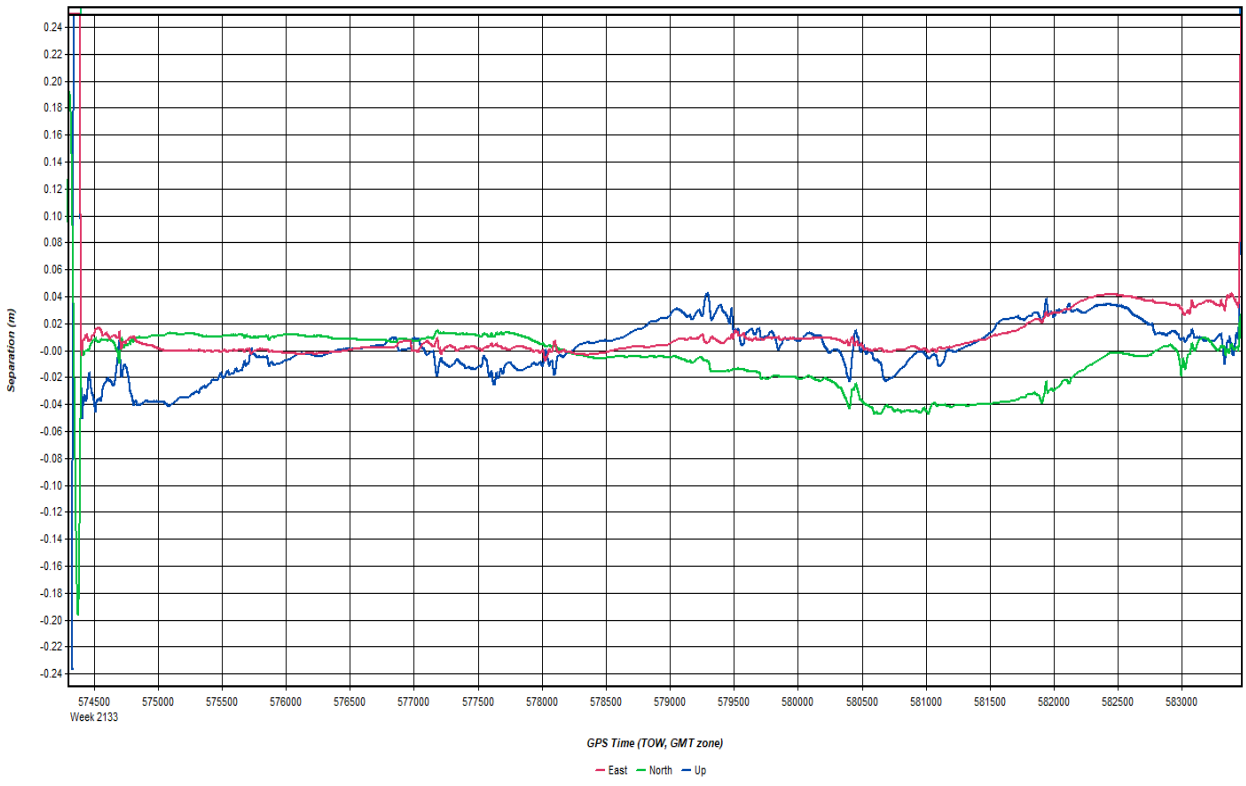
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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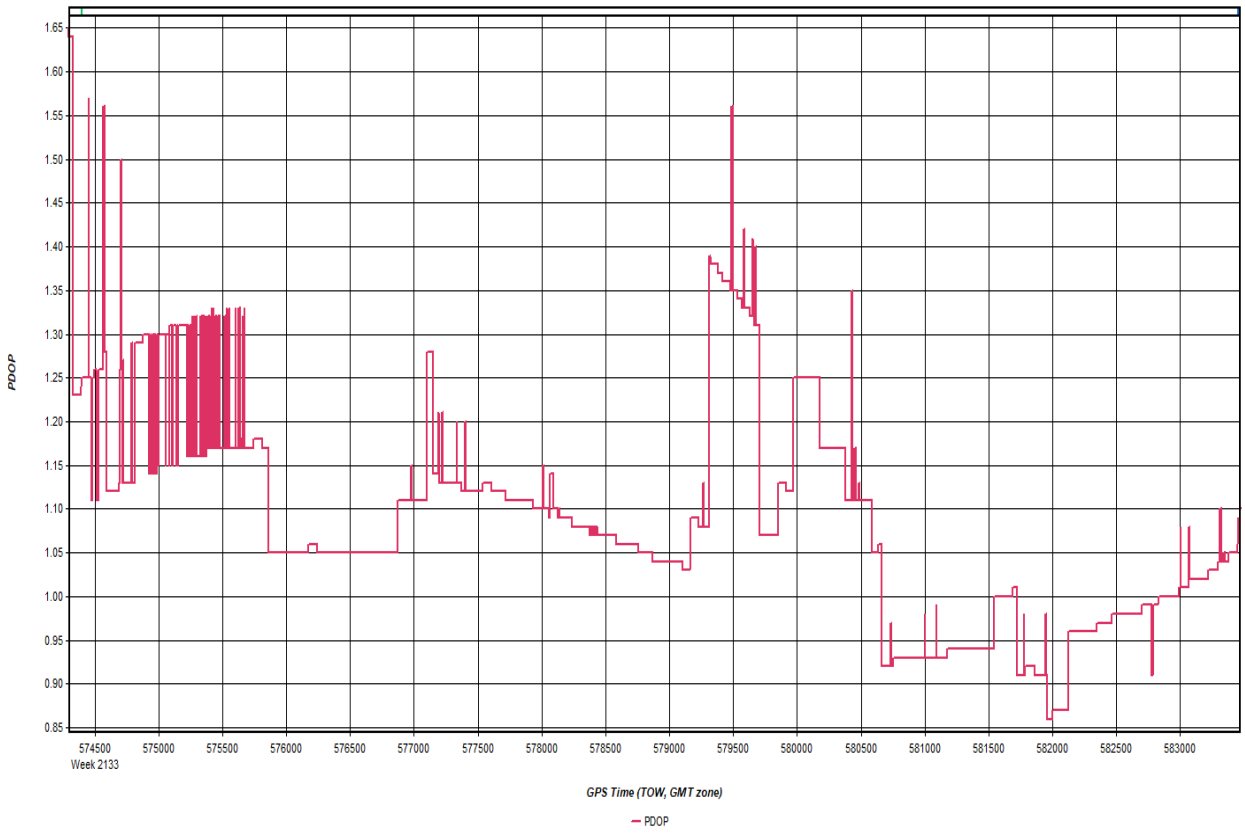
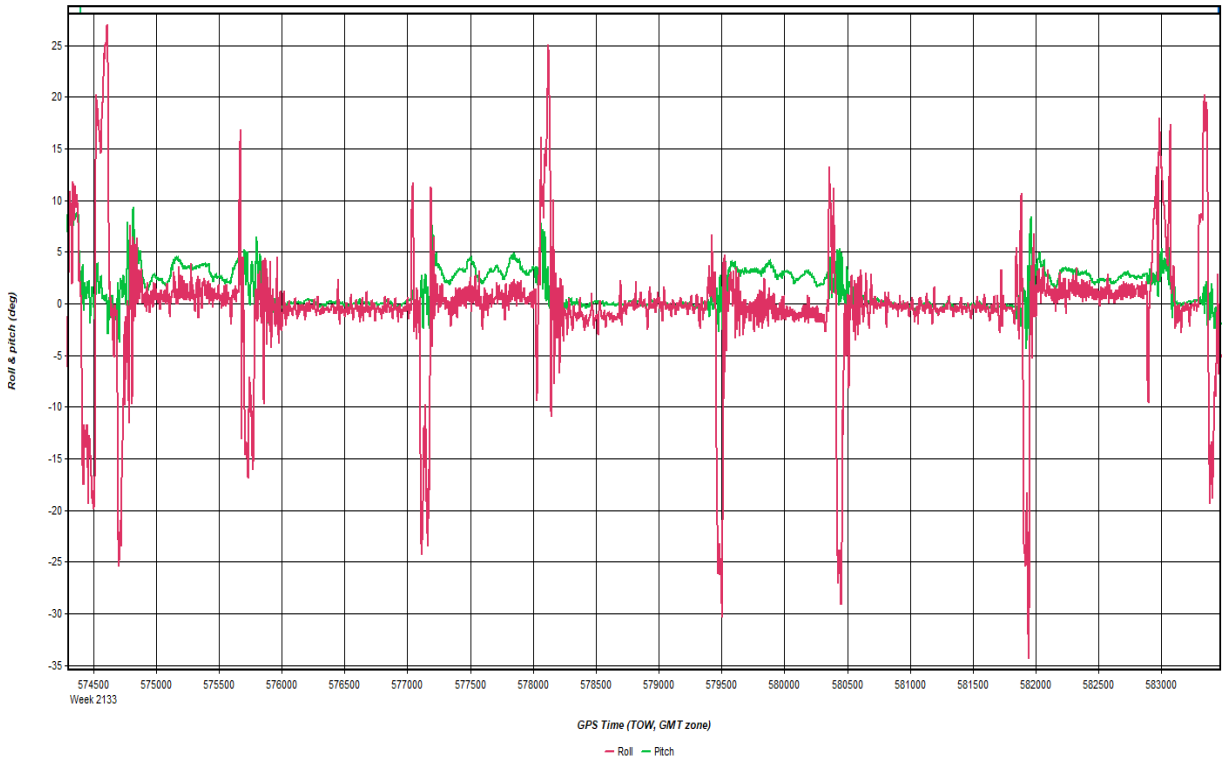


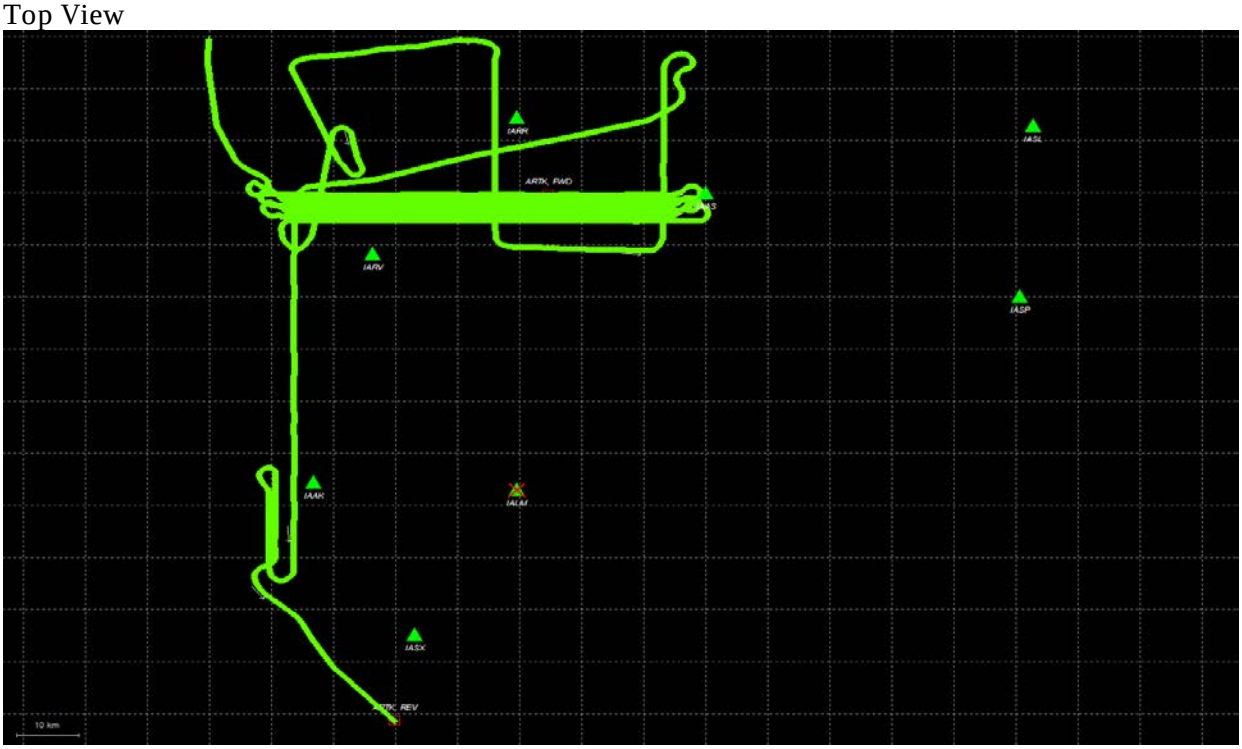
Roll & Pitch Plot



20201128-192627.docx QC Report - 06/22/2021 09:4:12

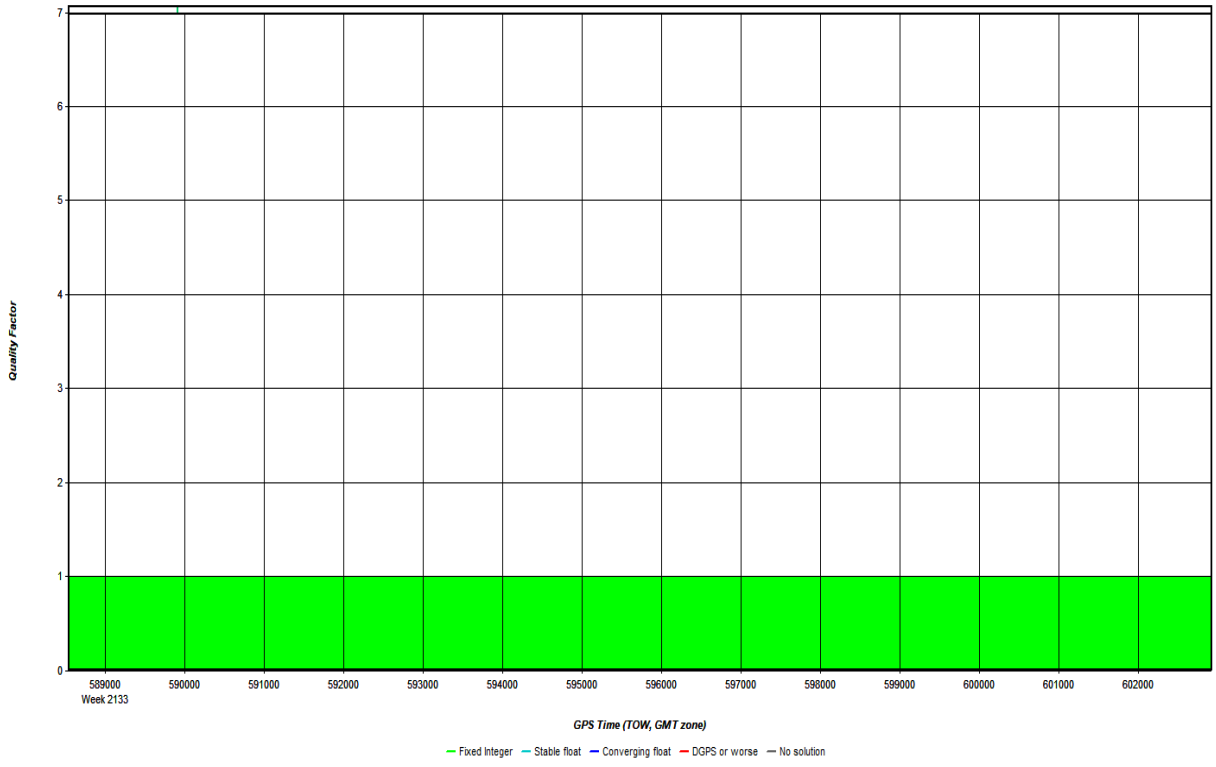
Smoothed Trajectory Information

Top View



GNSS QC

Quality Factor Plot



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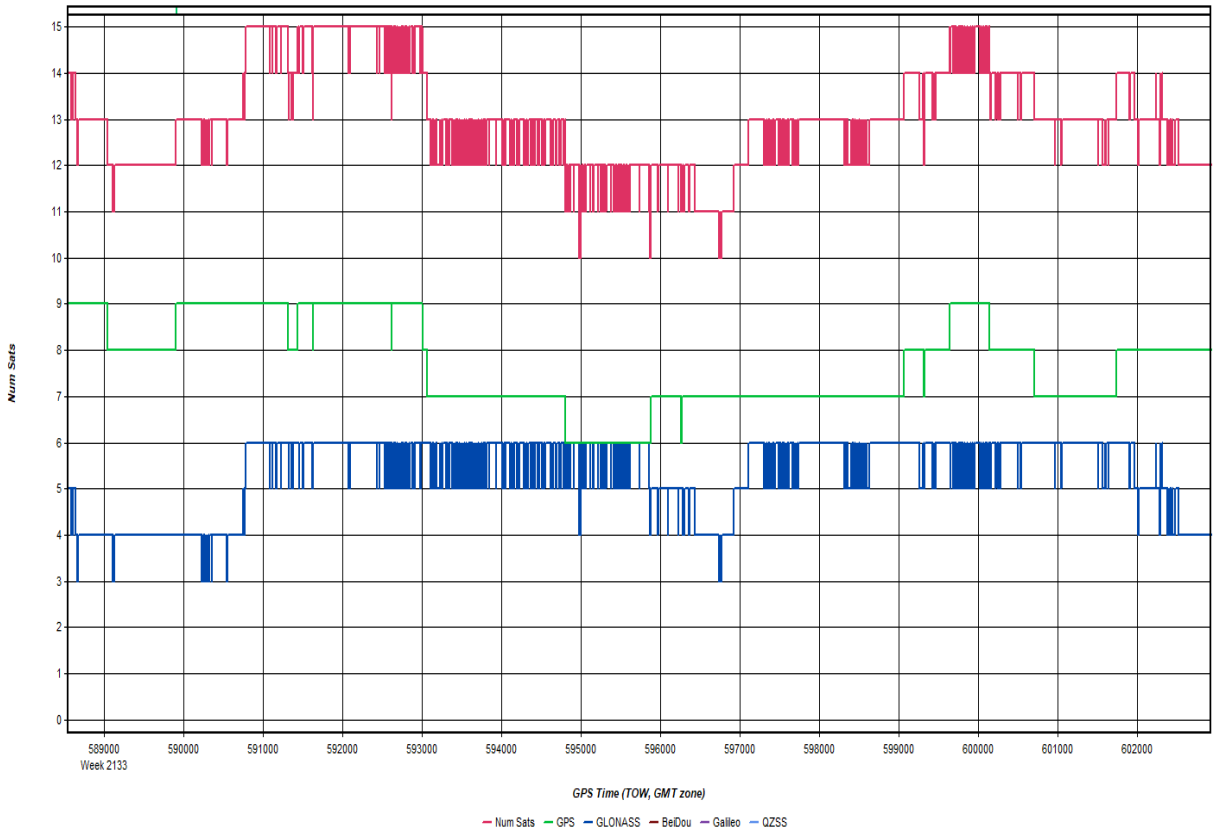
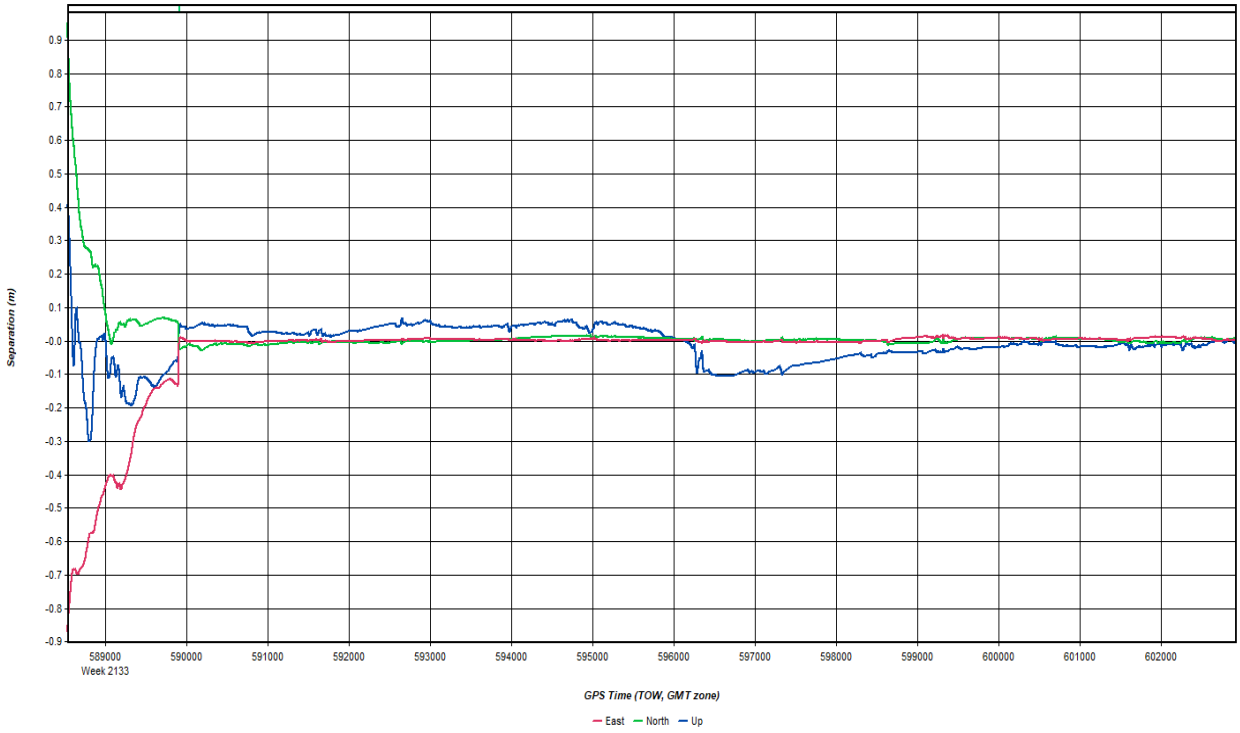


Forward/Reverse or Combined Separation Plot



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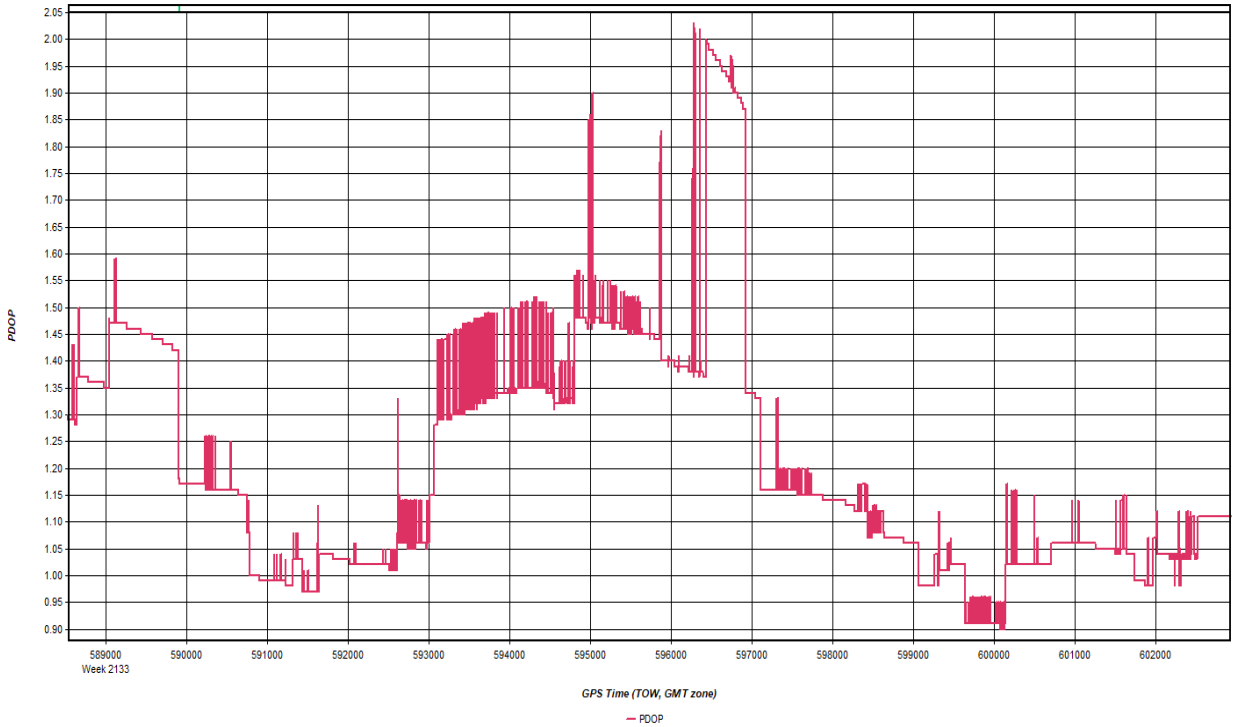
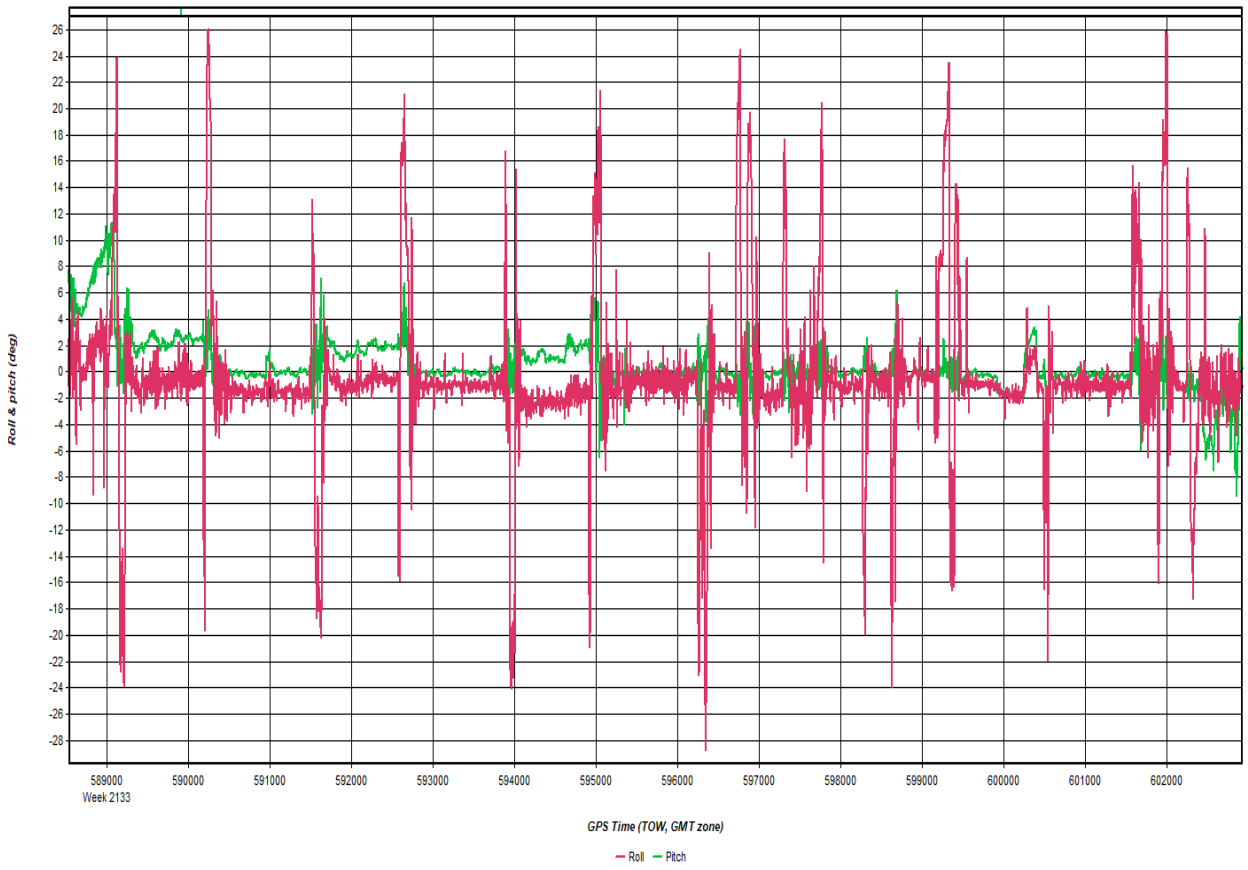


Roll & Pitch Plot



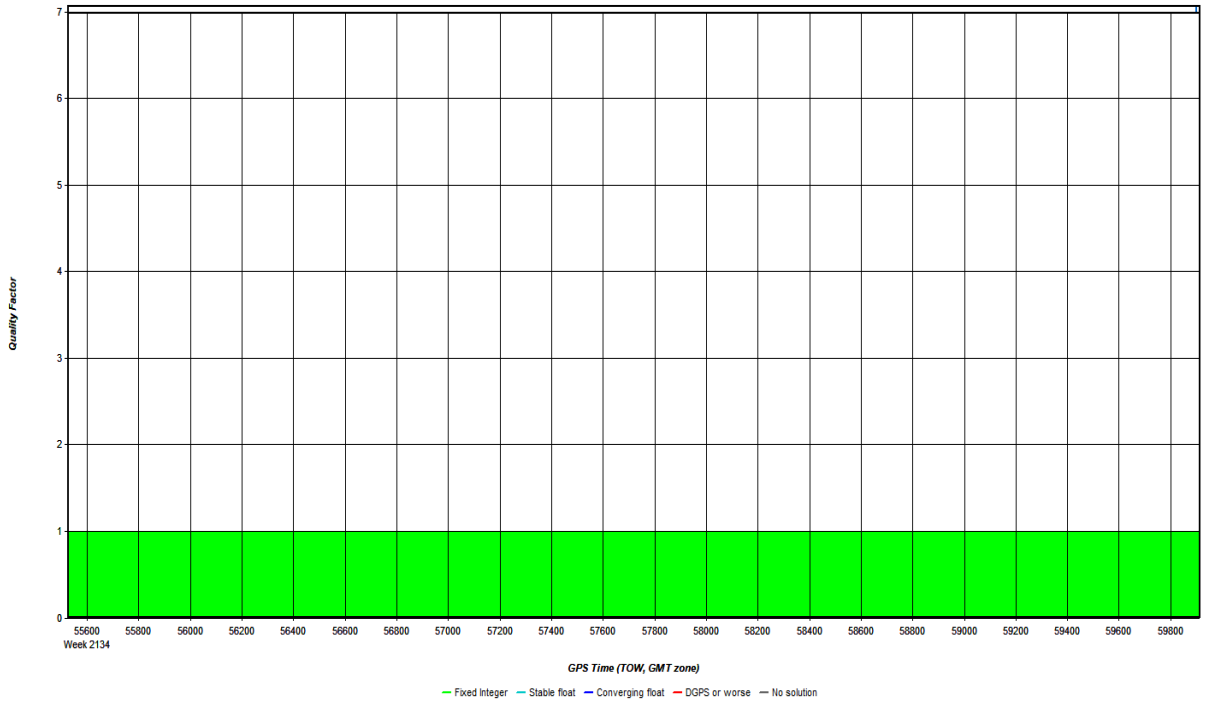
20201129-152321.docx QC Report - 06/22/2021 09:55:12

Smoothed Trajectory Information

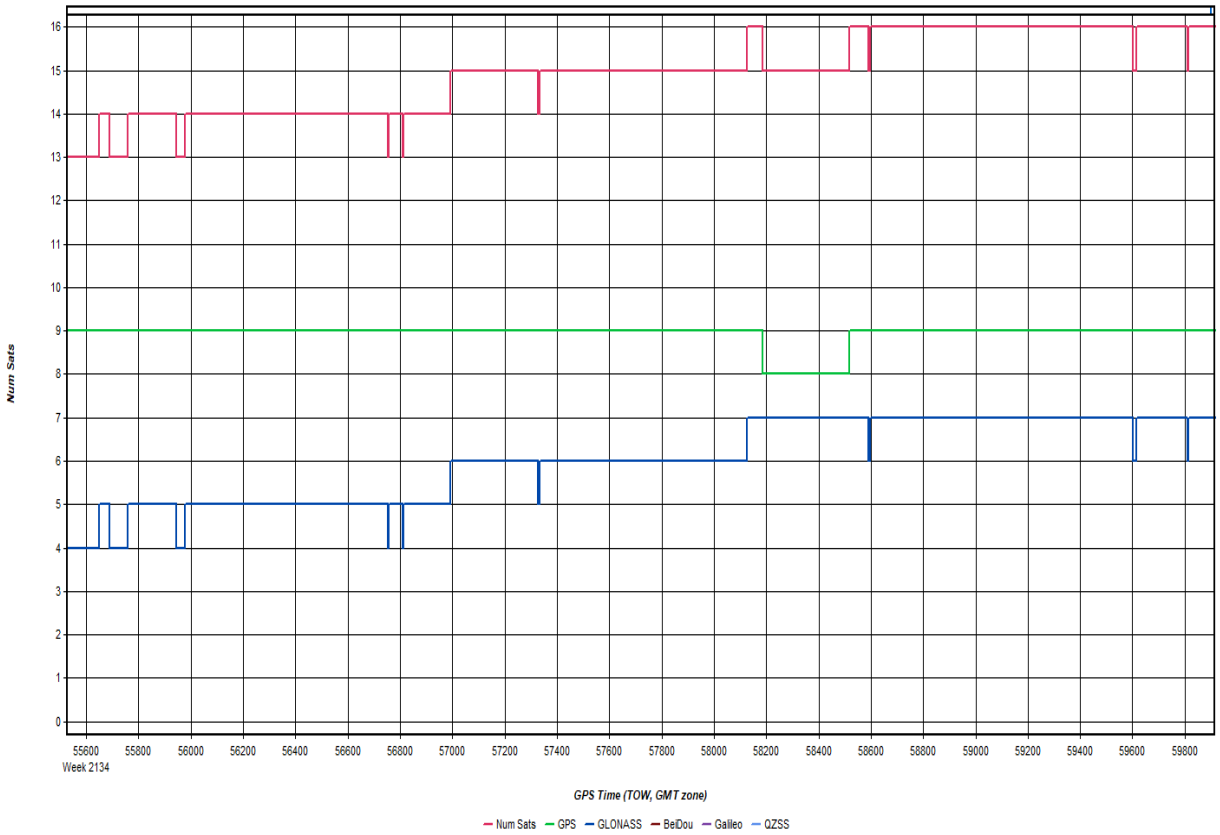
Top View

GNSS QC

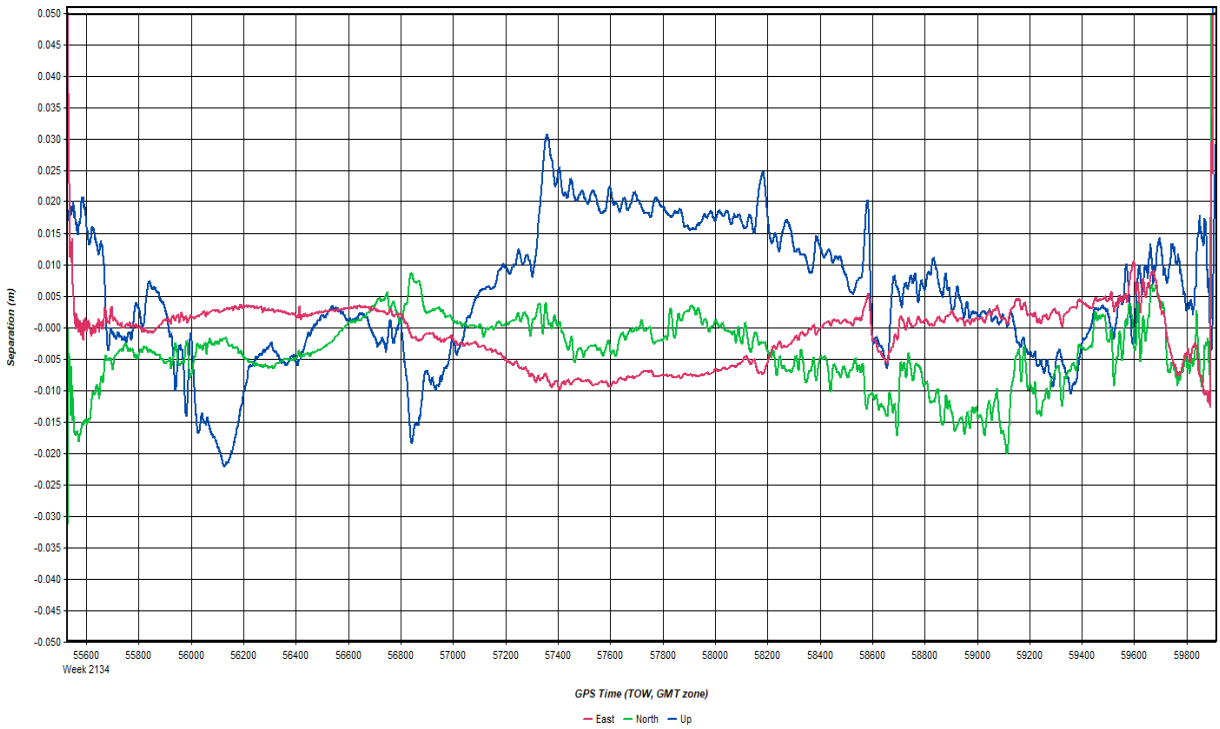
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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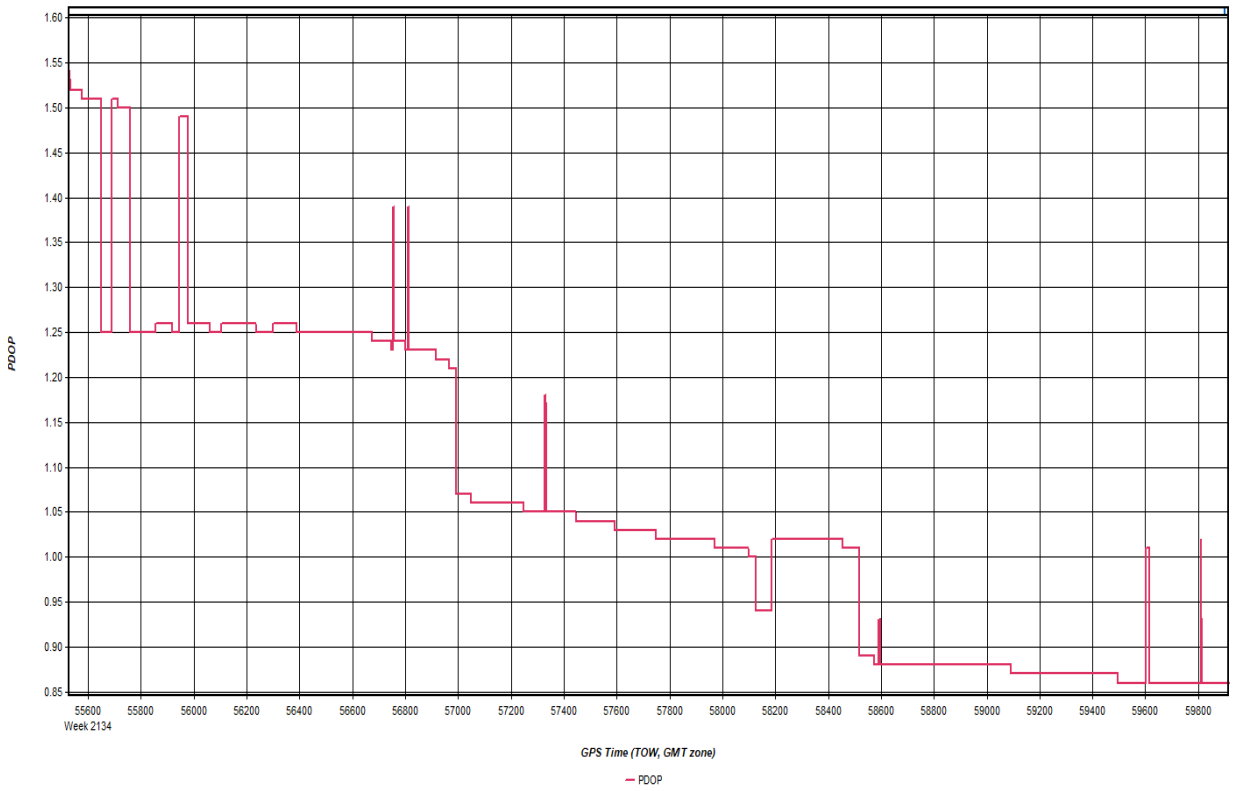
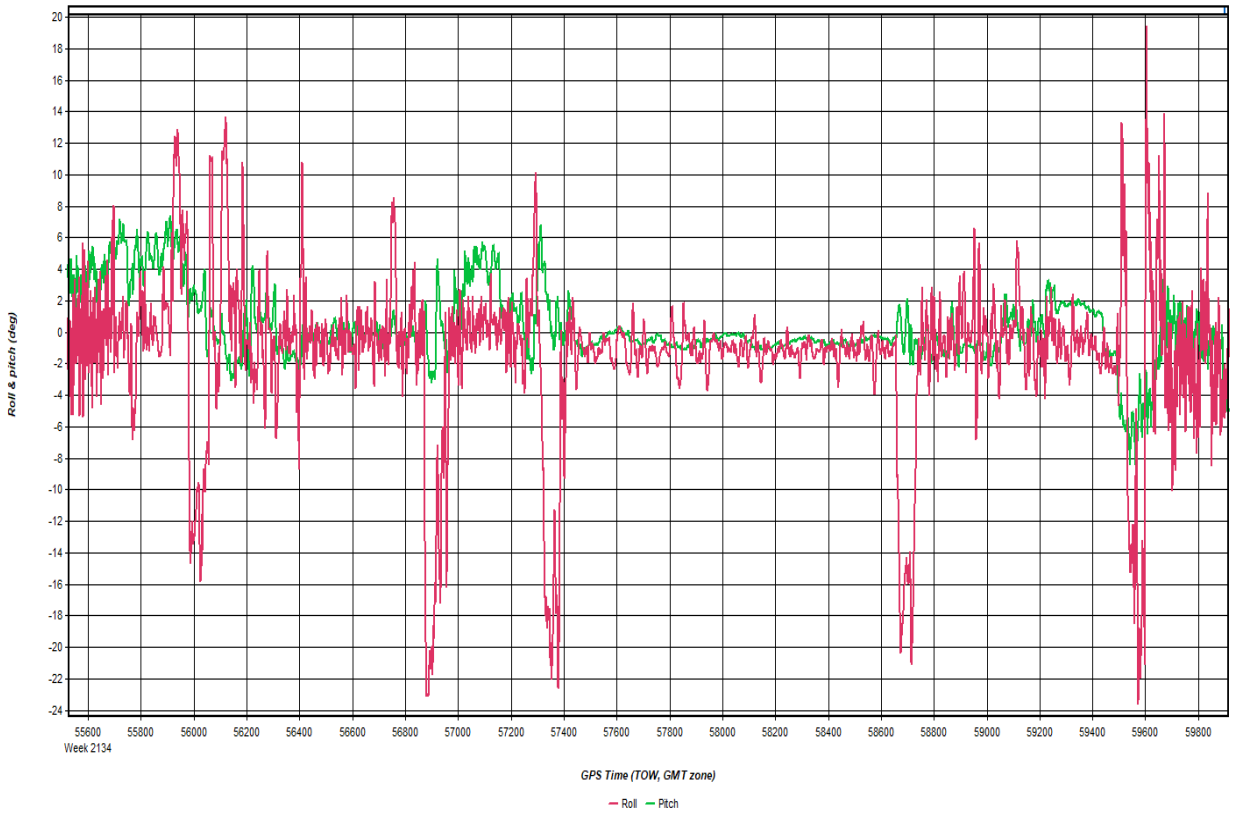


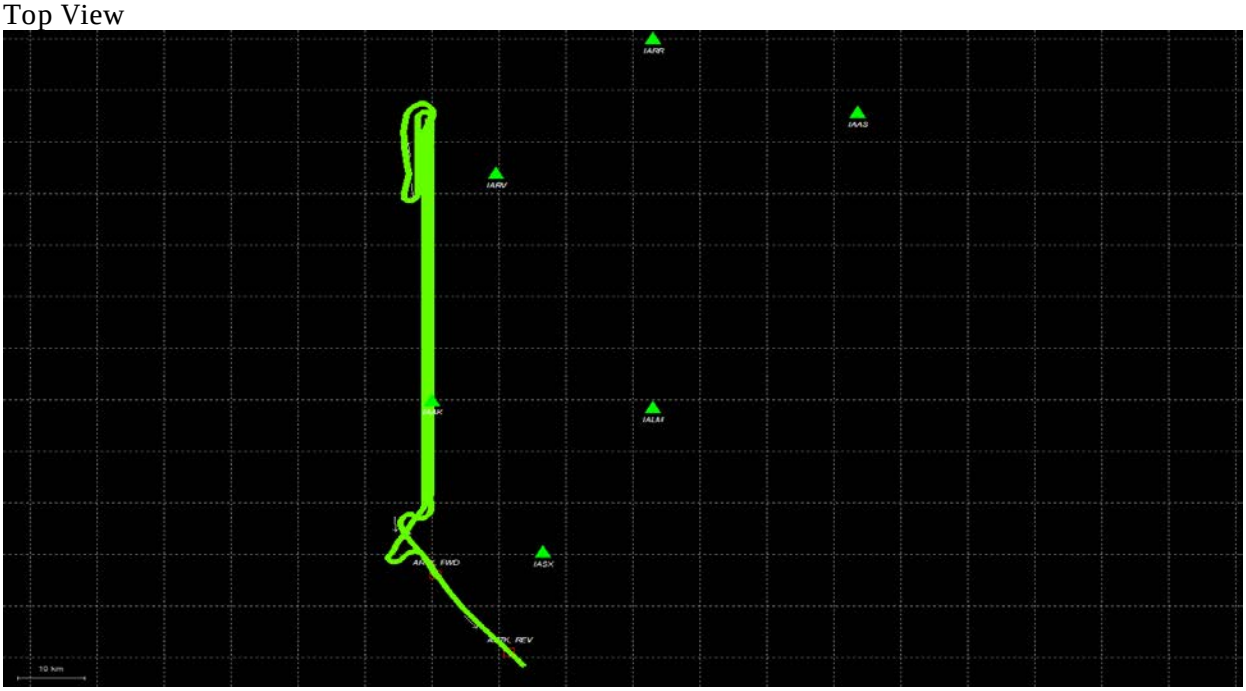
Roll & Pitch Plot



20201130_001852.docx QC Report - 06/22/2021 09:58:40

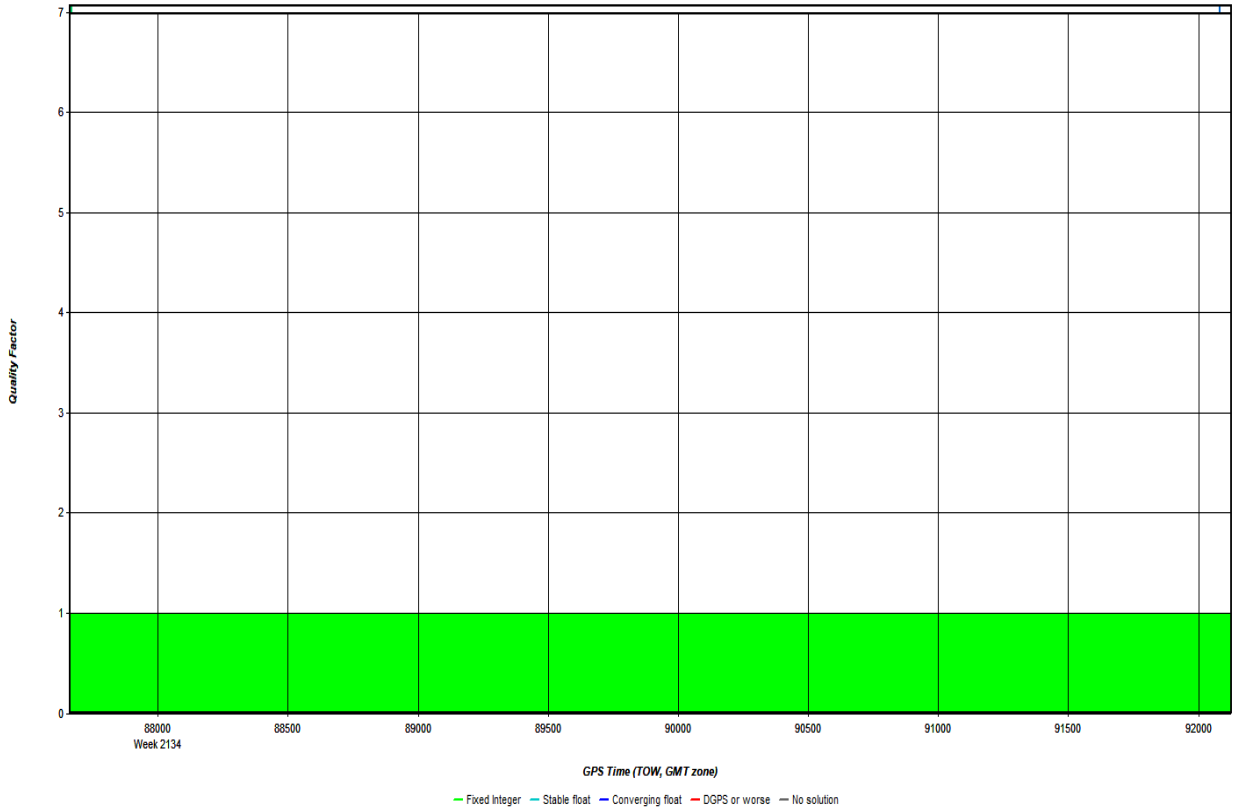
Smoothed Trajectory Information

Top View

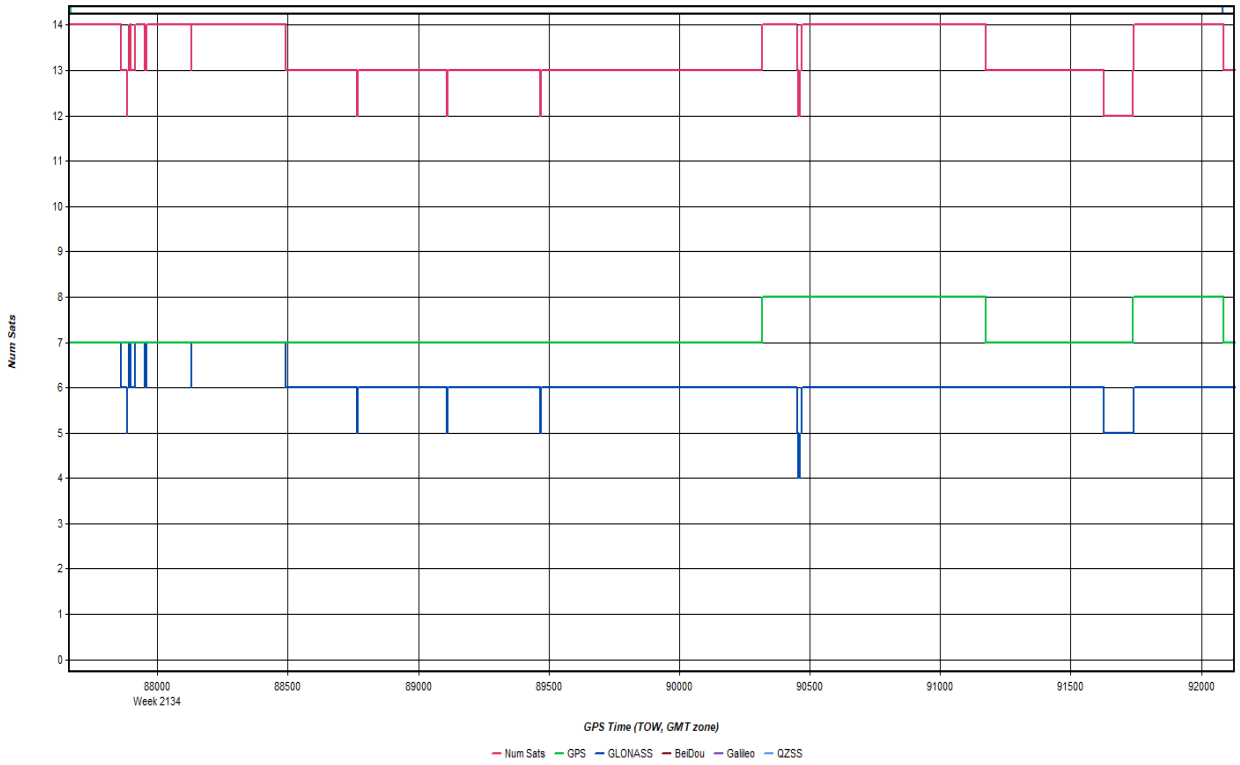


GNSS QC

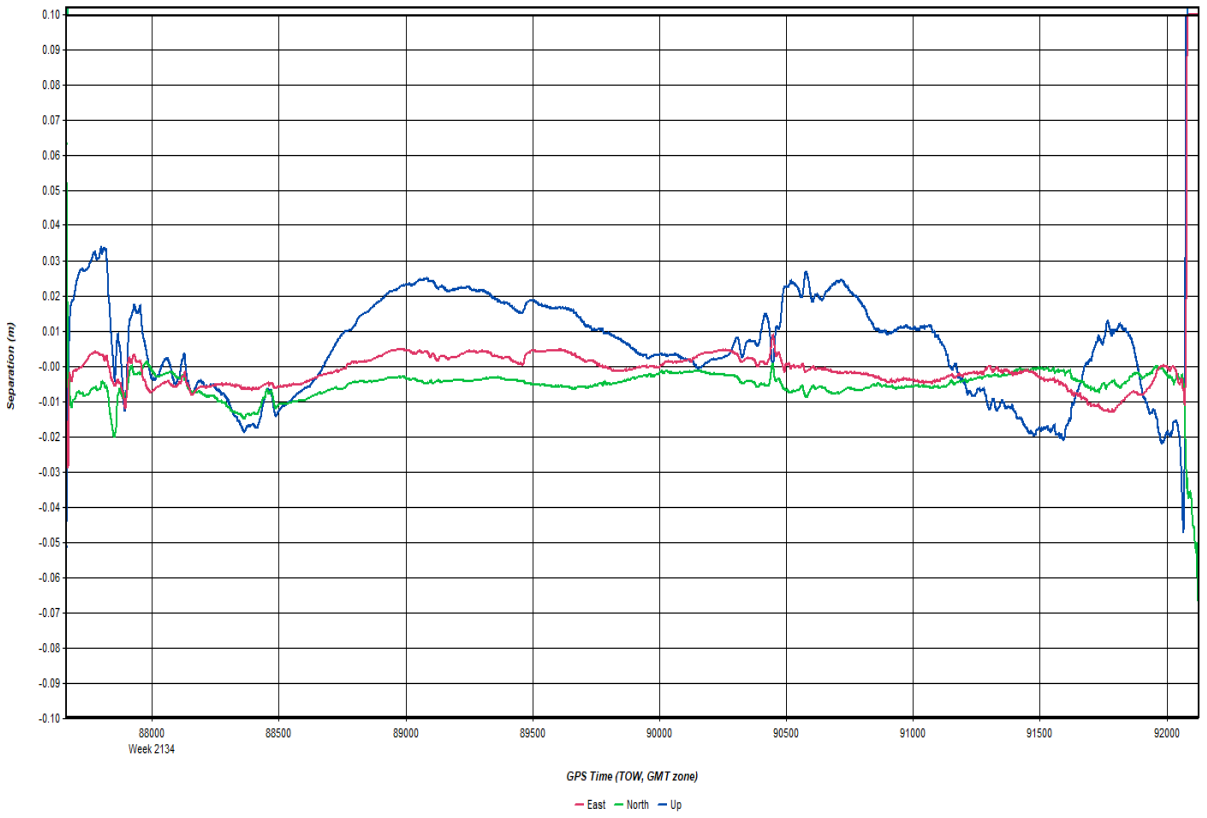
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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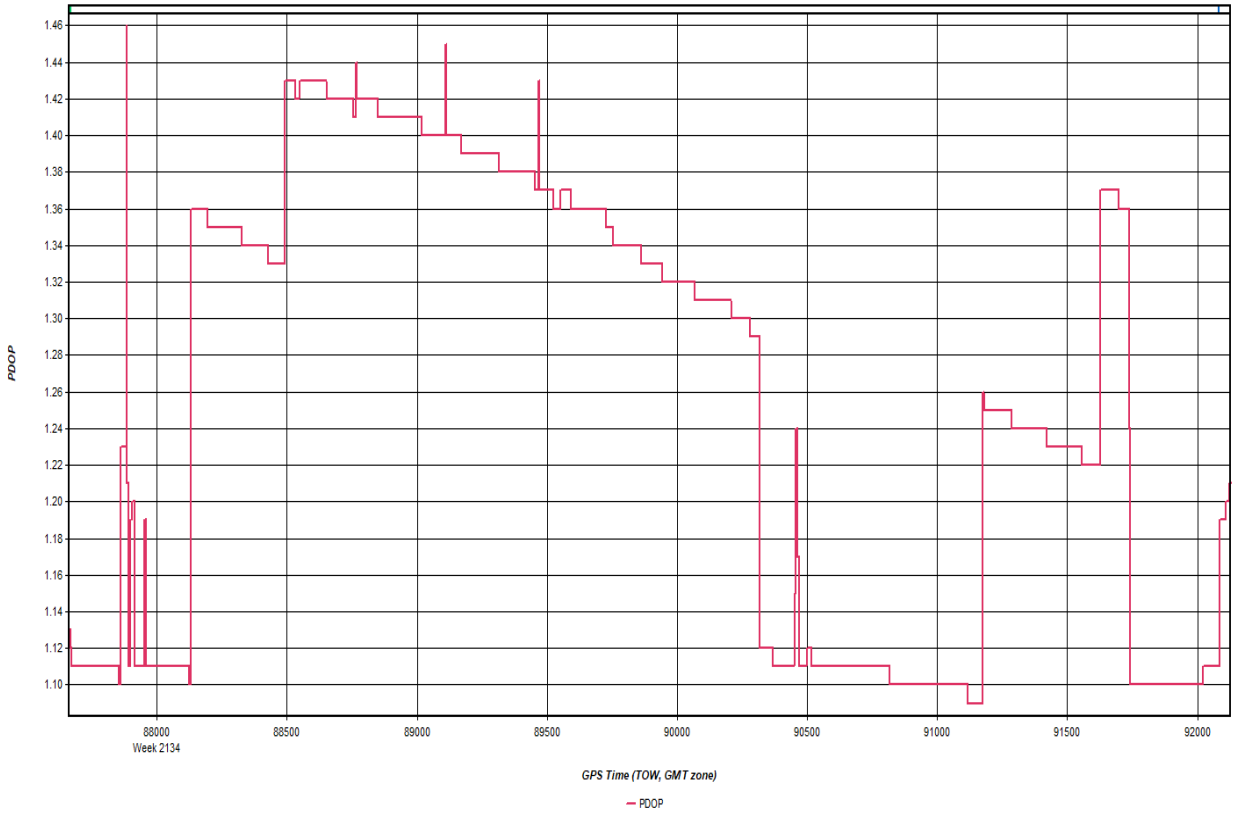
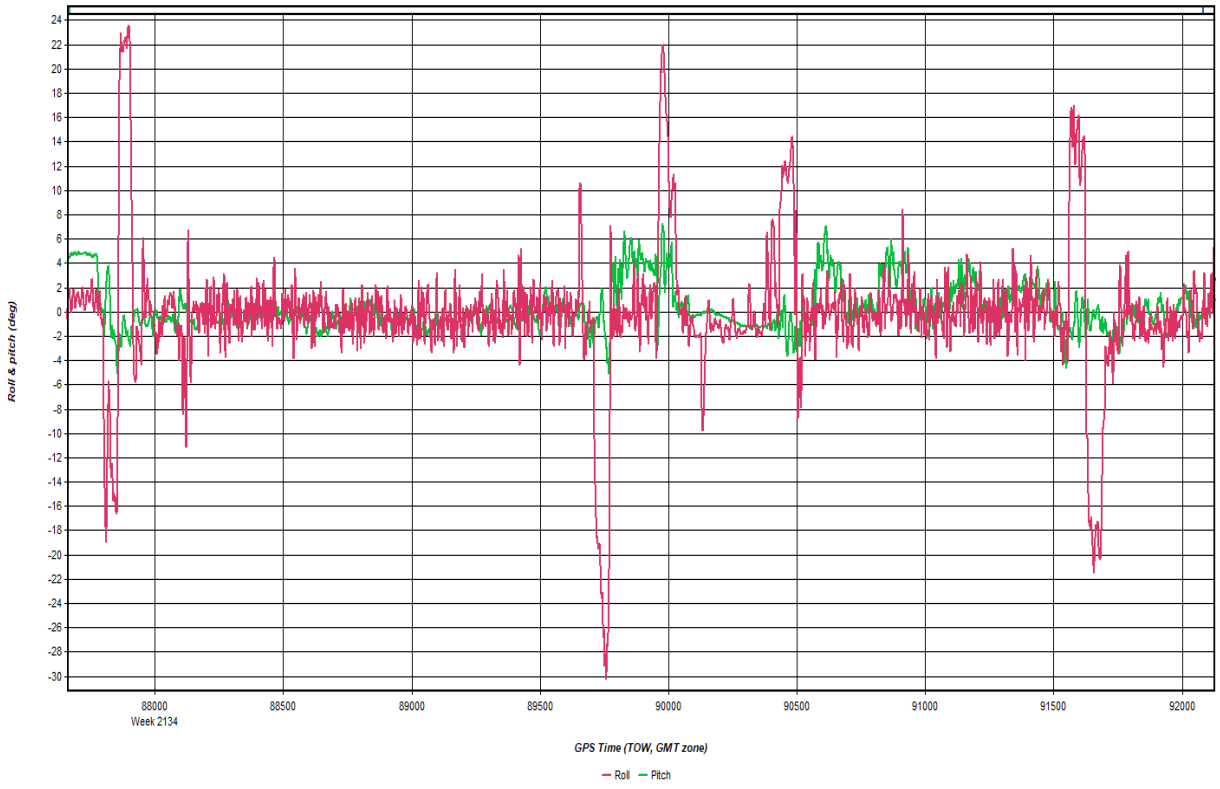


Roll & Pitch Plot



20201130_153954.docx QC Report - 06/22/2021 10:02:16

Smoothed Trajectory Information

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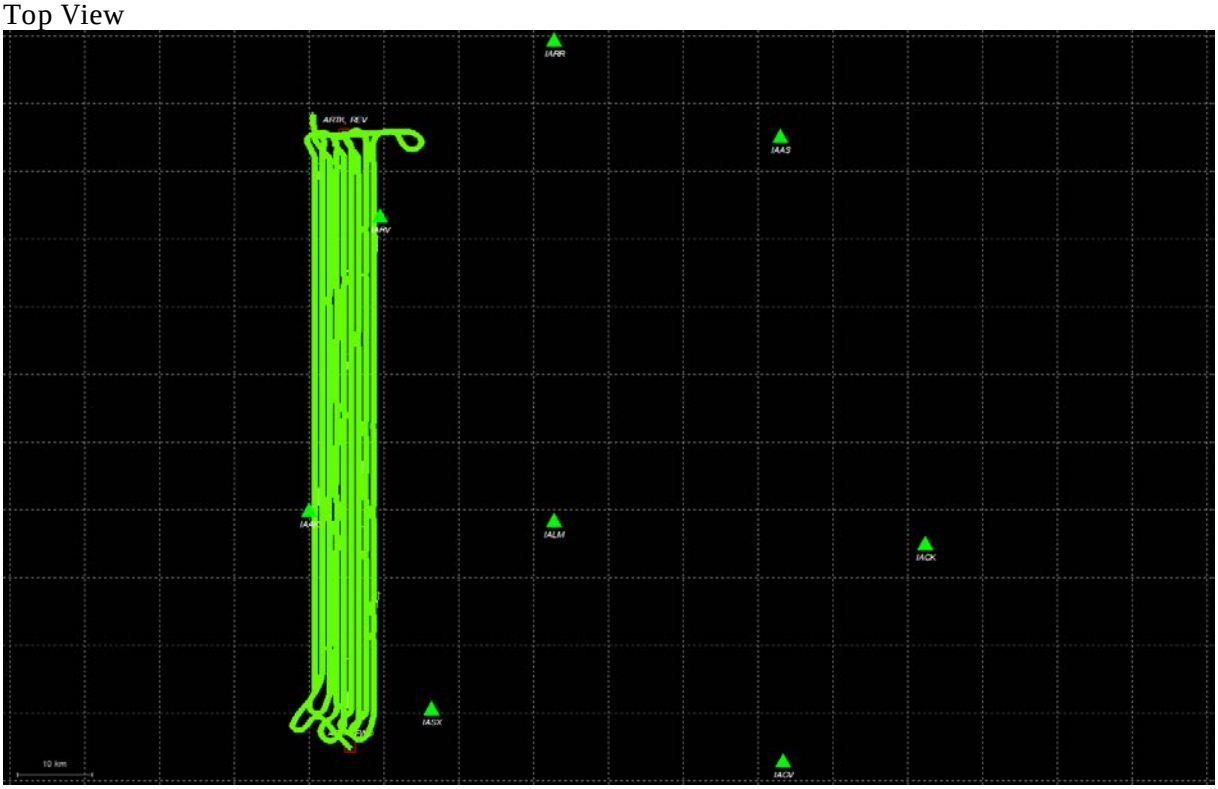
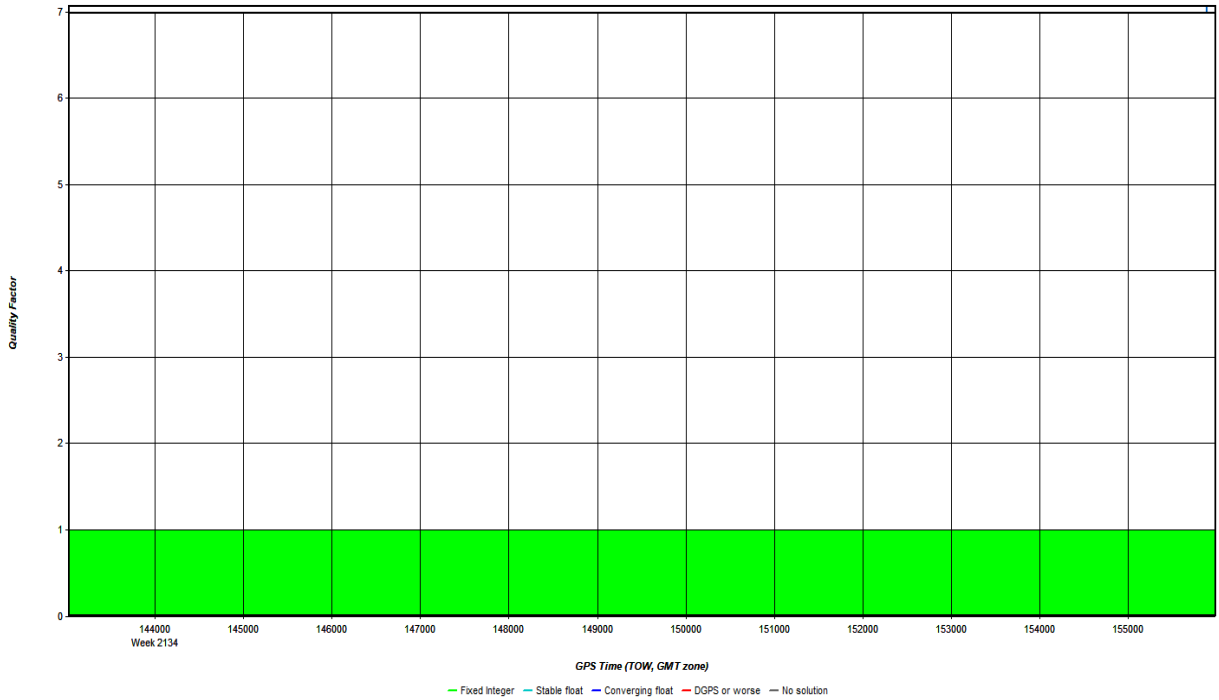
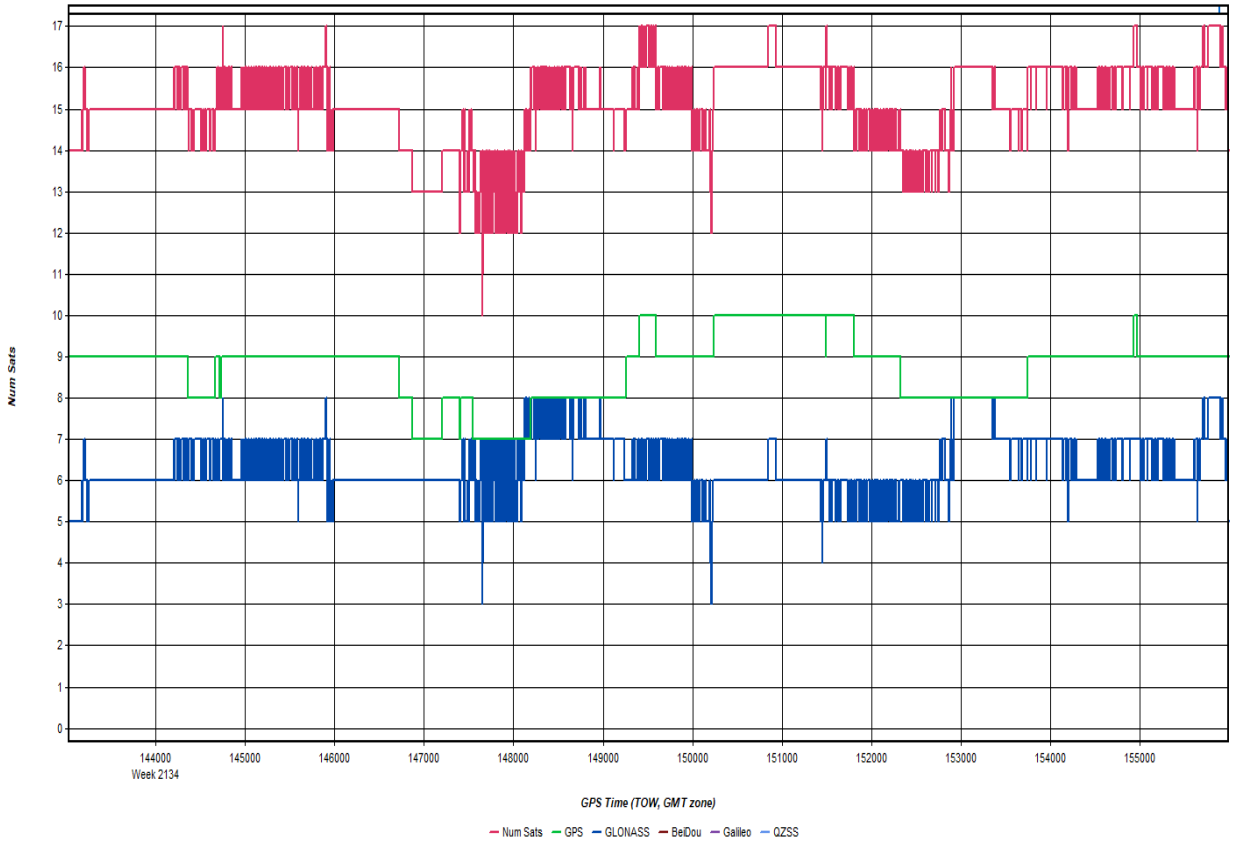


GNSS QC

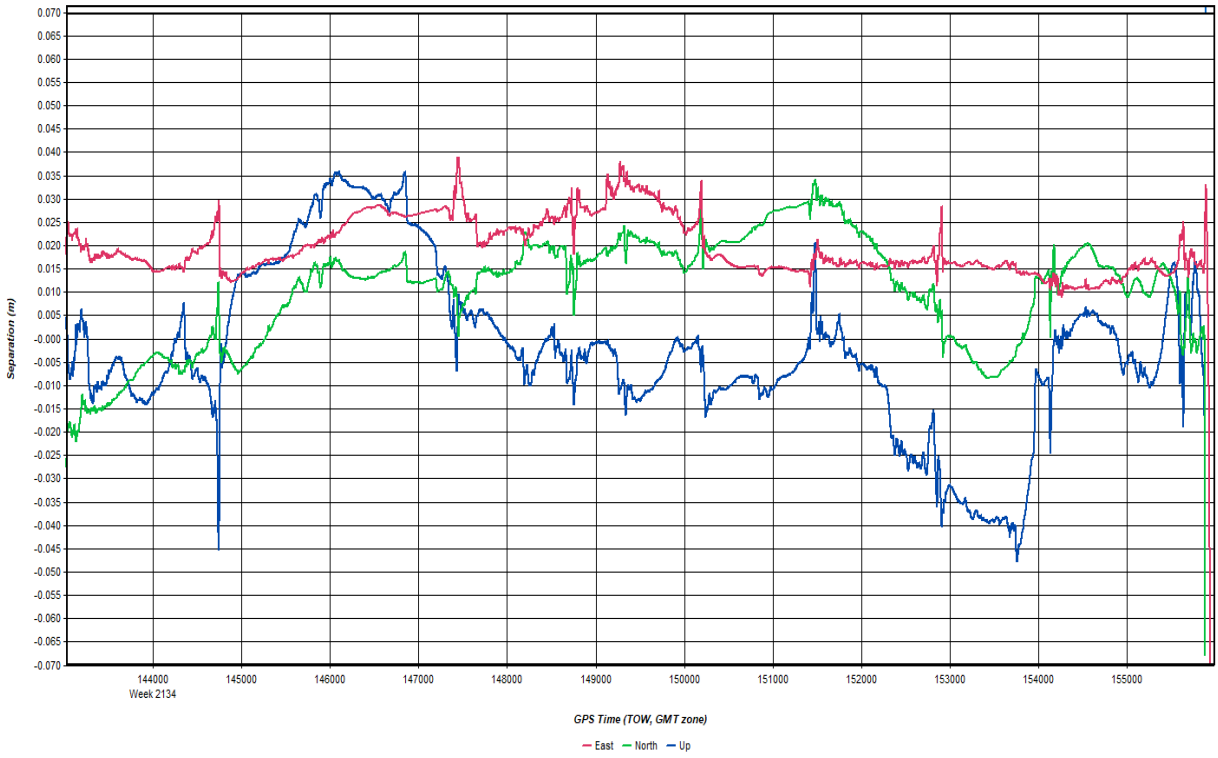
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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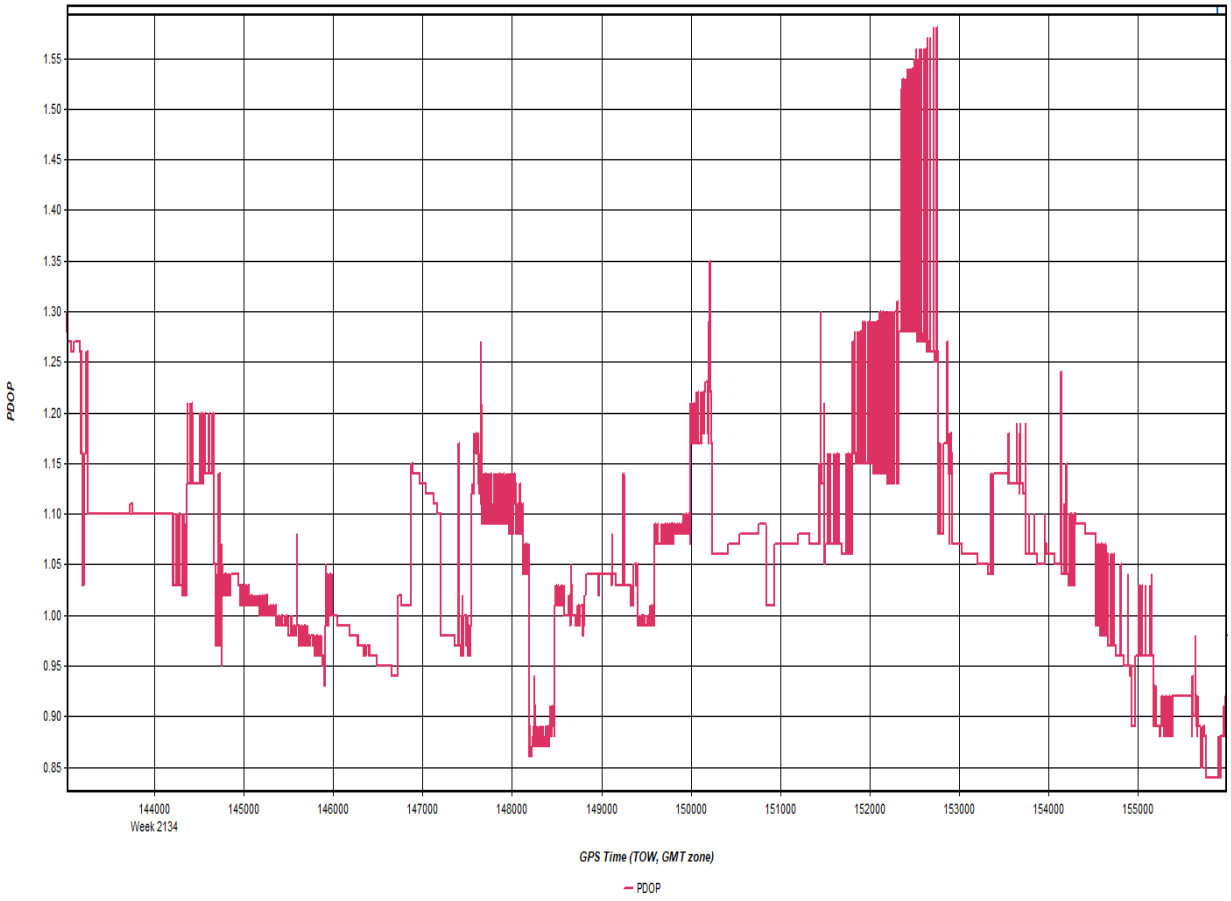
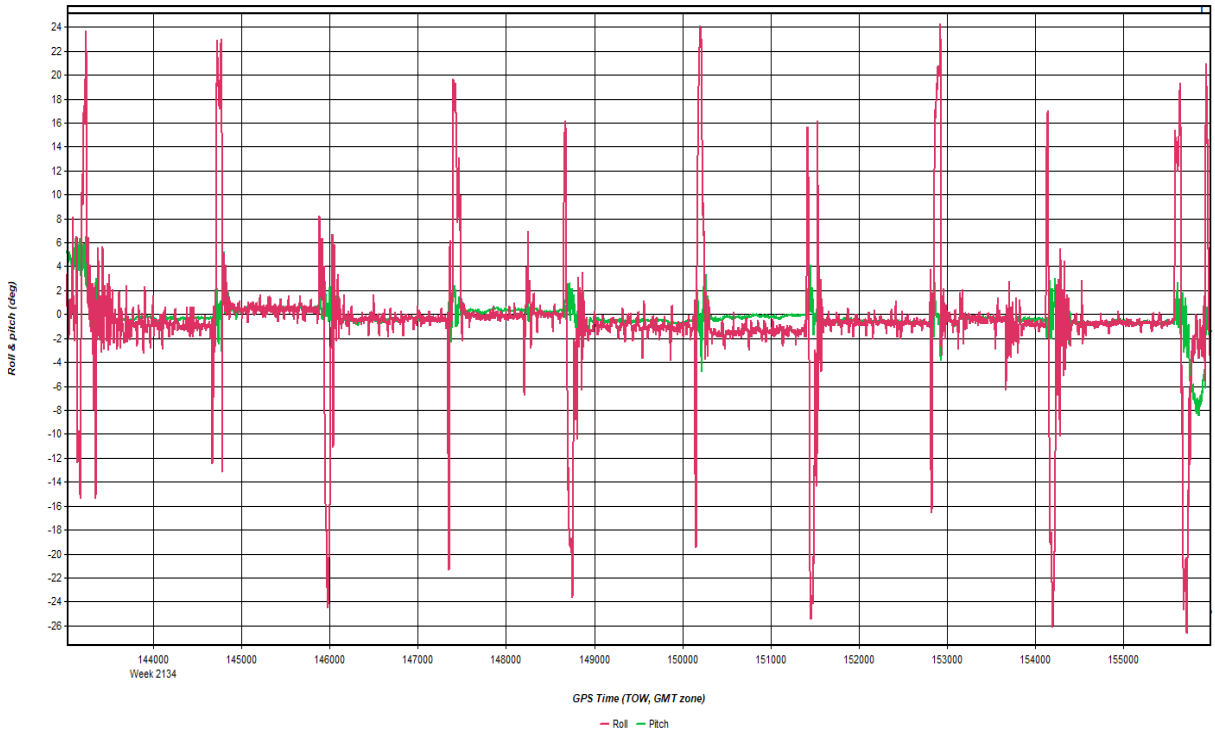


Roll & Pitch Plot



20201130_195930.docx QC Report - 06/22/2021 10:05:16

Smoothed Trajectory Information

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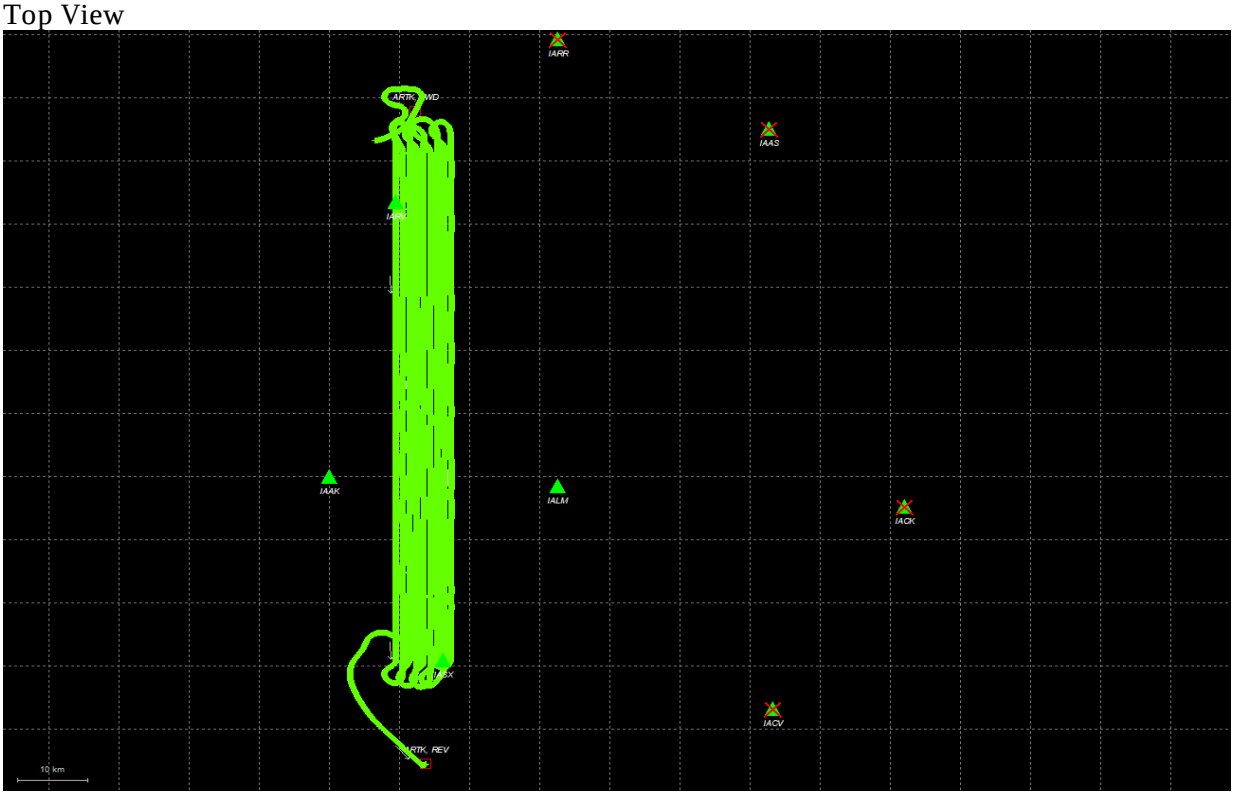
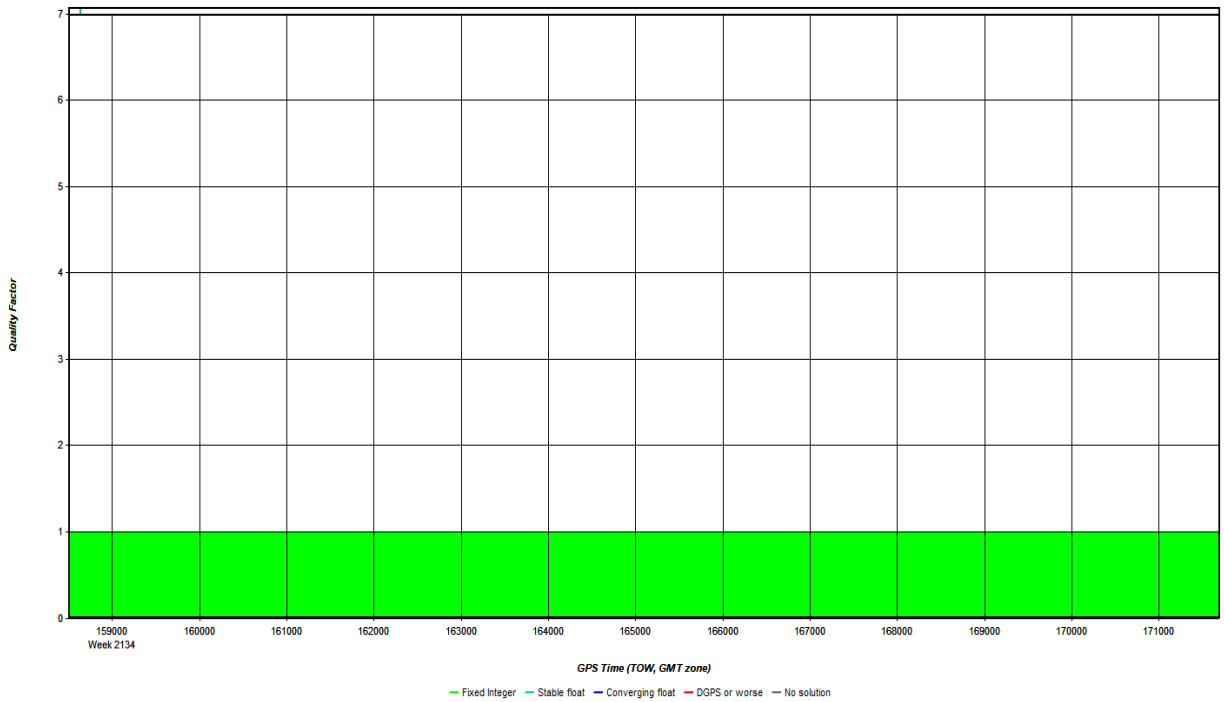
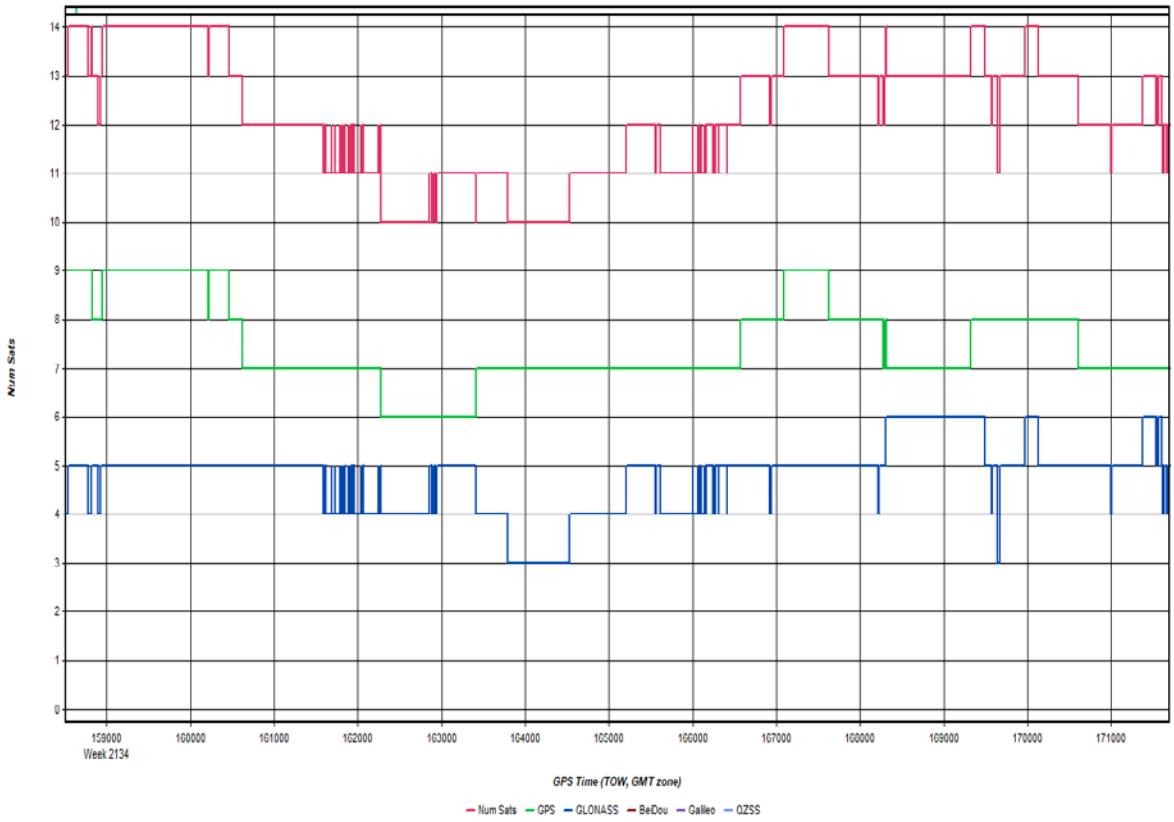


GNSS QC

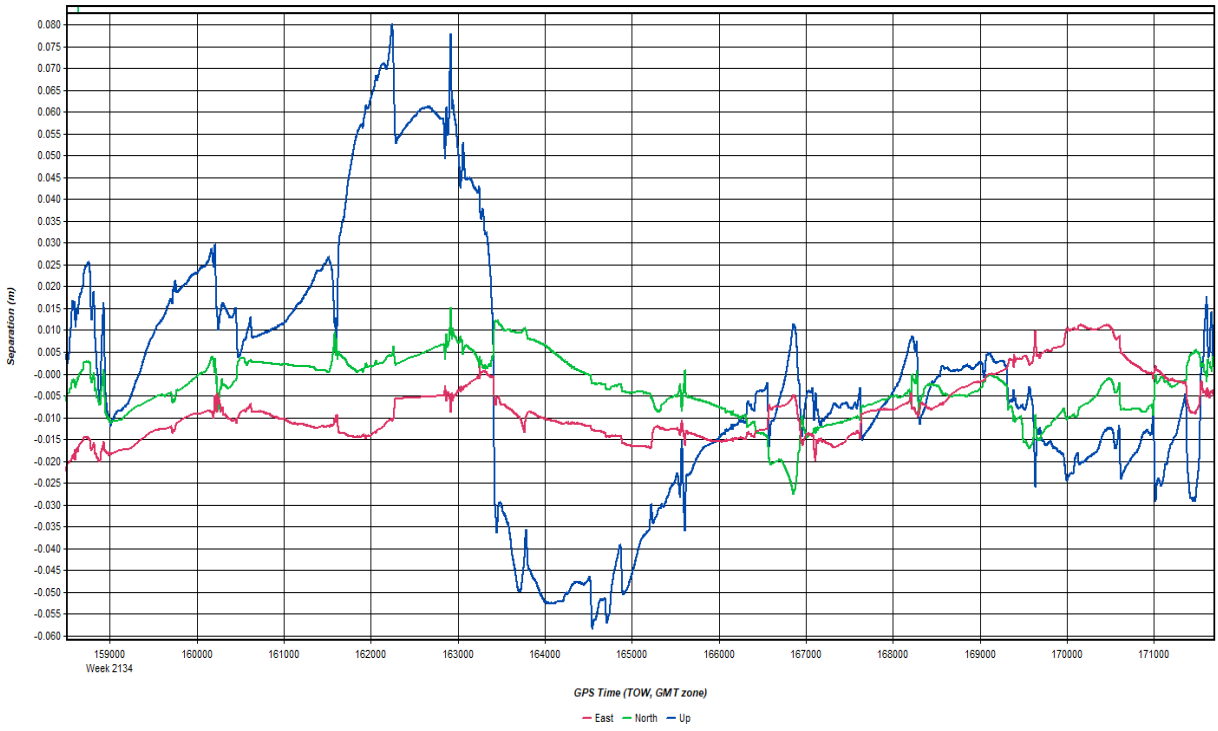
Quality Factor Plot



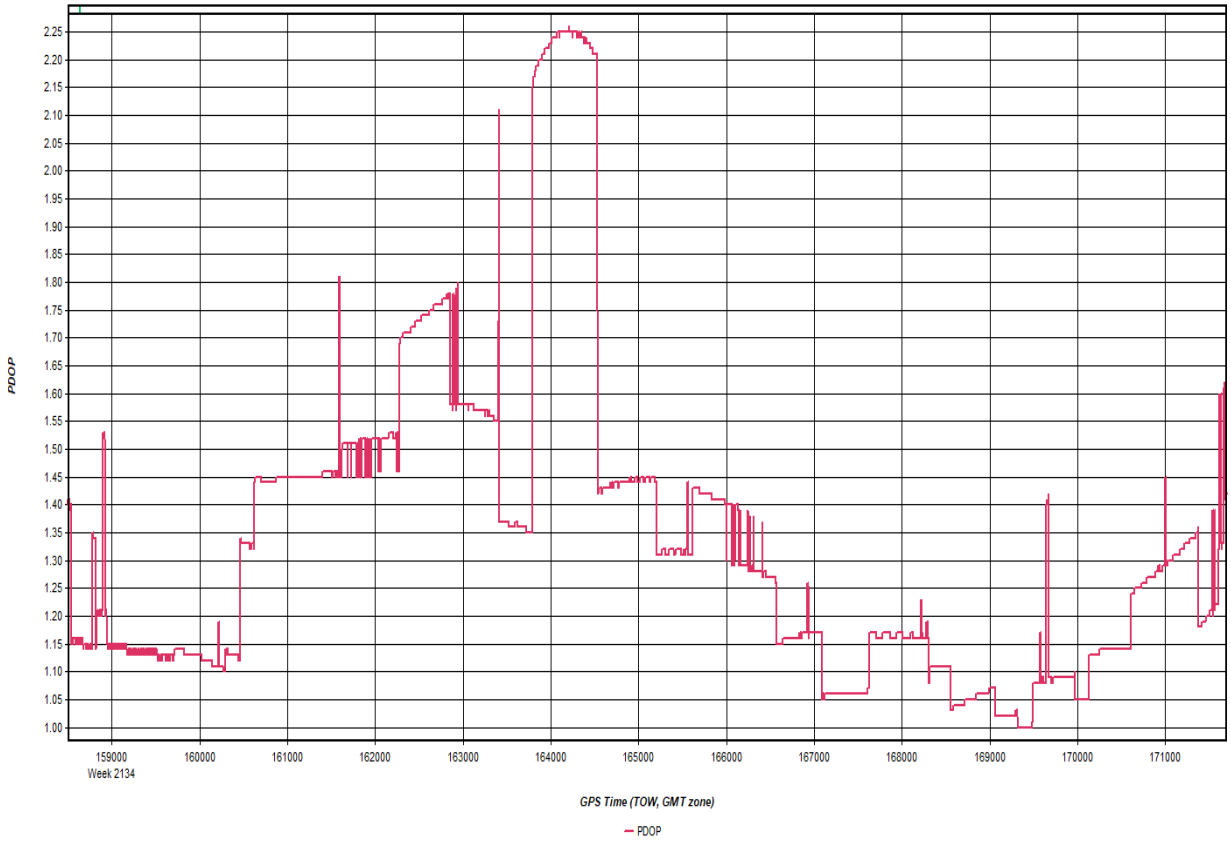
Number of Satellites Plot



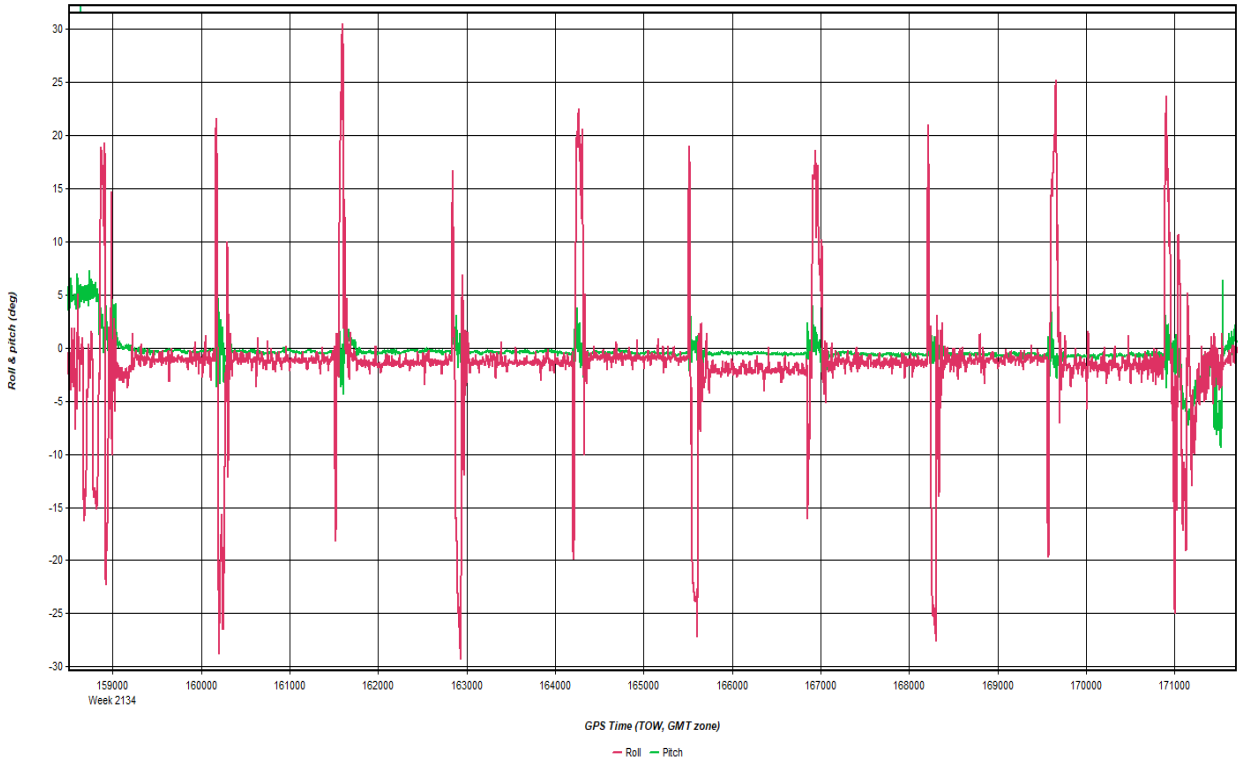
Forward/Reverse or Combined Separation Plot



PDOP Plot



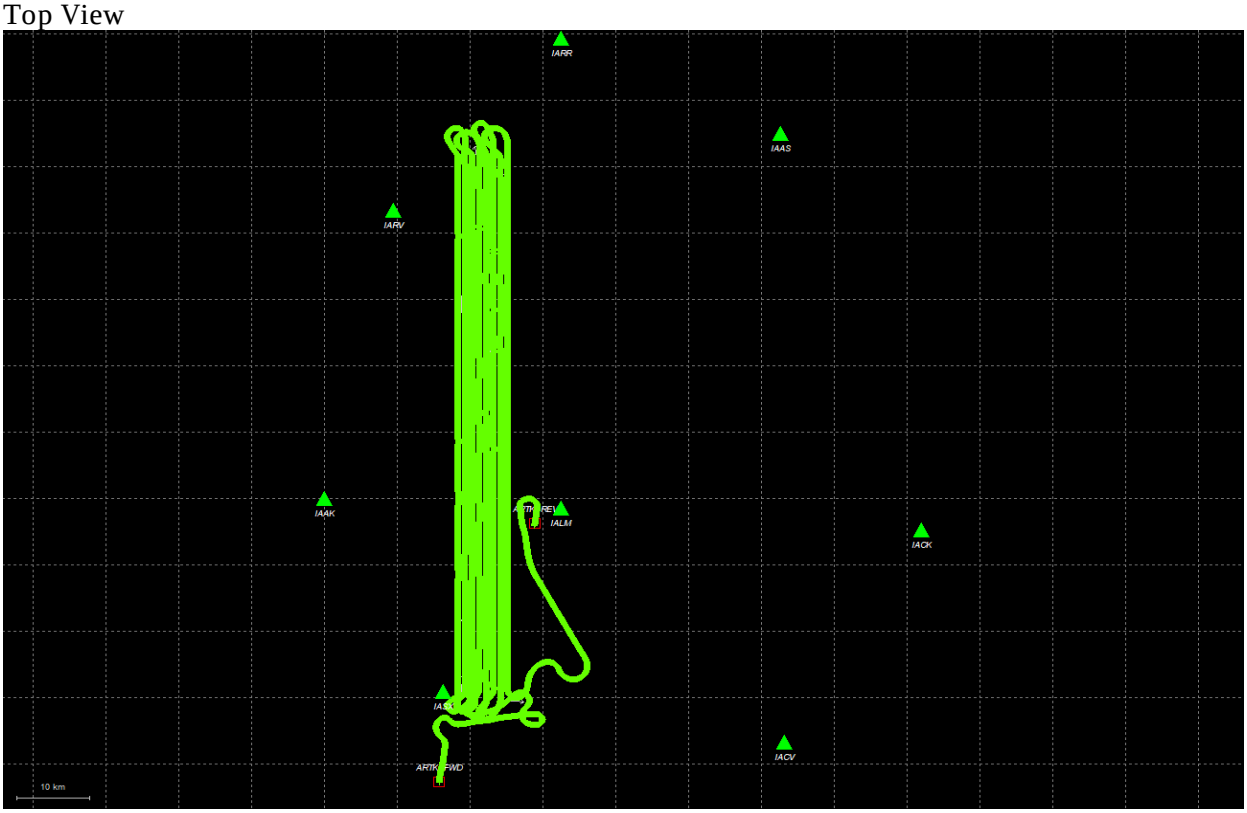
Roll & Pitch Plot



20201201_152944.docx QC Report - 06/22/2021 10:10:16

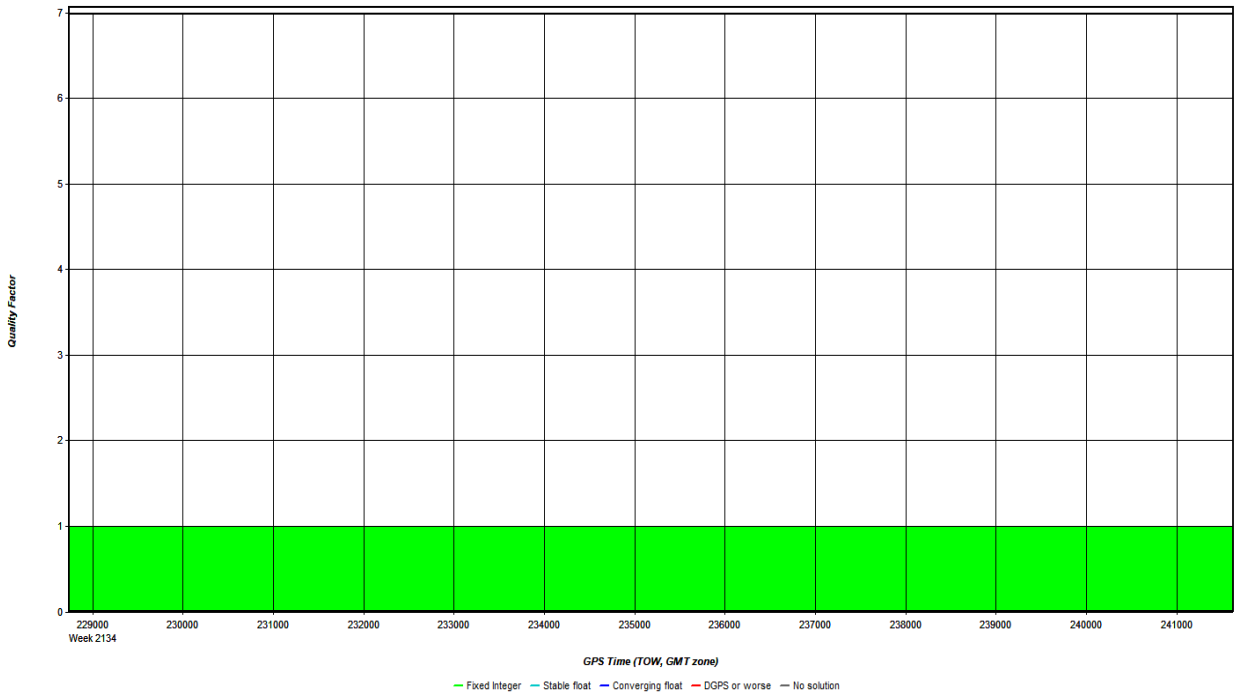
Smoothed Trajectory Information

Top View

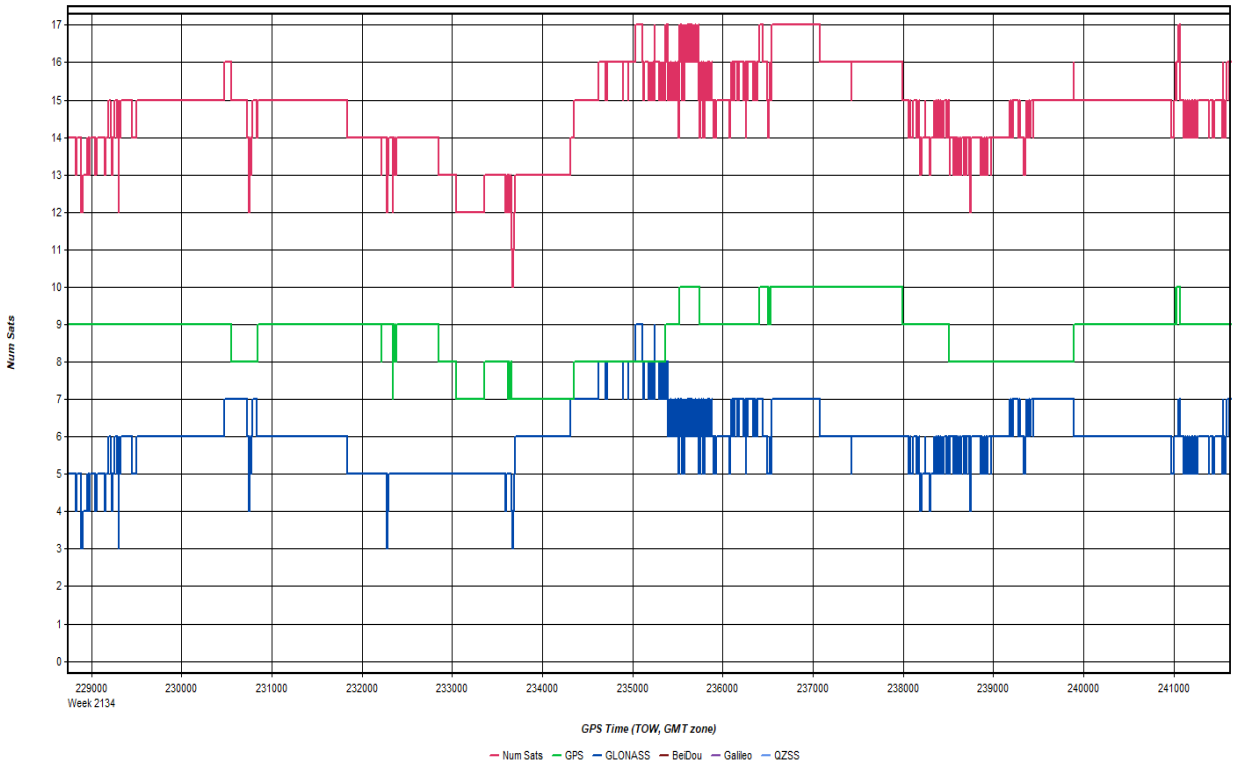


GNSS QC

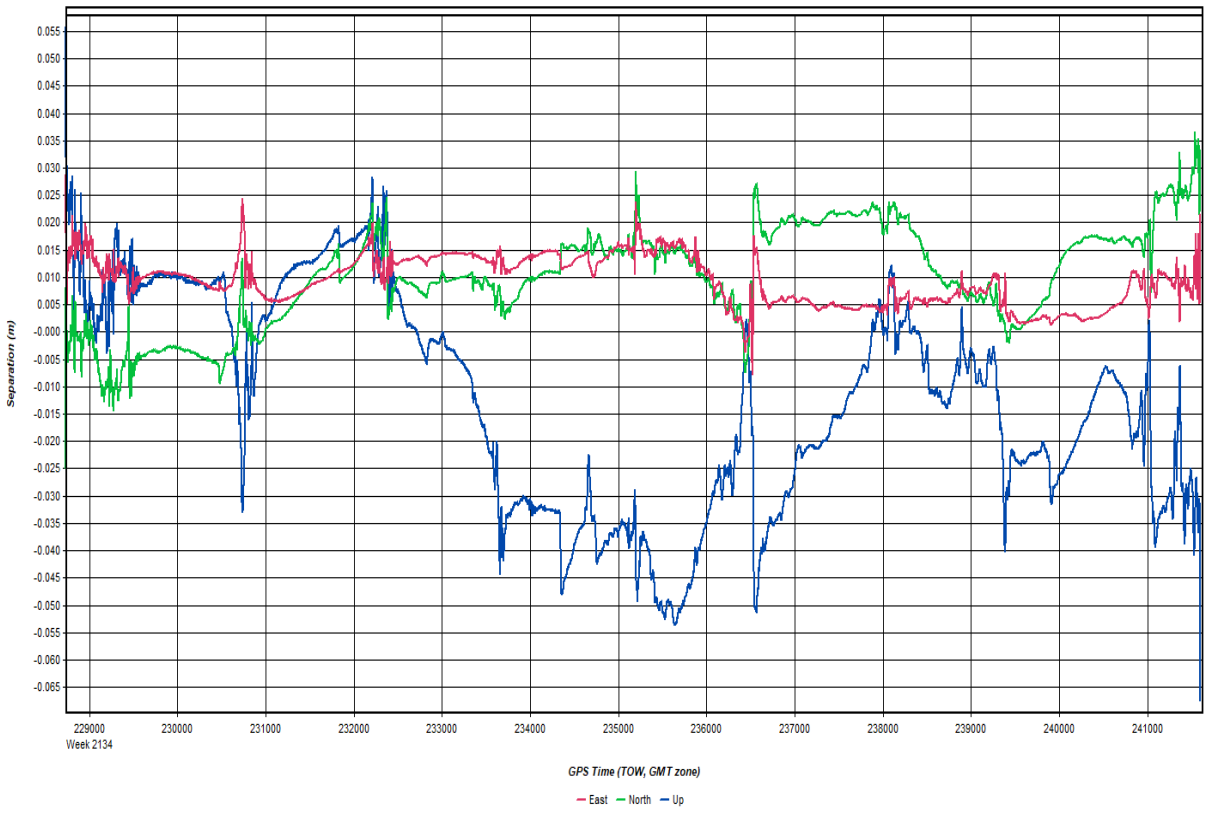
Quality Factor Plot



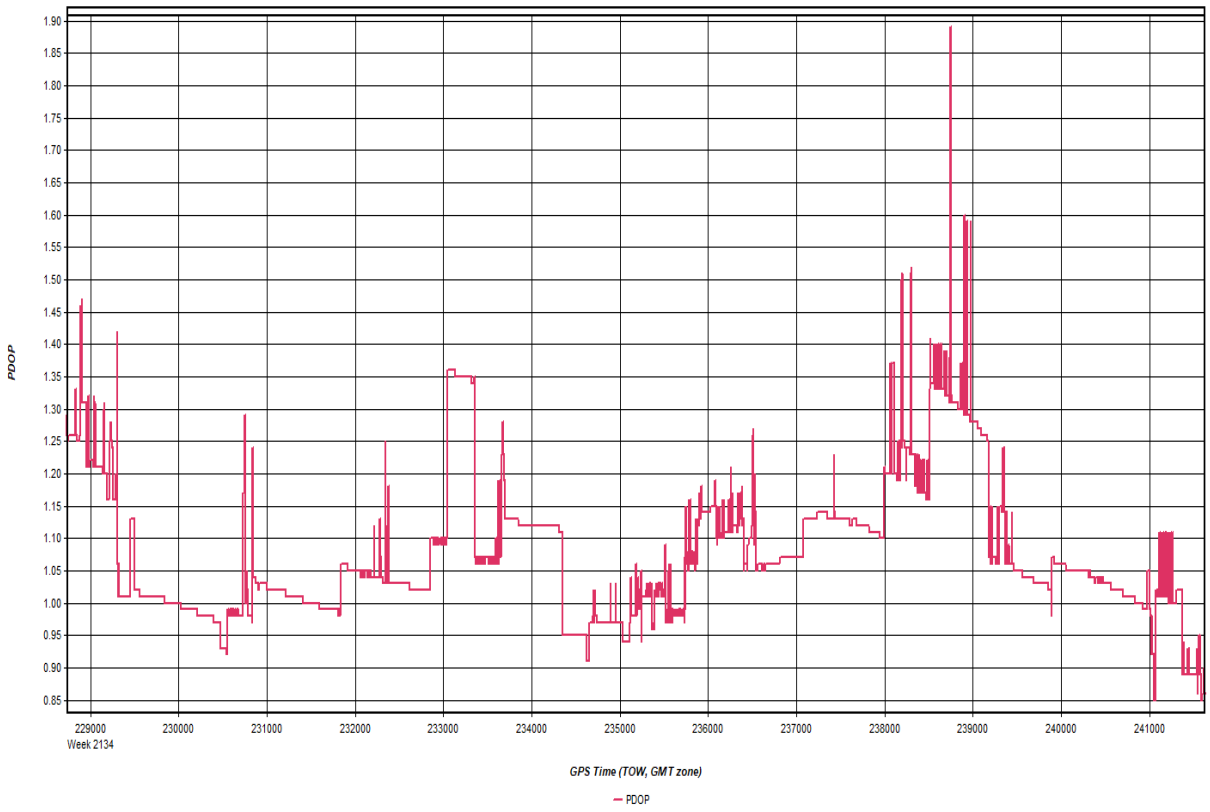
Number of Satellites Plot



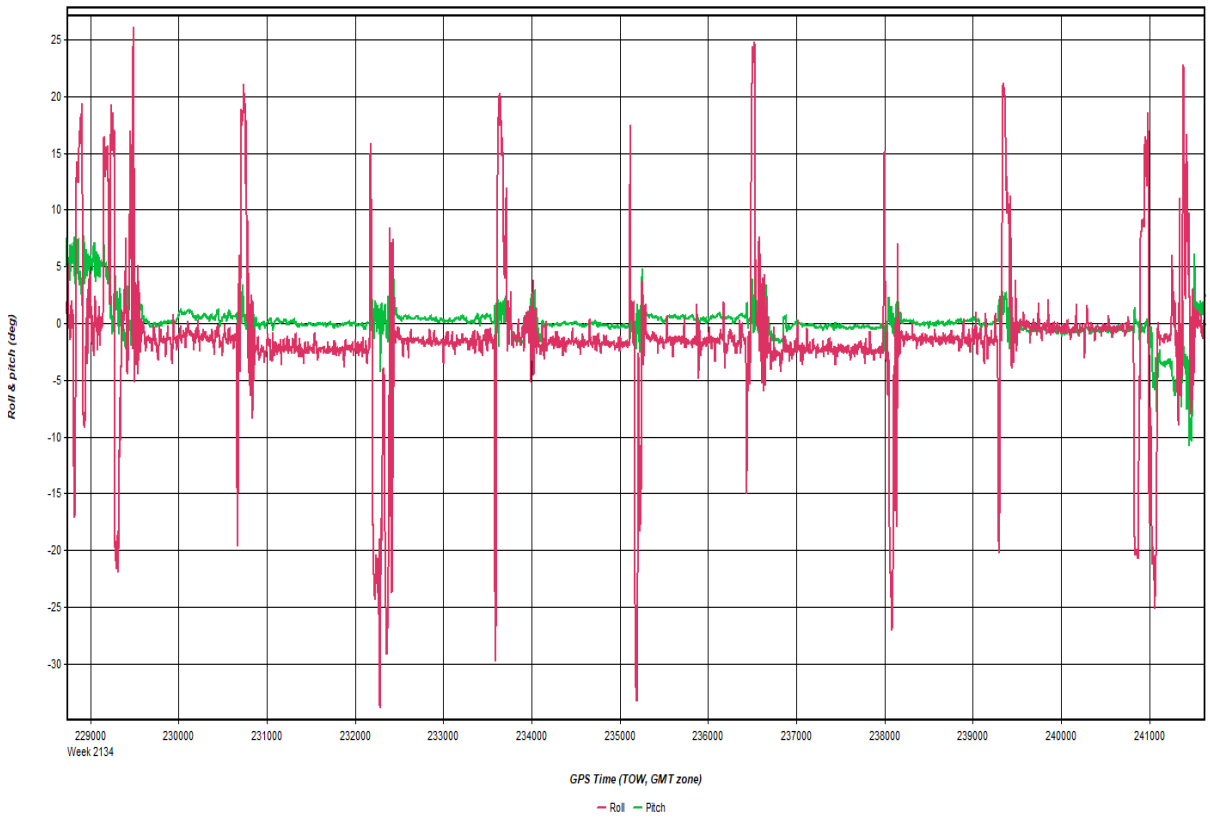
Forward/Reverse or Combined Separation Plot



PDOP Plot



Roll & Pitch Plot



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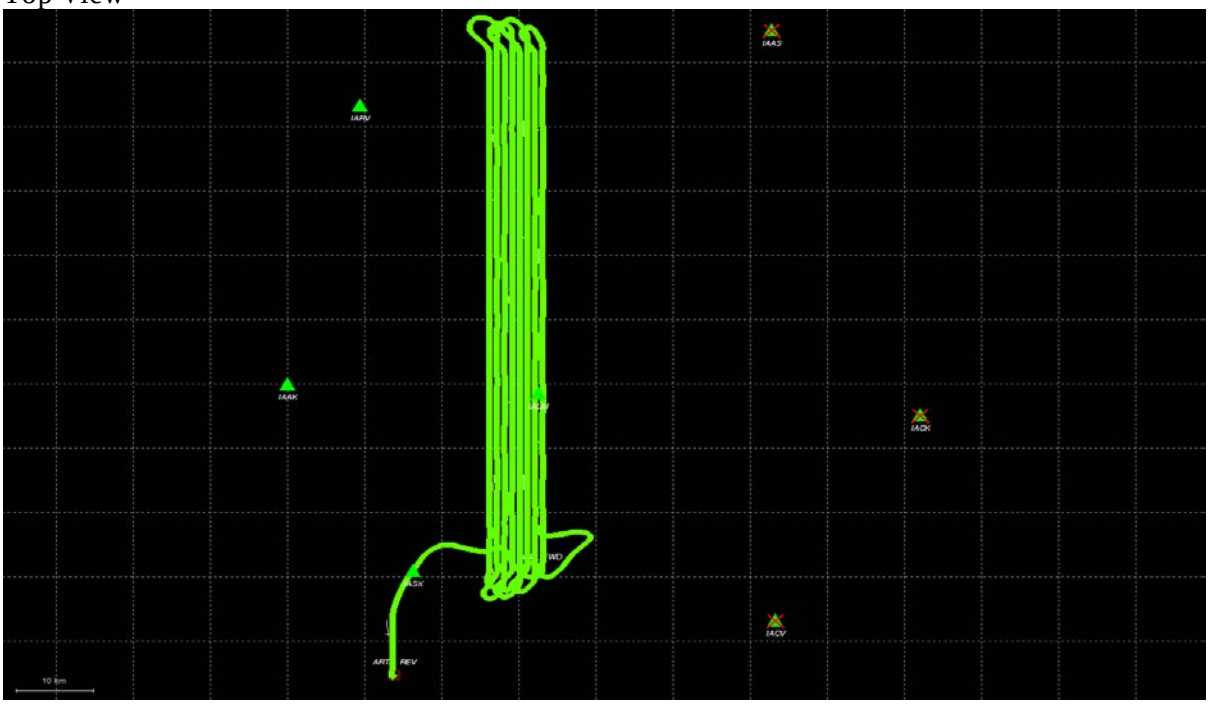
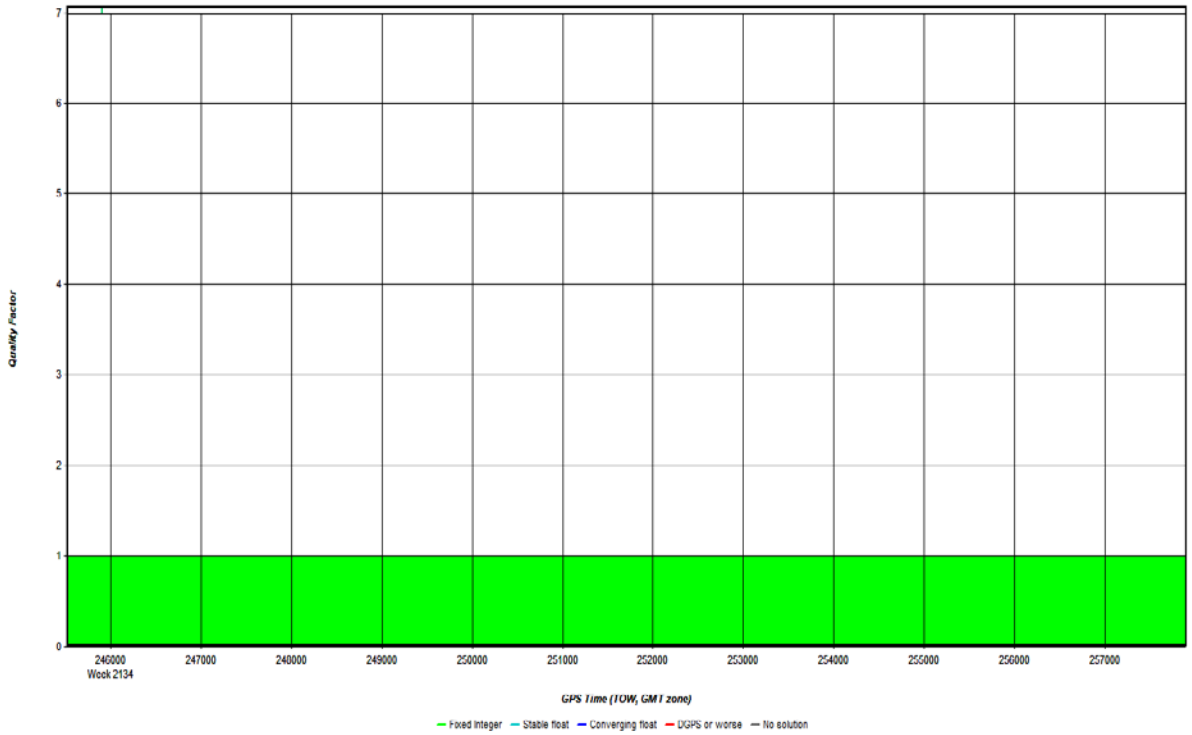
Smoothed Trajectory Information

Top View

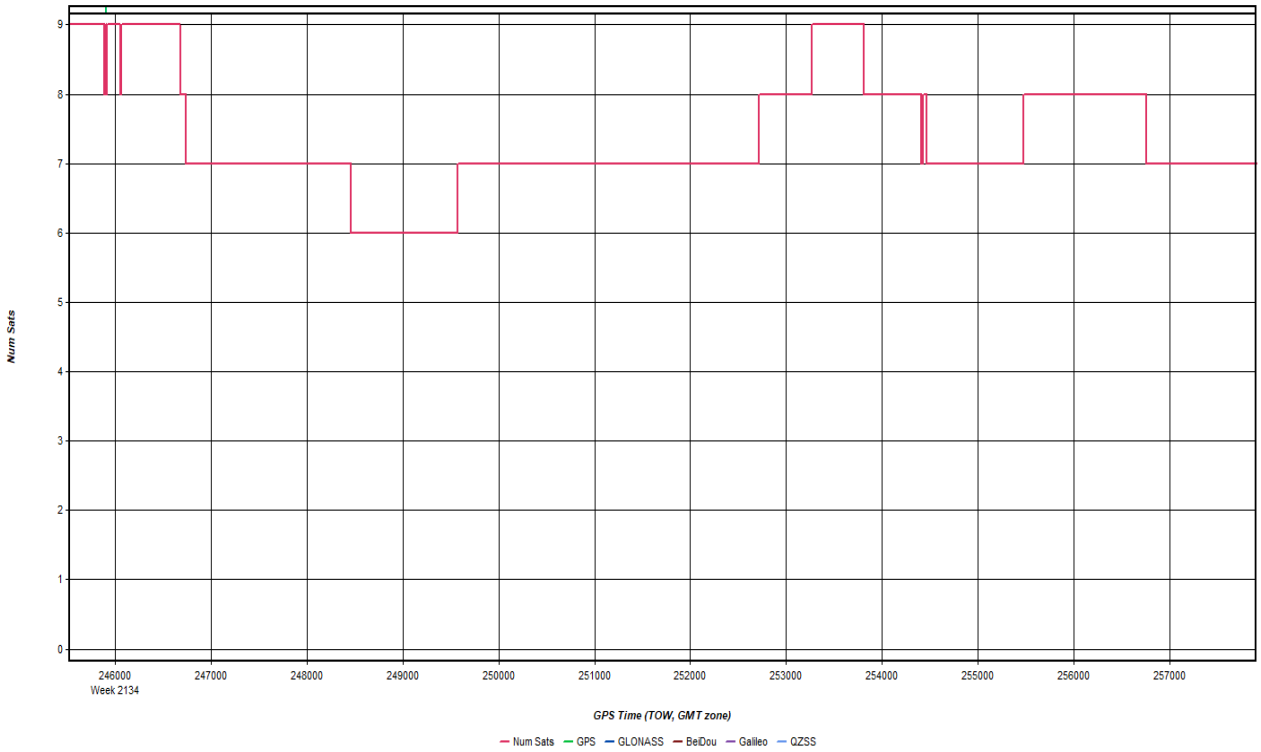


GNSS QC

Quality Factor Plot

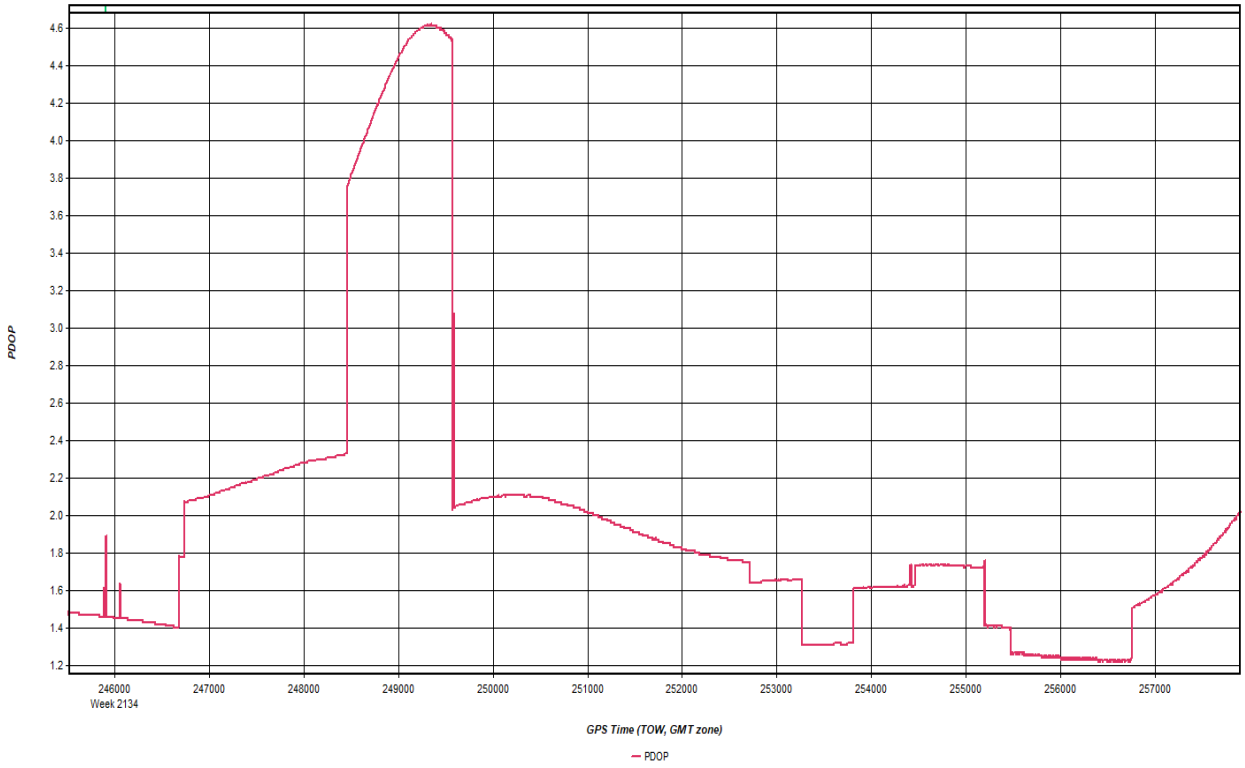


Number of Satellites Plot

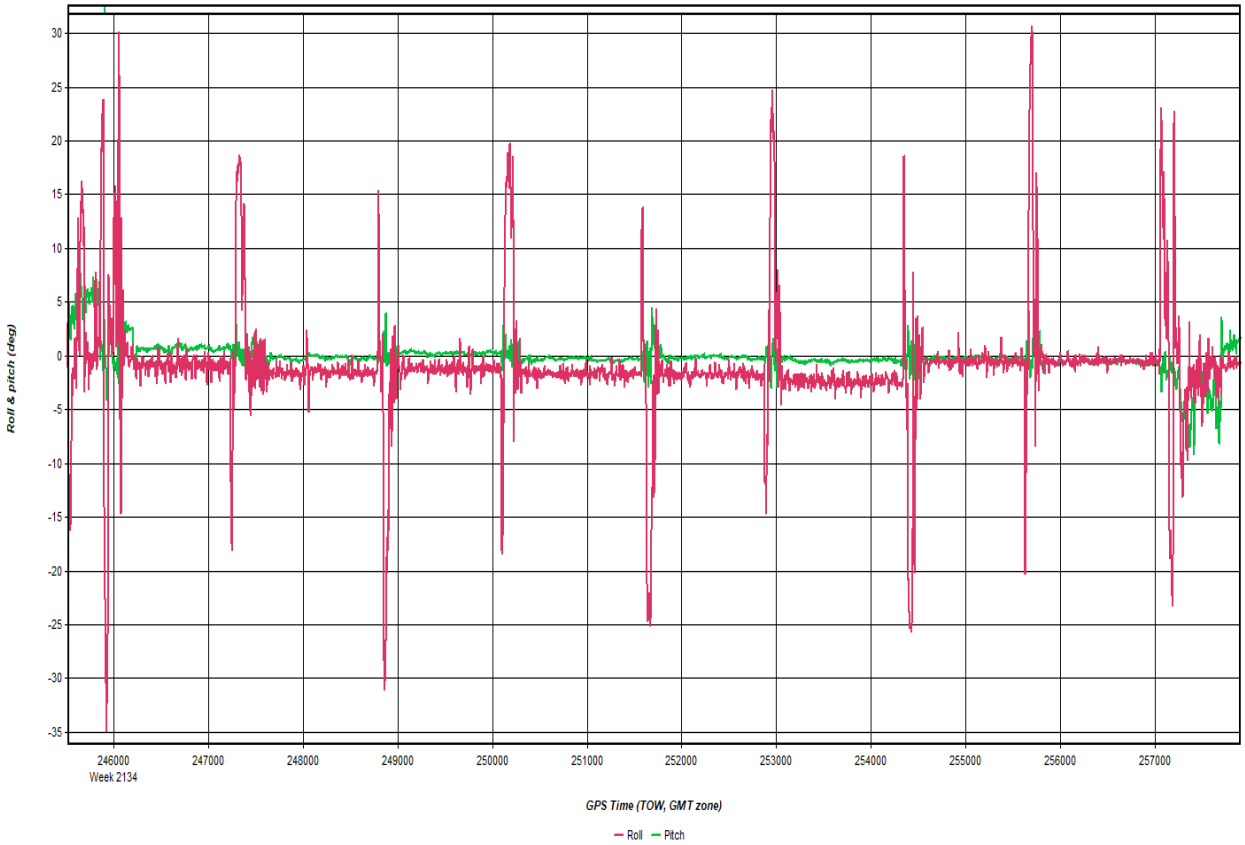


Forward/Reverse or Combined Separation Plot

PDOP Plot



Roll & Pitch Plot



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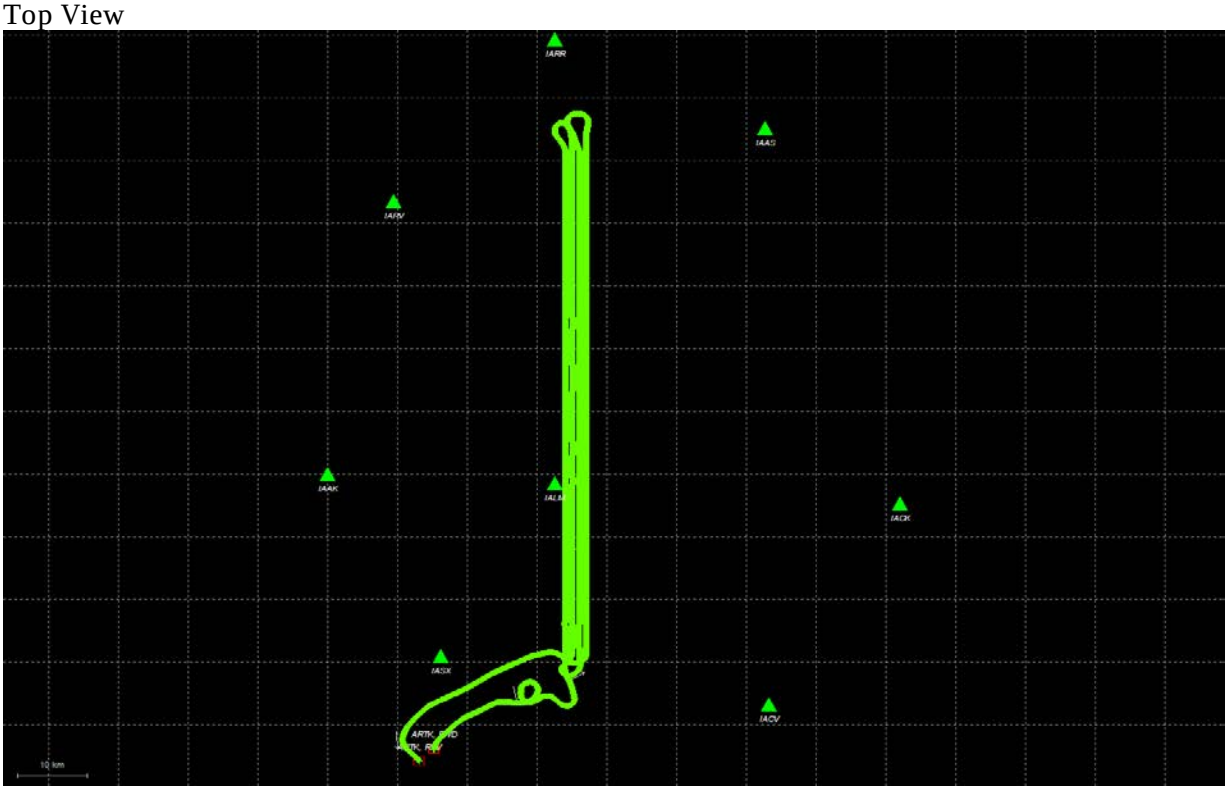
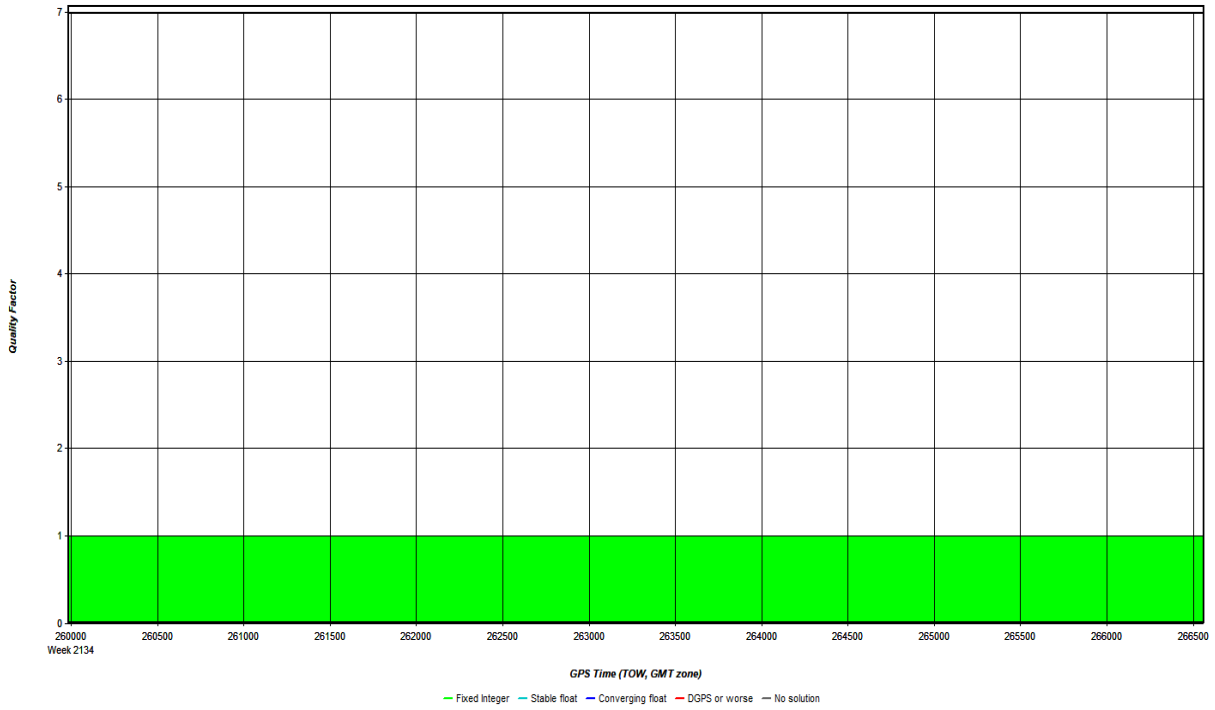
Smoothed Trajectory Information

Top View

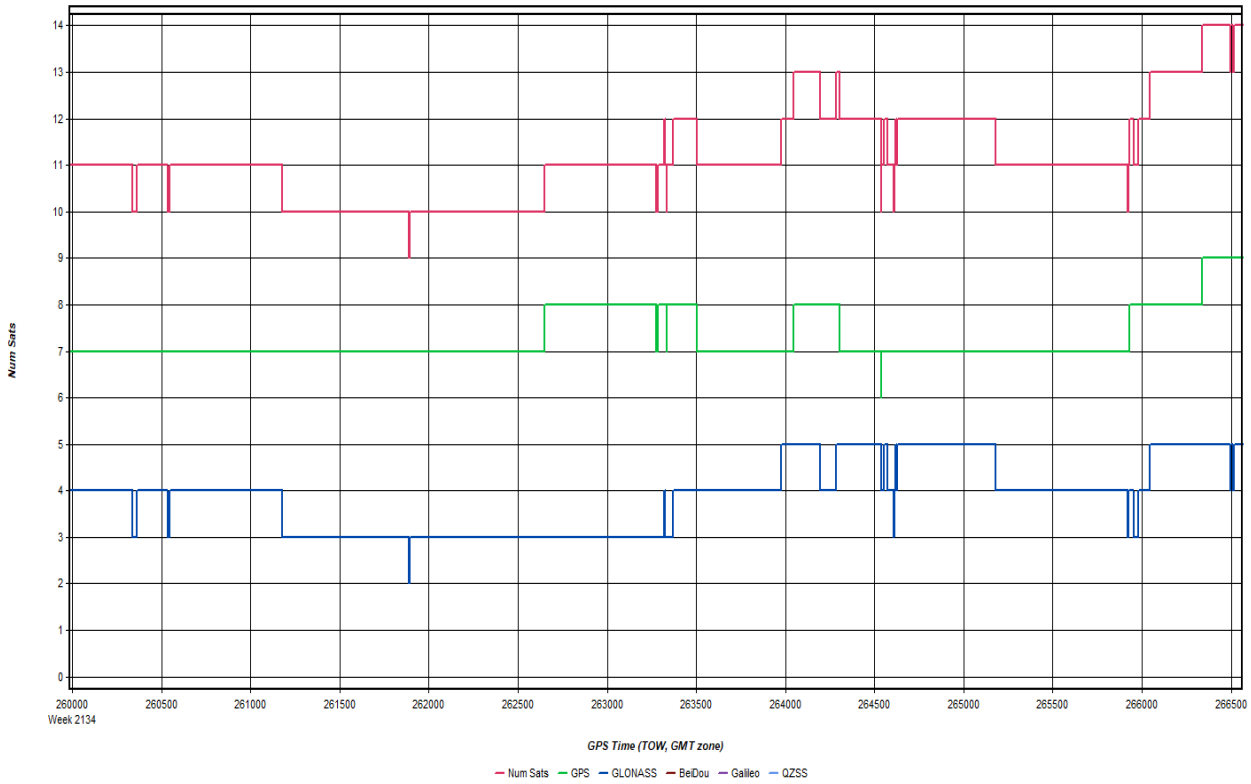


GNSS QC

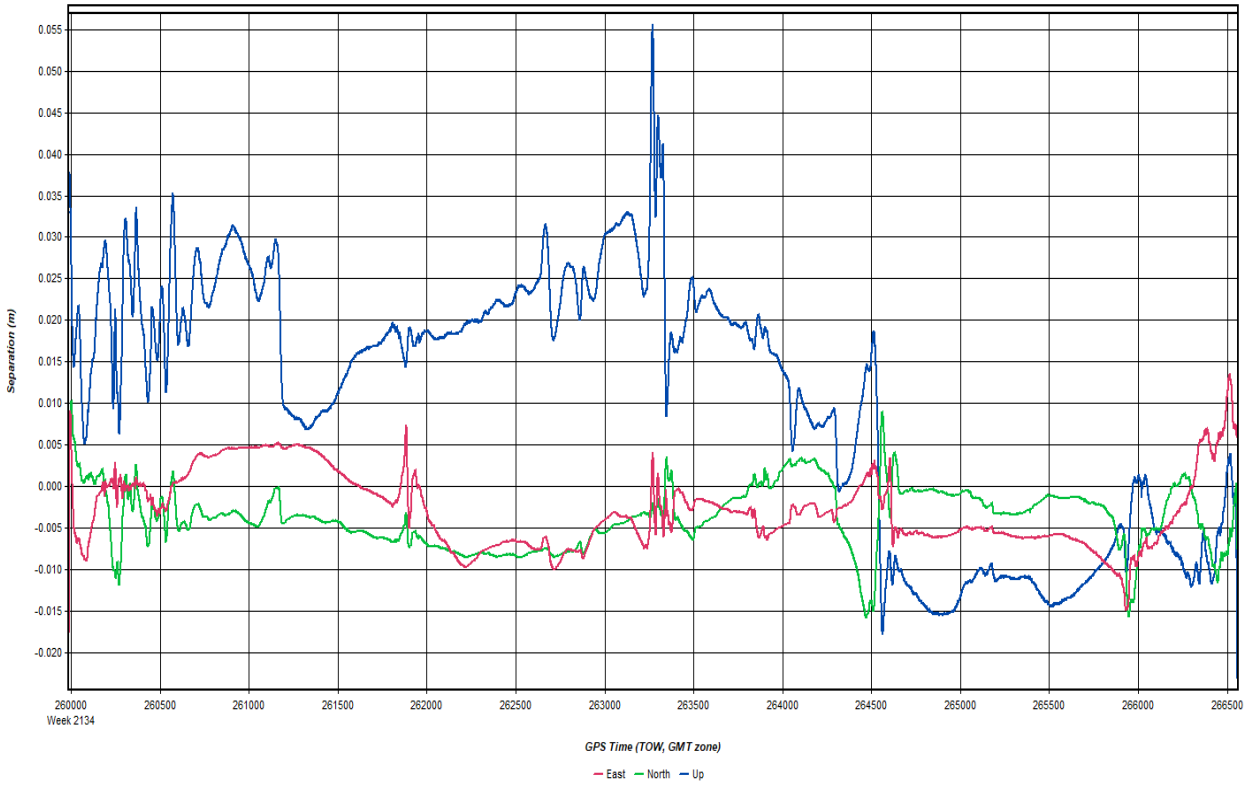
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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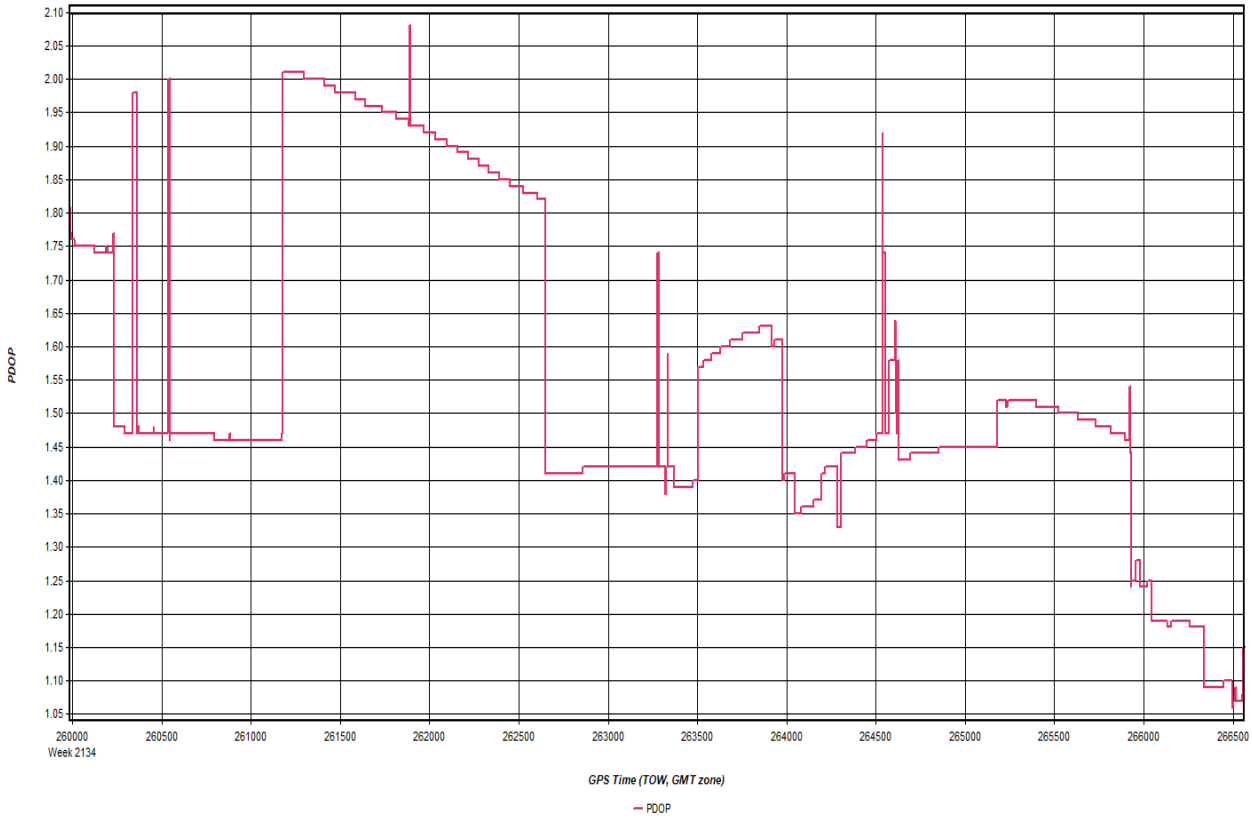
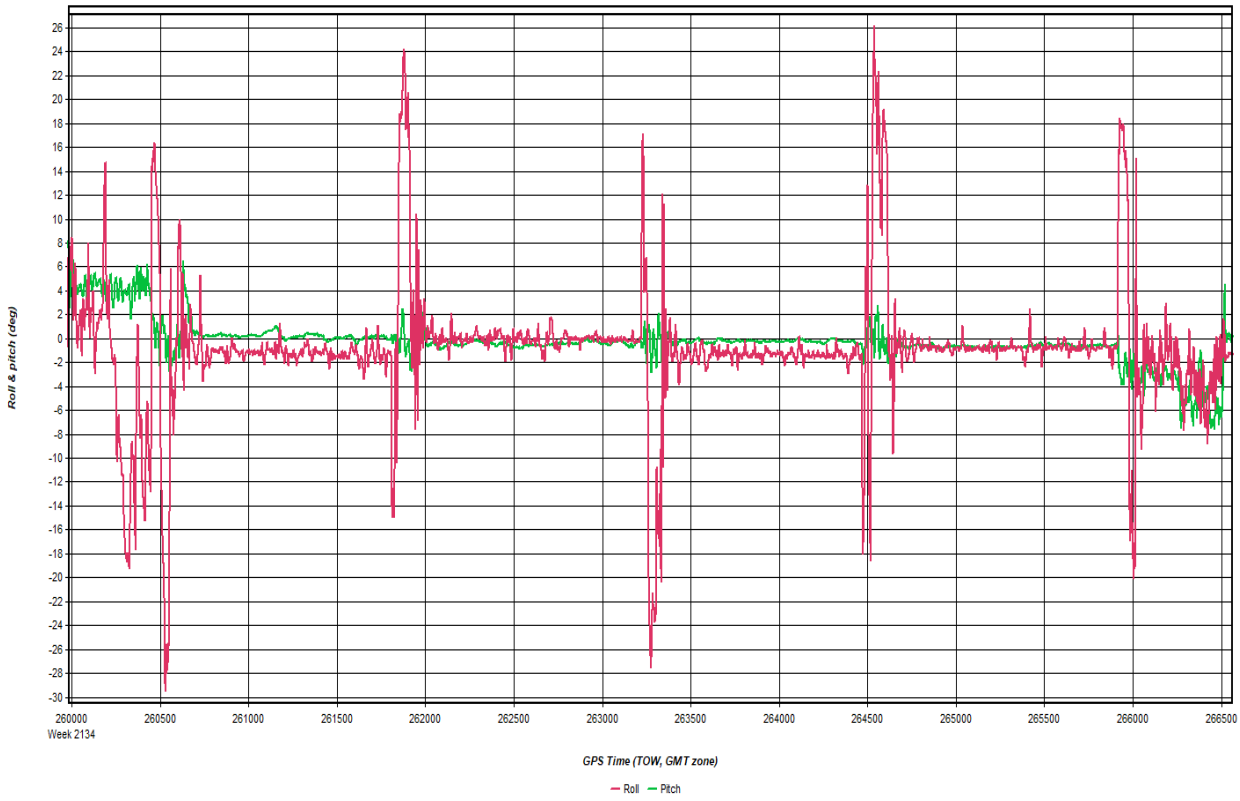


Roll & Pitch Plot



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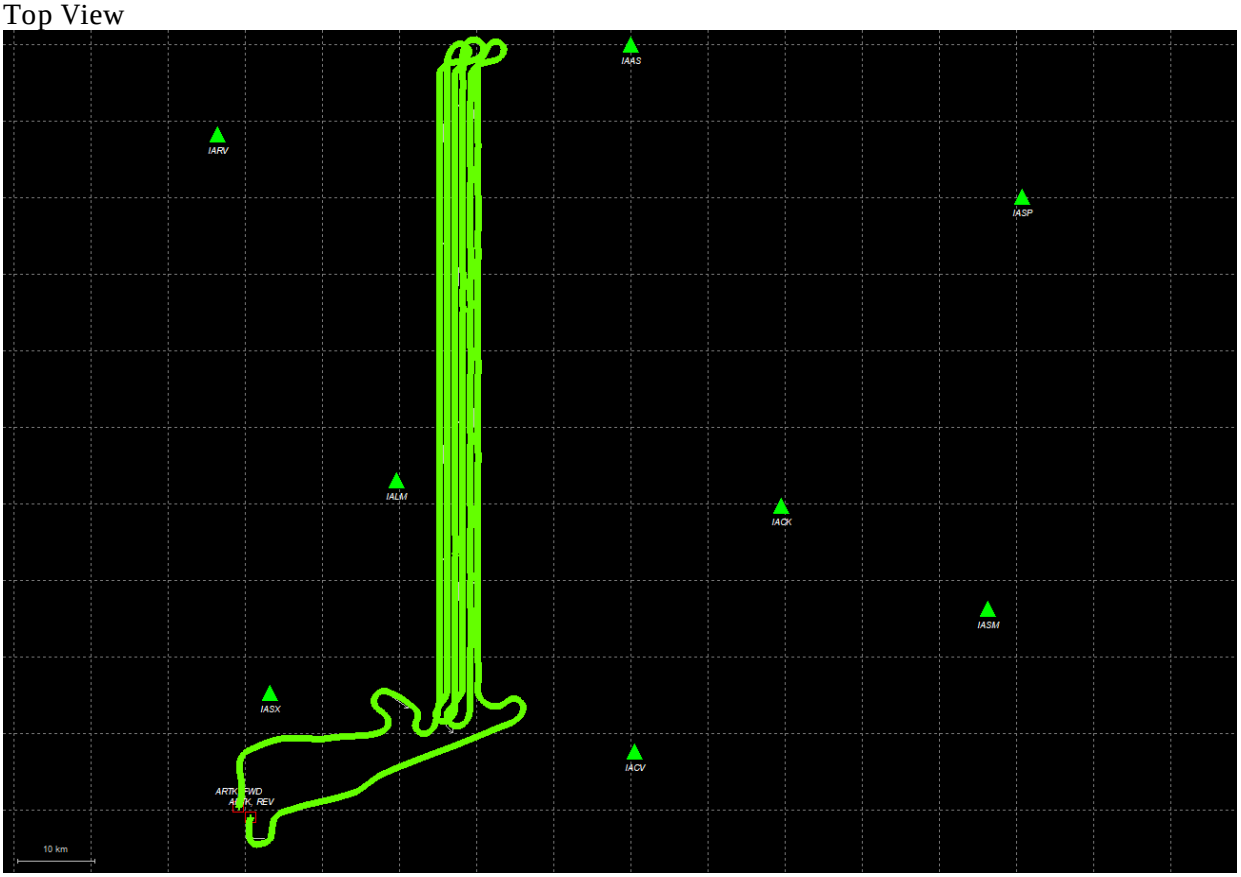
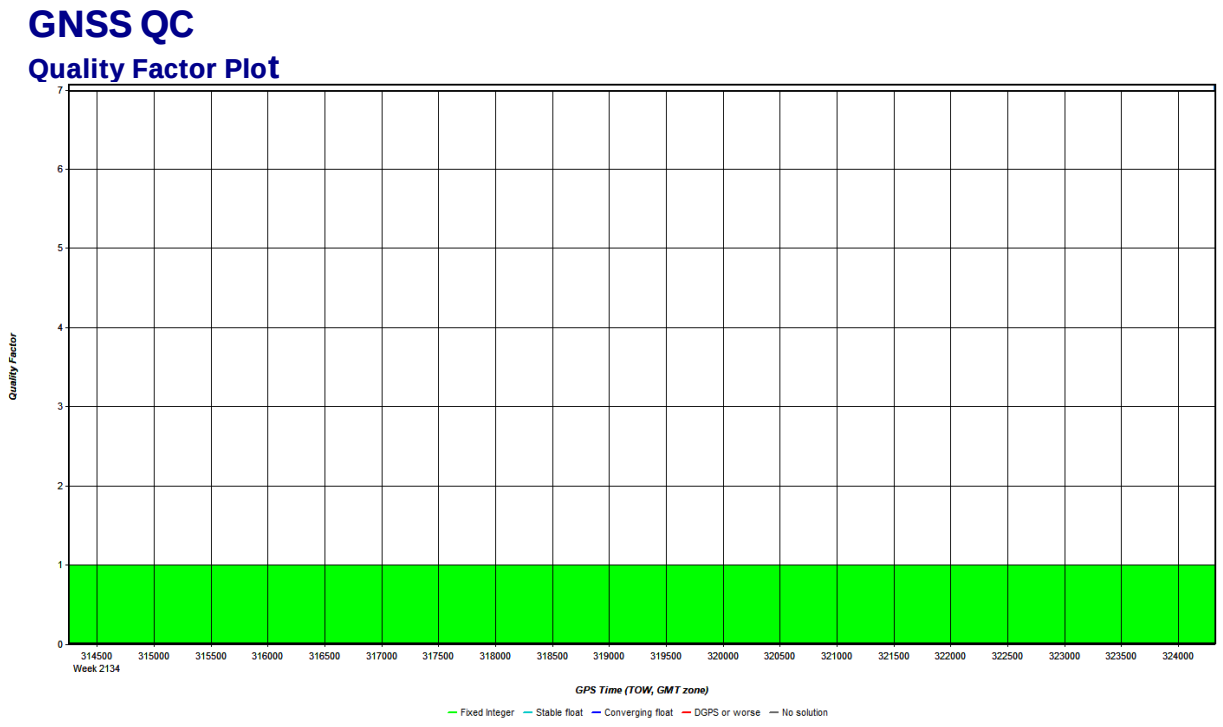
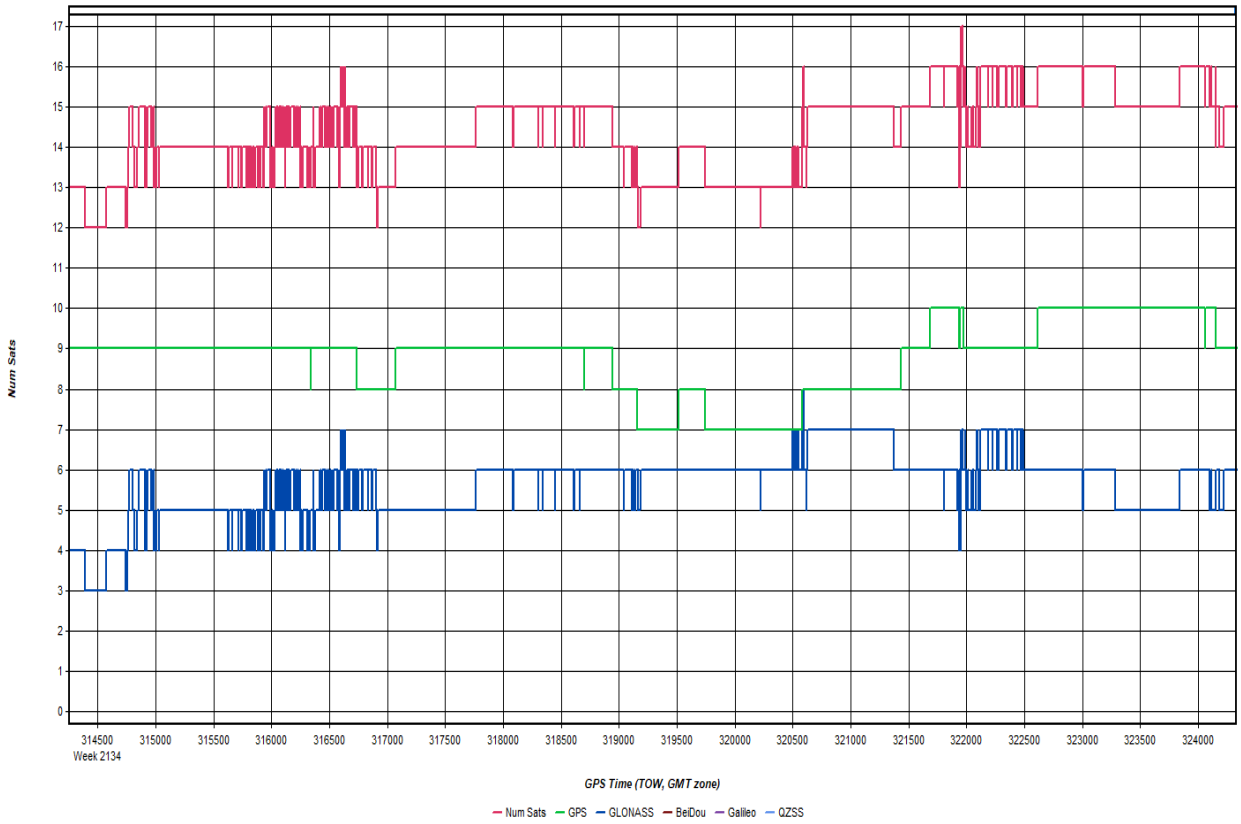
Smoothed Trajectory Information

Top View

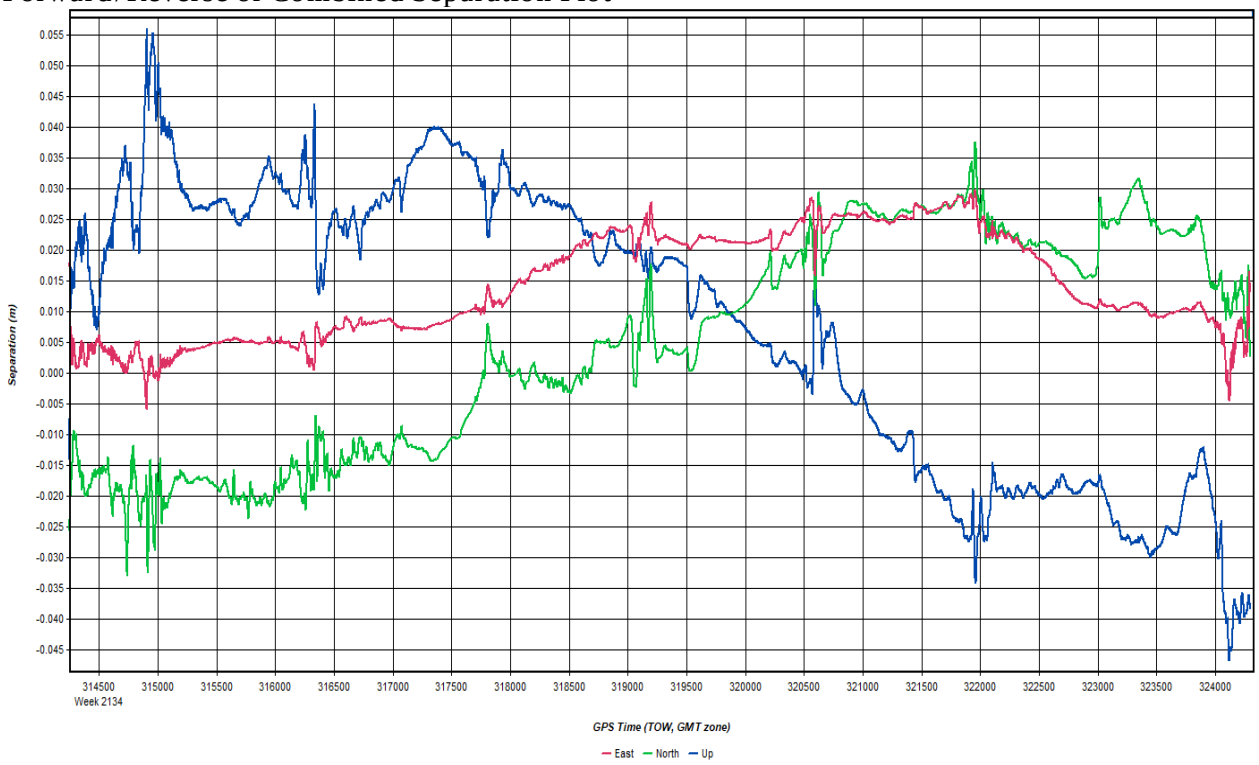




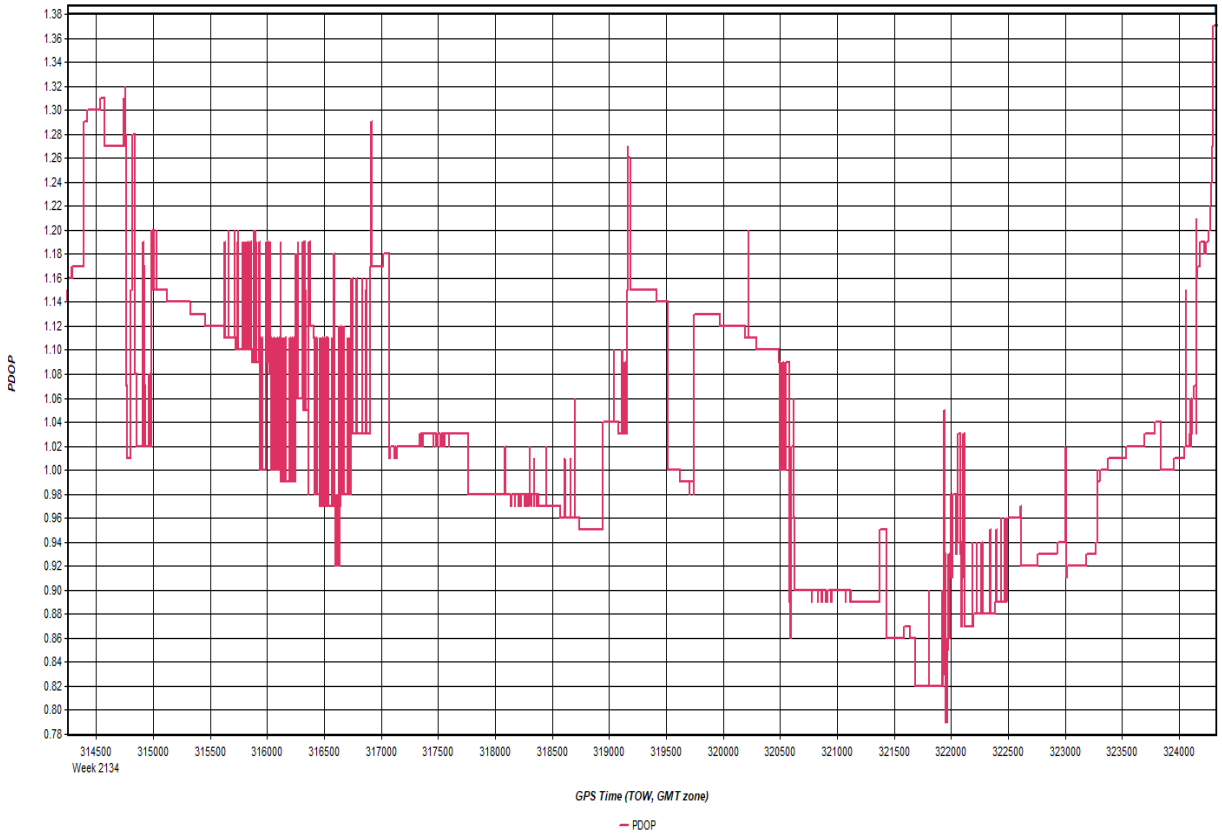
Number of Satellites Plot



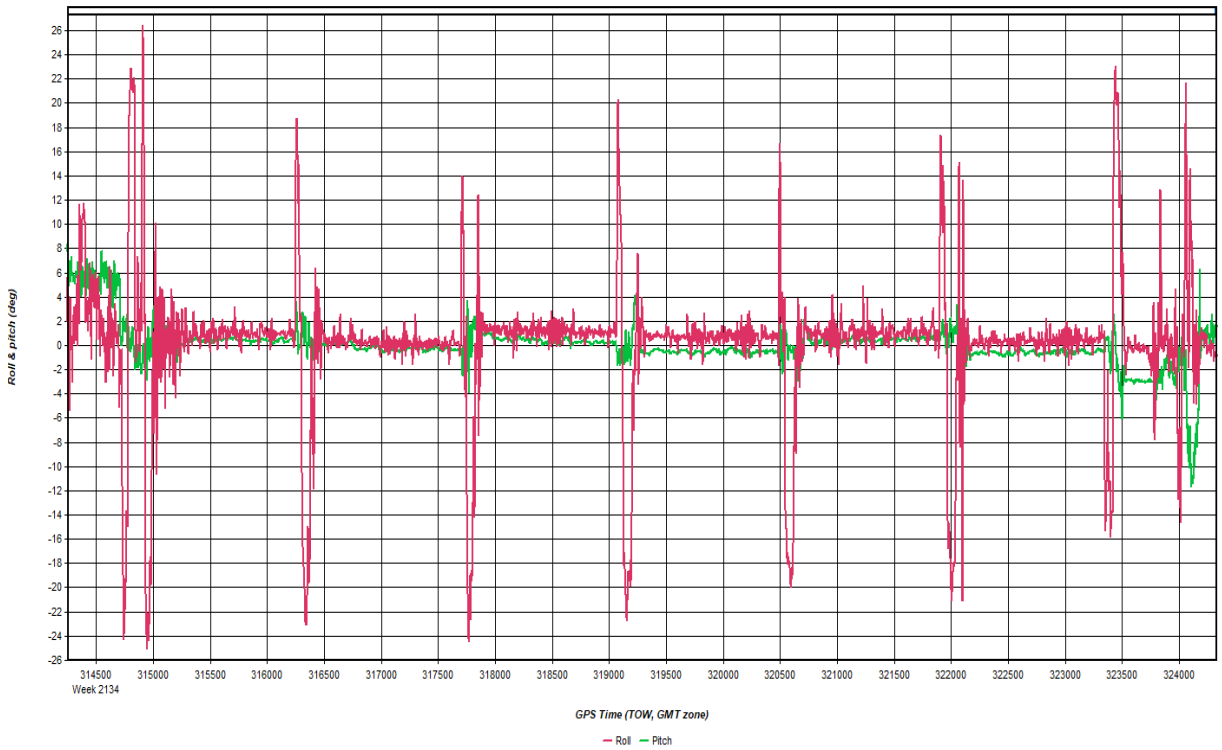
Forward/Reverse or Combined Separation Plot



PDOP Plot



Roll & Pitch Plot



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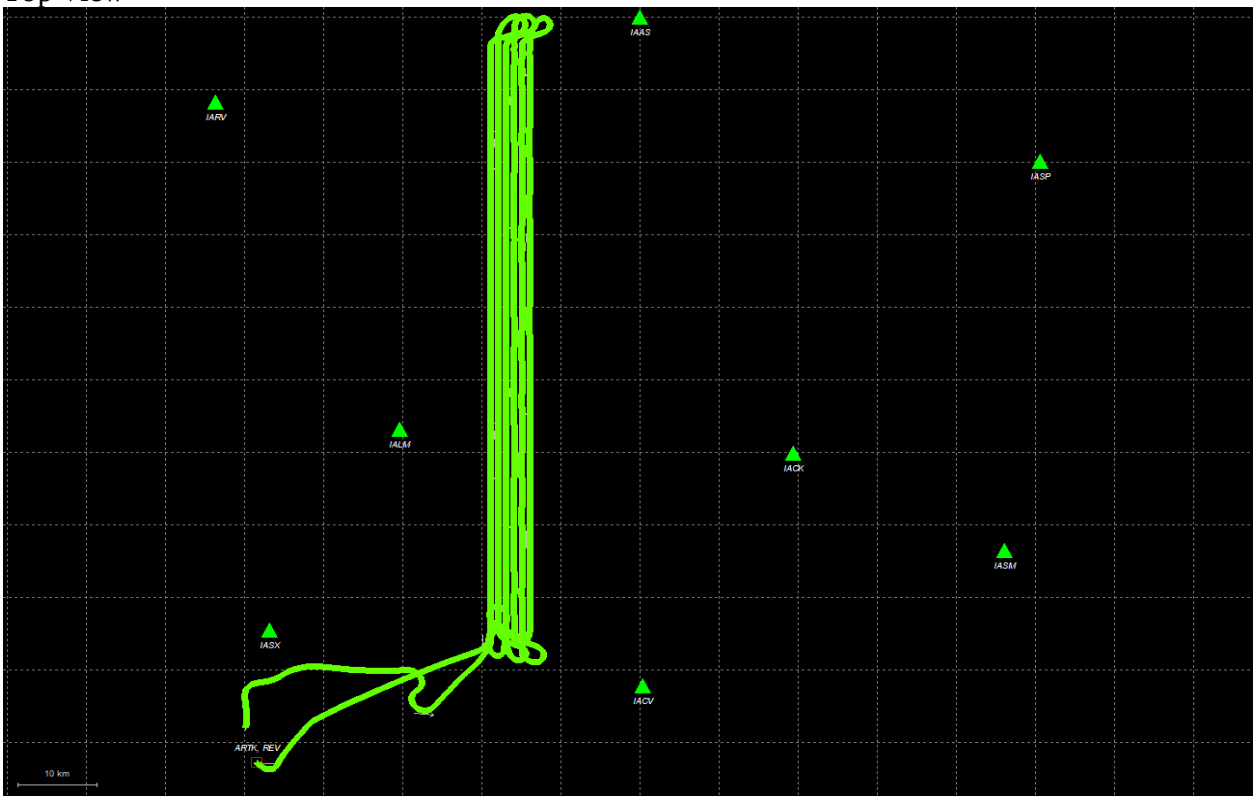
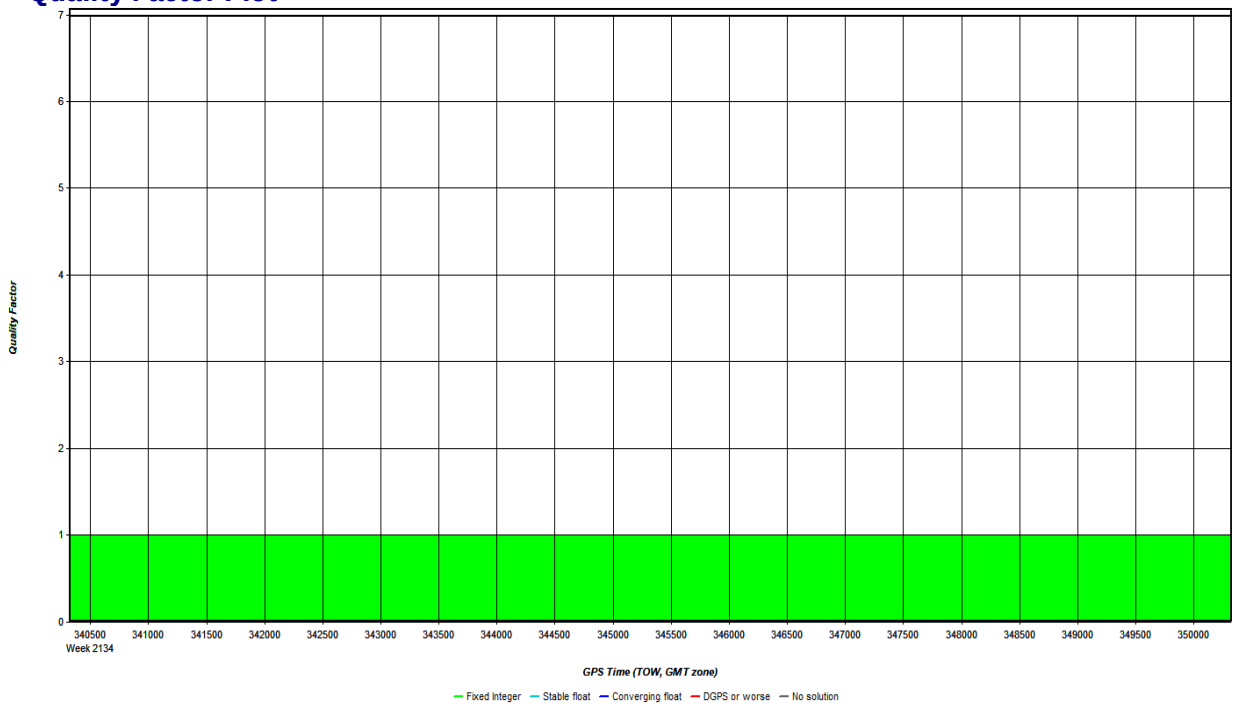
Smoothed Trajectory Information

Top View

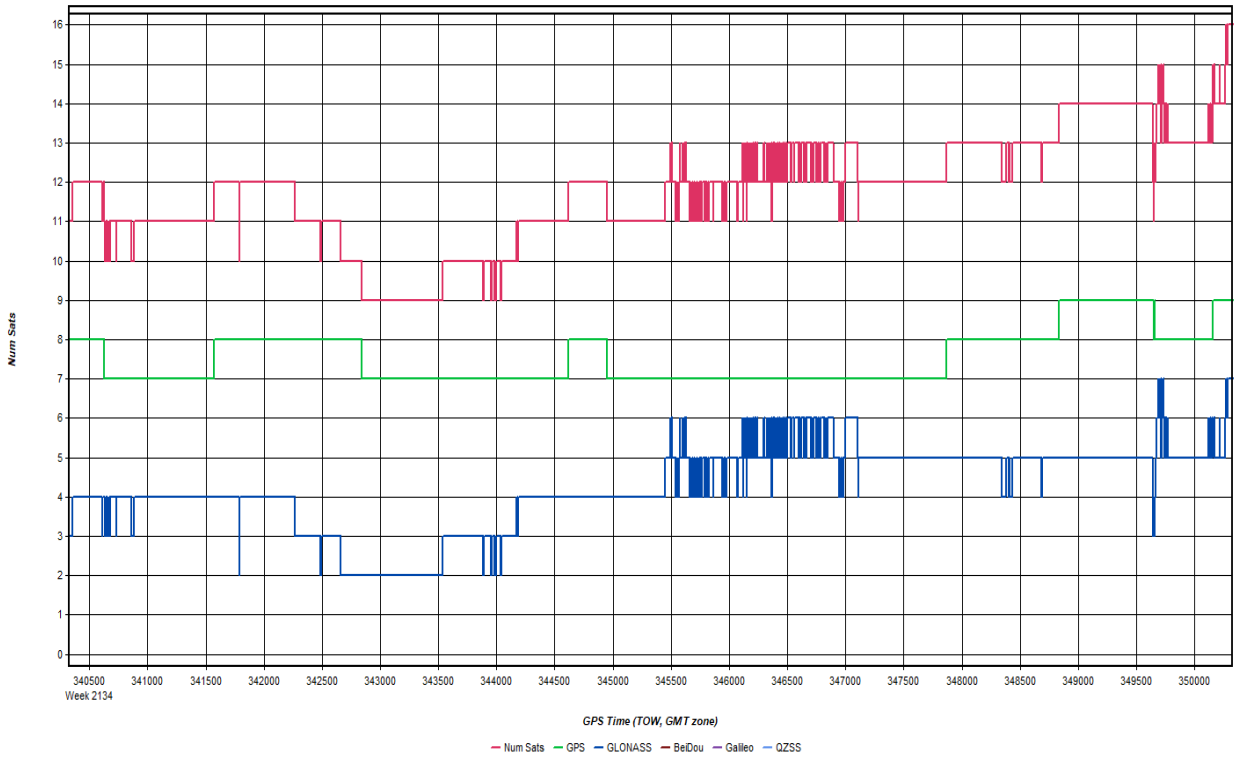


GNSS QC

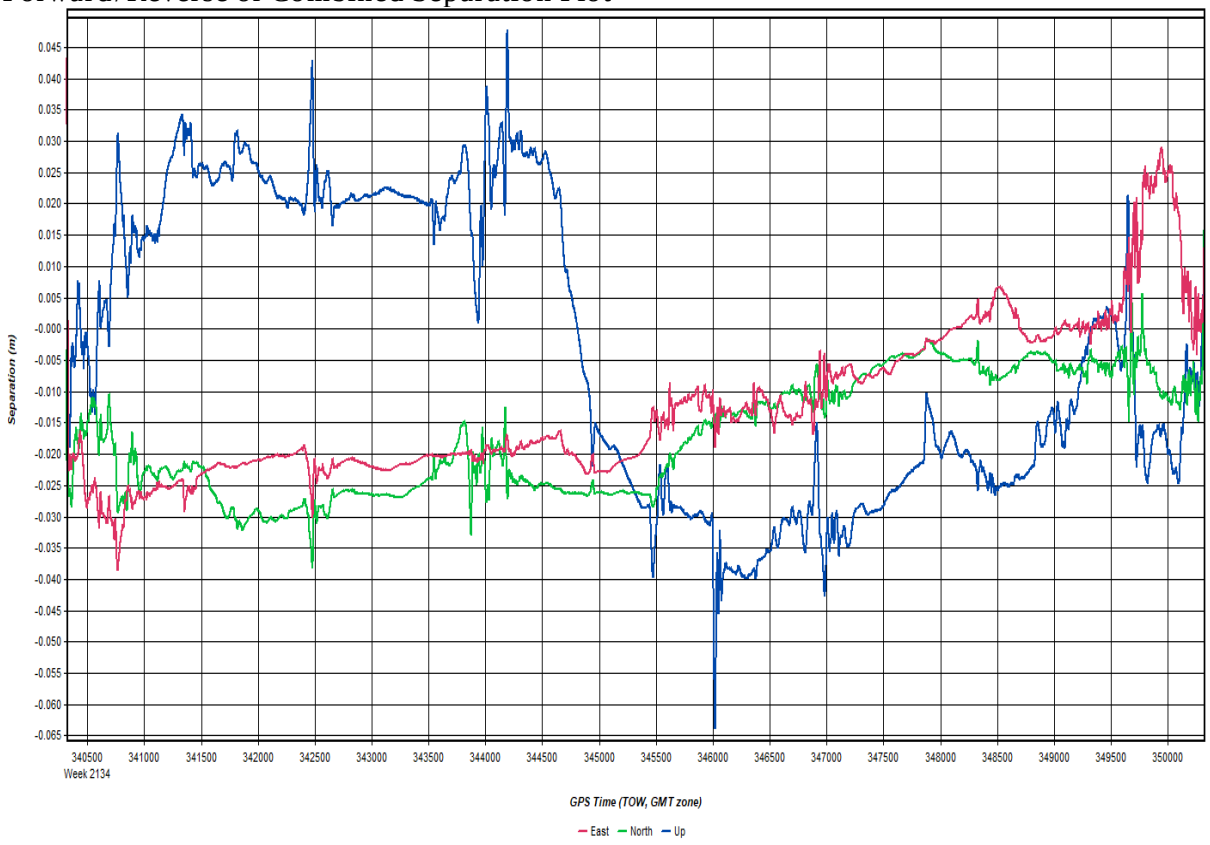
Quality Factor Plot



Number of Satellites Plot



Forward/Reverse or Combined Separation Plot



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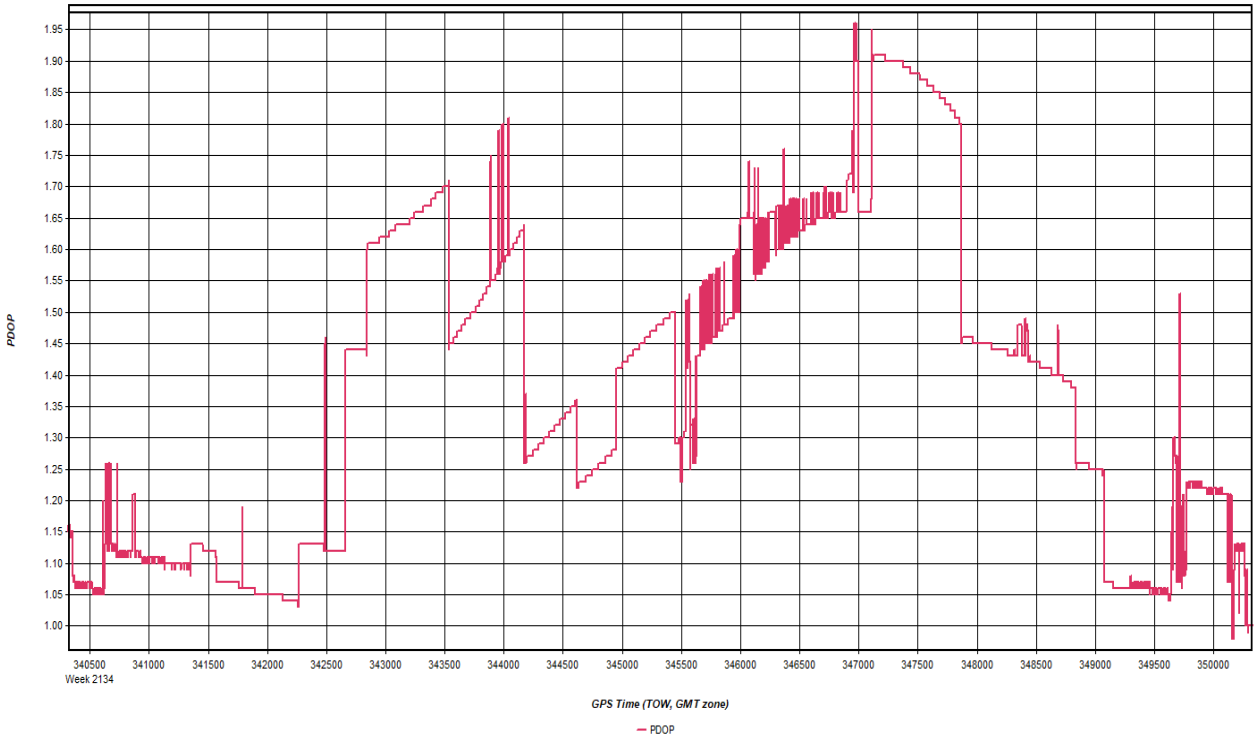
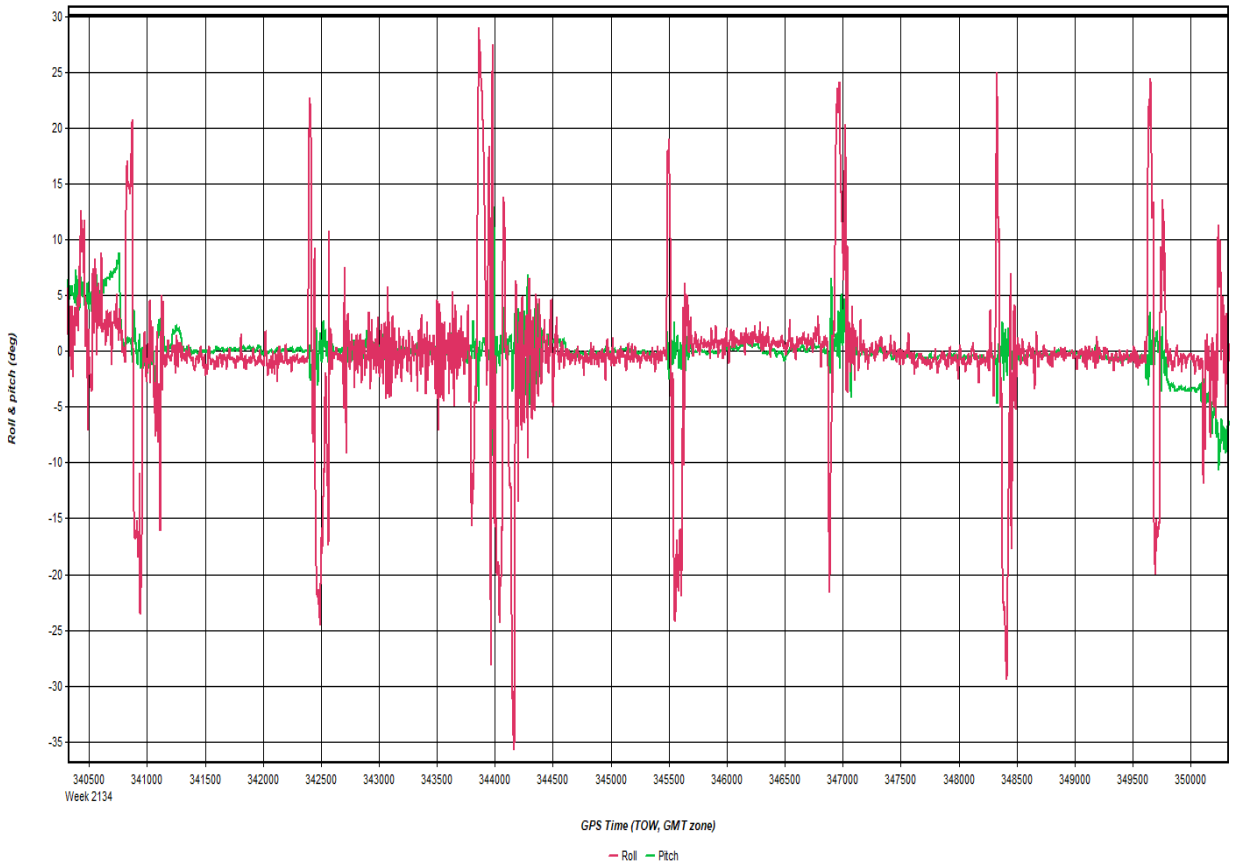


Roll & Pitch Plot



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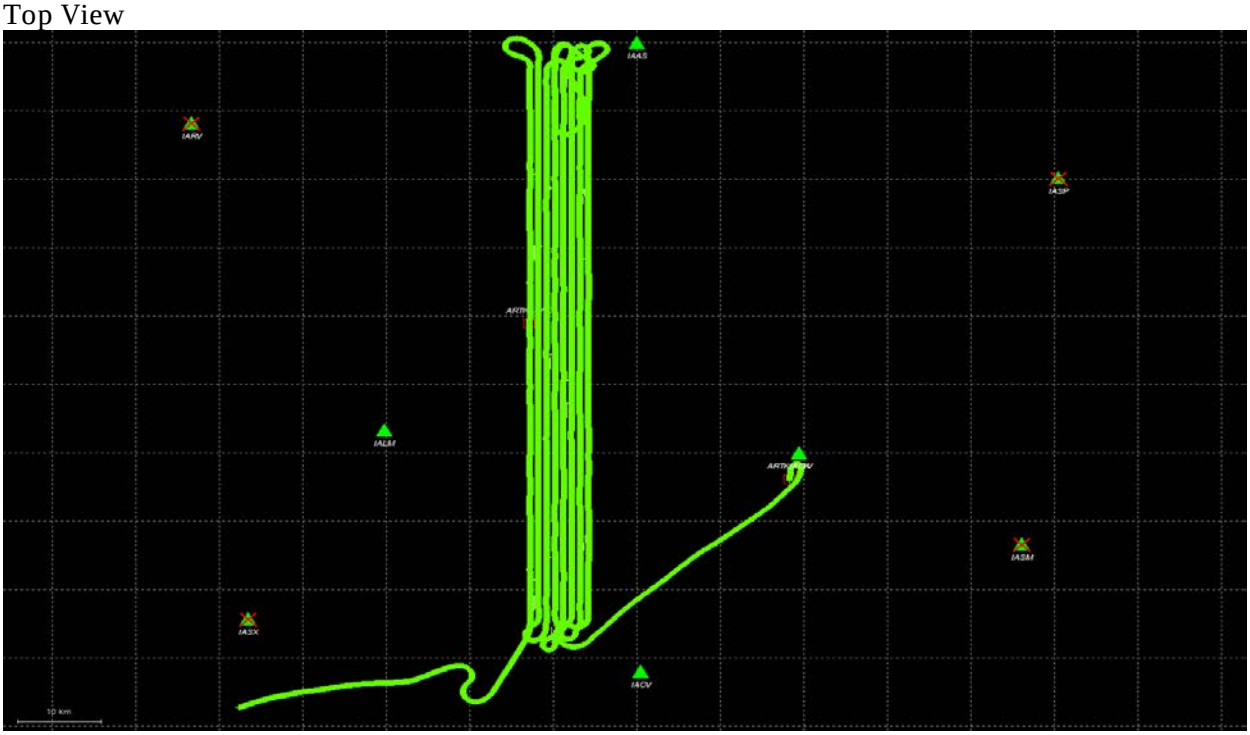
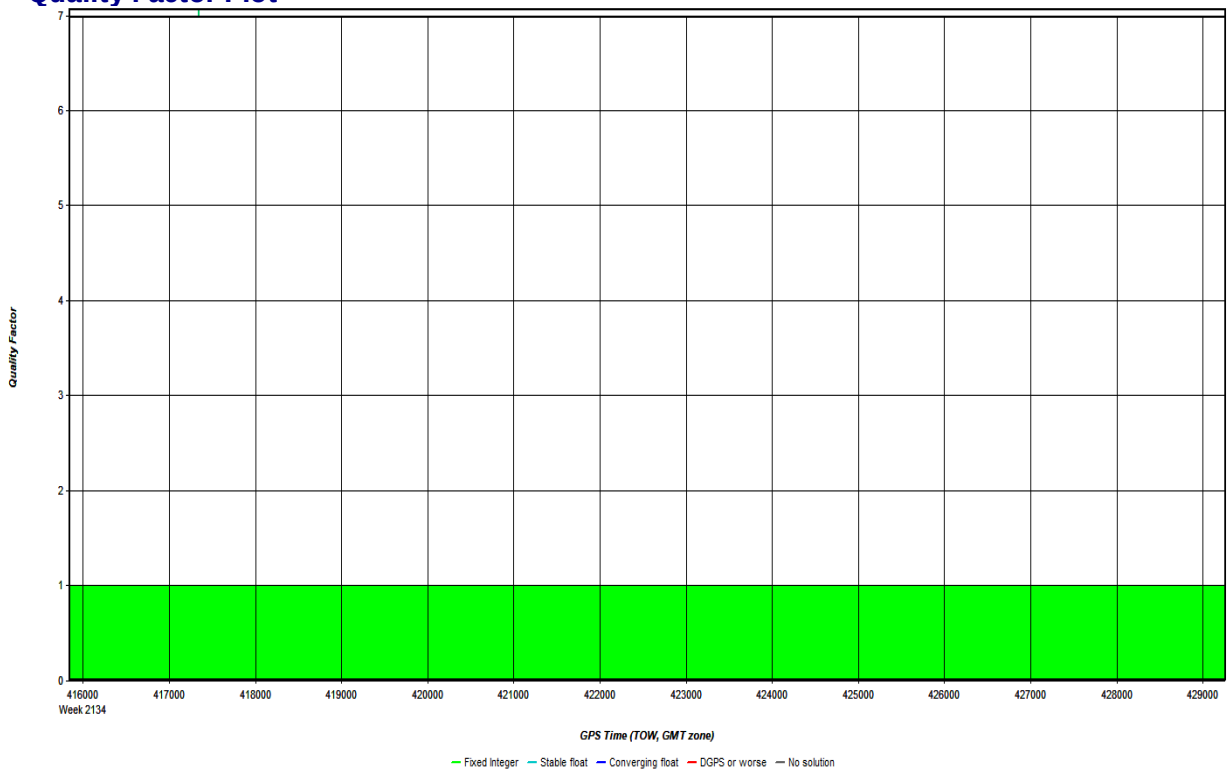
Smoothed Trajectory Information

Top View

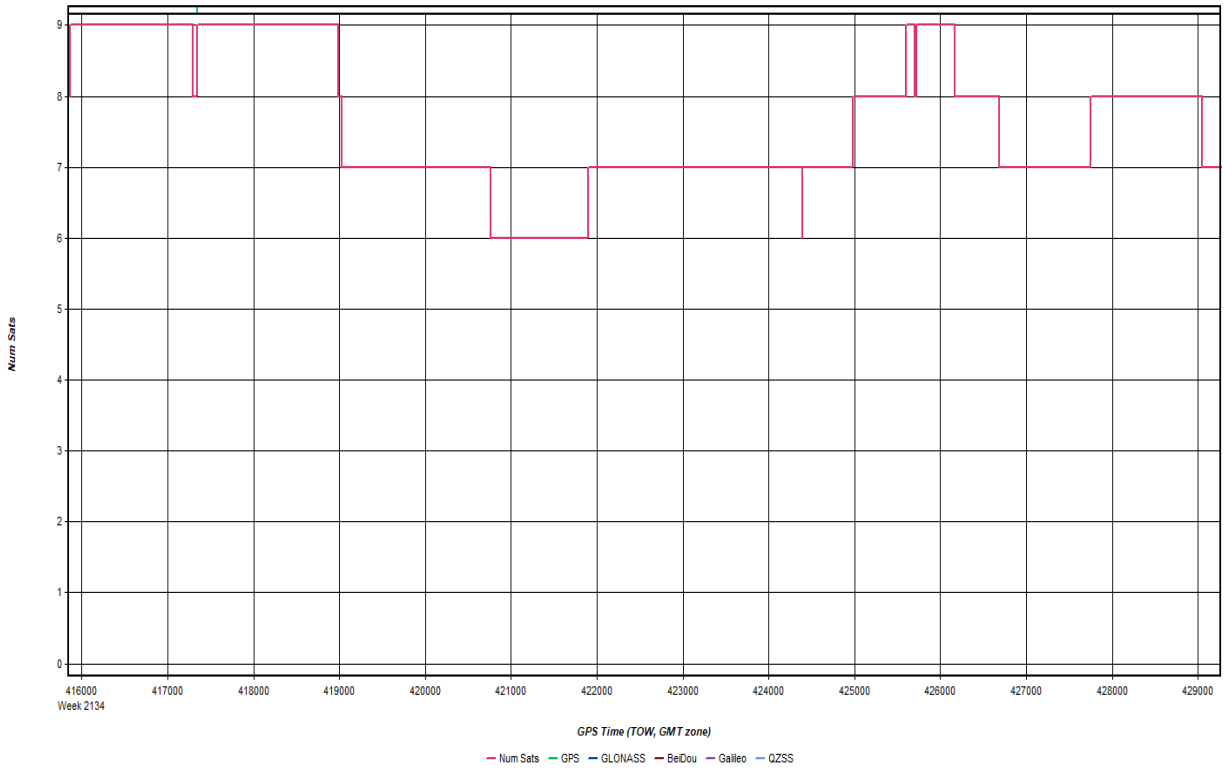


GNSS QC

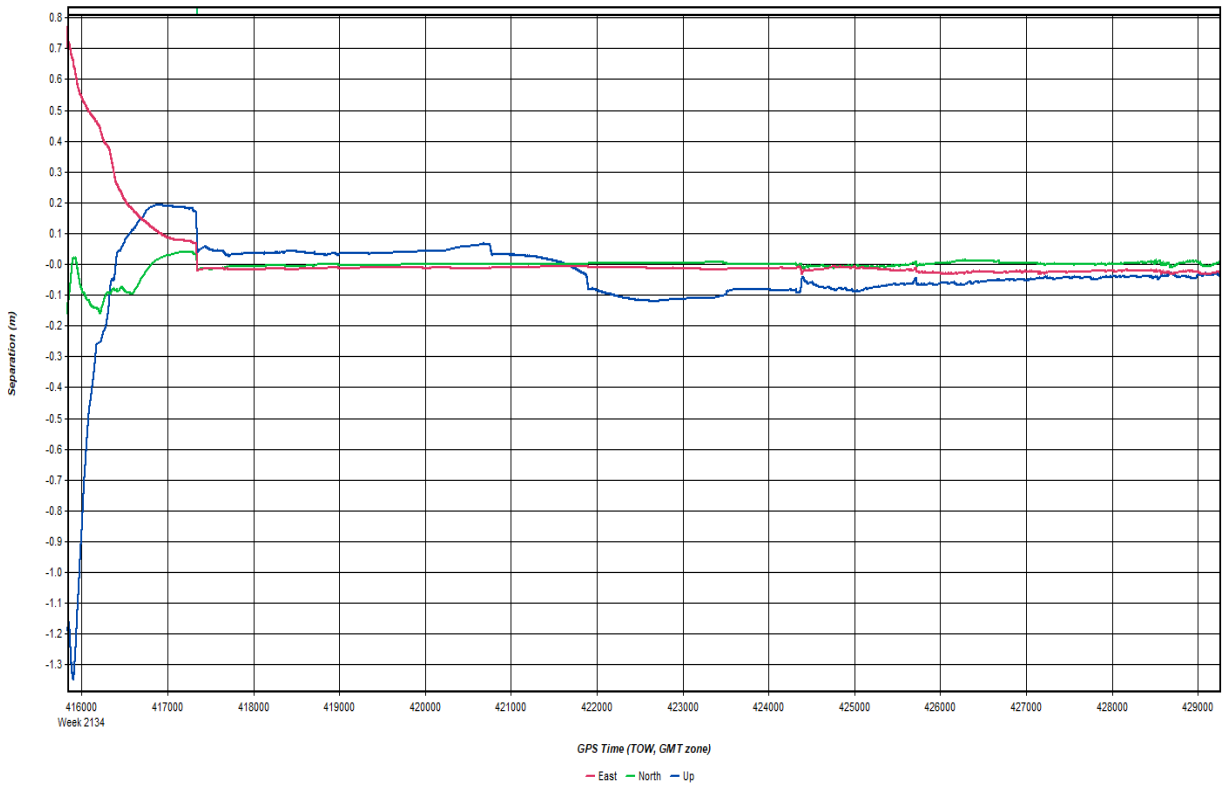
Quality Factor Plot



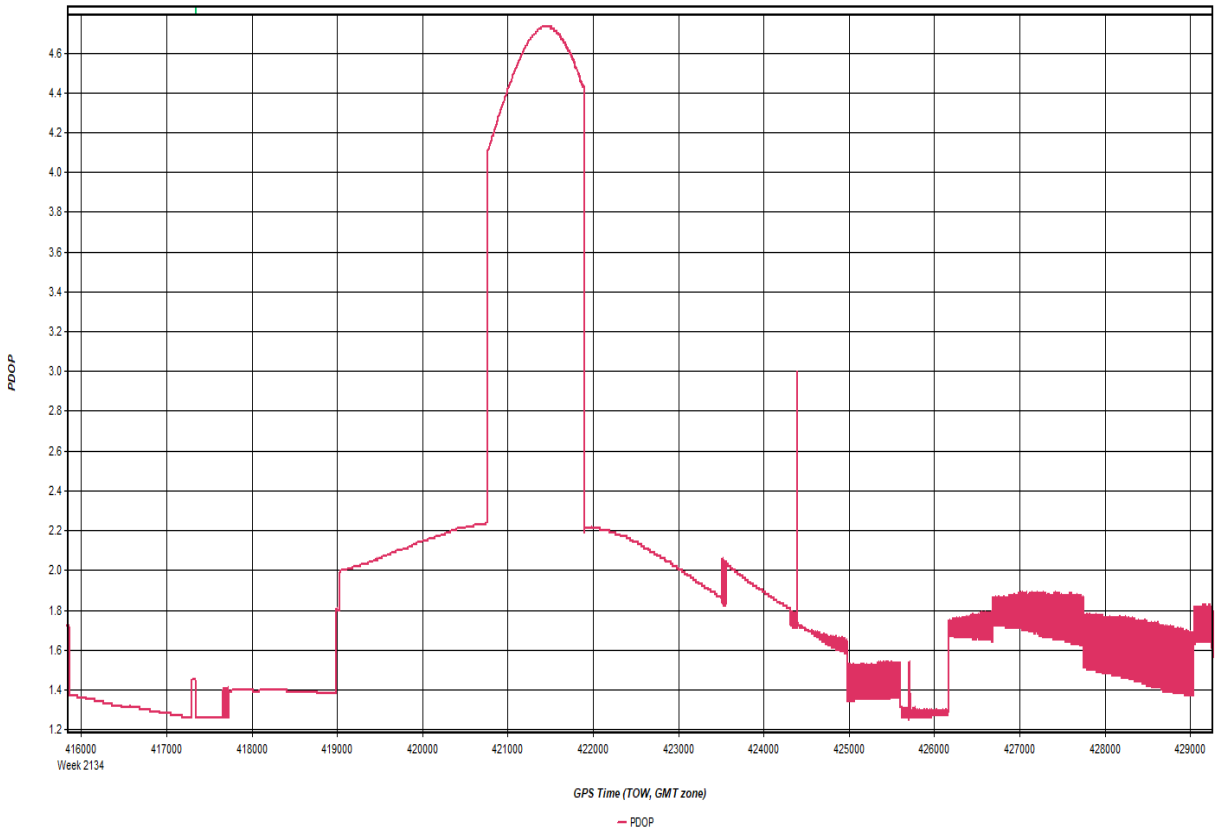
Number of Satellites Plot



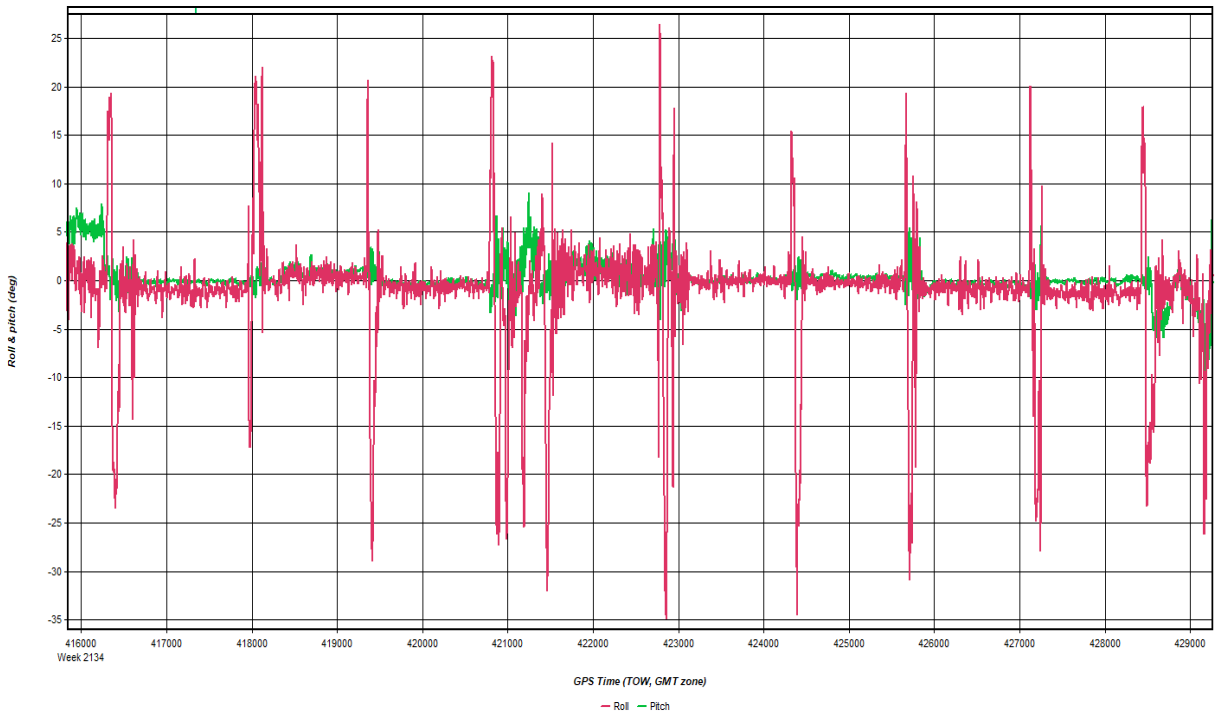
Forward/Reverse or Combined Separation Plot



PDOP Plot



Roll & Pitch Plot



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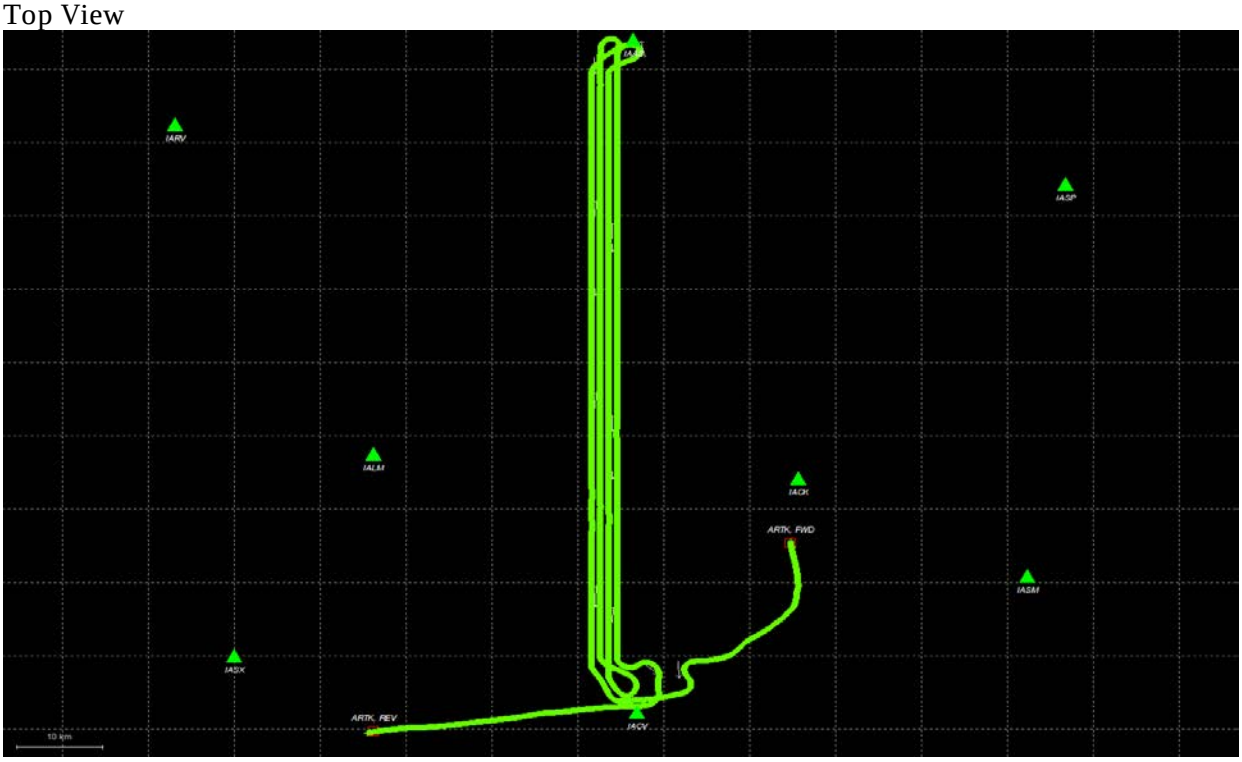
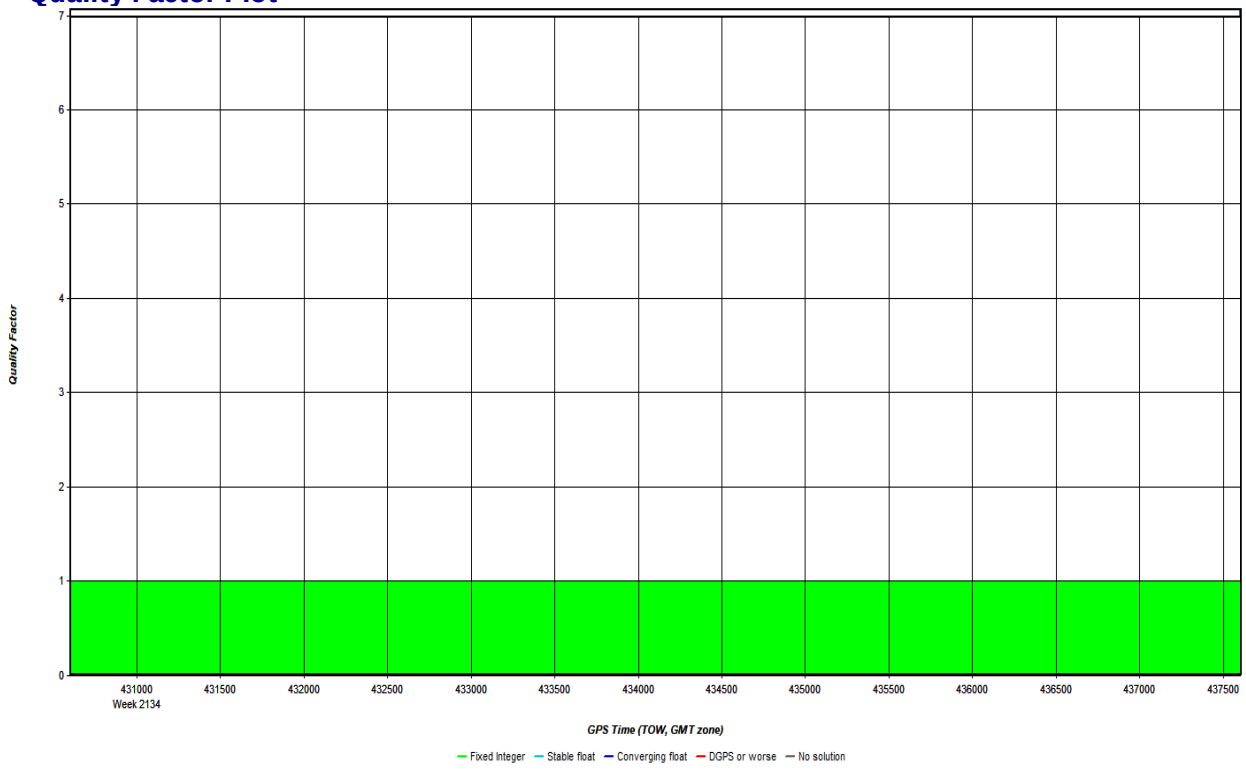
Smoothed Trajectory Information

Top View

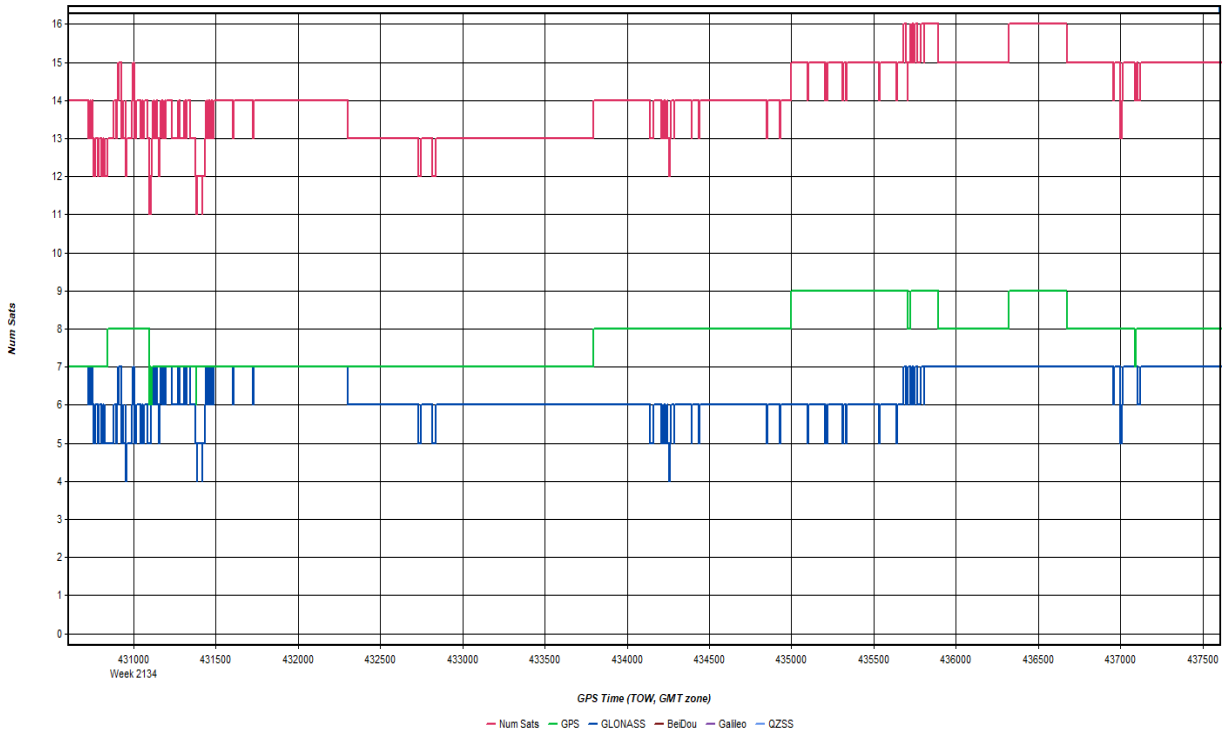


GNSS QC

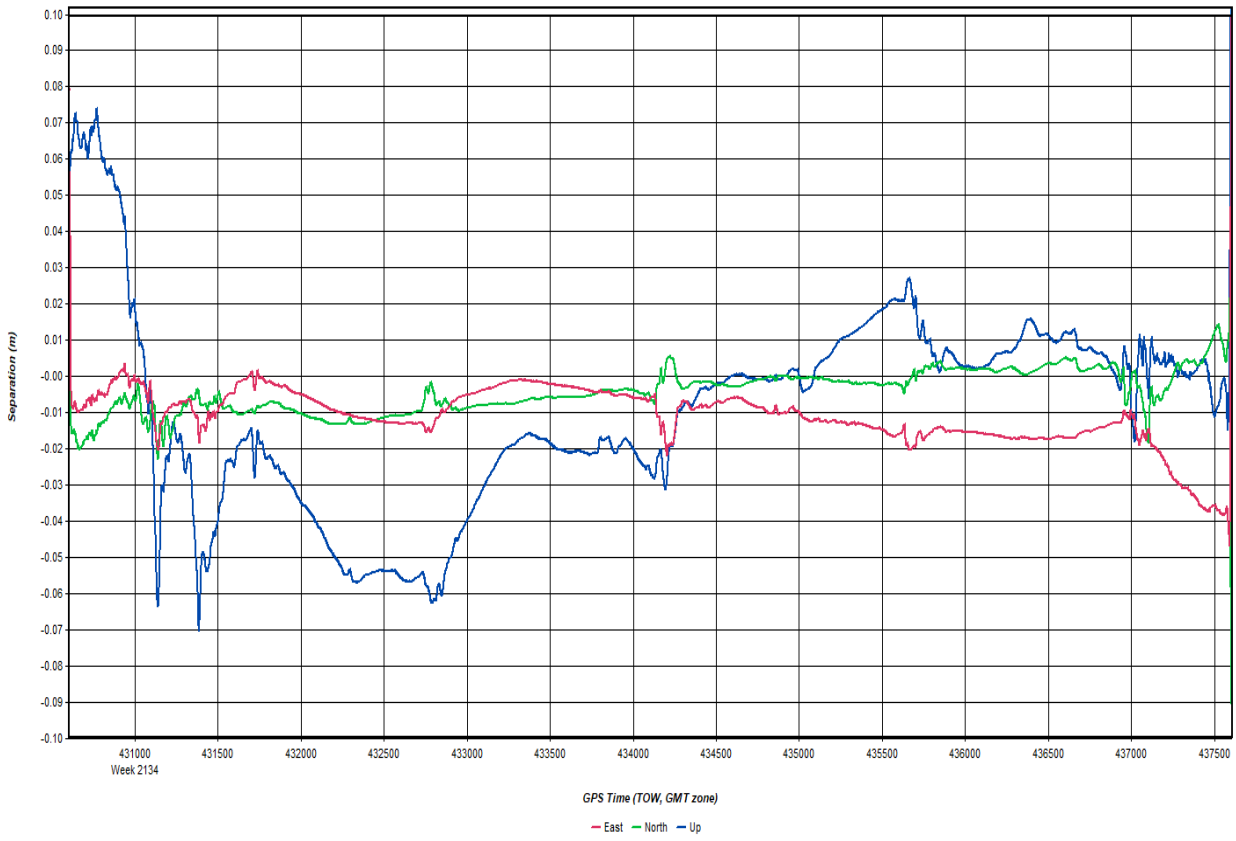
Quality Factor Plot



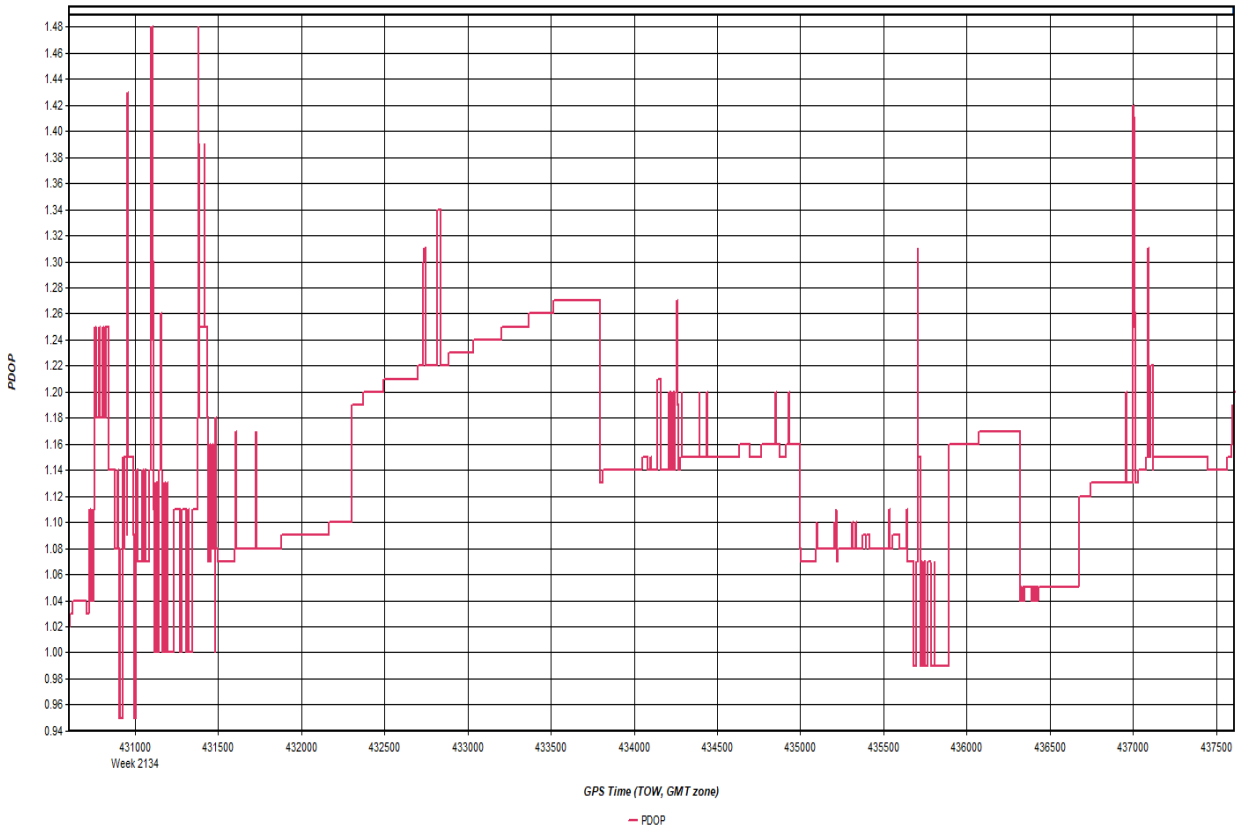
Number of Satellites Plot



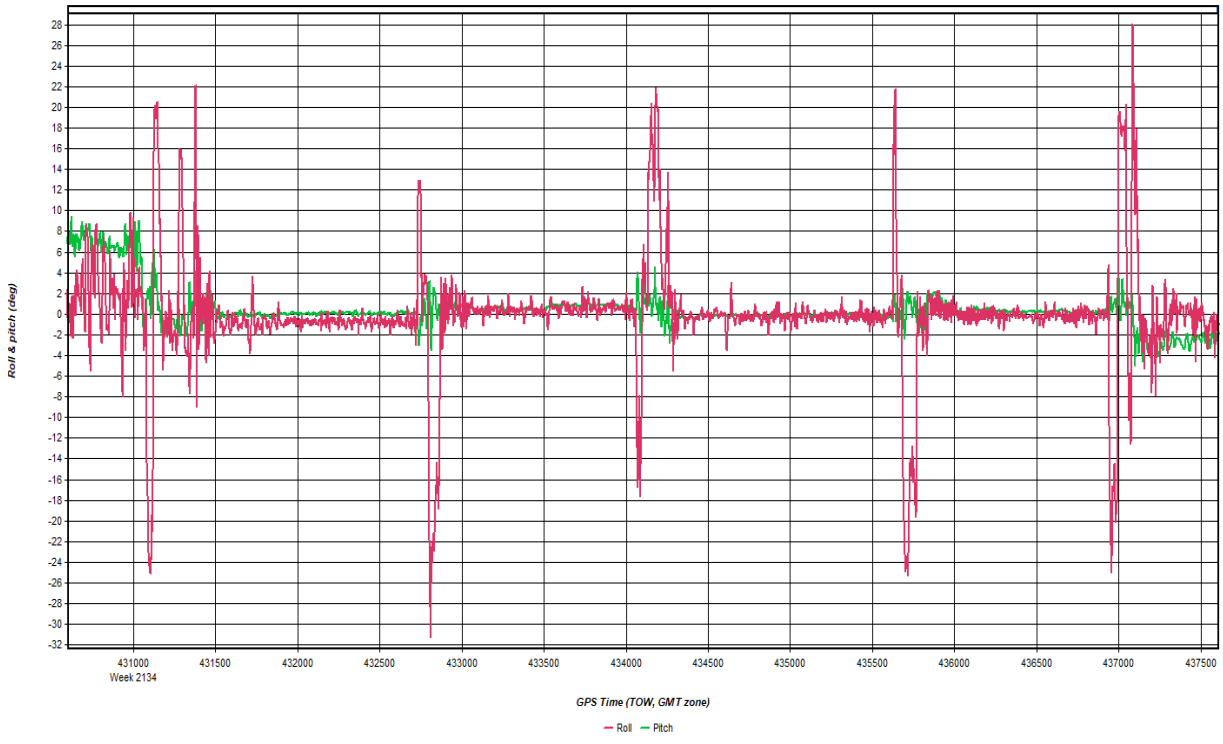
Forward/Reverse or Combined Separation Plot



PDOP Plot



Roll & Pitch Plot



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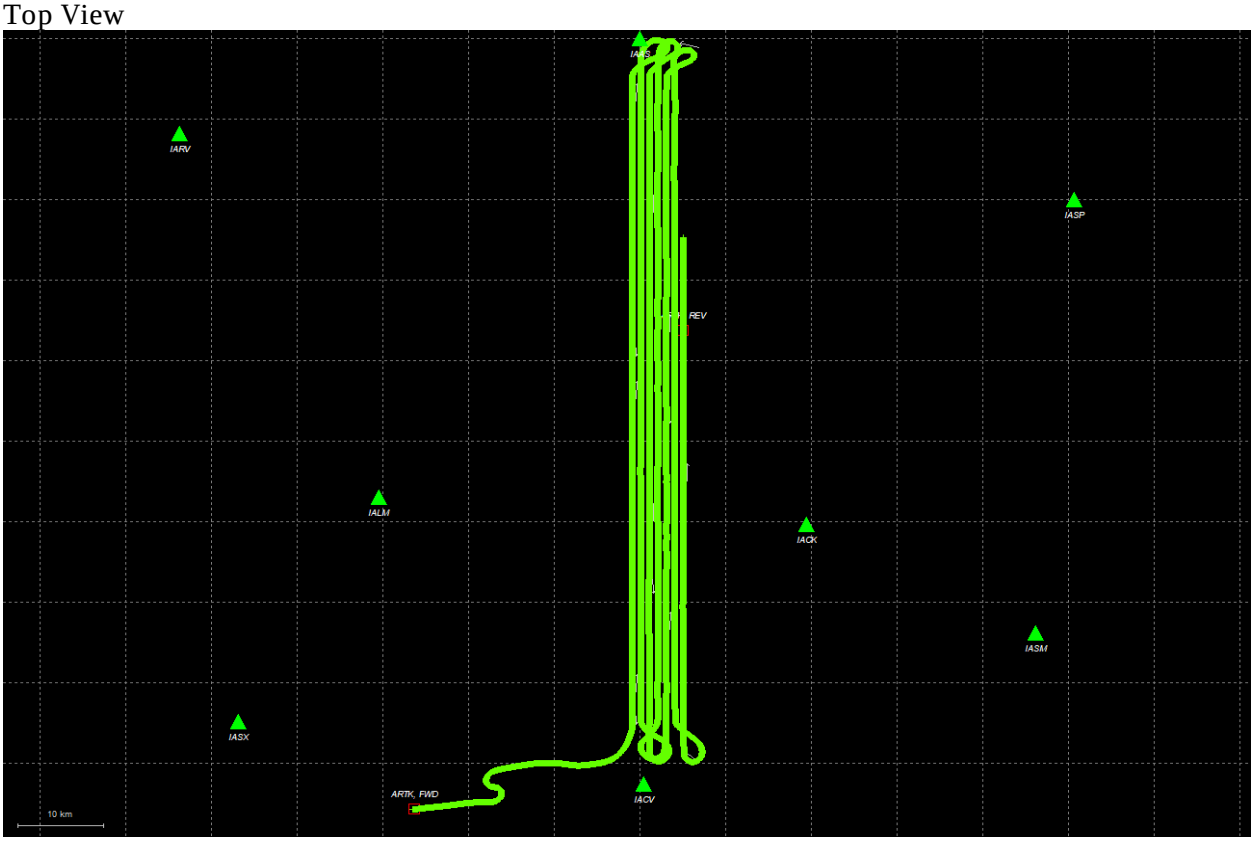
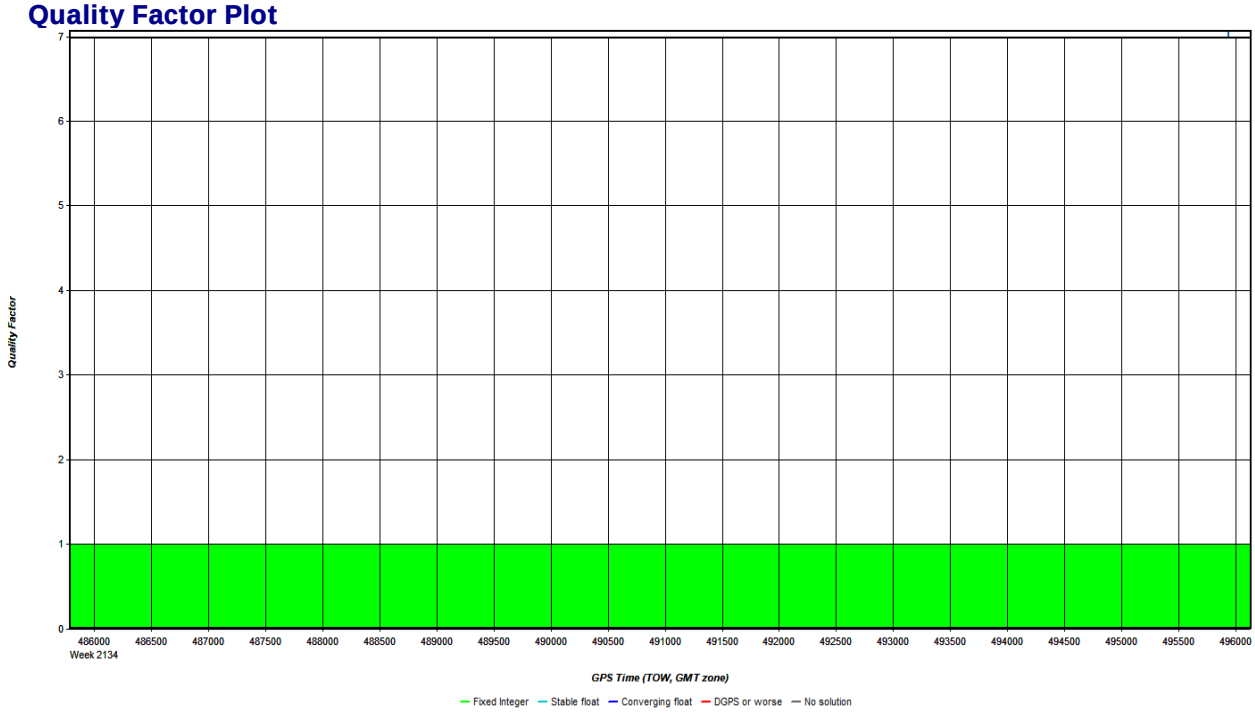
Smoothed Trajectory Information

Top View

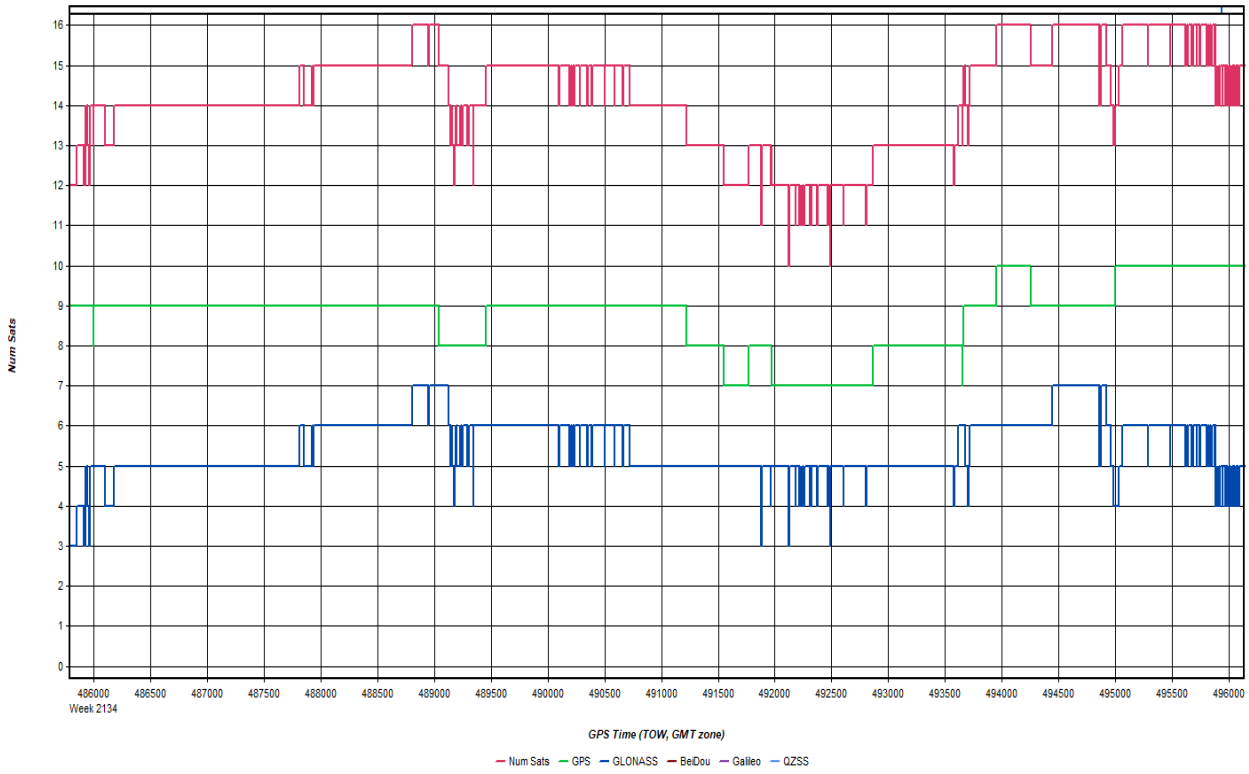


GNSS QC

Quality Factor Plot

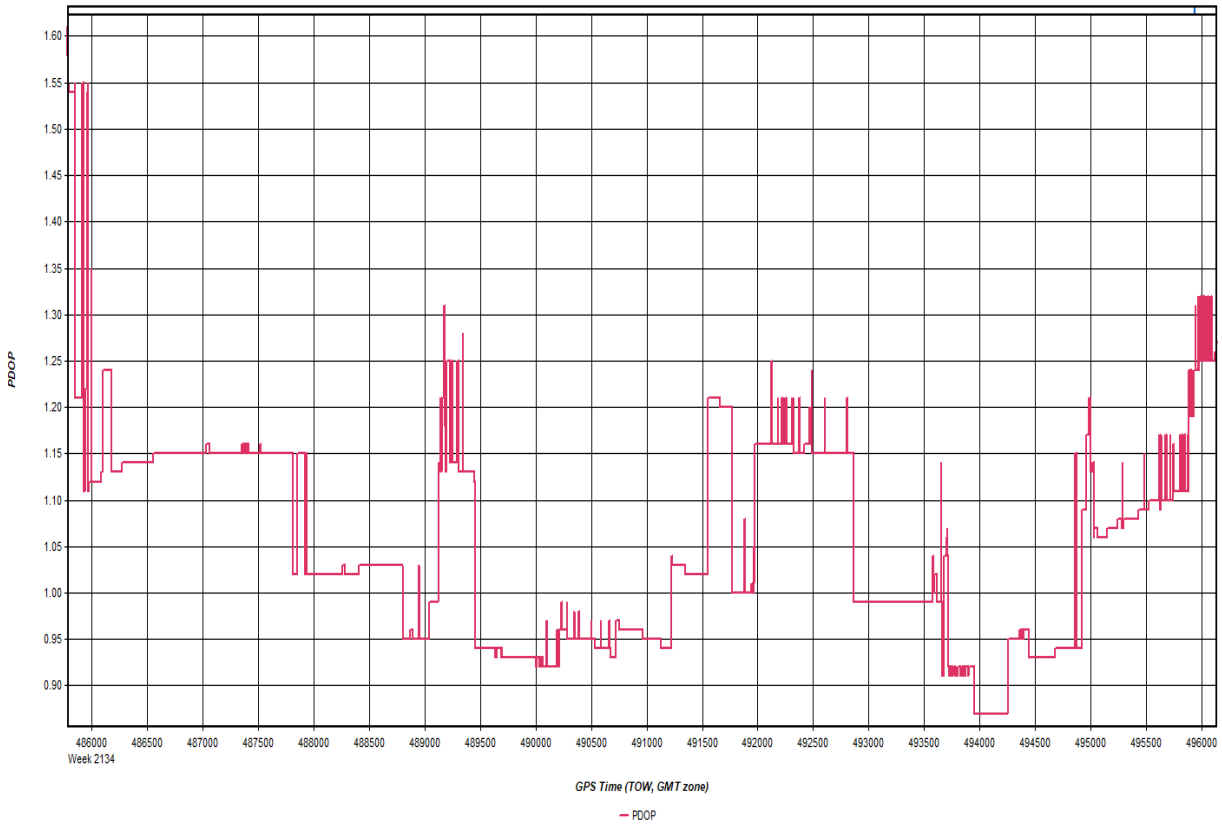


Number of Satellites Plot

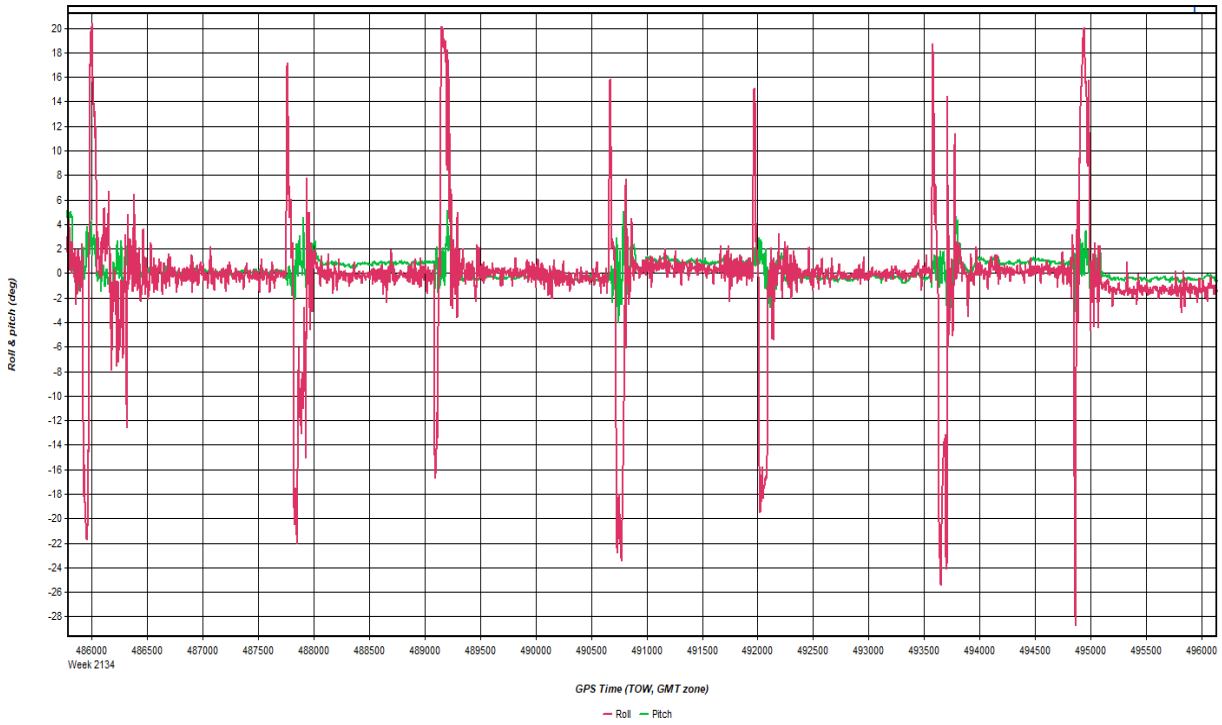


Forward/Reverse or Combined Separation Plot

PDOP Plot



Roll & Pitch Plot



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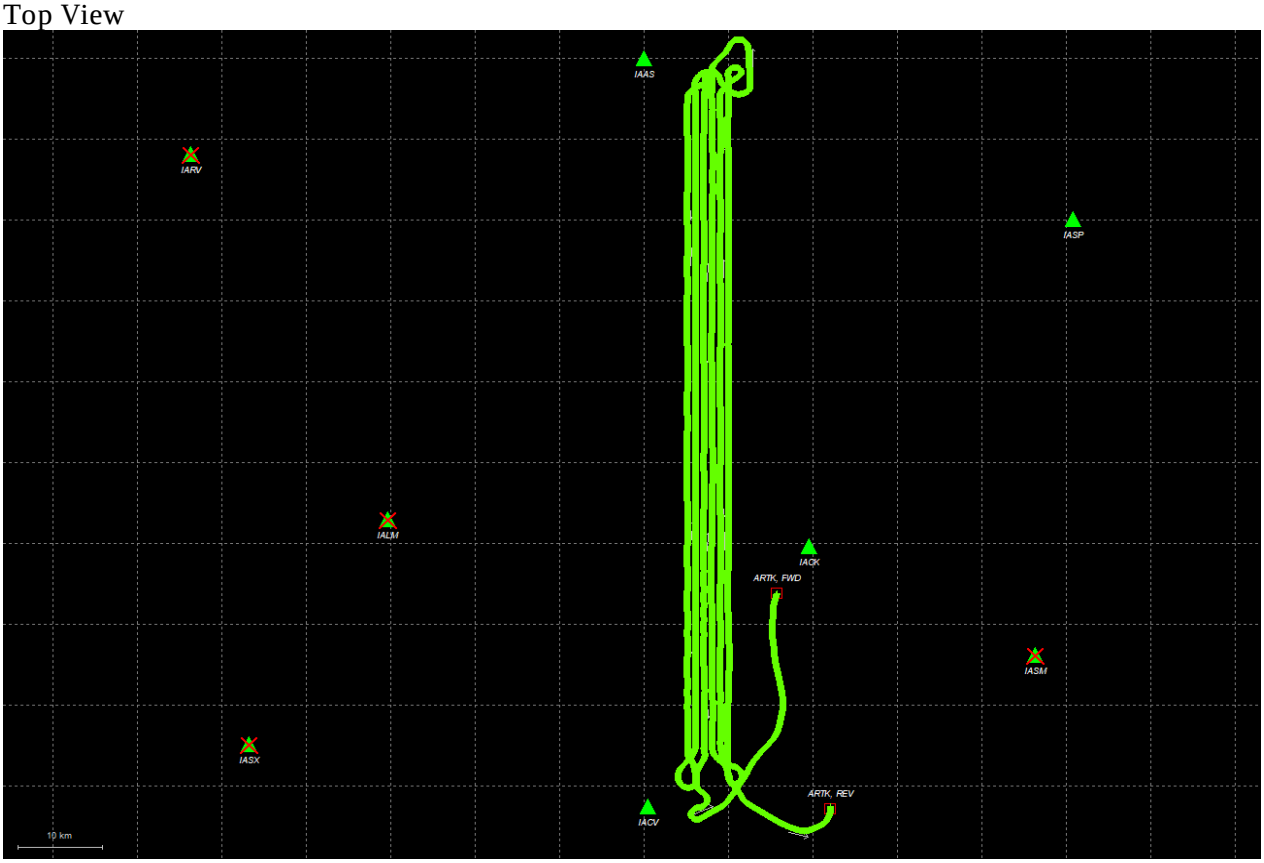
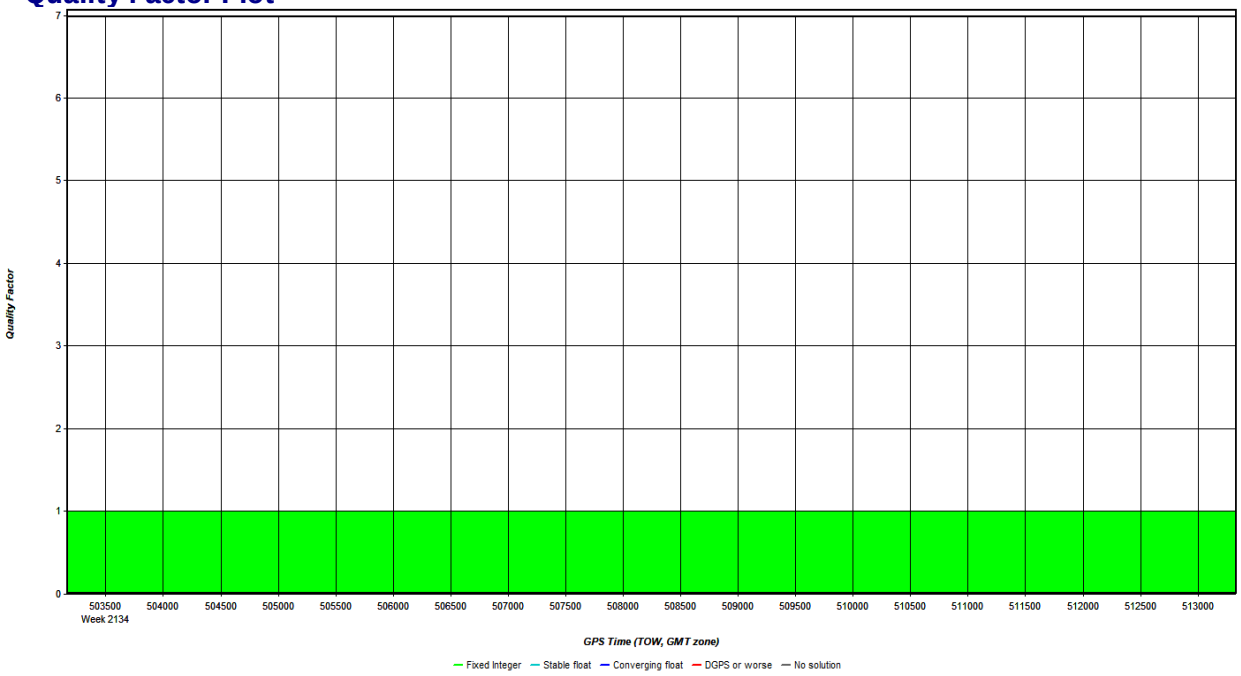
Smoothed Trajectory Information

Top View

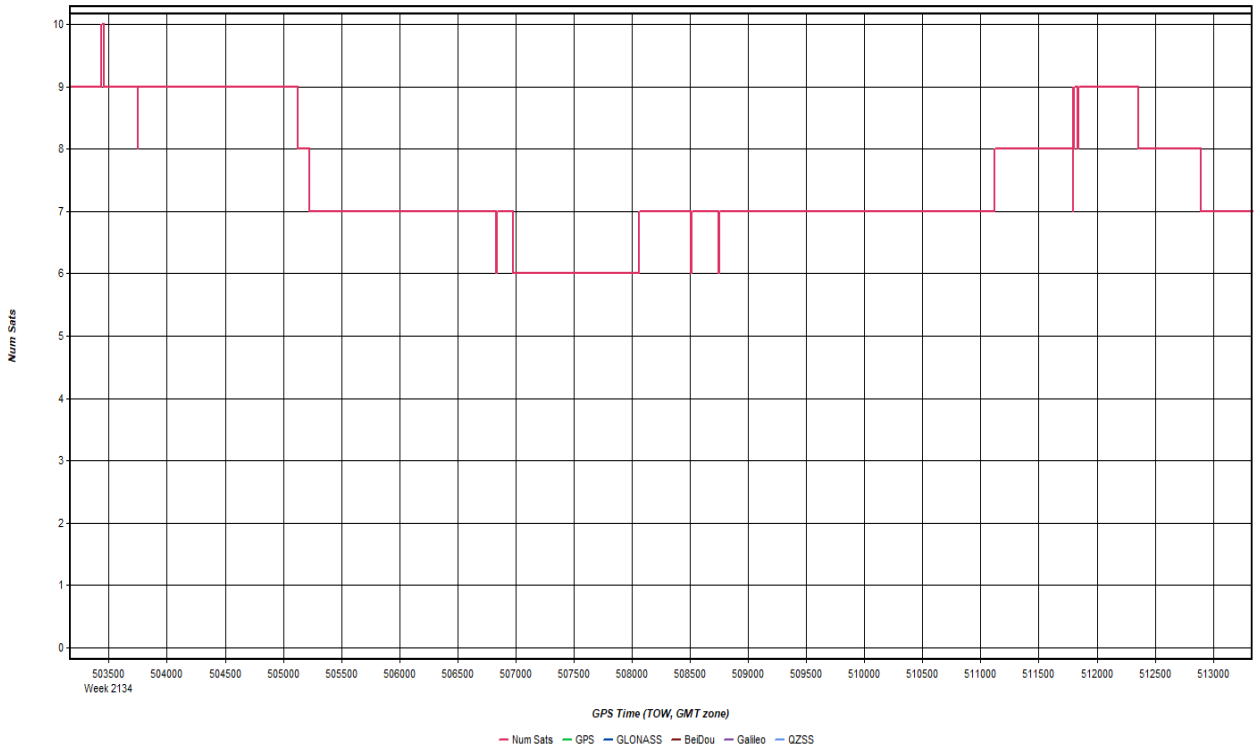


GNSS QC

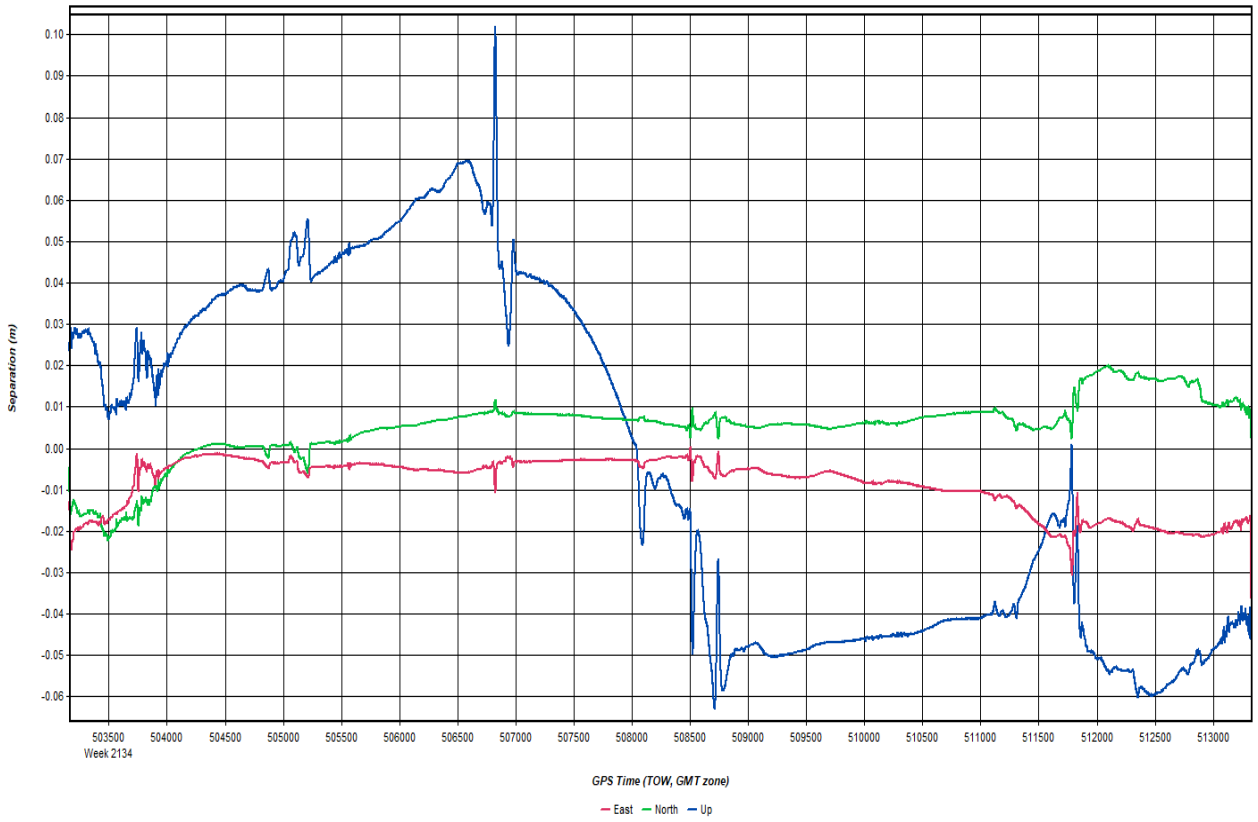
Quality Factor Plot



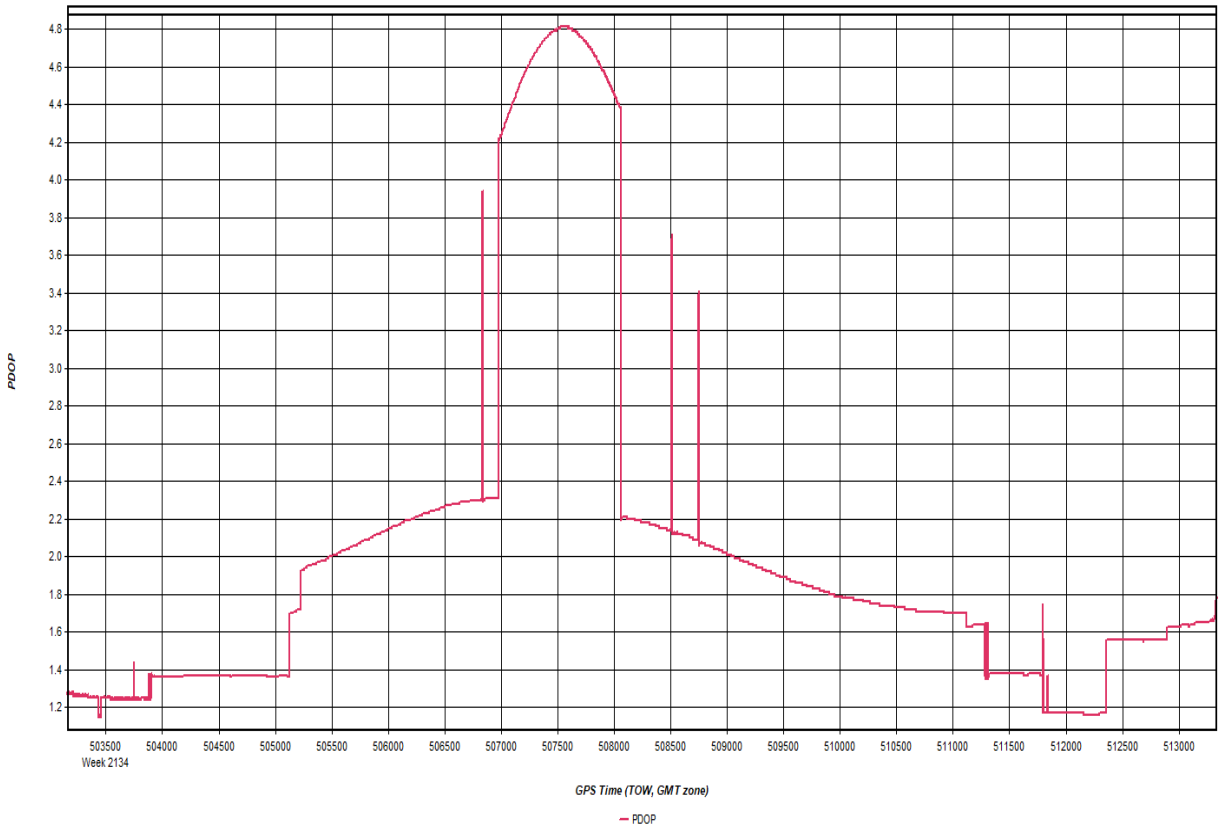
Number of Satellites Plot



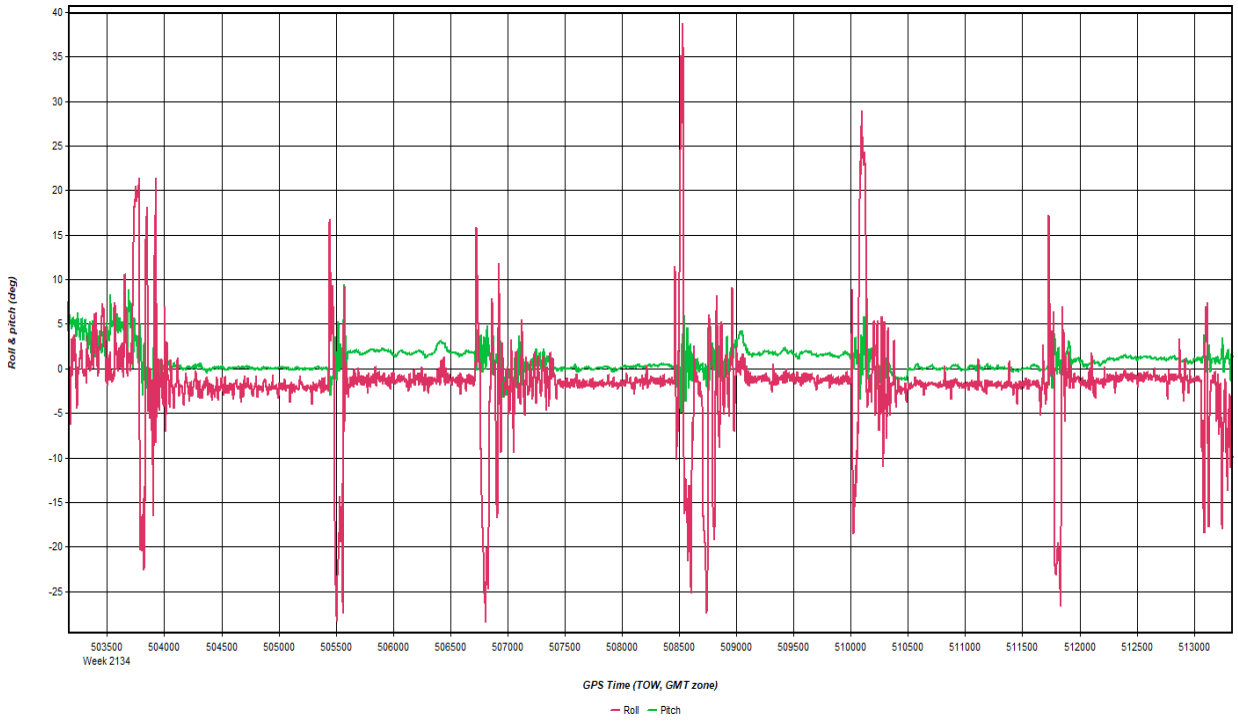
Forward/Reverse or Combined Separation Plot



PDOP Plot



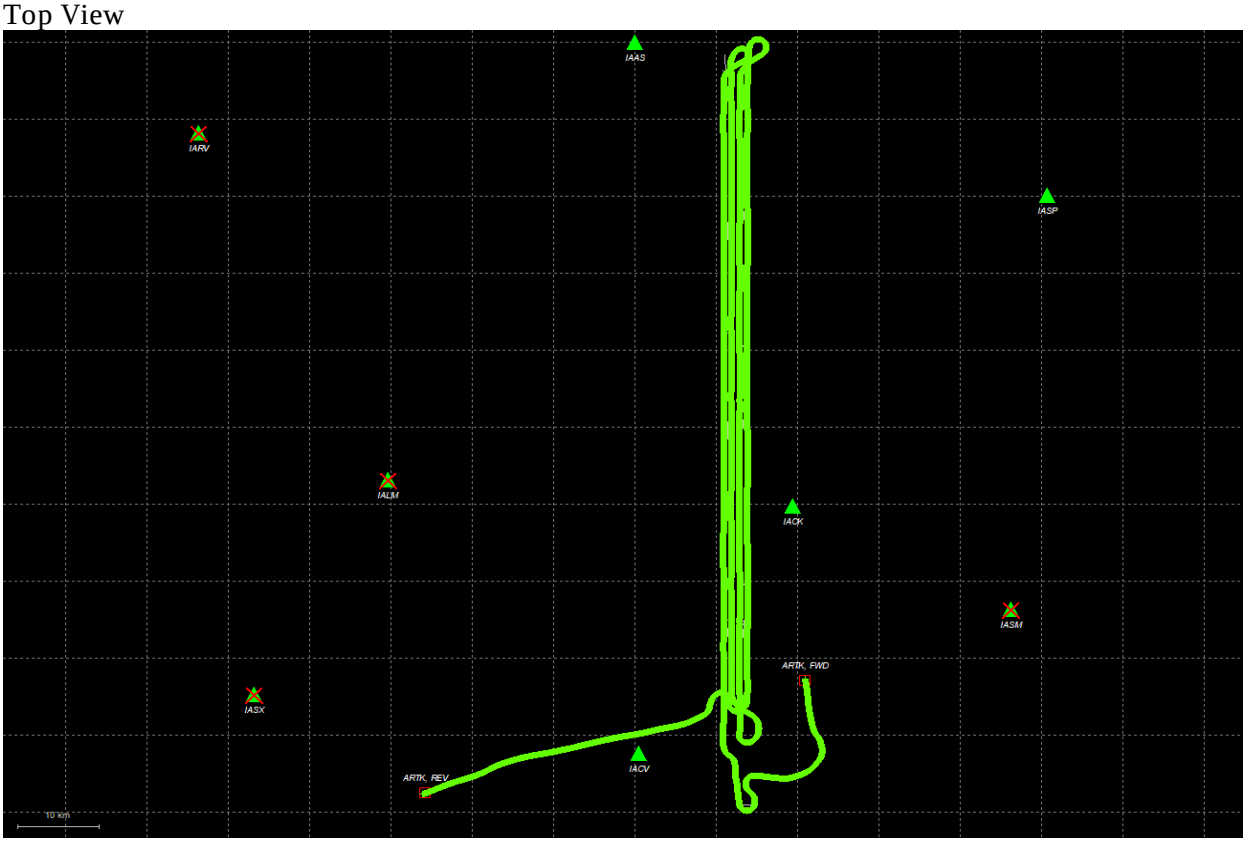
Roll & Pitch Plot



20201204_231634.docx QC Report - 06/22/2021 10:45:25

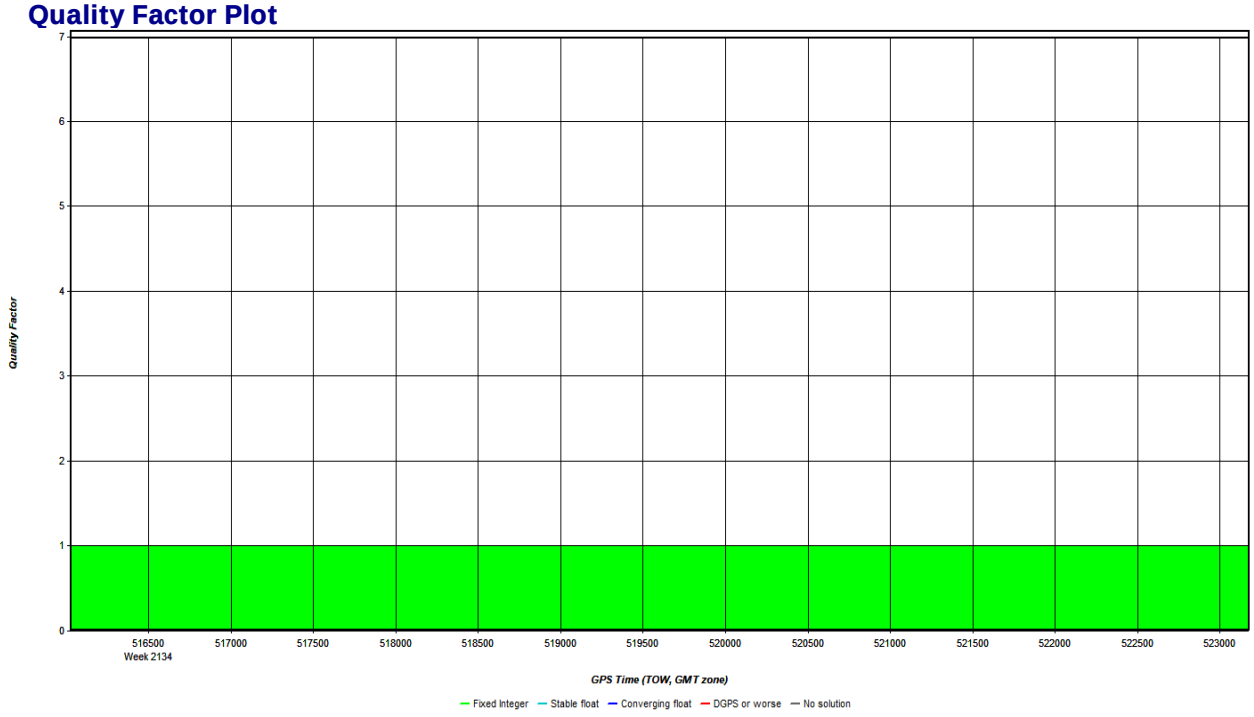
Smoothed Trajectory Information

Top View

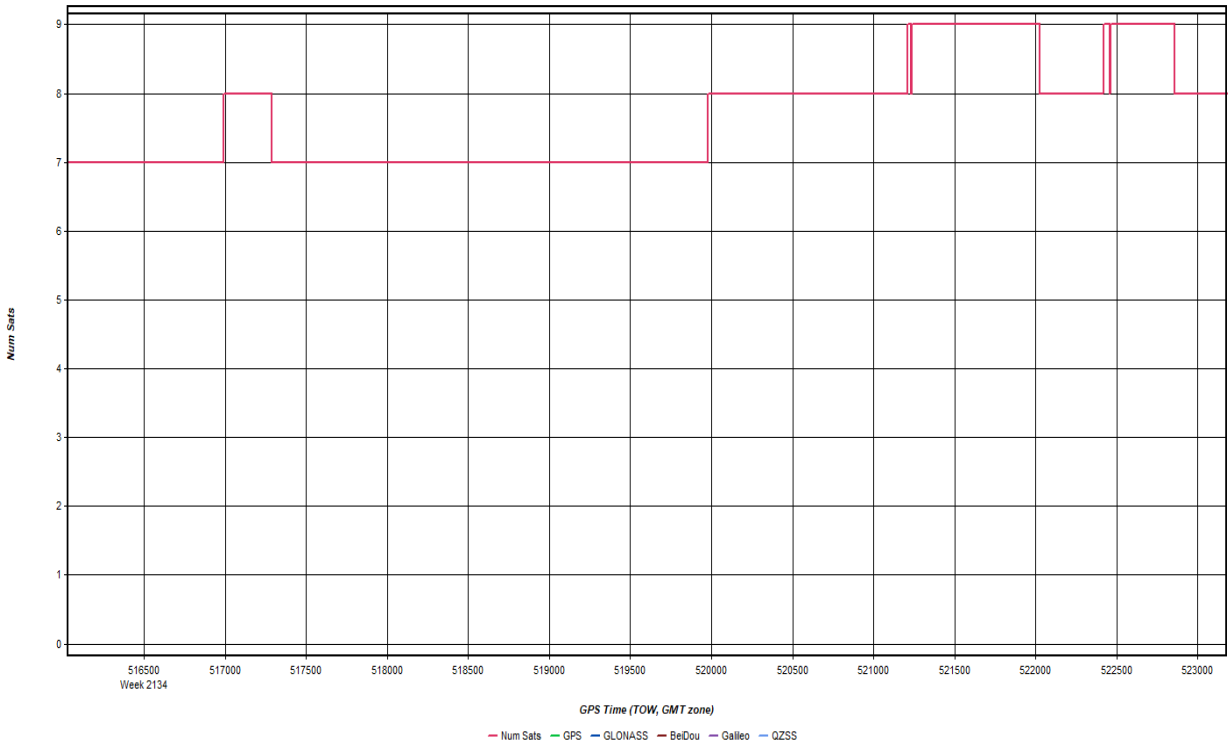


GNSS QC

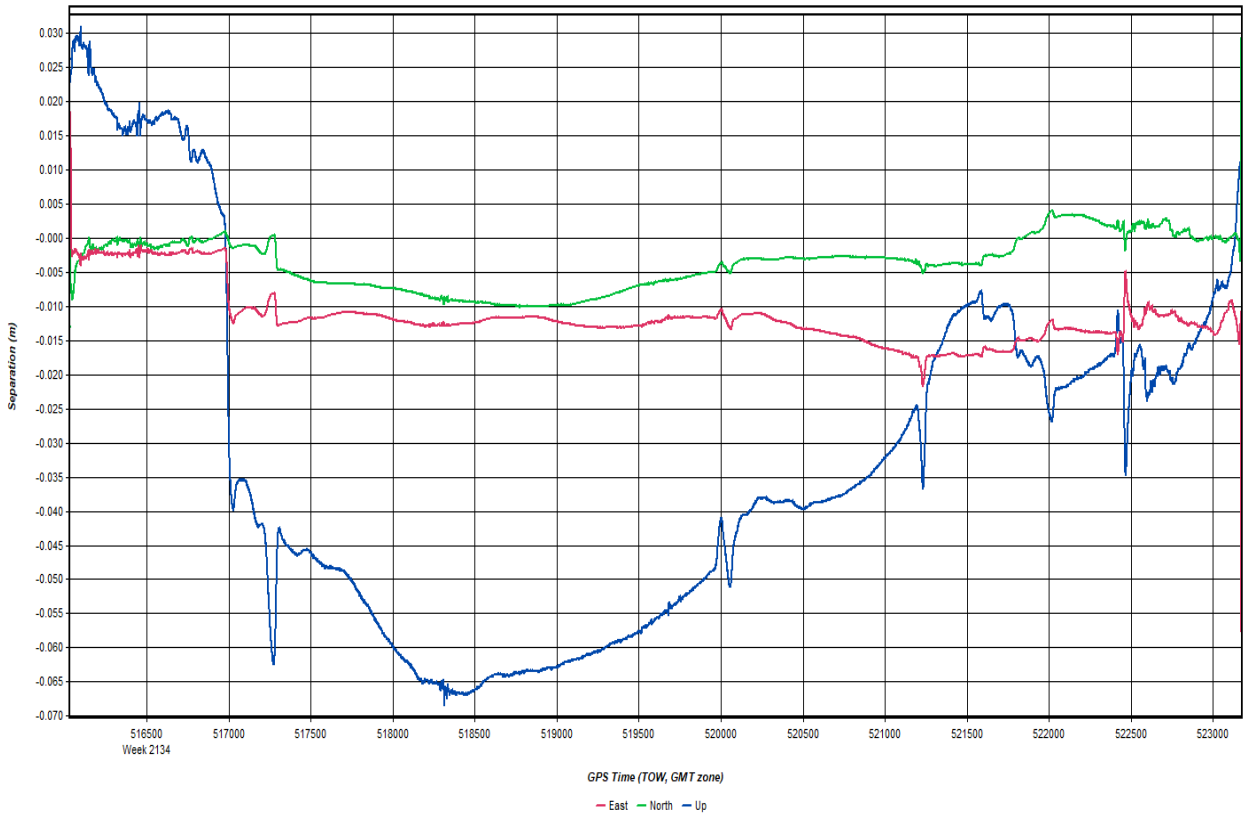
Quality Factor Plot



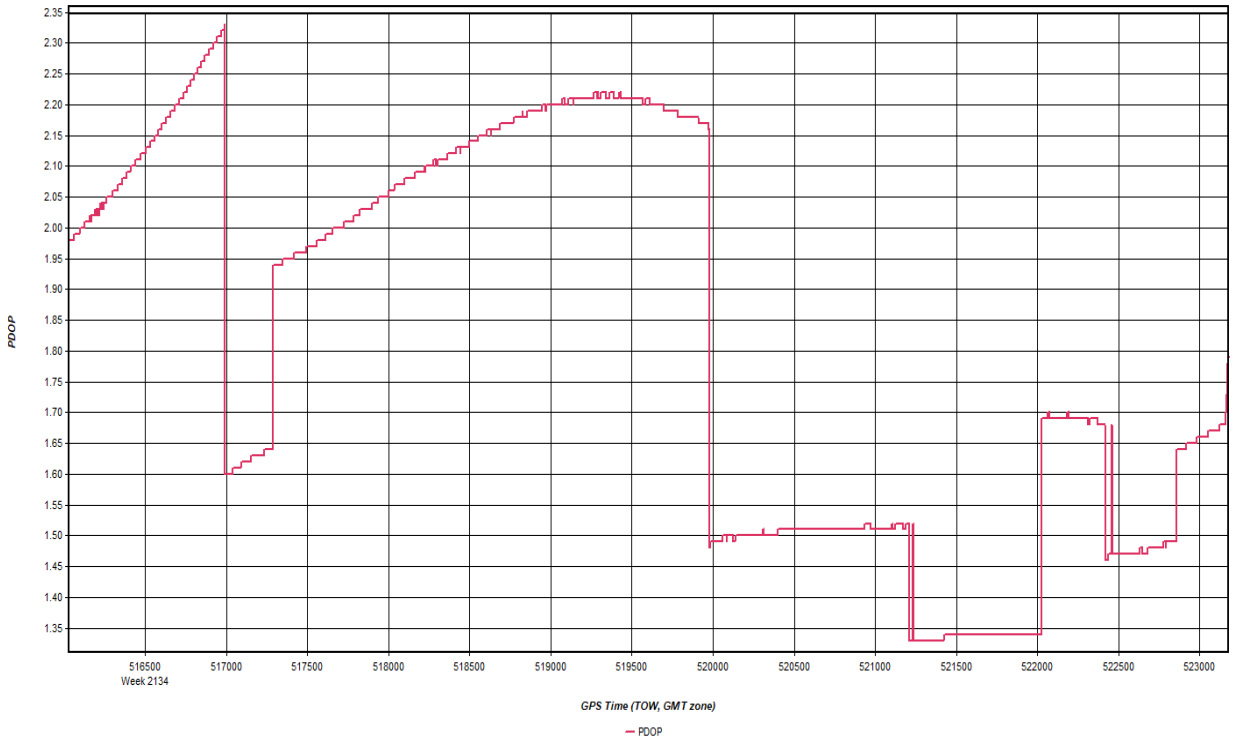
Number of Satellites Plot



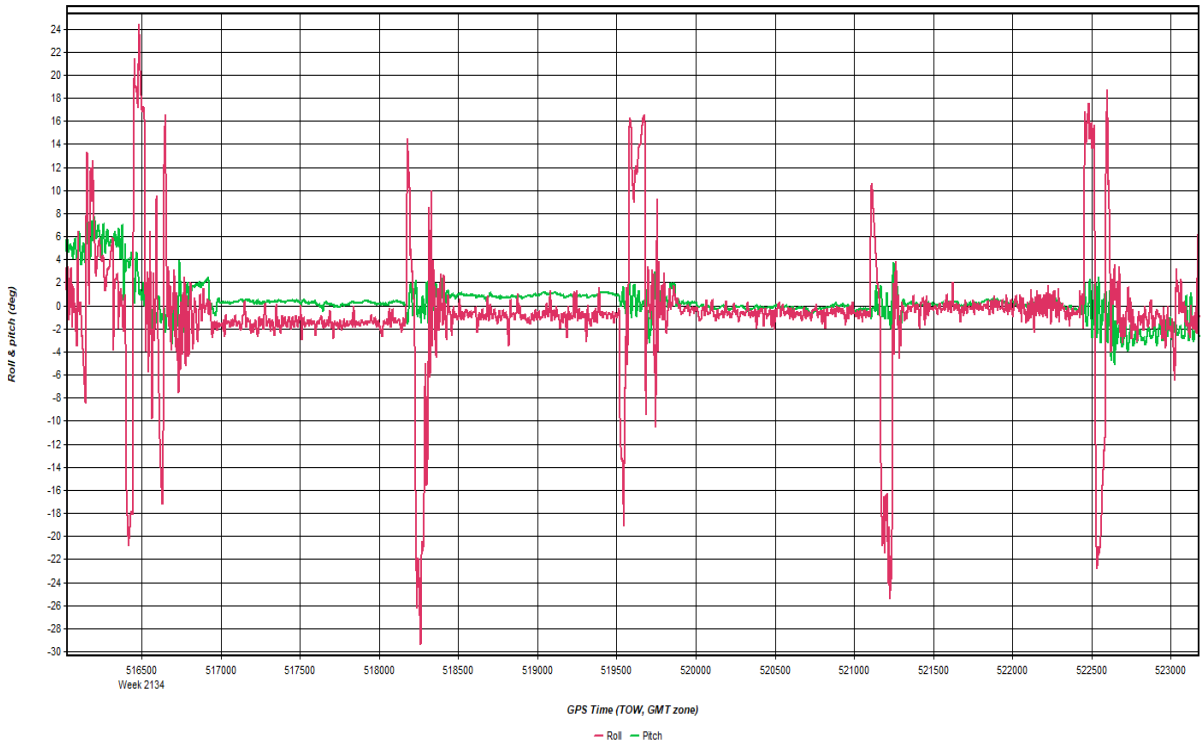
Forward/Reverse or Combined Separation Plot



PDOP Plot



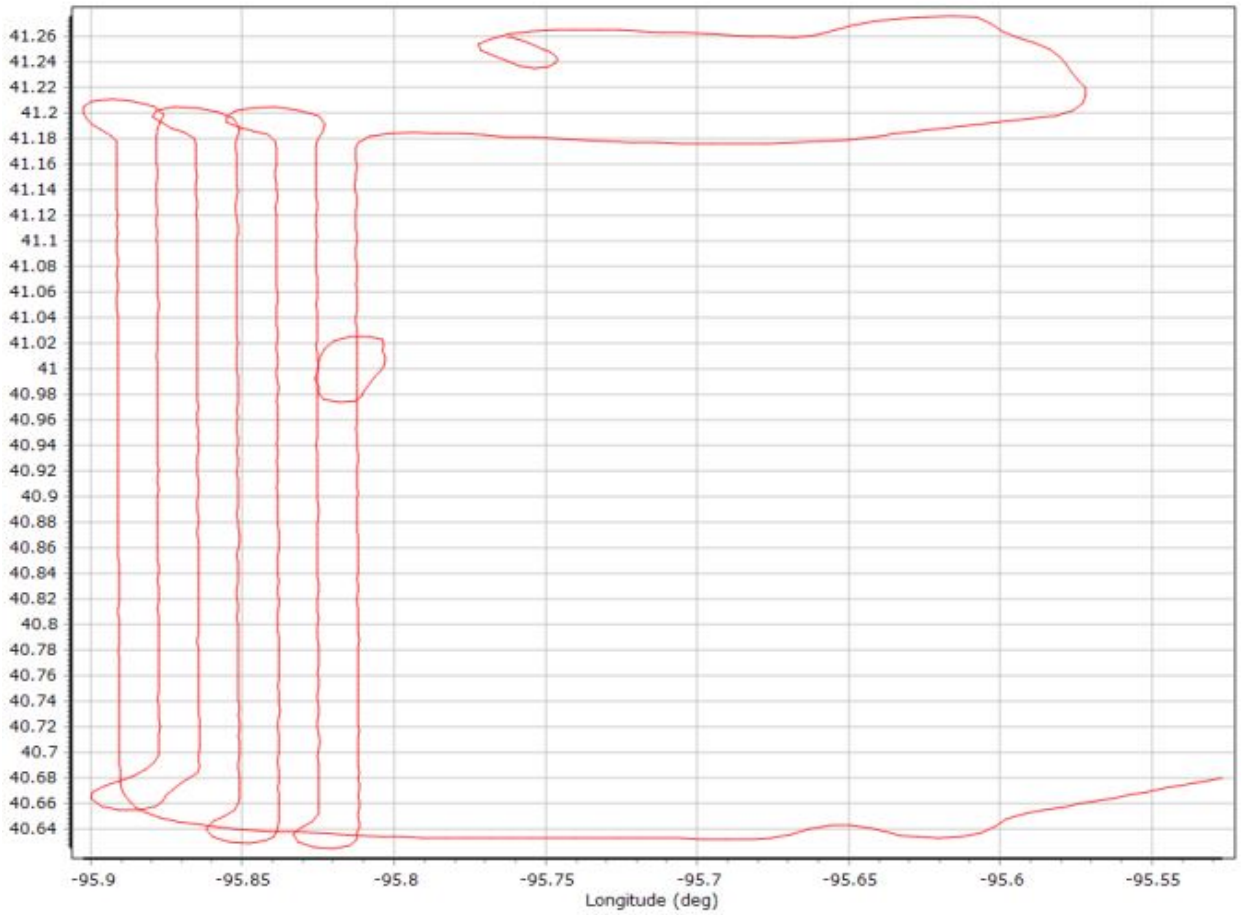
Roll & Pitch Plot



TAC Reports for Block A.

20201205_1_QC Report.docx QC Report – 8/27/2021 07:28:24
Smoothed Trajectory Information

Top View

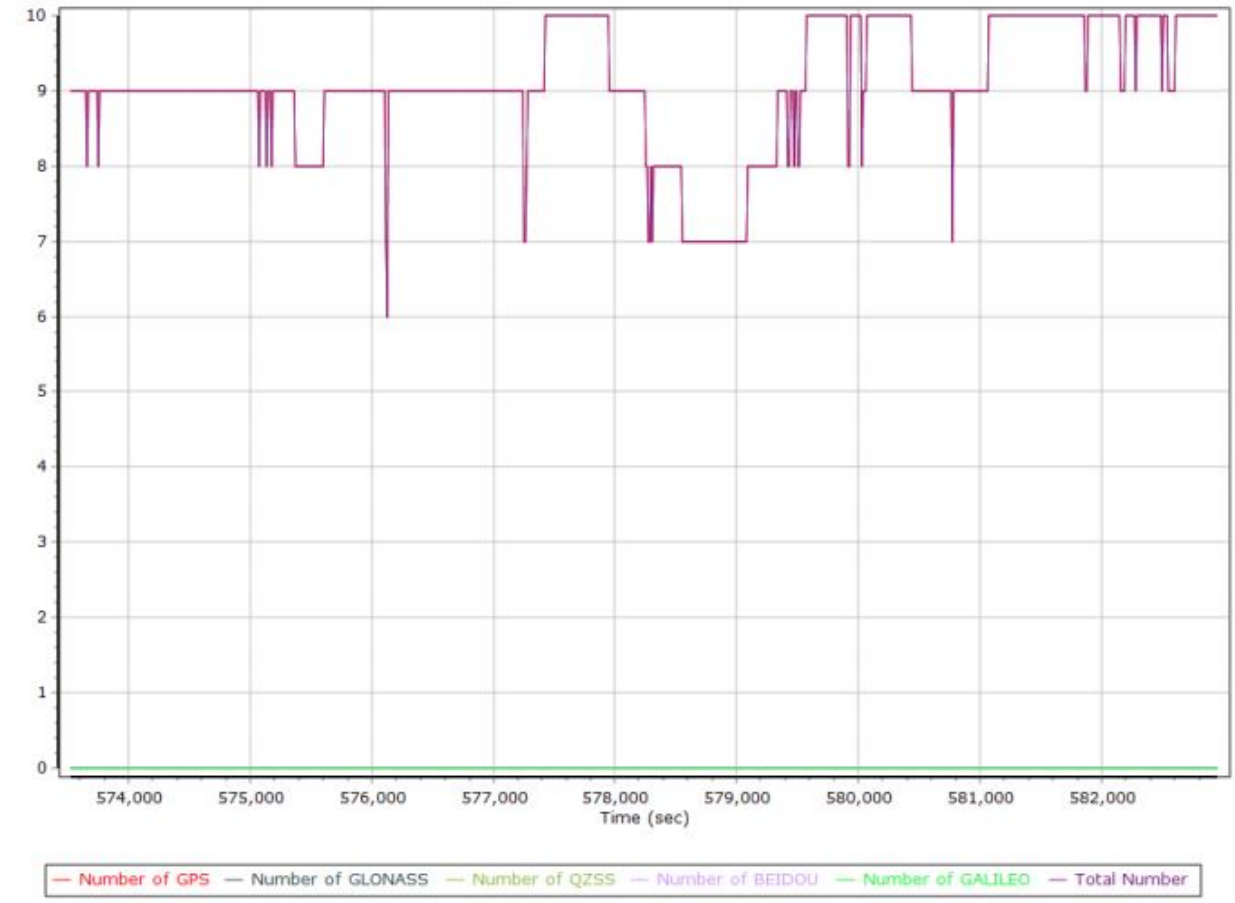


GNSS QC

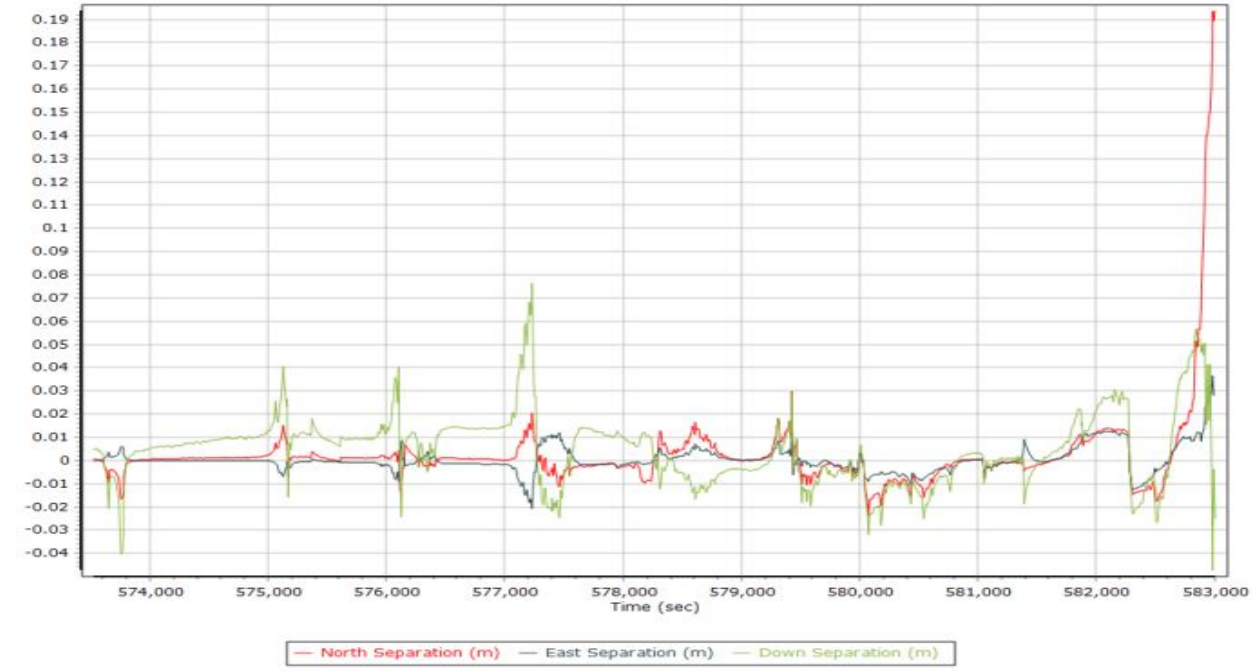
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	2.28	41.81	
Number of GPS SV	5	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	10	9
PDOP	1.53	6.02	1.78
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	9499.00	0.00	0.00
Percentage	100.00	0.00	0.00

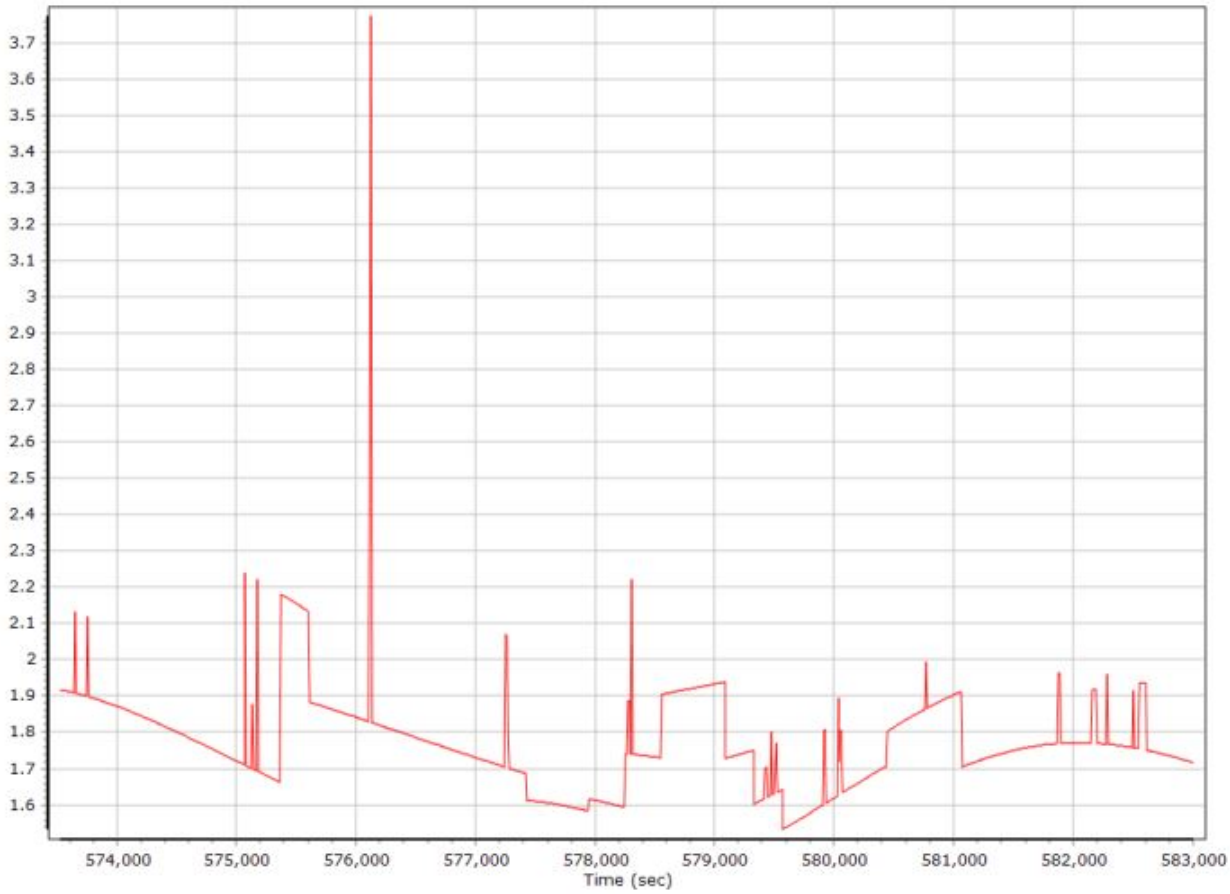
Number of Satellites



Forward/Reverse Separation



PDOP


3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
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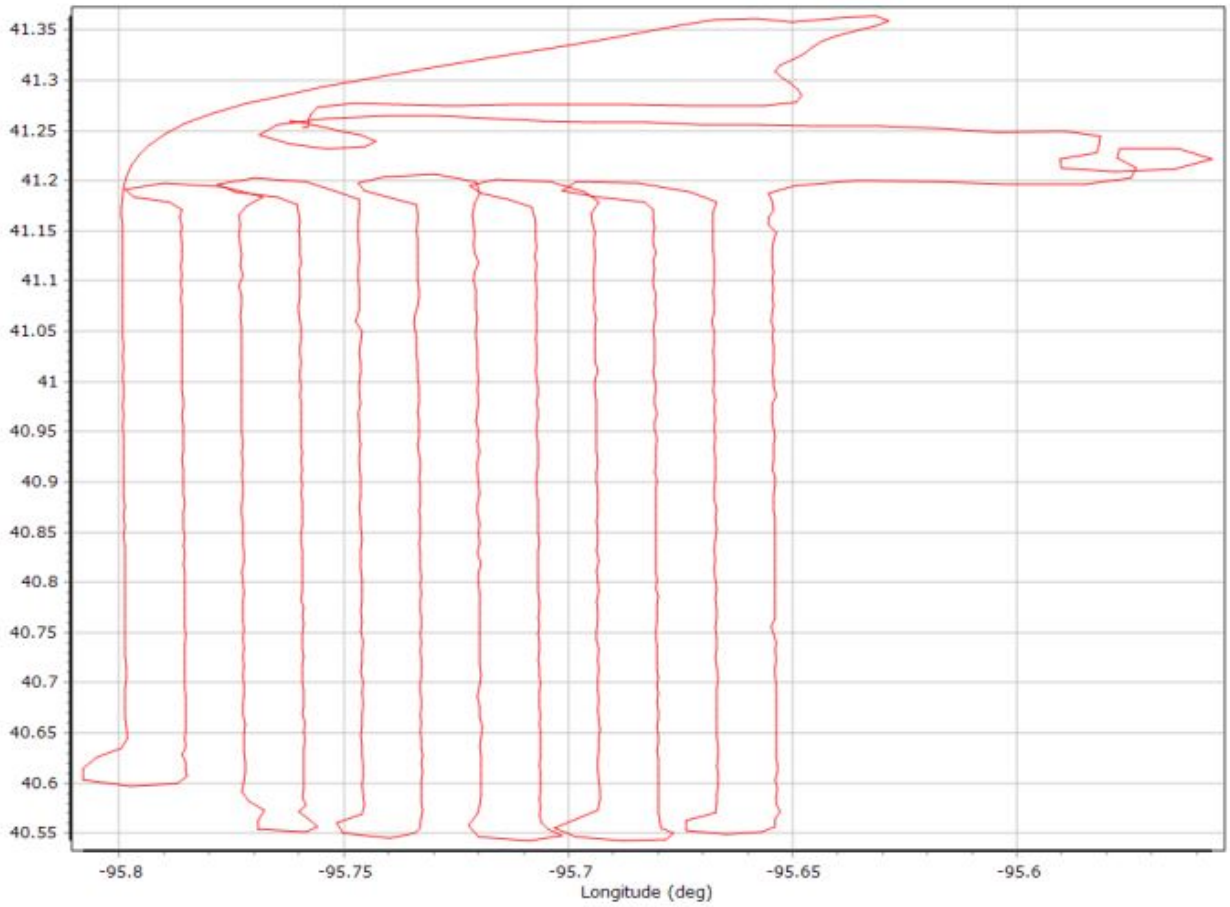
575,000
576,000
577,000
578,000
579,000
580,000
581,000
582,000
583,000
Time (sec)

20201205_2_QC Report.docx QC Report – 8/27/2021 07:28:24
Smoothed Trajectory Information

Top View

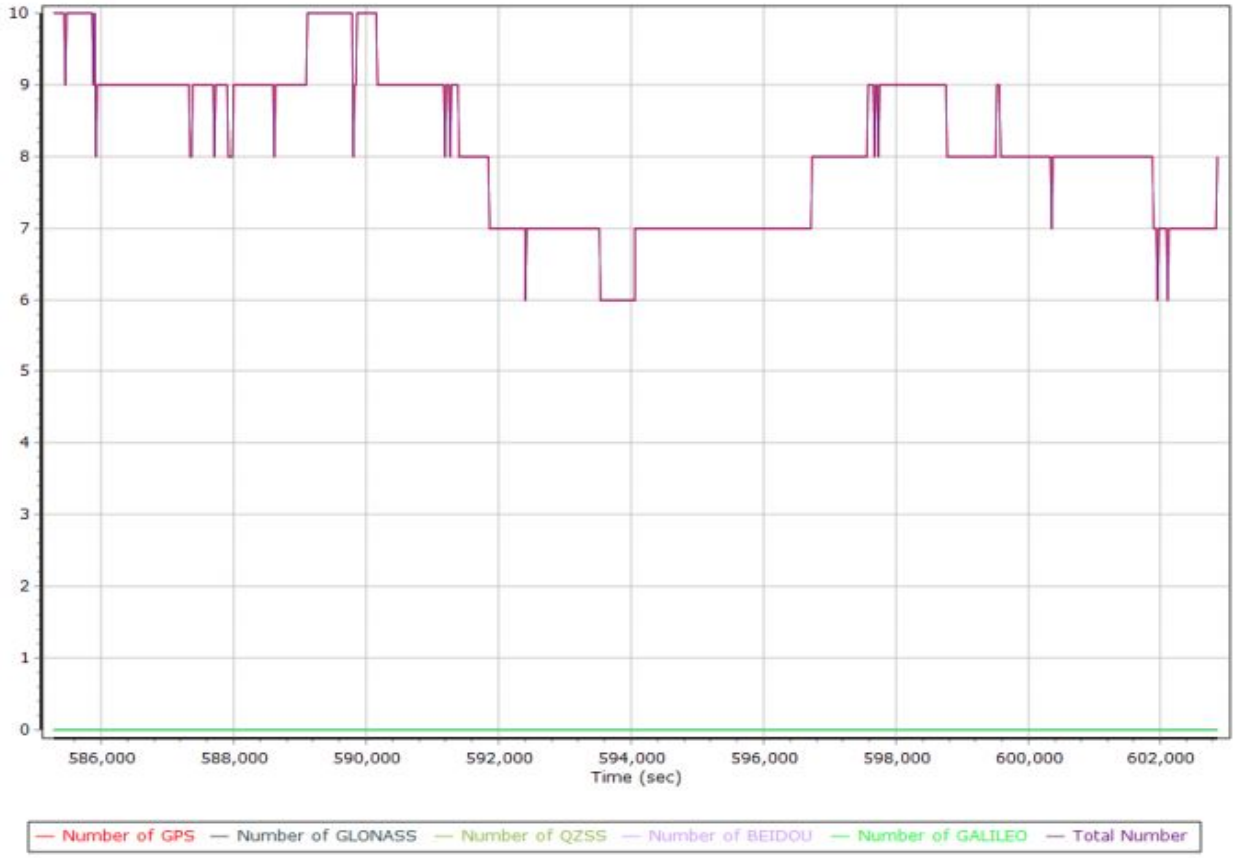


GNSS QC

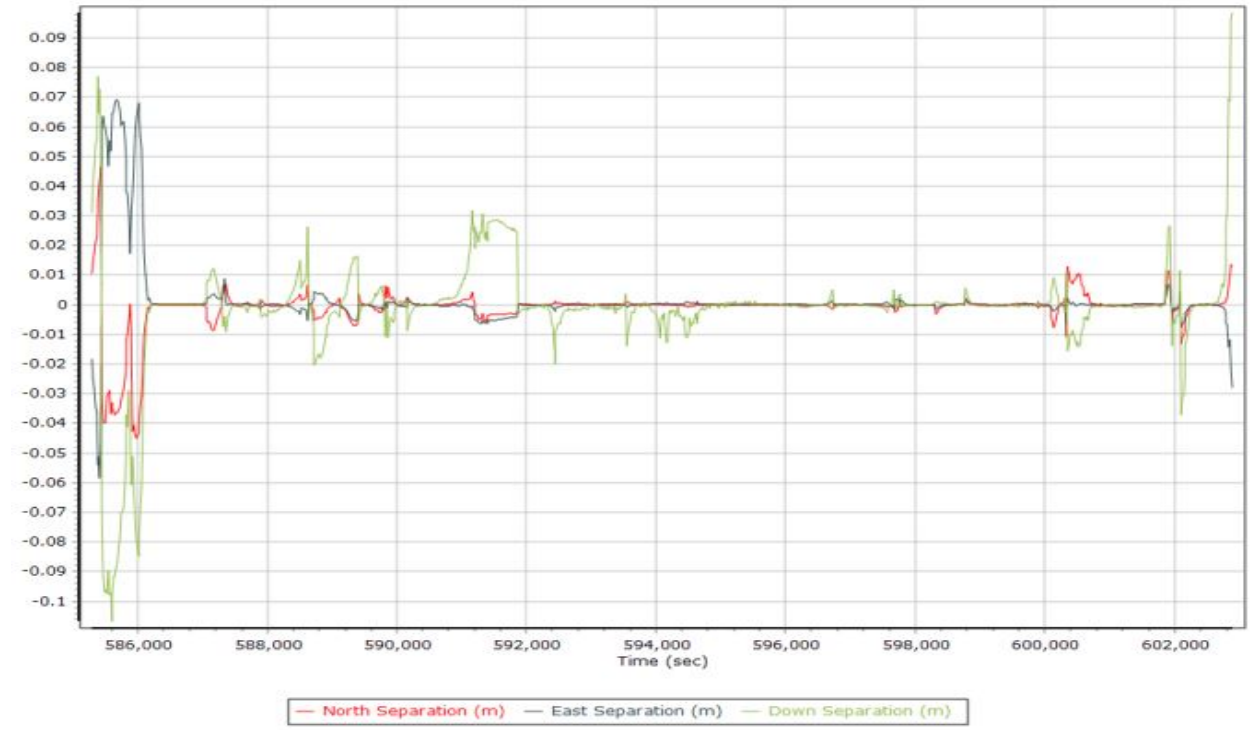
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.30	48.79	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	8
PDOP	1.53	5.01	2.09
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	17843.00	188.00	1.00
Percentage	98.95	1.04	0.01

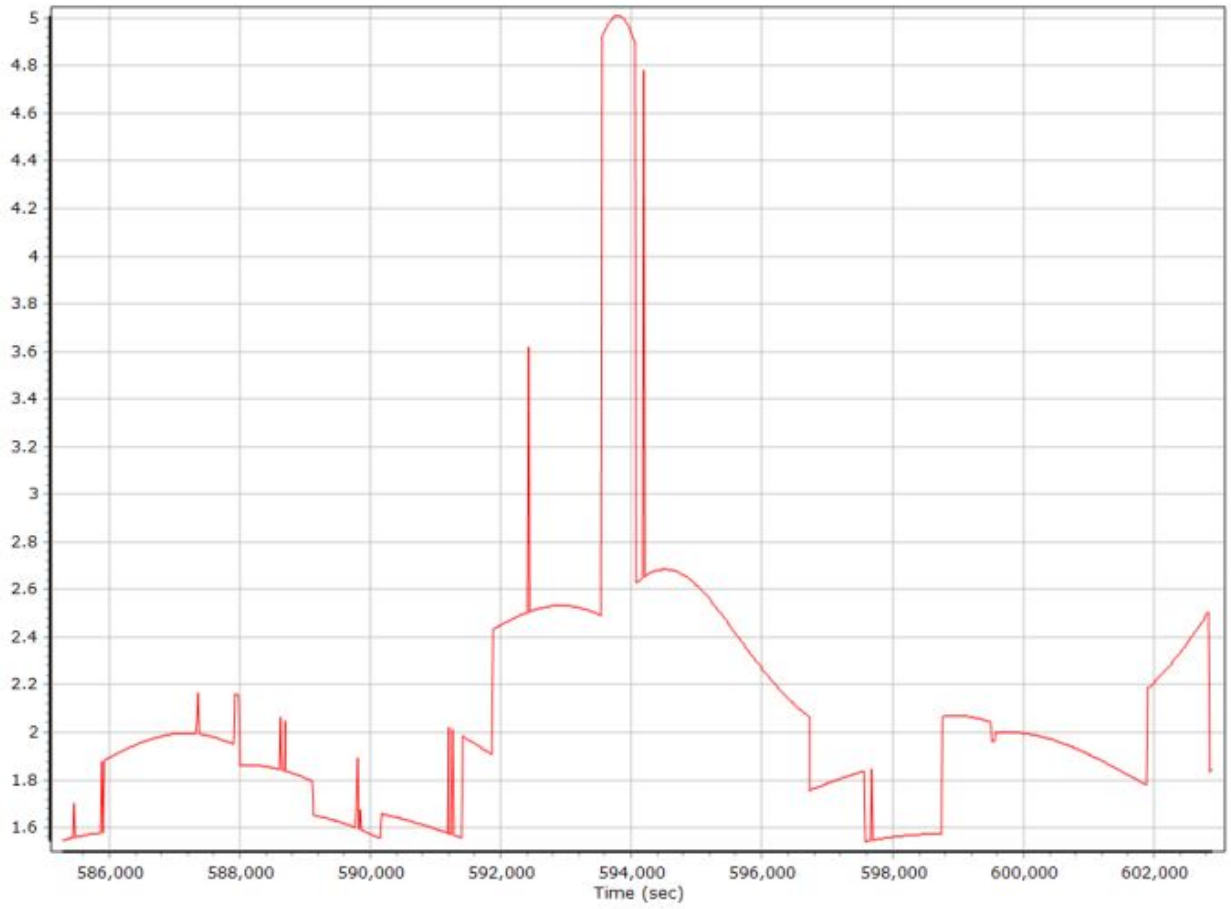
Number of Satellites



Forward/Reverse Separation



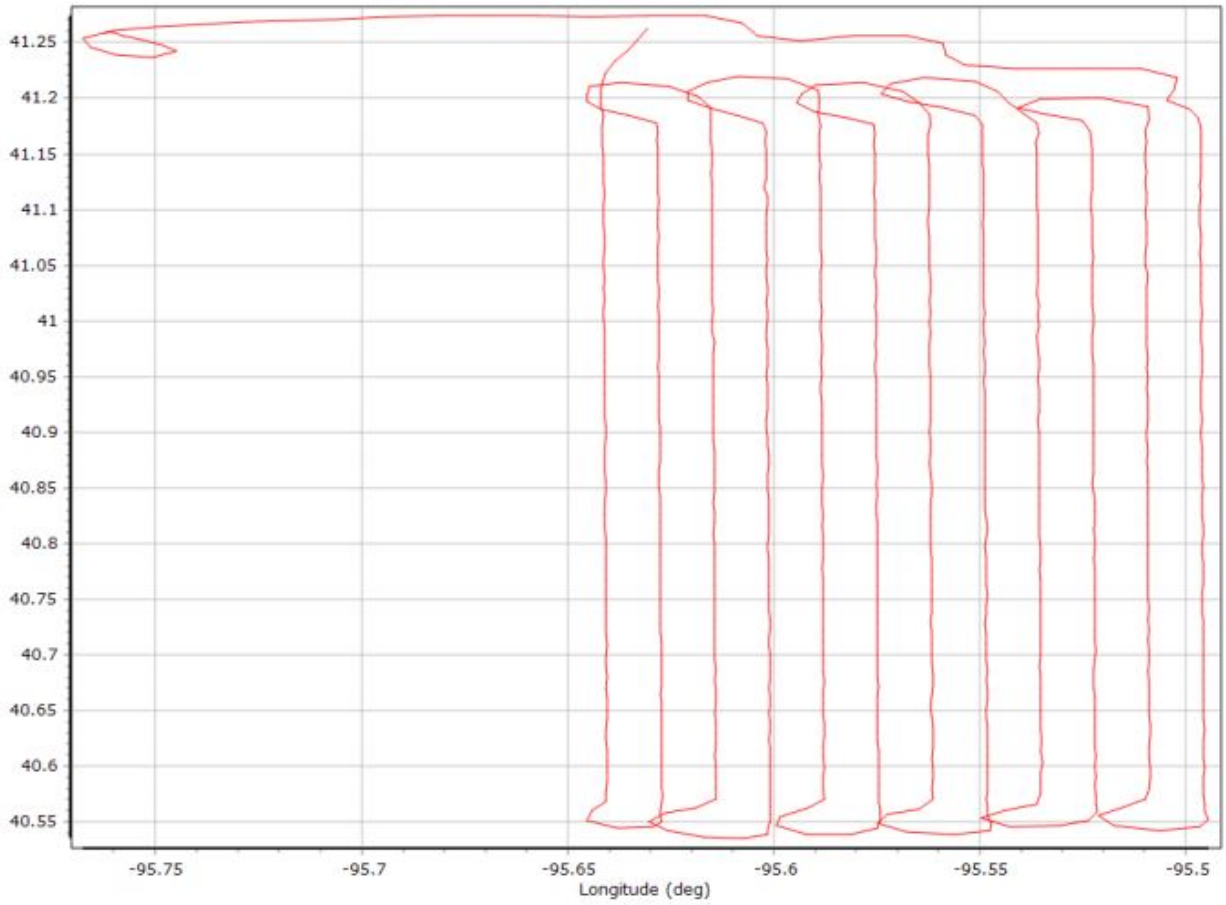
PDOP


5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
586,000
588,000
590,000
592,000
594,000
596,000
598,000
600,000
602,000
Time (sec)

20201207_QC Report.docx QC Report – 8/27/2021 07:39:22

Smoothed Trajectory Information

Top View

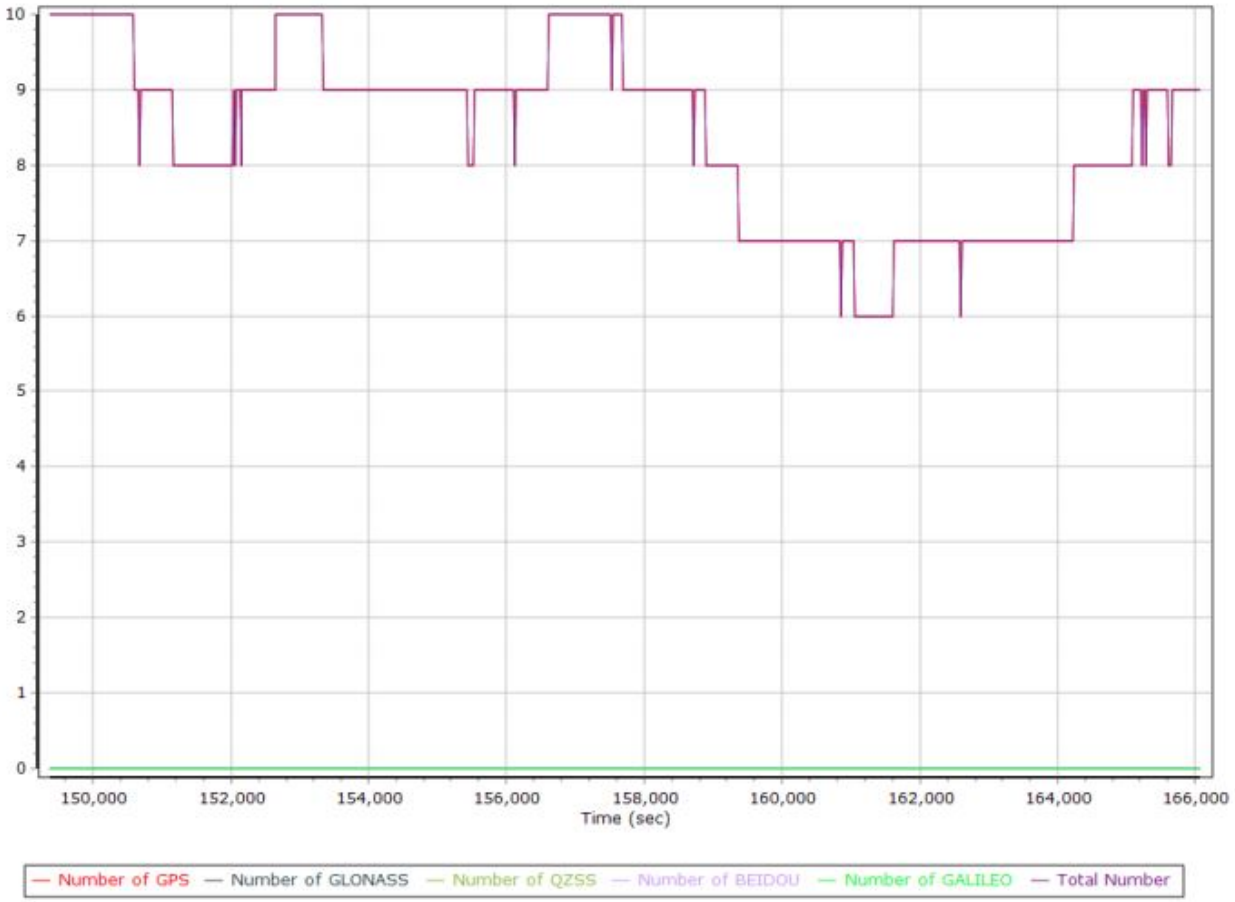


GNSS QC

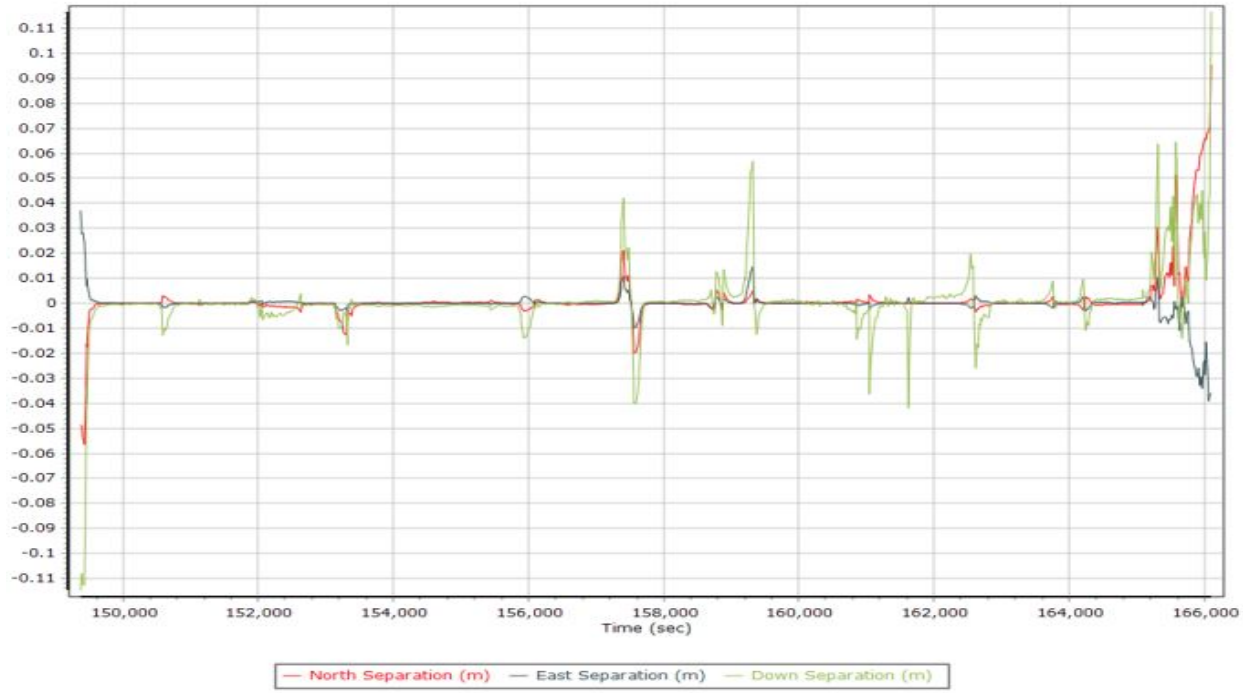
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.38	42.41	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	8
PDOP	1.53	5.02	2.10
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	17121.00	0.00	1.00
Percentage	99.99	0.00	0.01

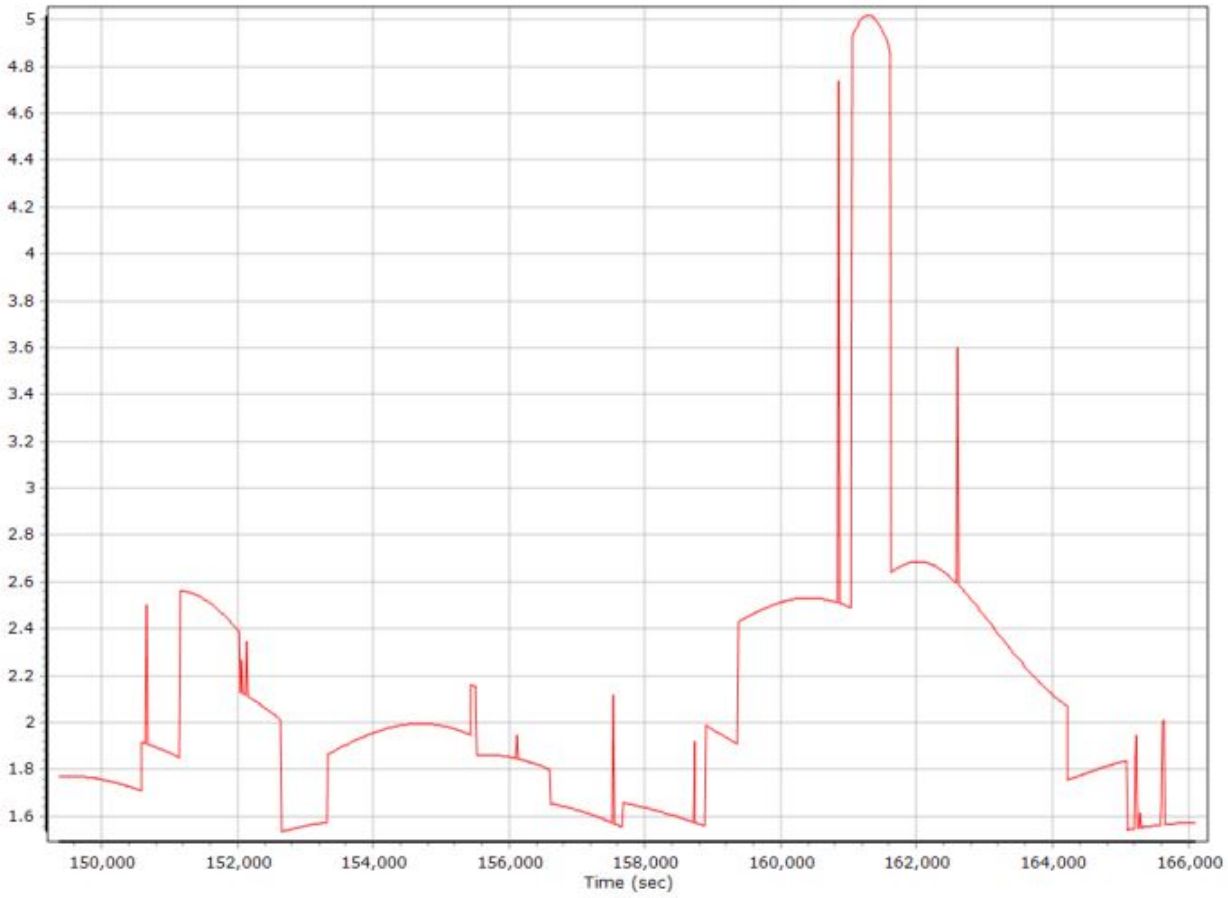
Number of Satellites



Forward/Reverse Separation



PDOP


5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
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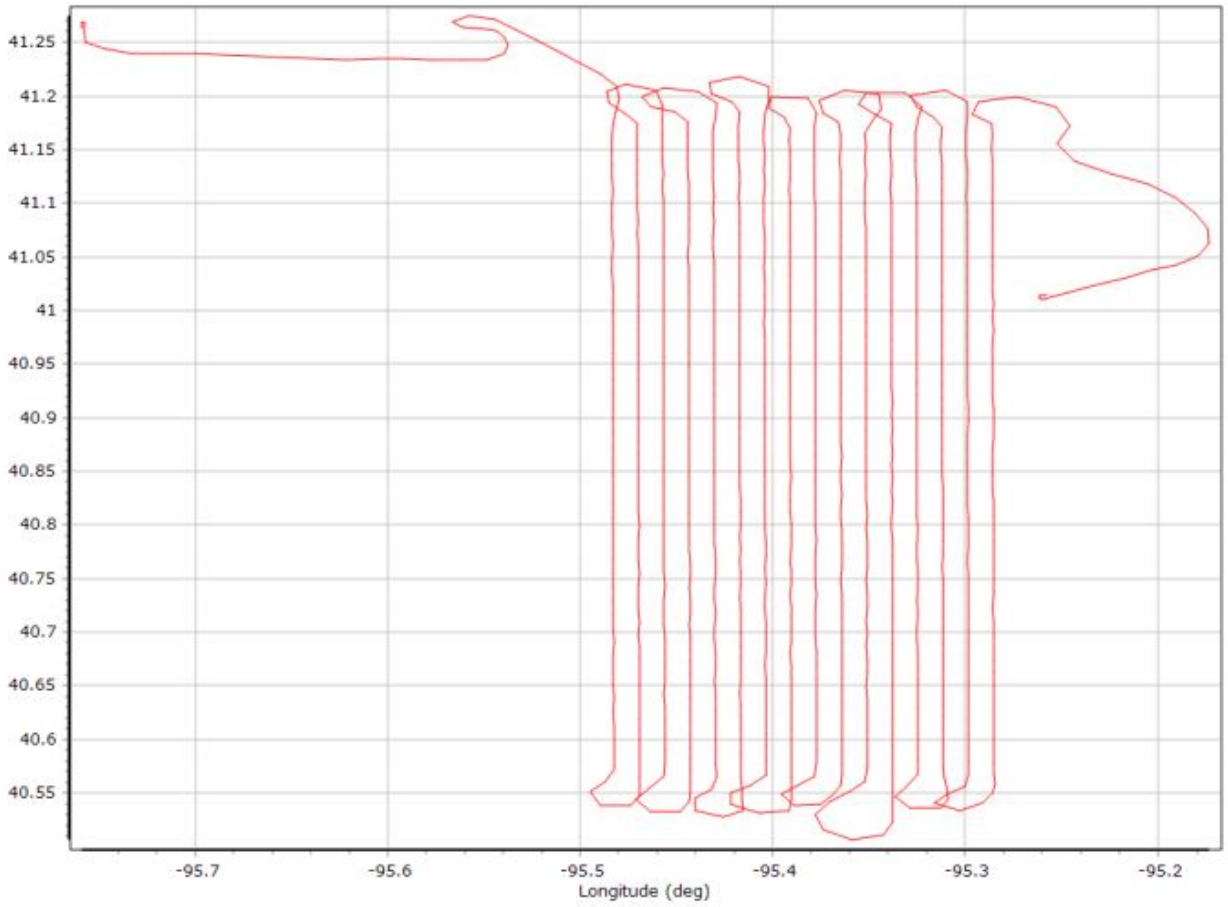
152,000
154,000
156,000
158,000
160,000
162,000
164,000
166,000
Time (sec)

20201208_QC Report.docx QC Report – 8/27/2021 07:43:44
Smoothed Trajectory Information

Top View

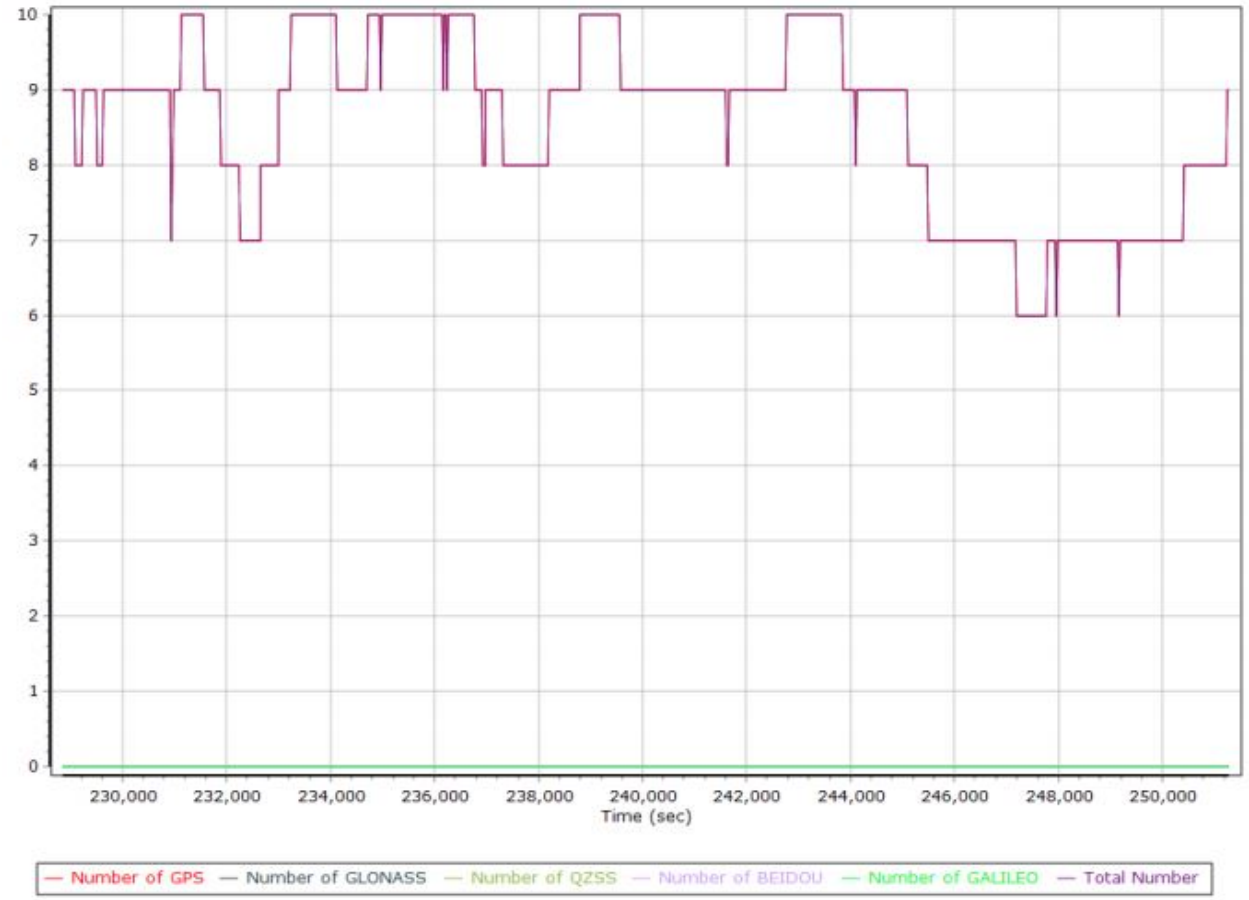


GNSS QC

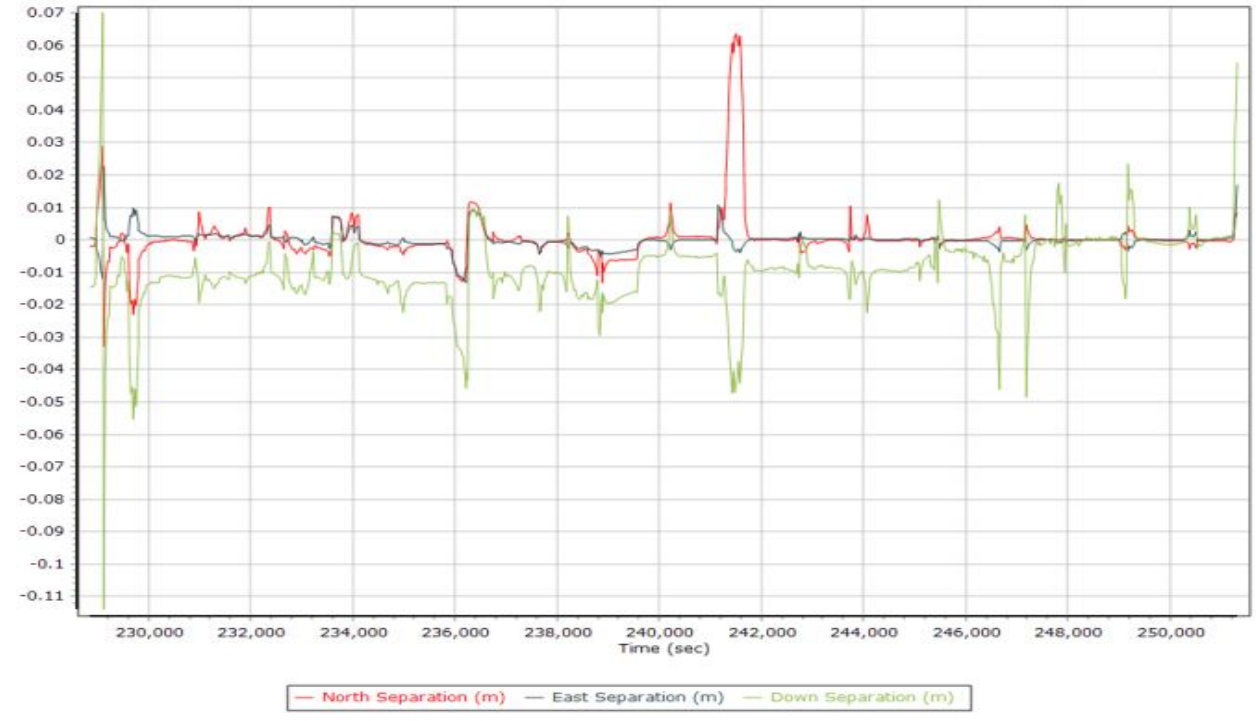
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.53	51.24	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.53	5.02	2.02
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	22924.00	0.00	1.00
Percentage	100.00	0.00	0.00

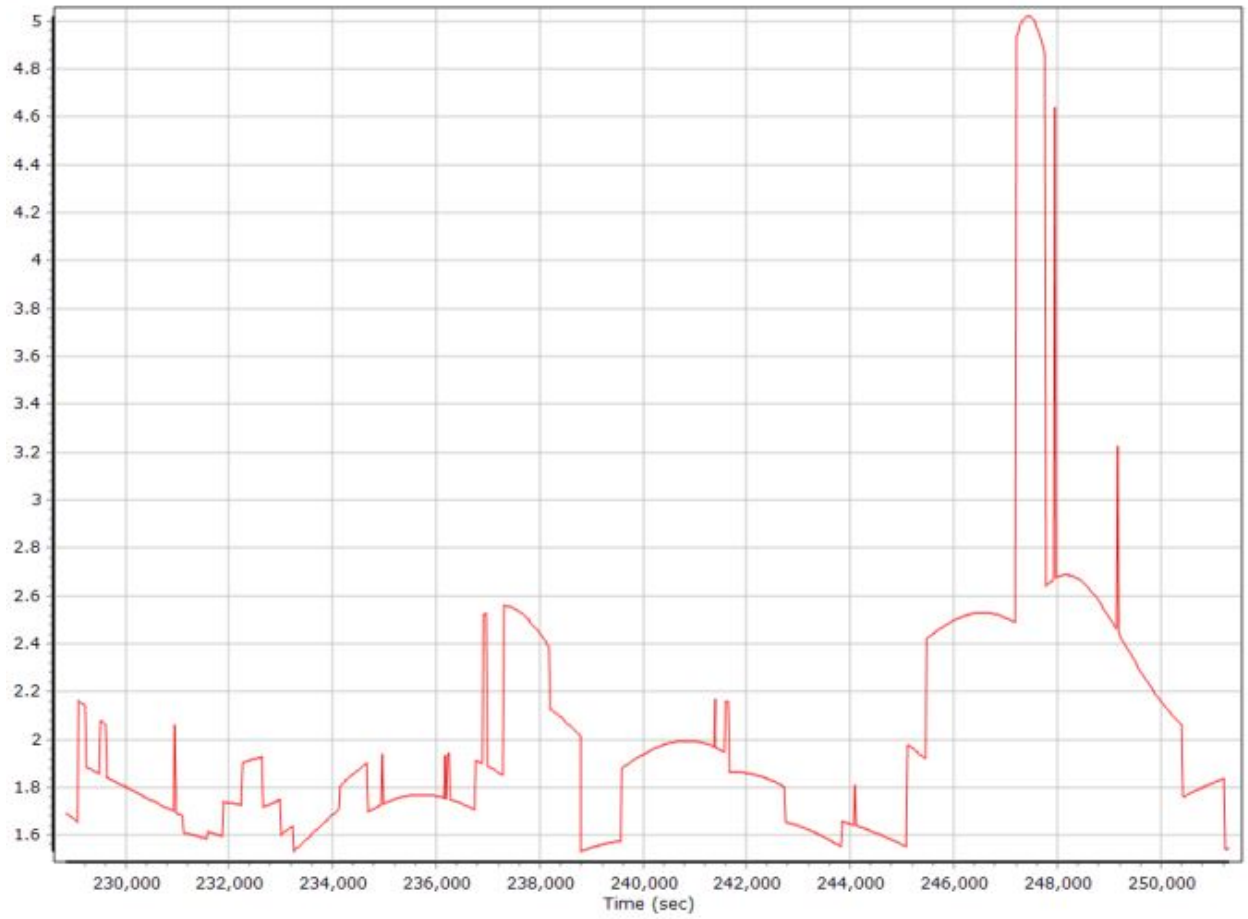
Number of Satellites



Forward/Reverse Separation



PDOP


5
4.8
4.6
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4
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3.4
3.2
3
2.8
2.6
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240,000
242,000
244,000
246,000
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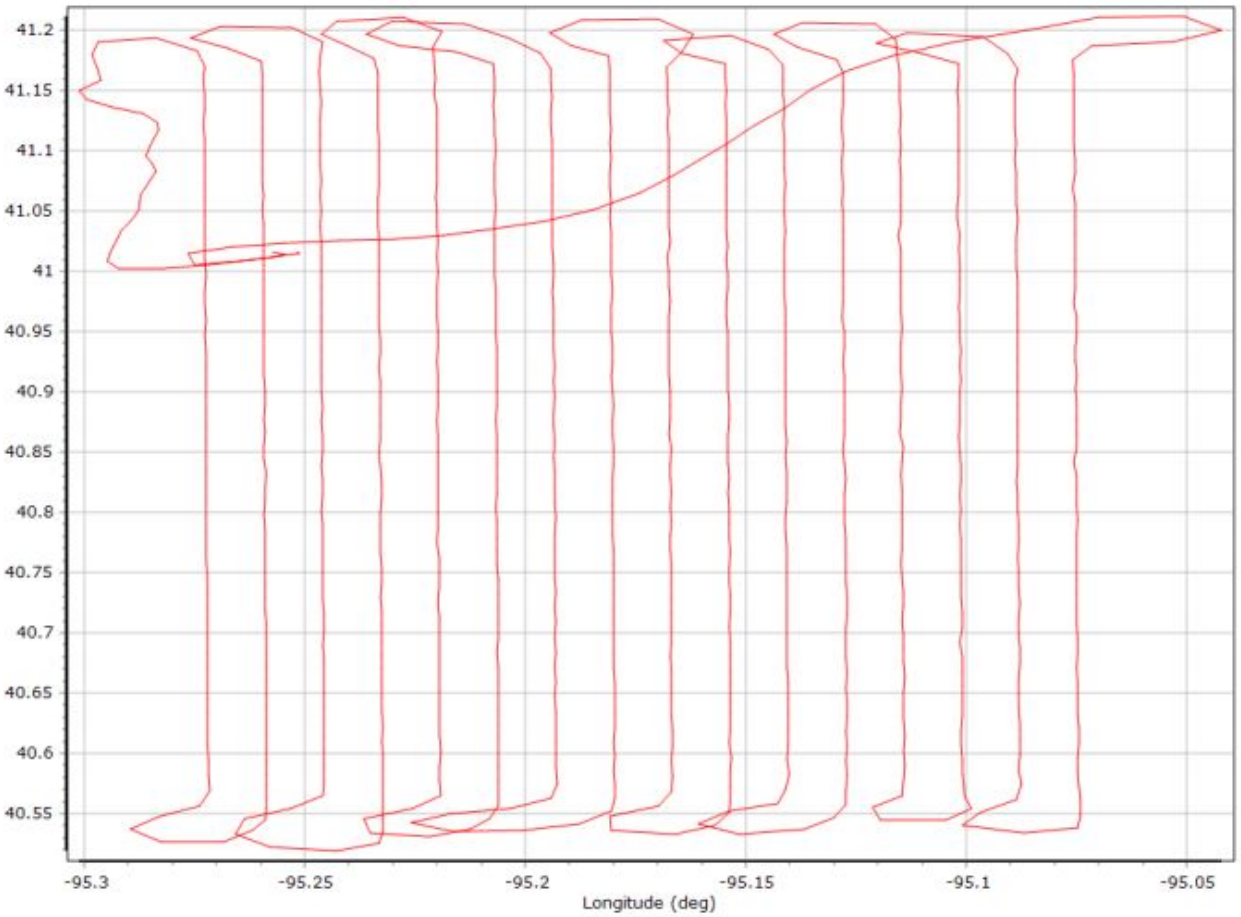
250,000
Time (sec)

20201209_1_QC Report.docx QC Report – 8/27/2021 07:53:24
Smoothed Trajectory Information

Top View

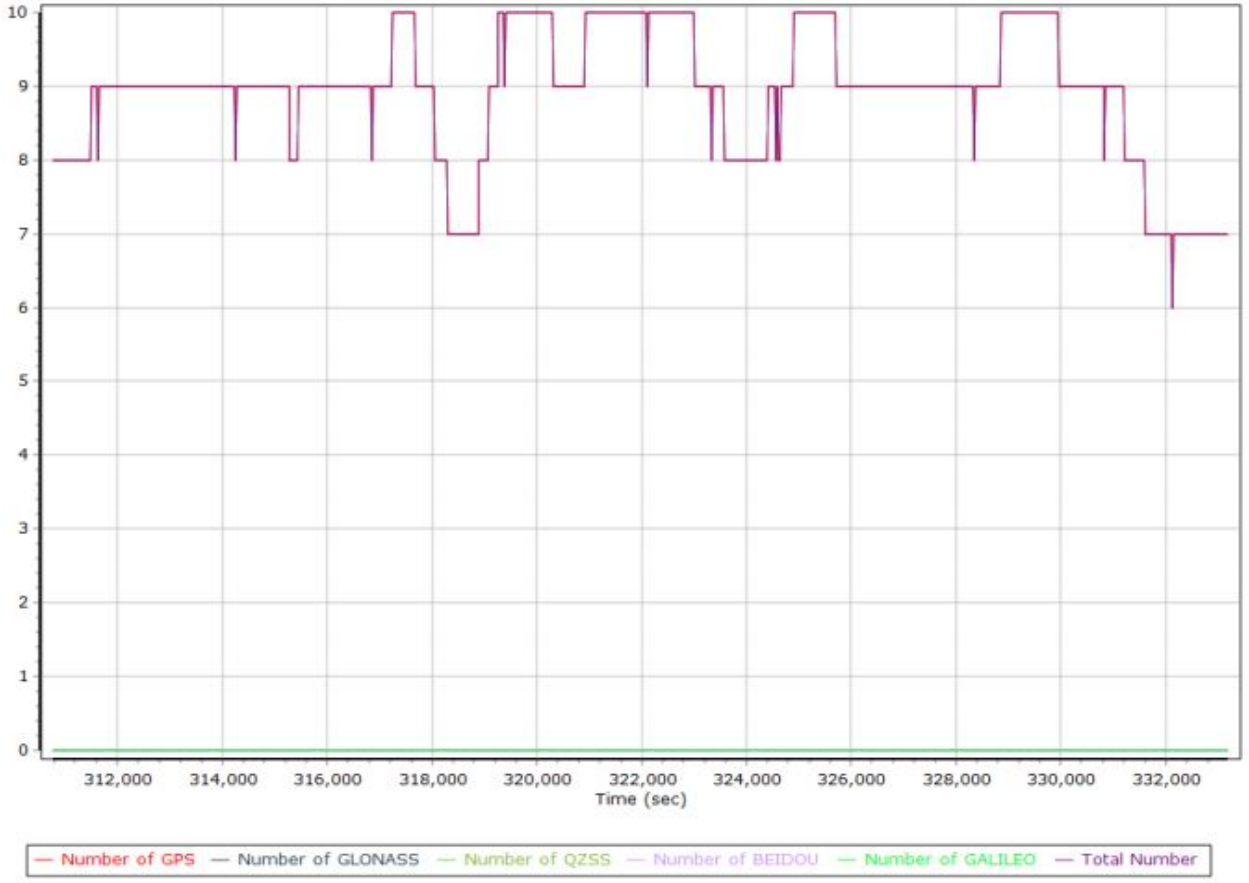


GNSS QC

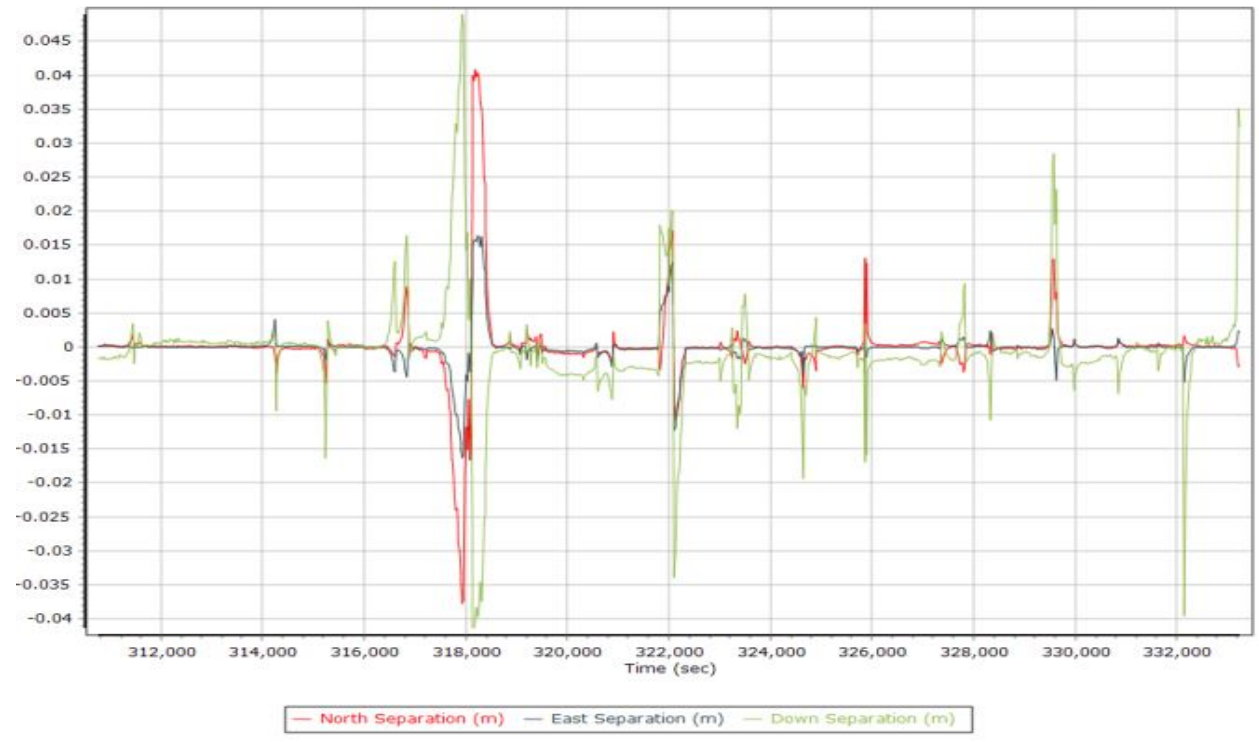
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.28	40.98	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.51	3.55	1.89
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	22867.00	0.00	1.00
Percentage	100.00	0.00	0.00

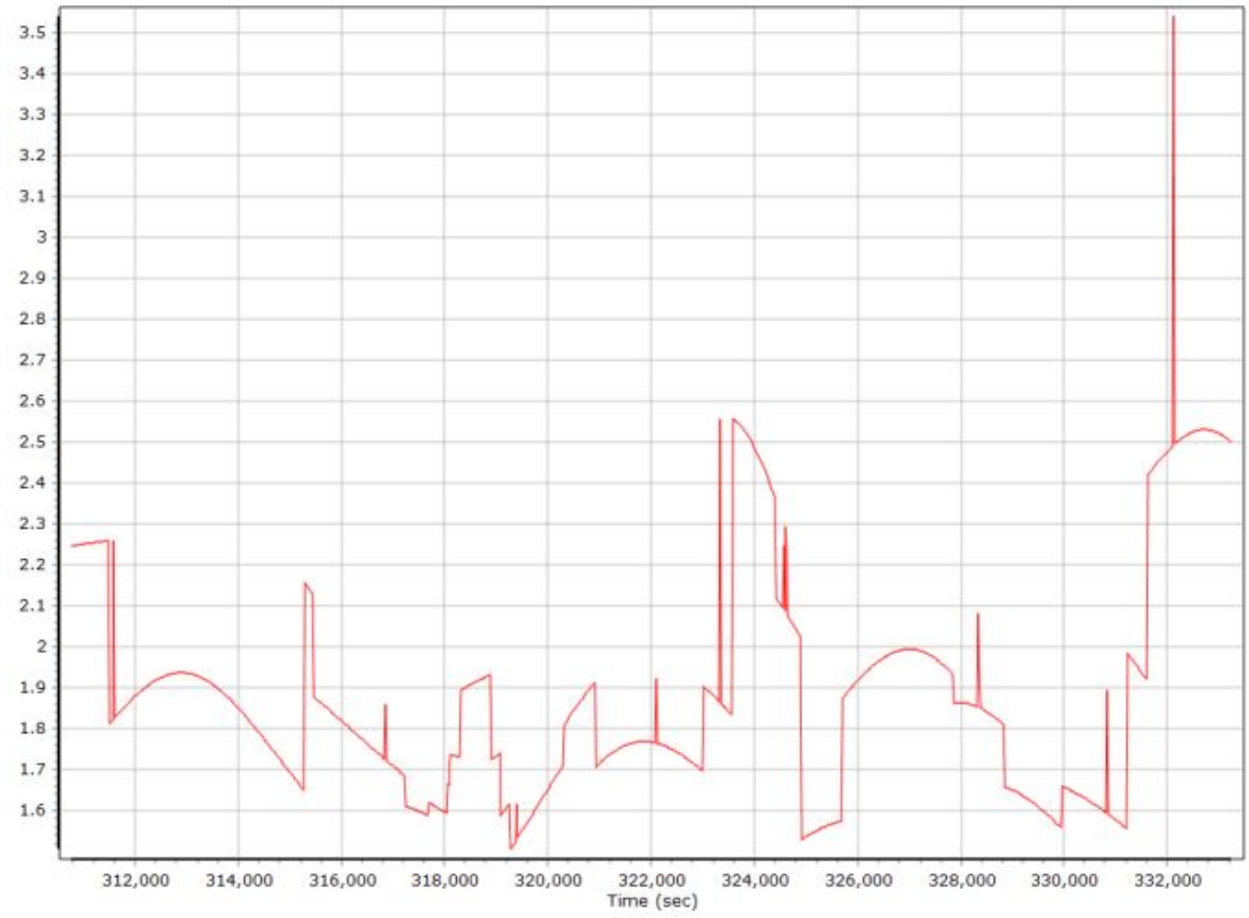
Number of Satellites



Forward/Reverse Separation



PDOP


3.5
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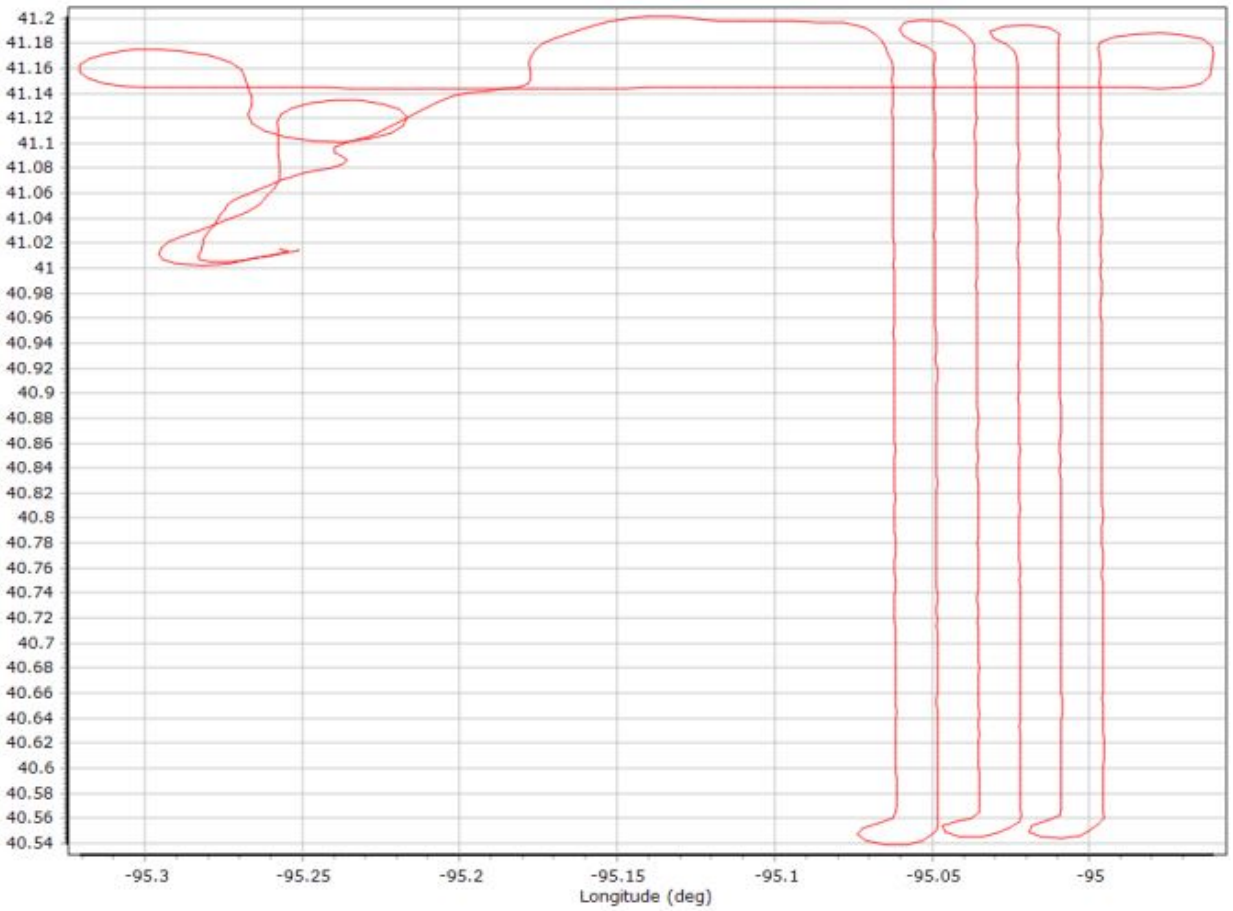
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000
328,000
330,000
332,000
Time (sec)

20201209_2_QC Report.docx QC Report – 8/27/2021 08:01:24
Smoothed Trajectory Information

Top View

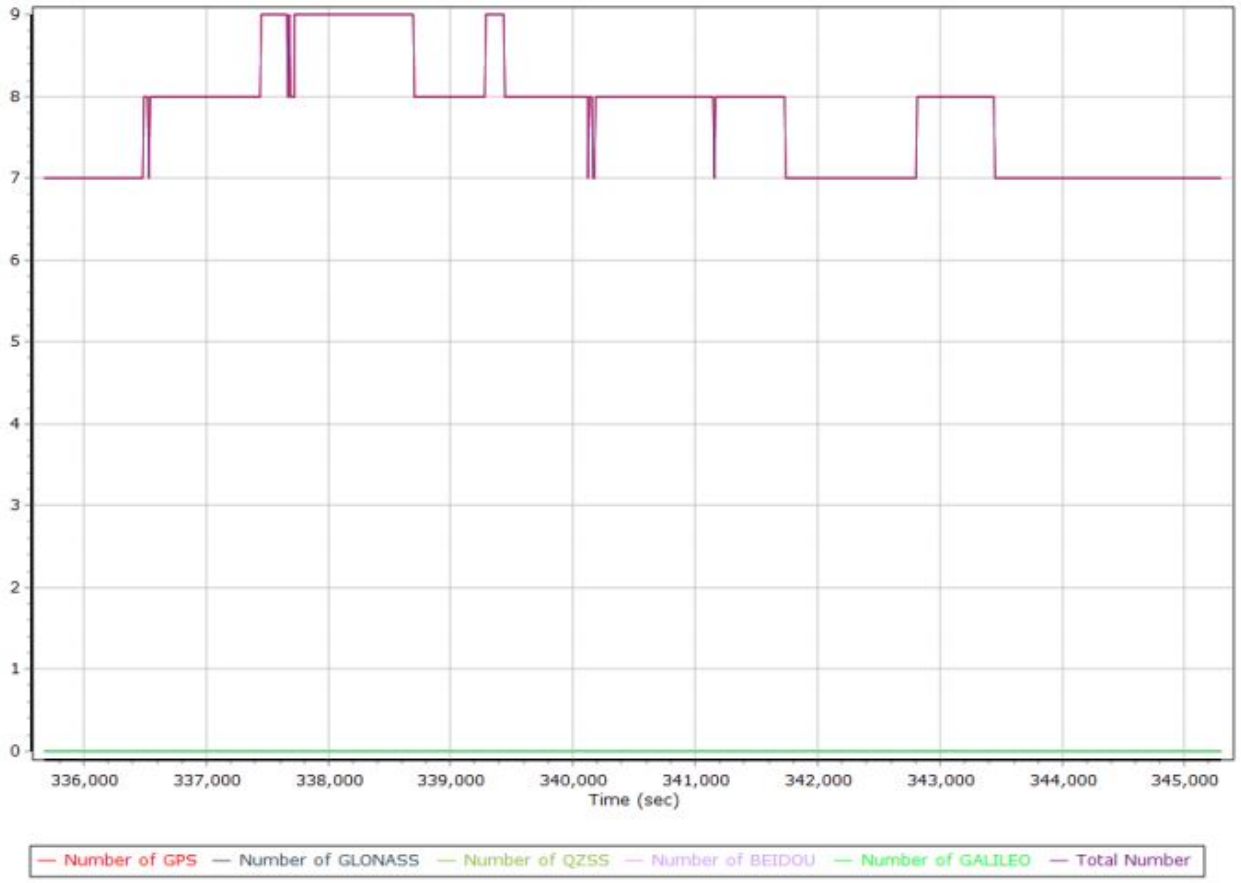


GNSS QC

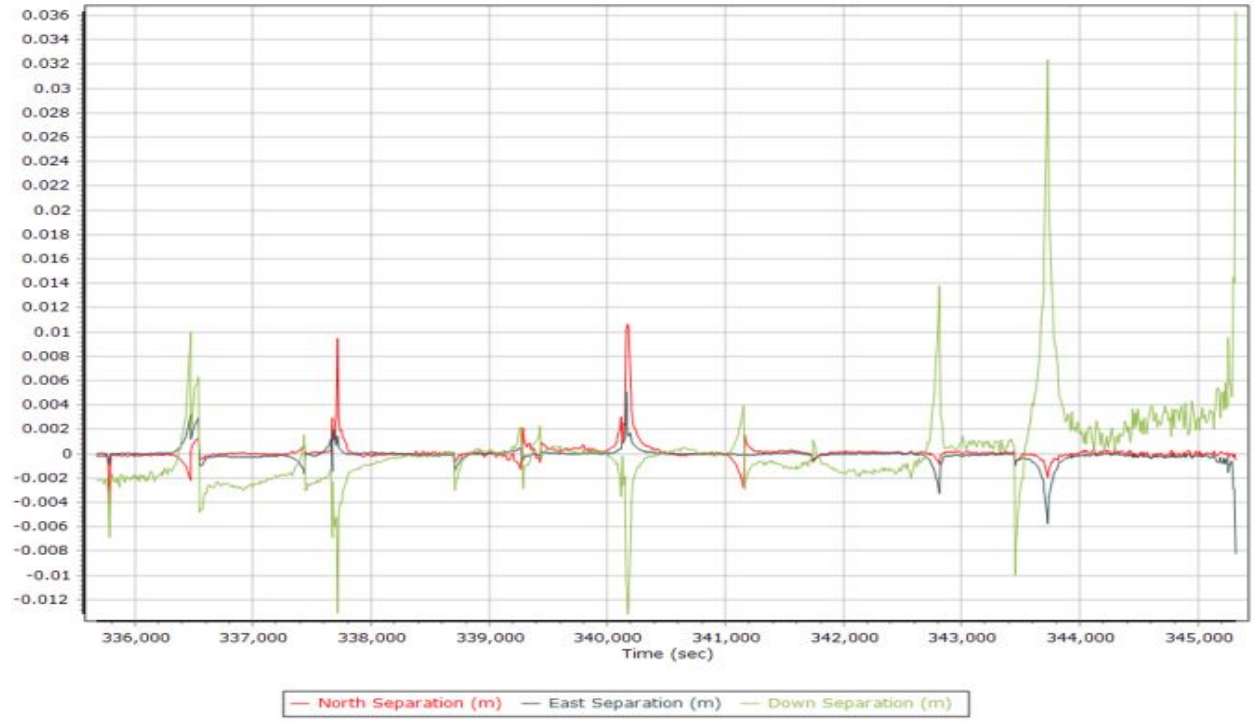
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	1.86	43.19	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	9	8
PDOP	1.55	4.87	2.11
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	10067.00	0.00	1.00
Percentage	99.99	0.00	0.01

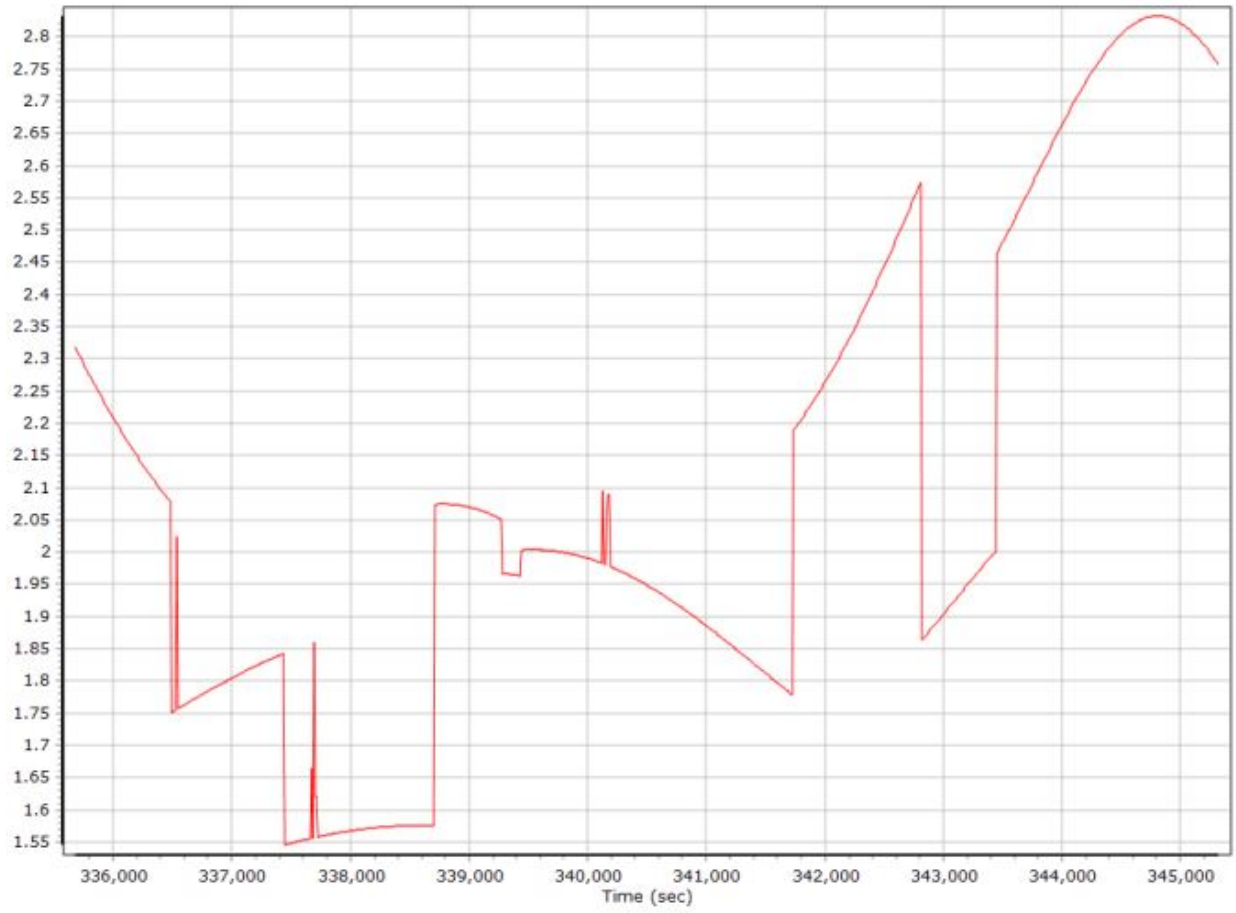
Number of Satellites



Forward/Reverse Separation



PDOP


2.8
2.75
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2.65
2.6
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2.45
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
336,000
337,000
338,000
339,000
340,000
341,000
342,000
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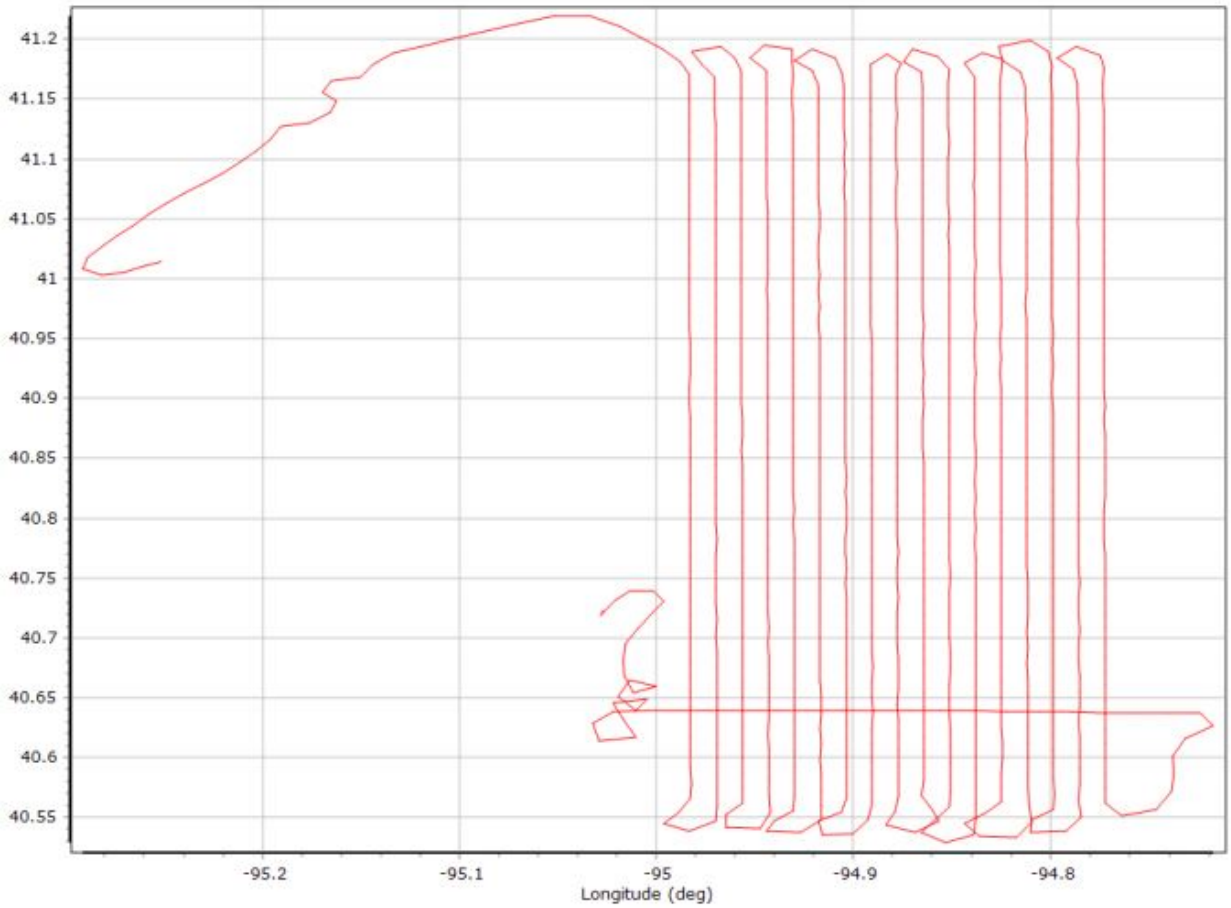
Time (sec)

20201210_1_QC Report.docx QC Report – 8/27/2021 08:08:14
Smoothed Trajectory Information

Top View

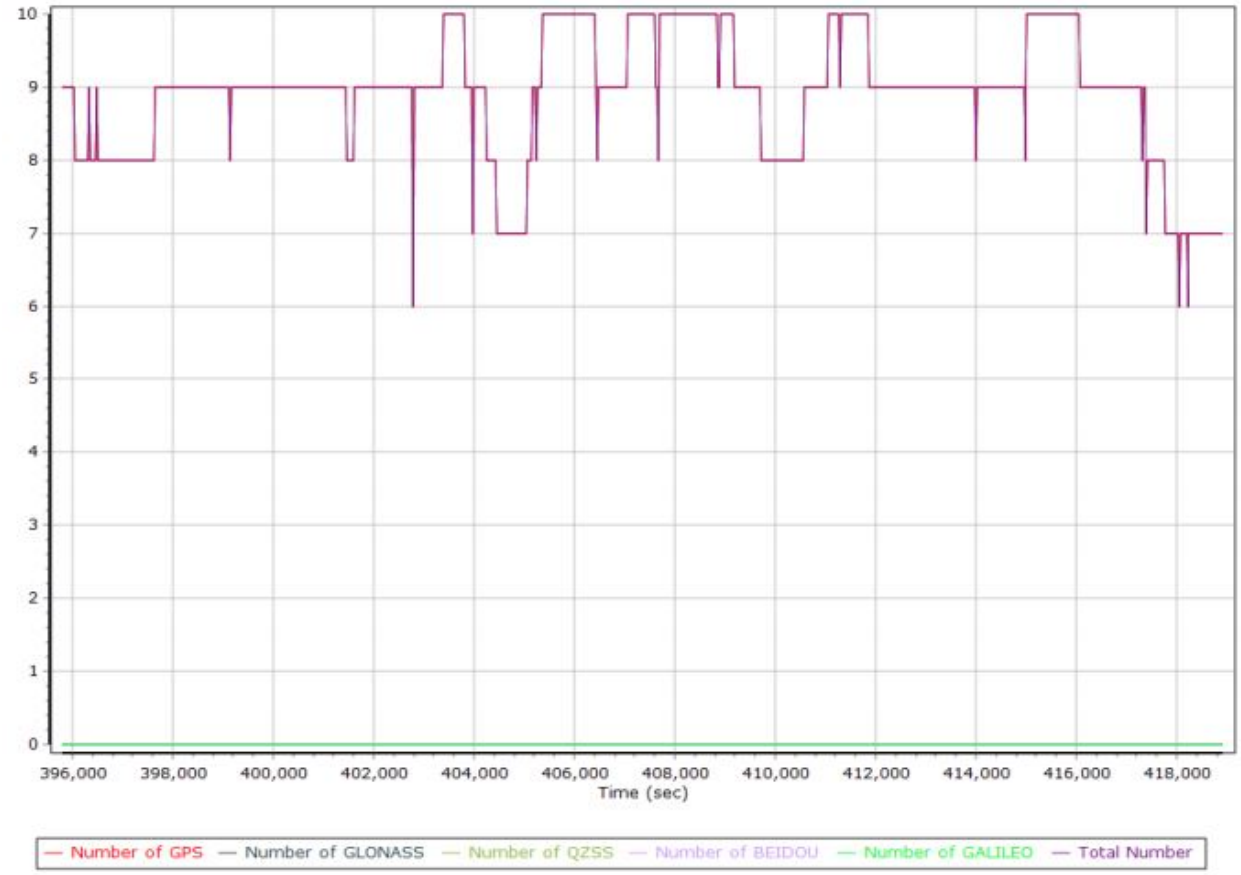


GNSS QC

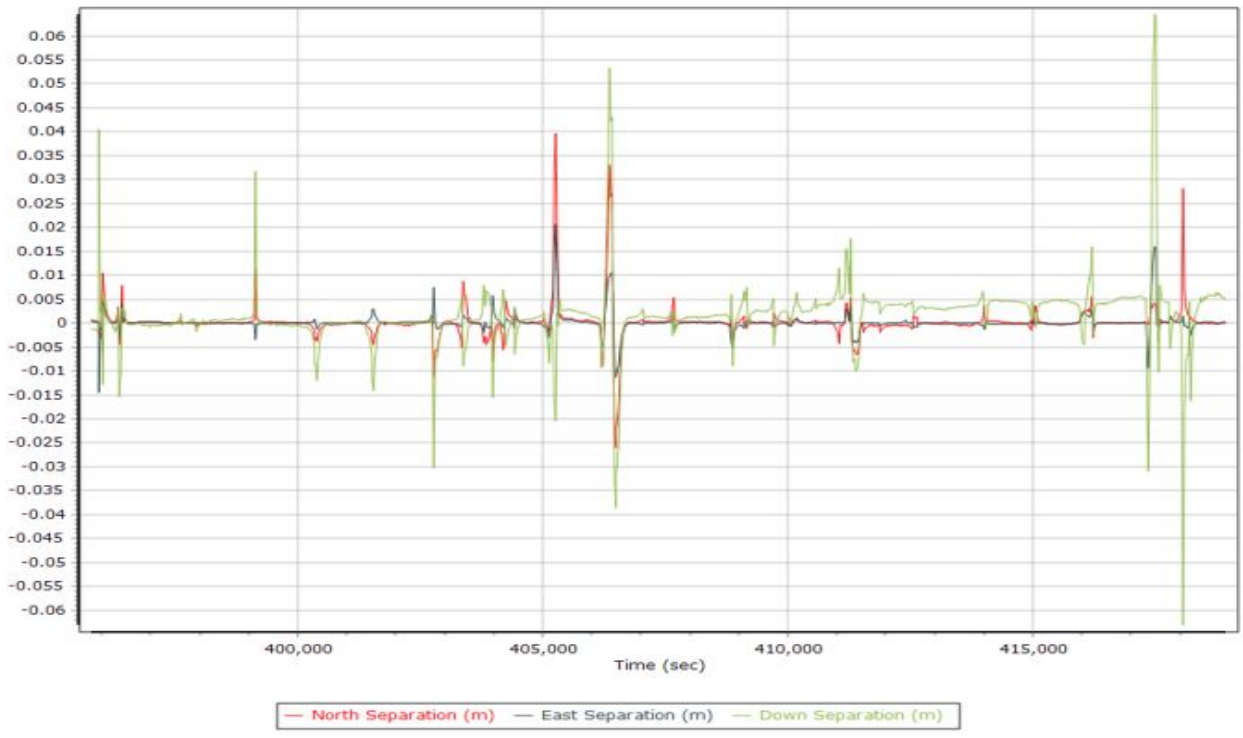
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.23	41.43	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.47	4.26	1.87
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	23550.00	0.00	1.00
Percentage	100.00	0.00	0.00

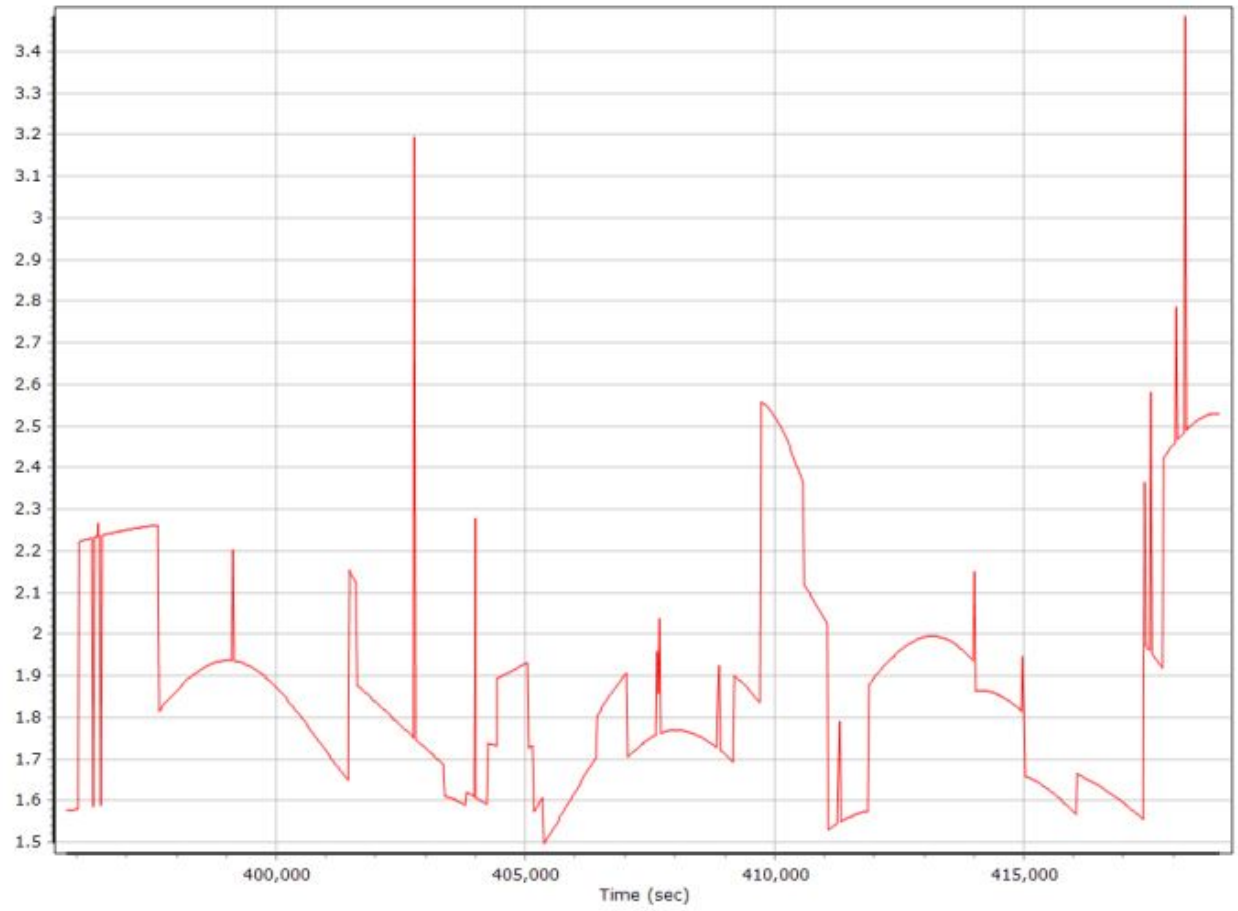
Number of Satellites



Forward/Reverse Separation



PDOP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3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
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2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
400,000
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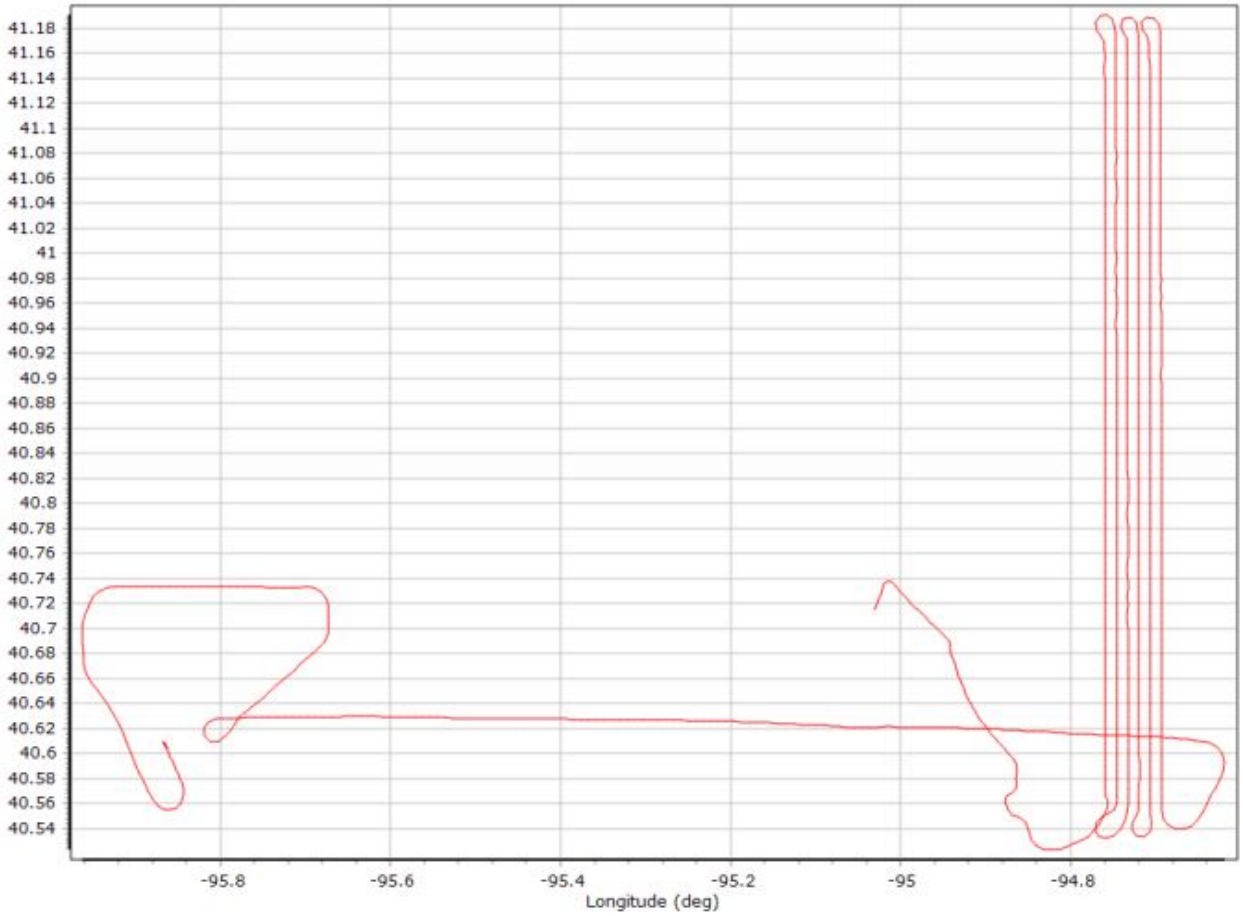
410,000
415,000
Time (sec)

20201210_2_QC Report.docx QC Report – 8/27/2021 08:15:12

Smoothed Trajectory Information

Top View

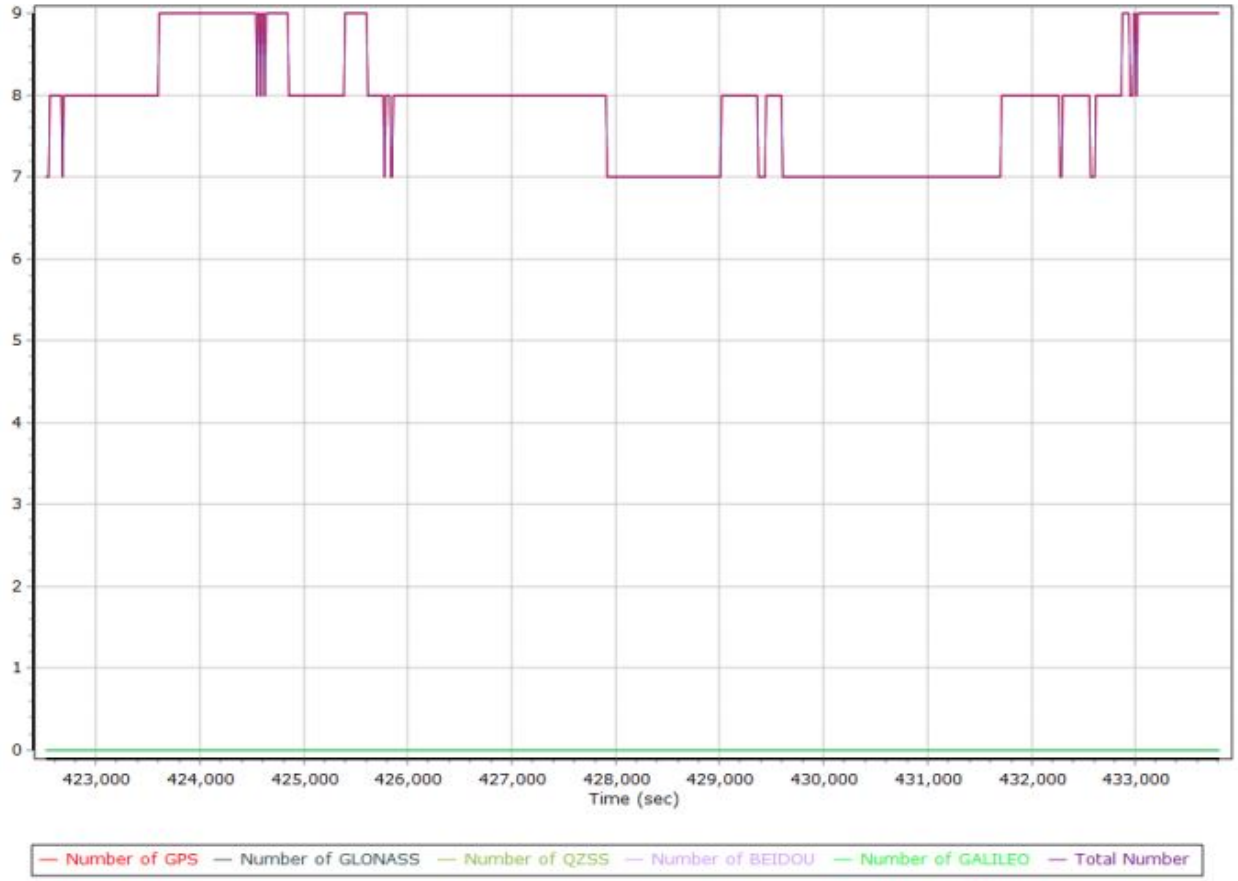


GNSS QC

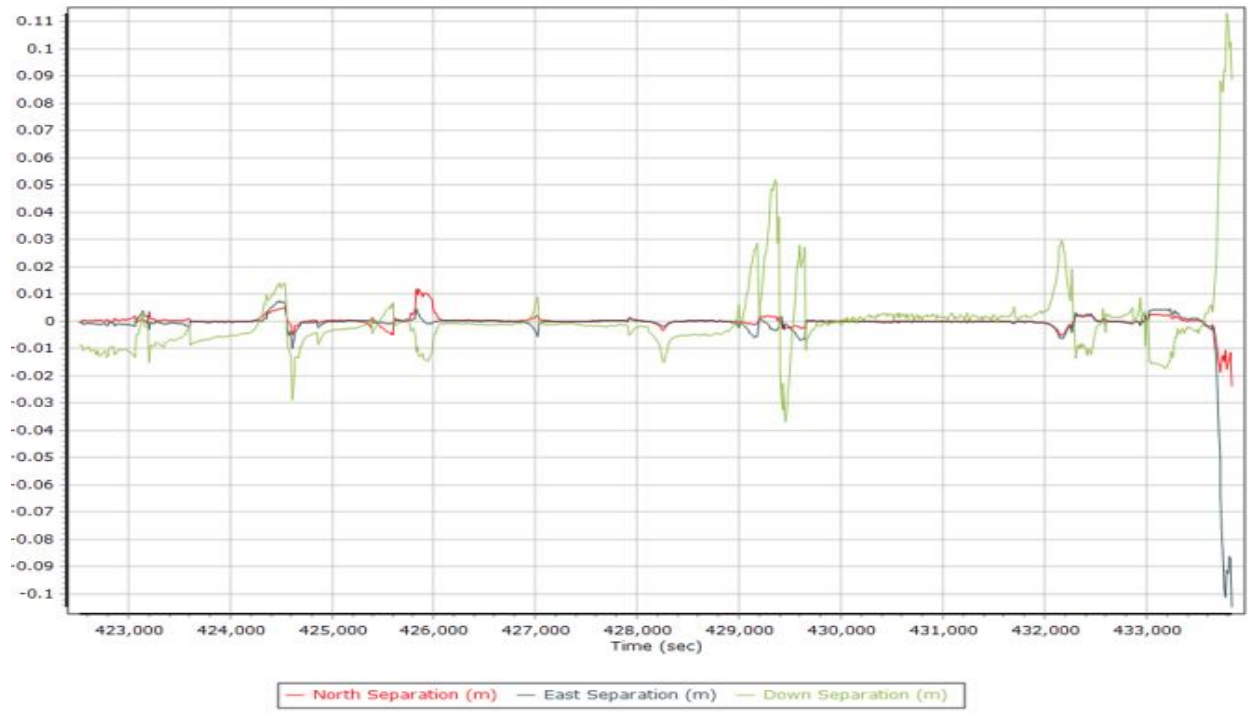
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	5.93	85.00	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	9	8
PDOP	1.55	4.45	2.06
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11717.00	0.00	1.00
Percentage	99.99	0.00	0.01

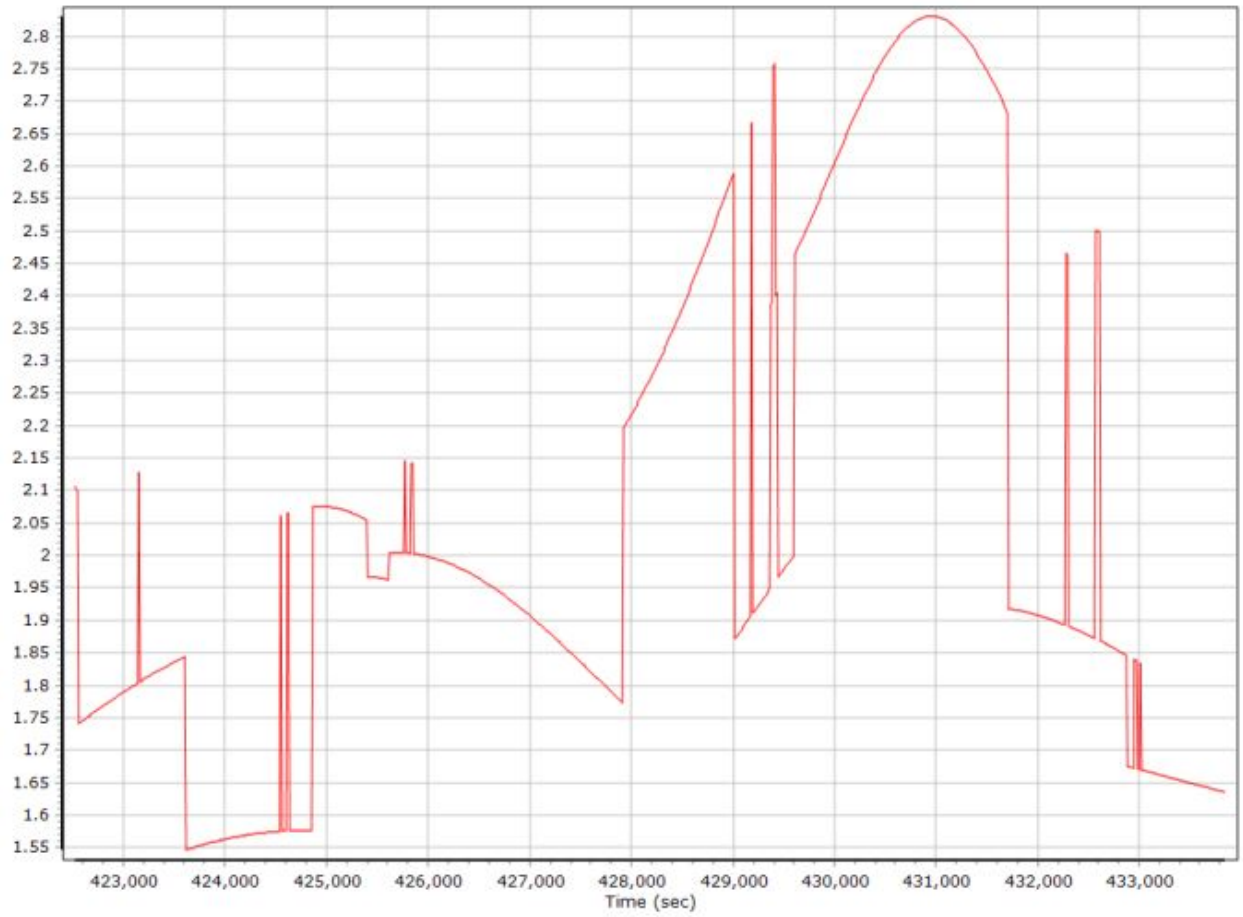
Number of Satellites



Forward/Reverse Separation



PDOP


2.8
2.75
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2.5
2.45
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
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1.85
1.8
1.75
1.7
1.65
1.6
1.55
423,000
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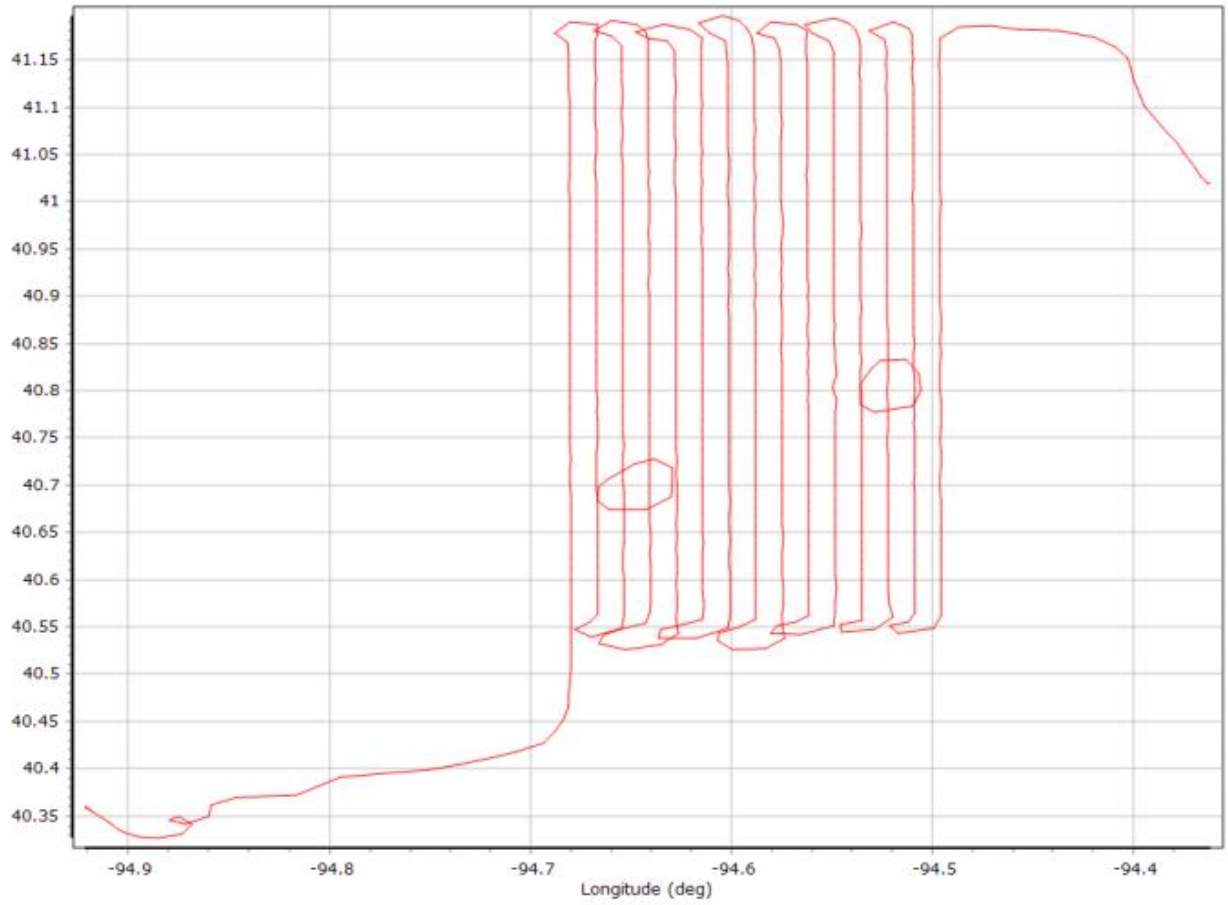
426,000
427,000
428,000
429,000
430,000
431,000
432,000
433,000
Time (sec)

20201222_1_QC Report.docx QC Report – 8/27/2021 08:32:12
Smoothed Trajectory Information

Top View

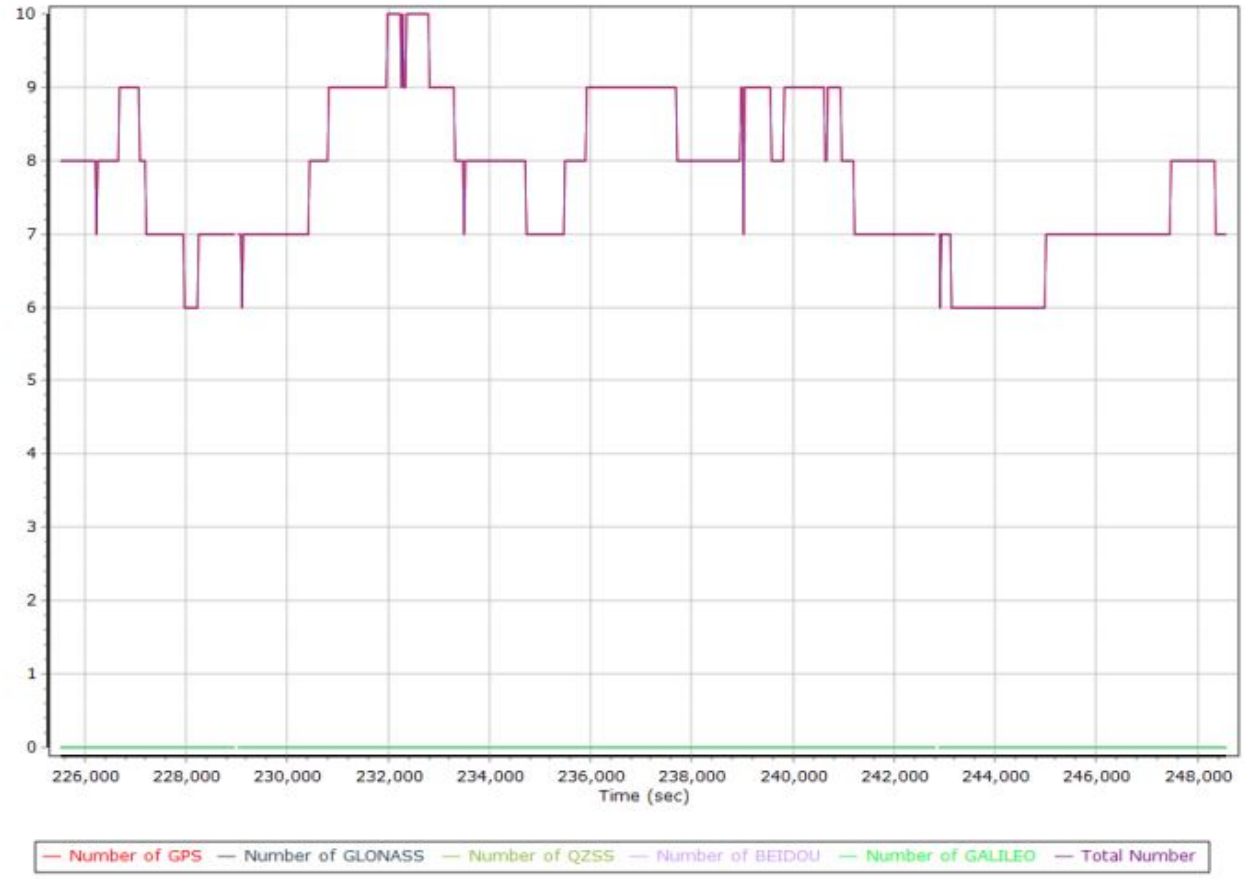


GNSS QC

GNSS QC Statistics

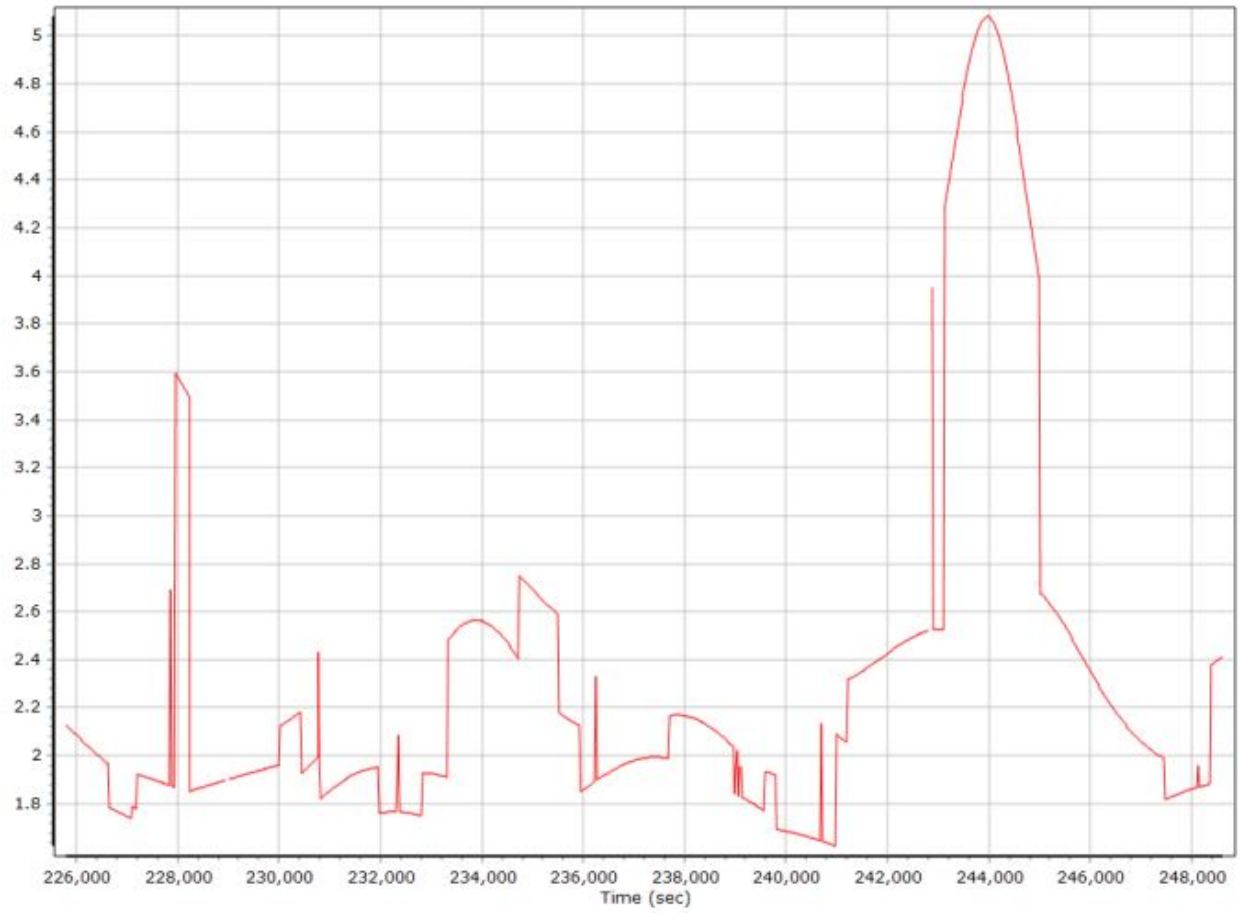
Statistics	Min	Max	Mean
Baseline length (km)	0.48	62.39	
Number of GPS SV	5	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	10	8
PDOP	1.62	5.60	2.32
QC Solution Gaps	1.00	41.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	23199.00	0.00	352.00
Percentage	98.51	0.00	1.49

Number of Satellites



Forward/Reverse Separation

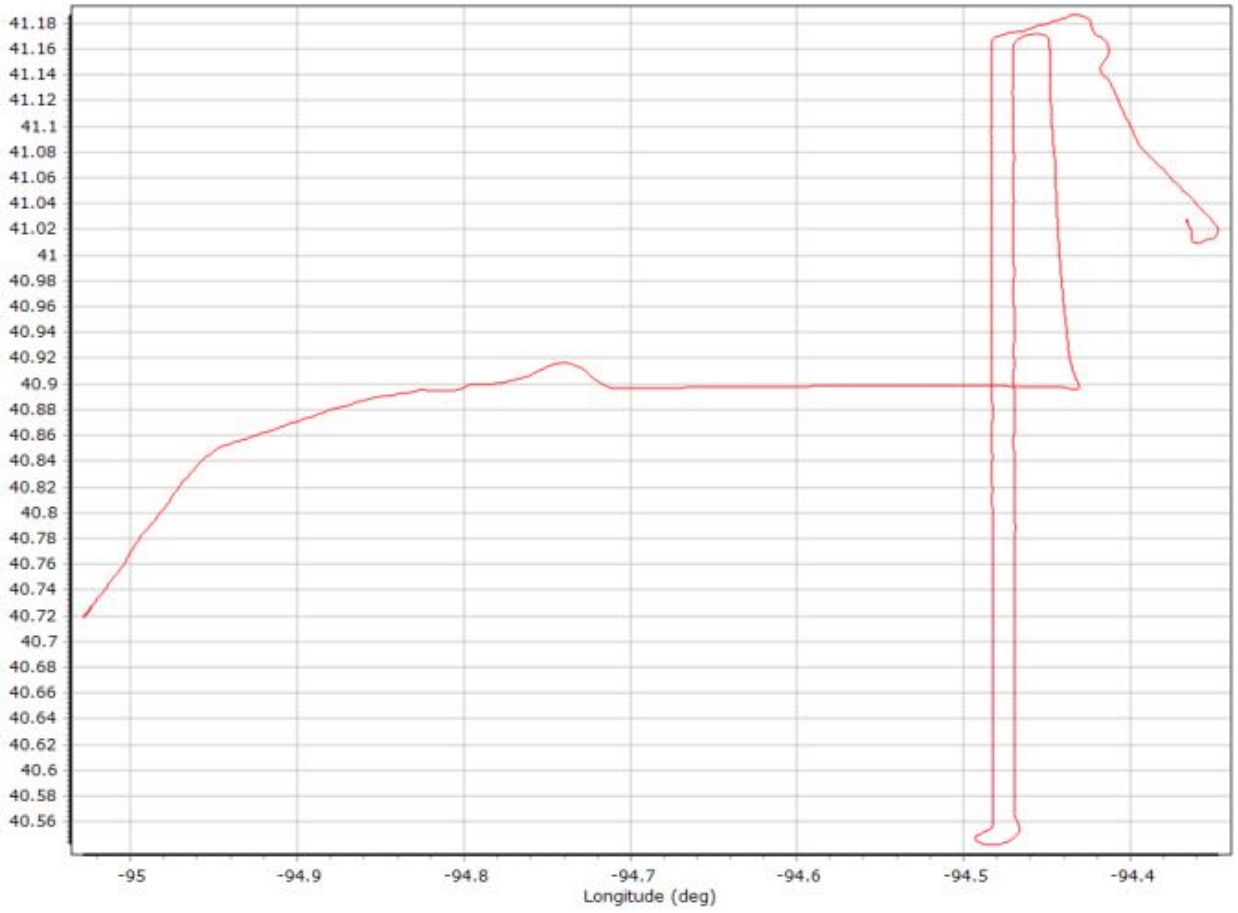
PDOP


5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
226,000
228,000
230,000
232,000
234,000
236,000
238,000
240,000
242,000
244,000
246,000
248,000
Time (sec)

20201222_2_QC Report.docx QC Report – 8/27/2021 08:38:52

Smoothed Trajectory Information

Top View

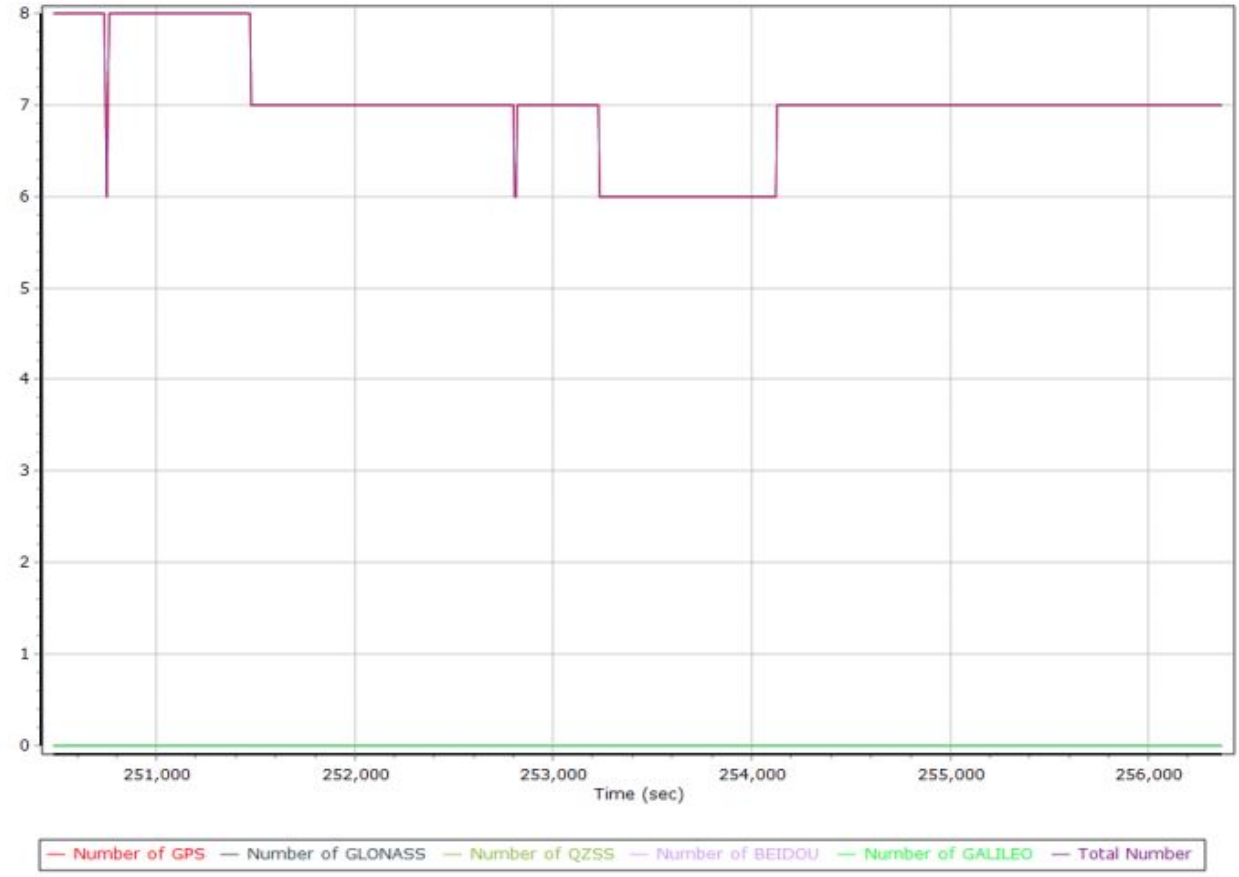


GNSS QC

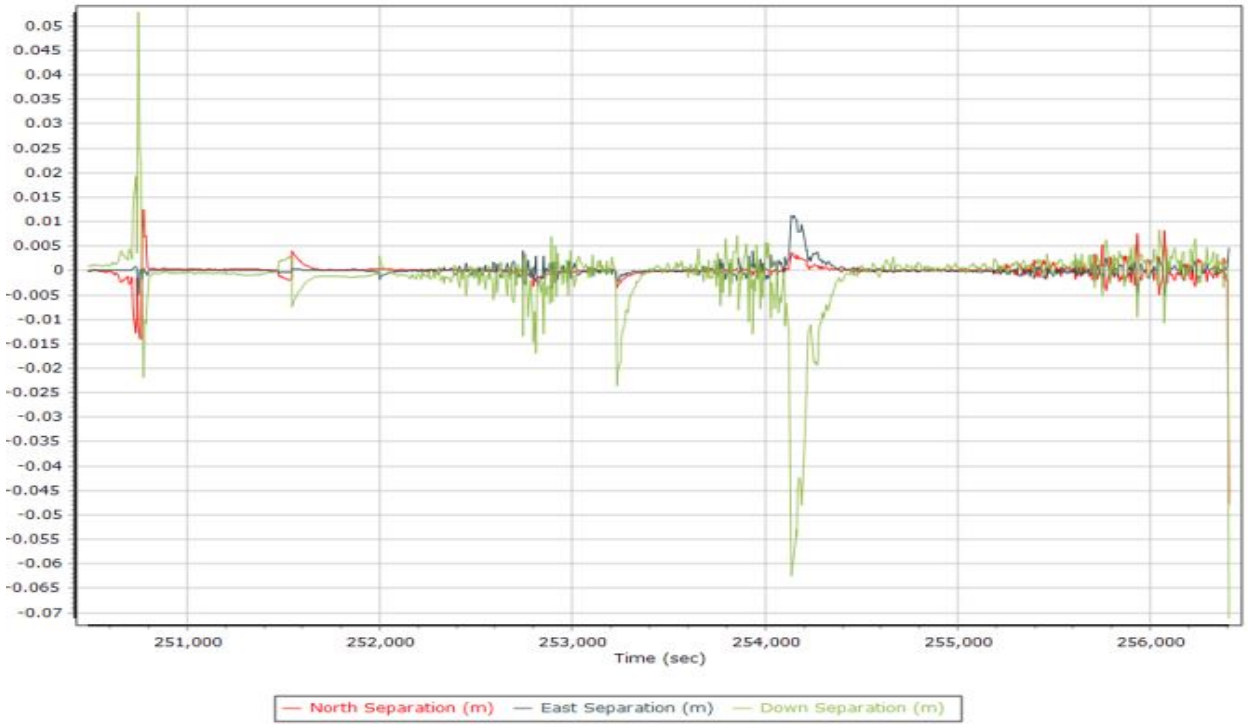
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	1.50	45.65	
Number of GPS SV	6	8	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	8	7
PDOP	1.88	4.83	2.61
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6369.00	0.00	1.00
Percentage	99.98	0.00	0.02

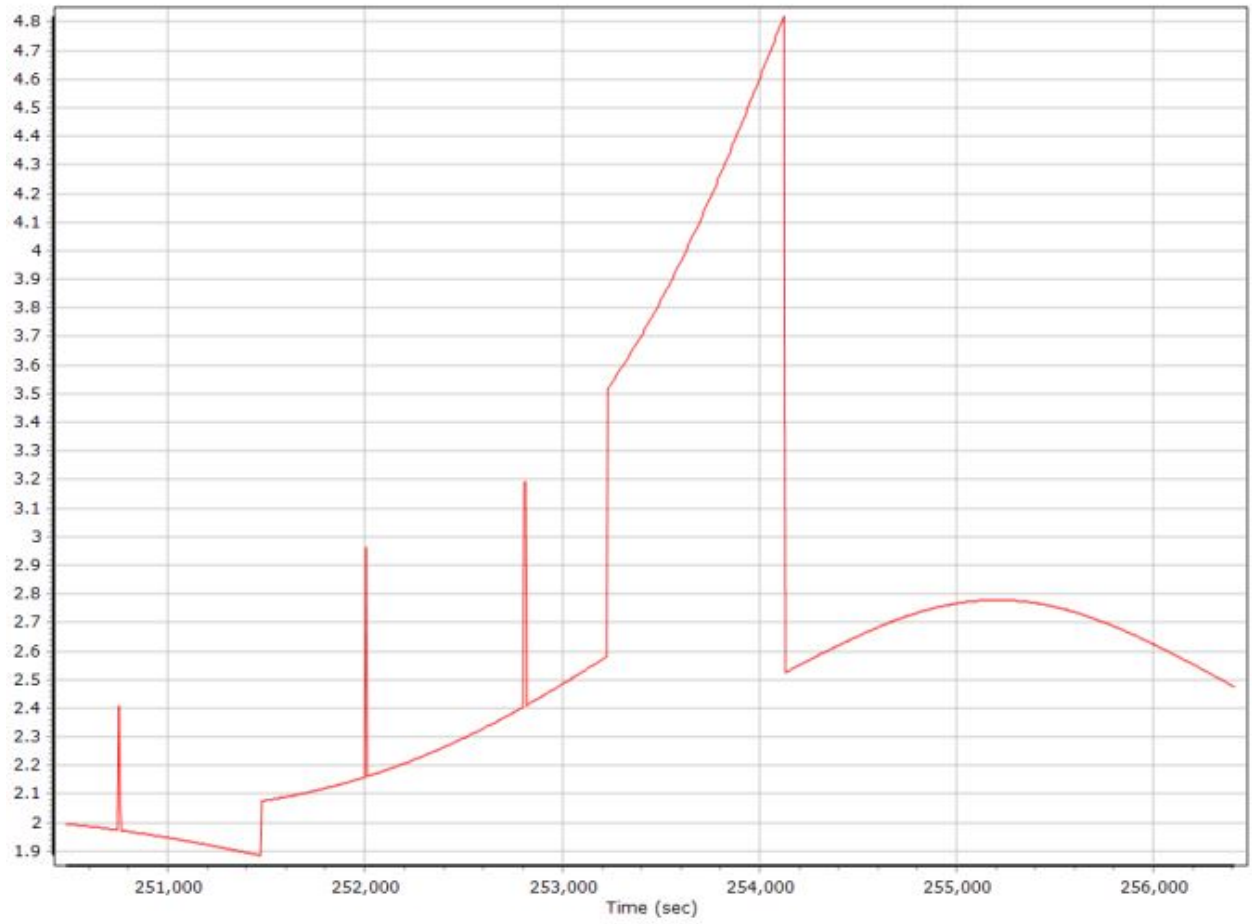
Number of Satellites



Forward/Reverse Separation

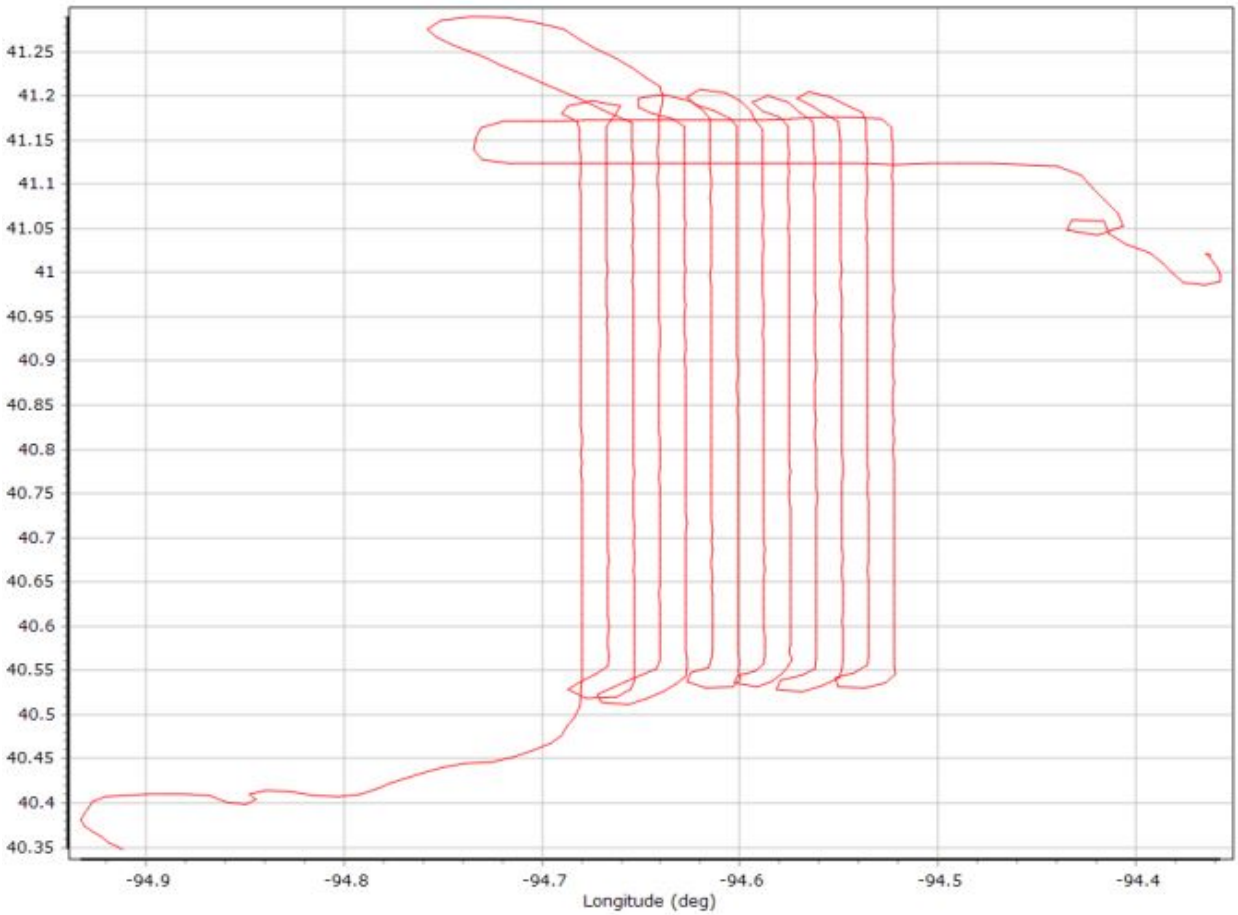


PDOP


4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
251,000
252,000
253,000
254,000
255,000
256,000
Time (sec)

20210311_1_QC Report.docx QC Report – 8/27/2021 08:44:02
Smoothed Trajectory Information

Top View

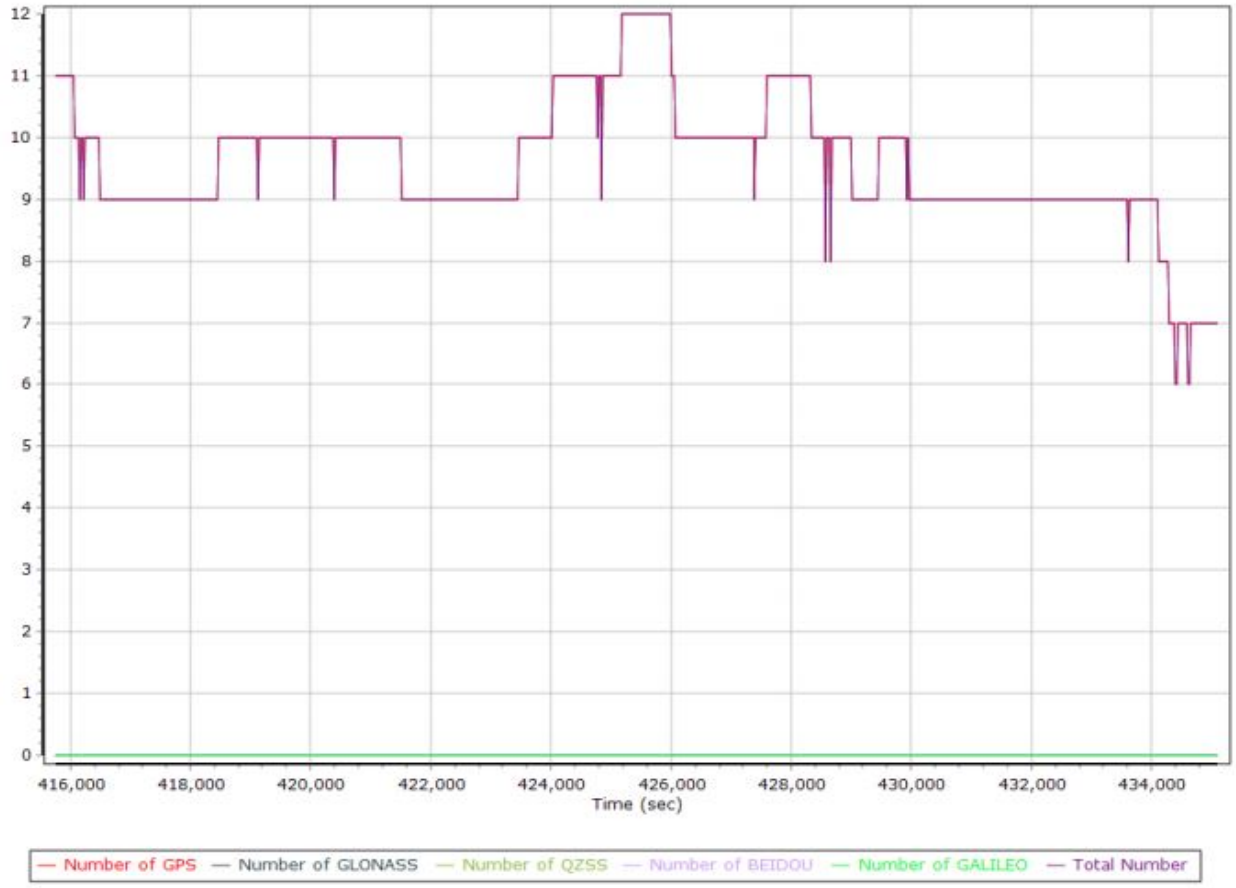


GNSS QC

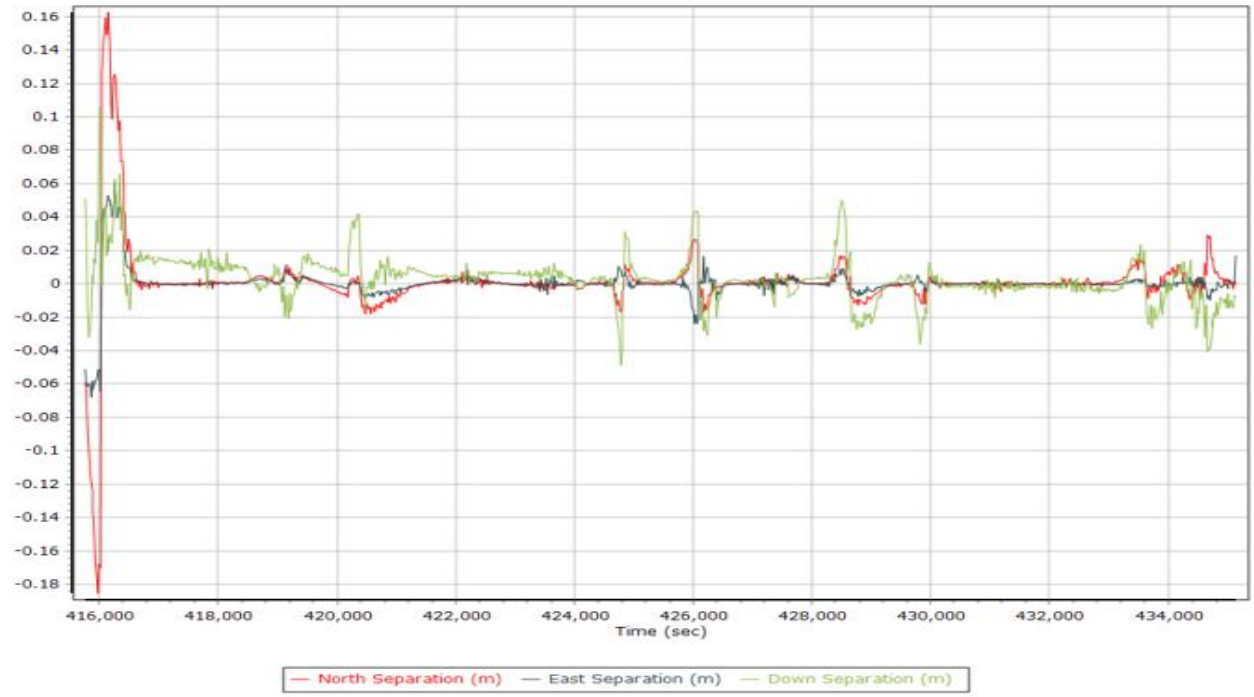
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.20	61.75	
Number of GPS SV	6	12	10
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	12	10
PDOP	1.26	3.11	1.75
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	19795.00	0.00	1.00
Percentage	99.99	0.00	0.01

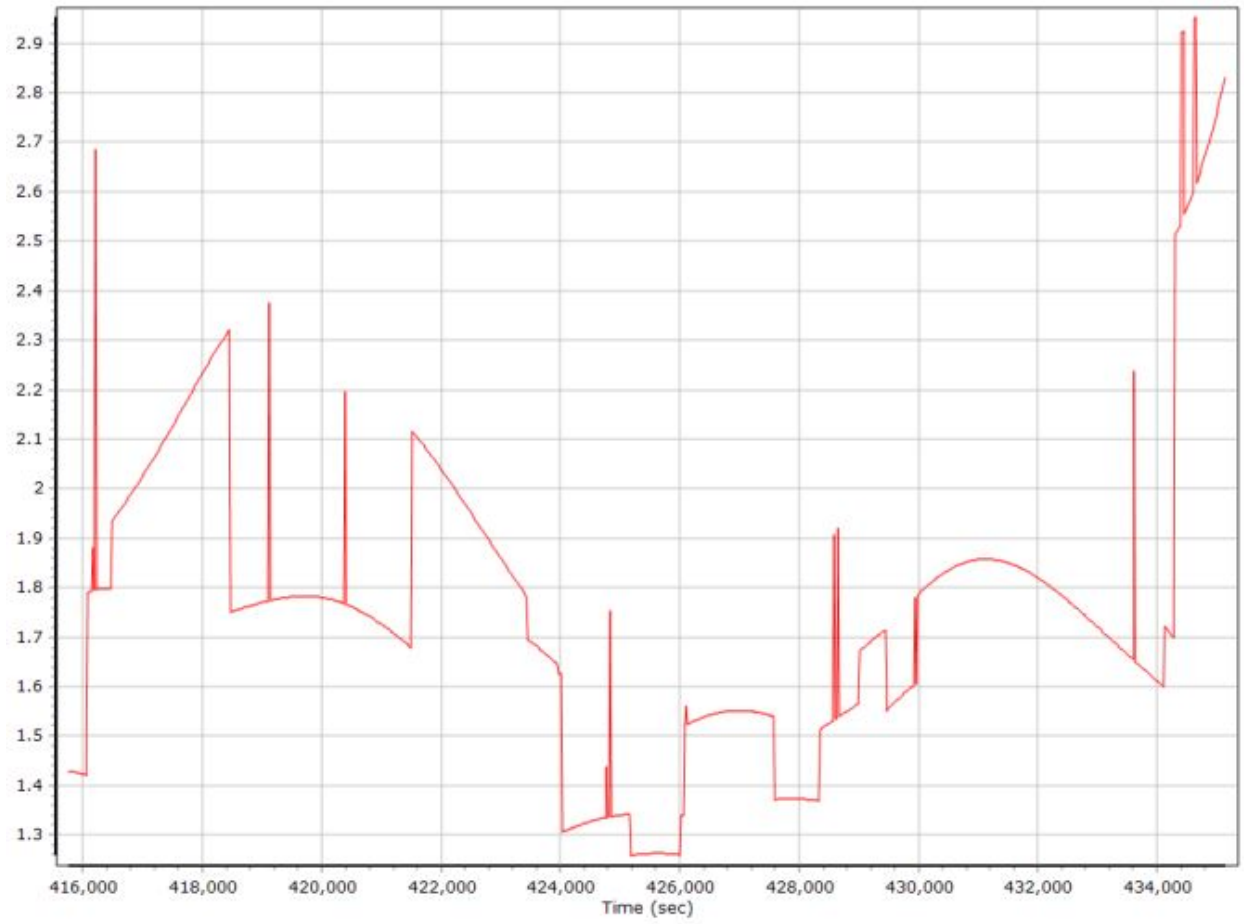
Number of Satellites



Forward/Reverse Separation

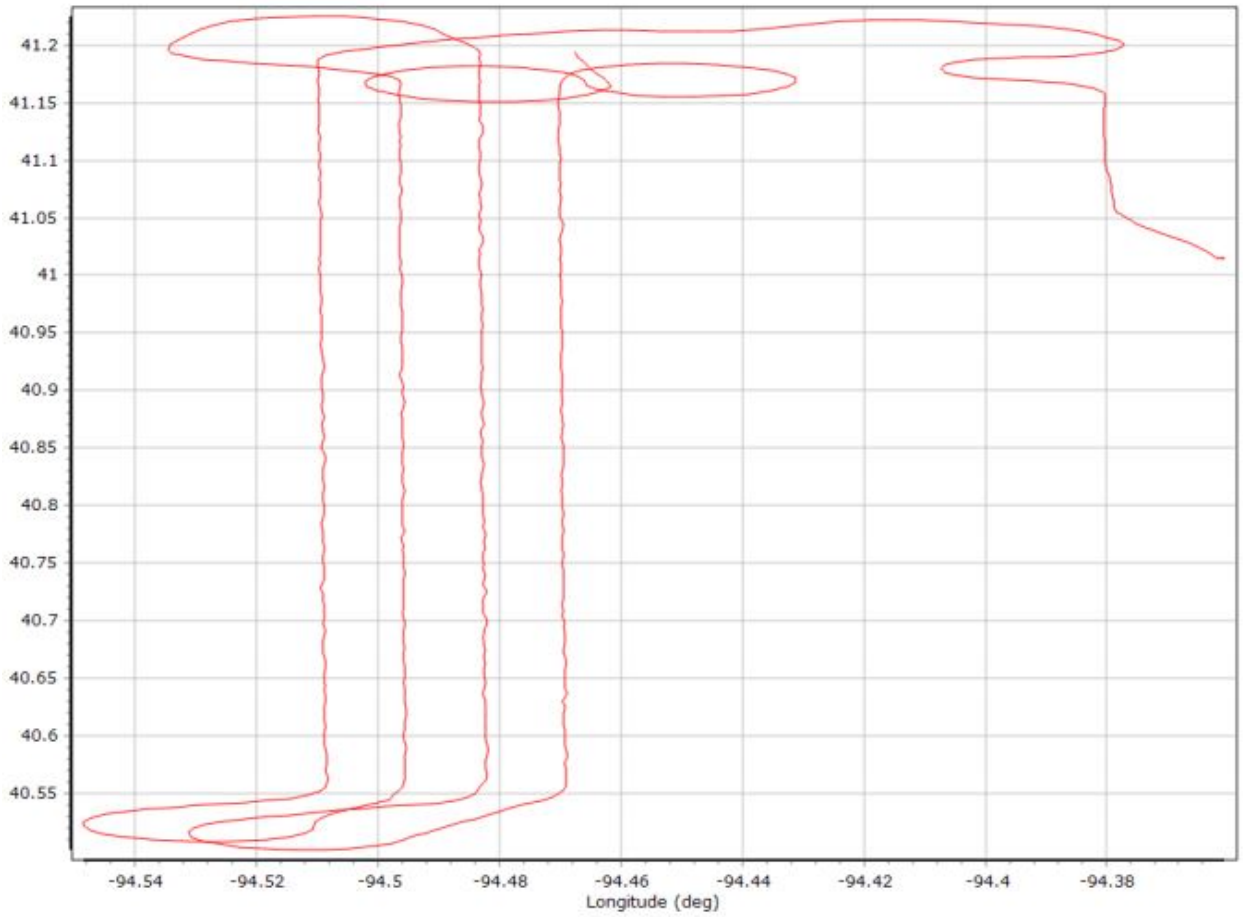


PDOP


2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
416,000
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)

20210311_2_QC Report.docx QC Report – 8/27/2021 09:35:02
Smoothed Trajectory Information

Top View

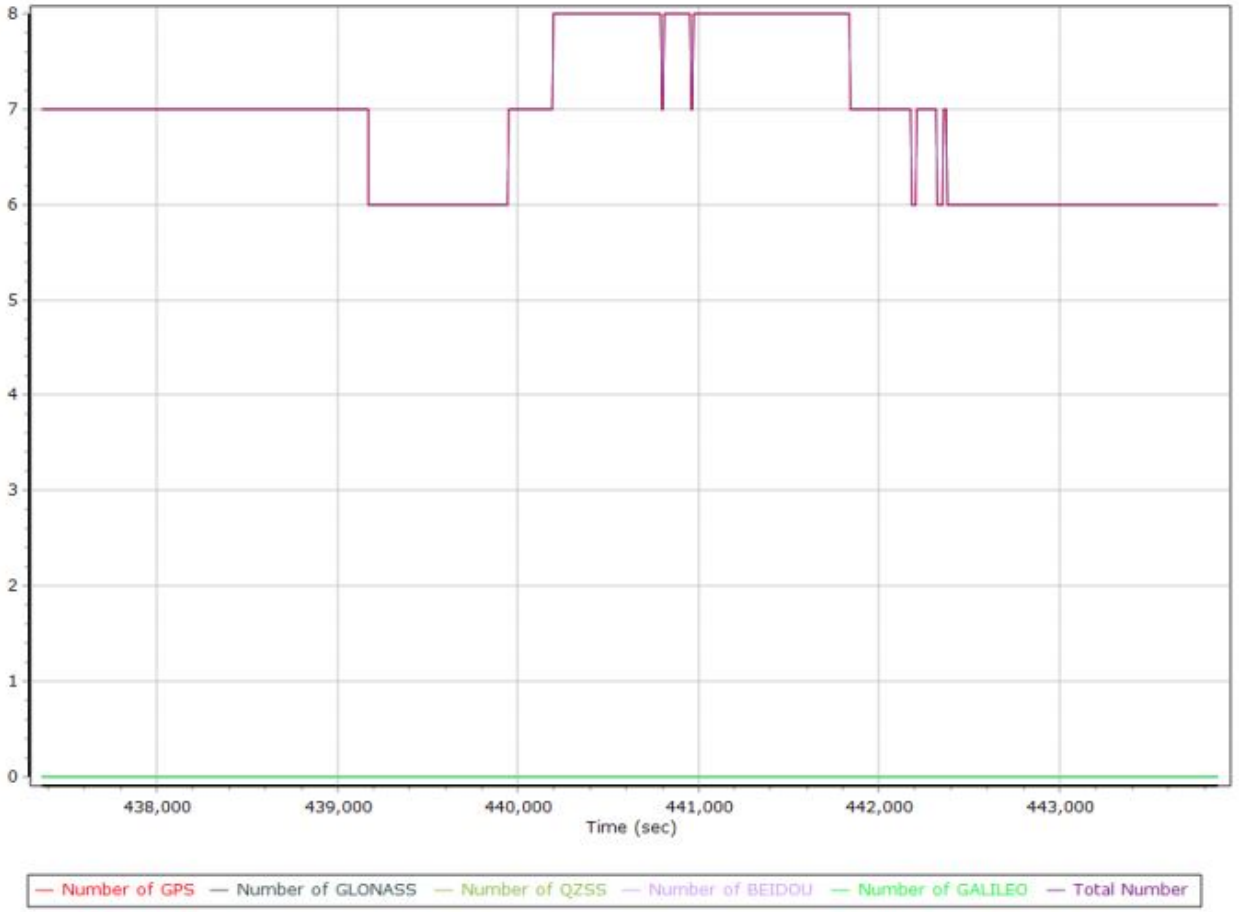


GNSS QC

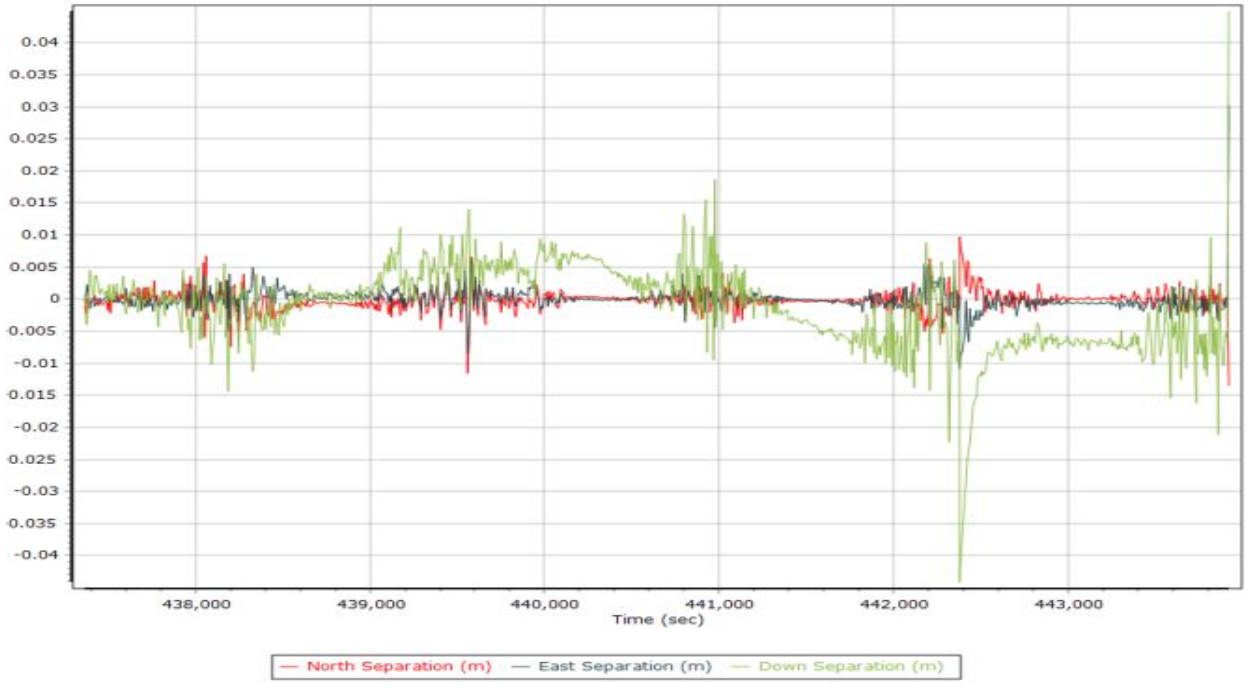
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.23	45.80	
Number of GPS SV	6	8	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	8	7
PDOP	1.77	3.04	2.27
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6995.00	0.00	1.00
Percentage	99.99	0.00	0.01

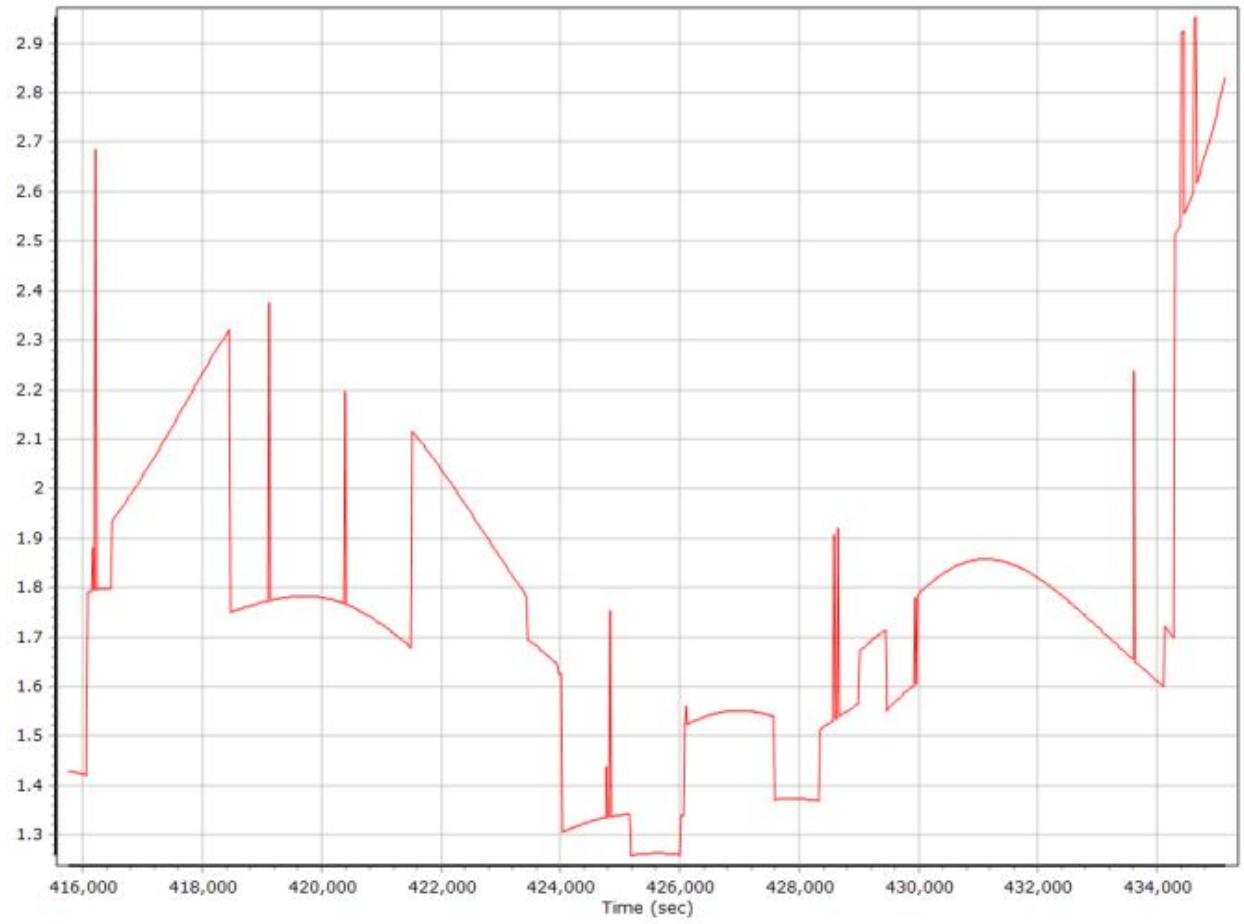
Number of Satellites



Forward/Reverse Separation

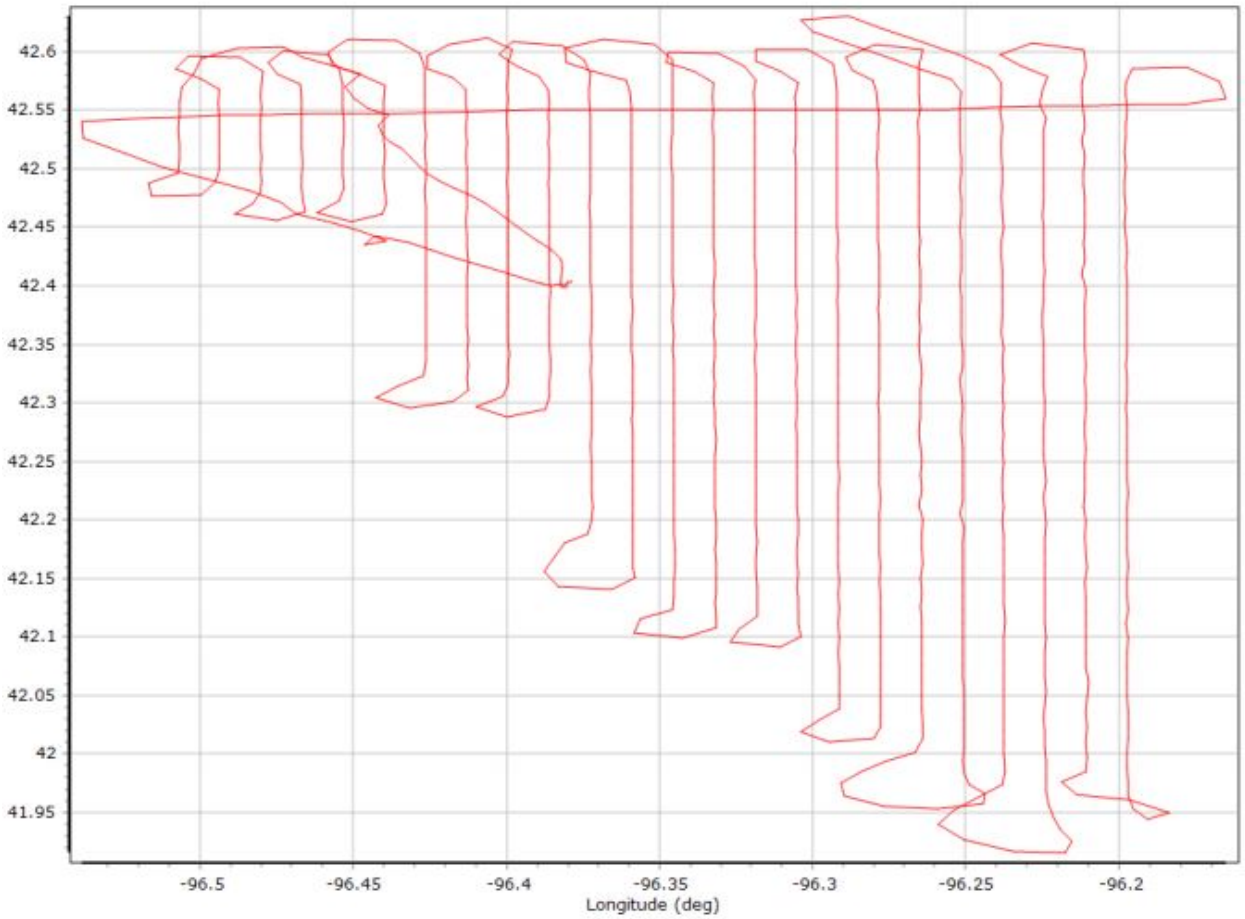


PDOP


2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
416,000
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)

Block C 20210328_1_QC Report.docx QC Report – 8/27/2021 09:50:02
Smoothed Trajectory Information

Top View

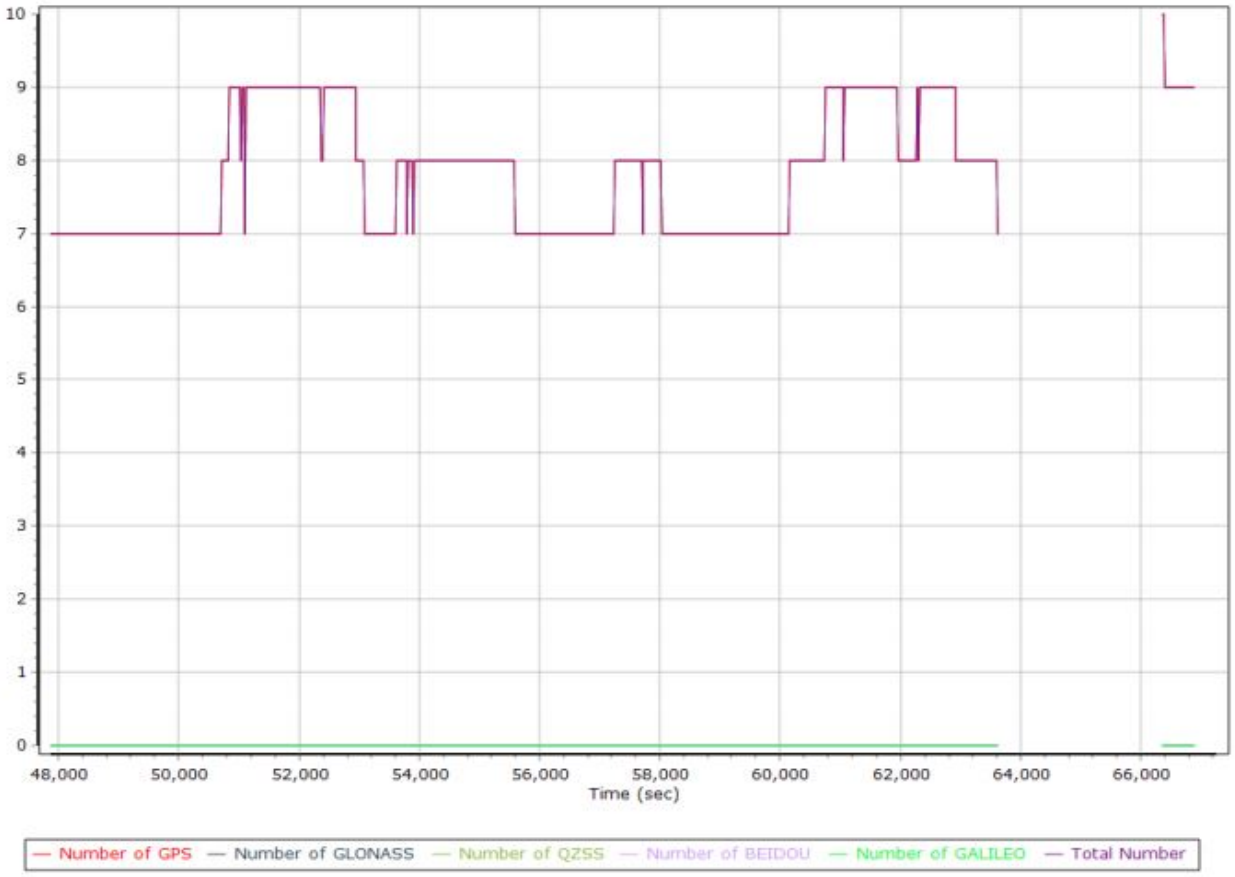


GNSS QC

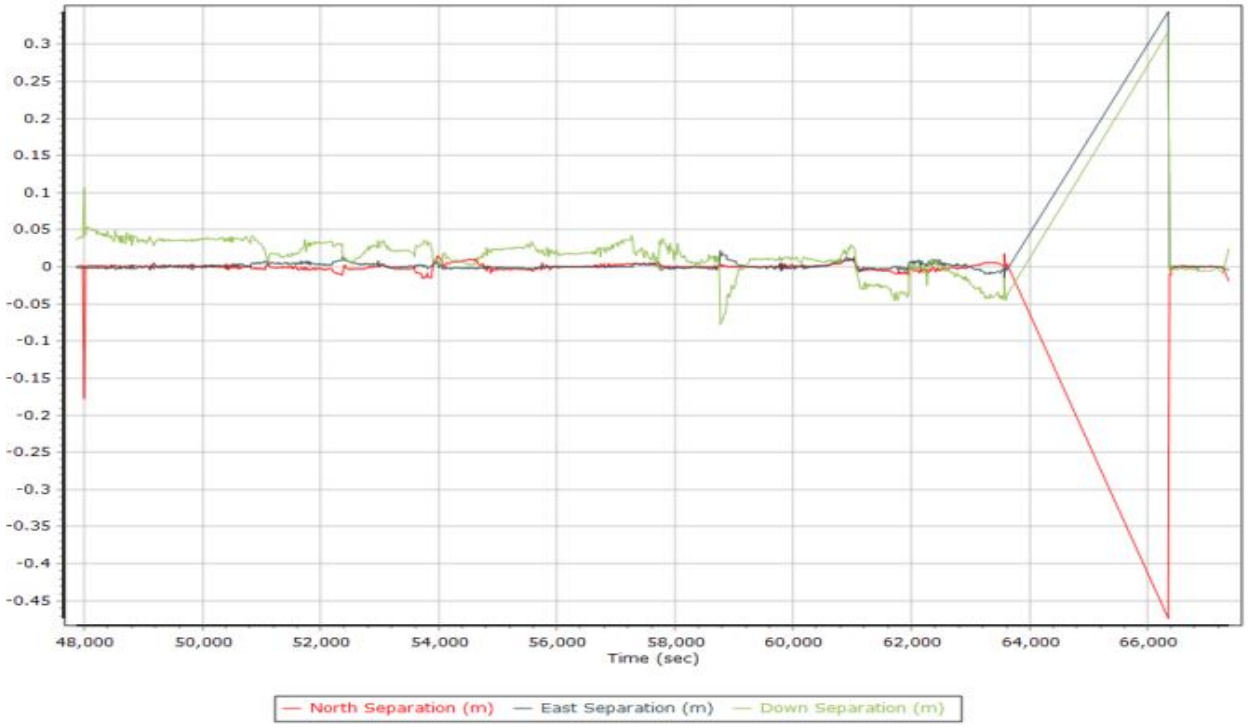
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.35	45.72	
Number of GPS SV	5	11	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	11	8
PDOP	1.42	5.19	2.17
QC Solution Gaps	1.00	2719.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	16948.00	0.00	3050.00
Percentage	84.75	0.00	15.25

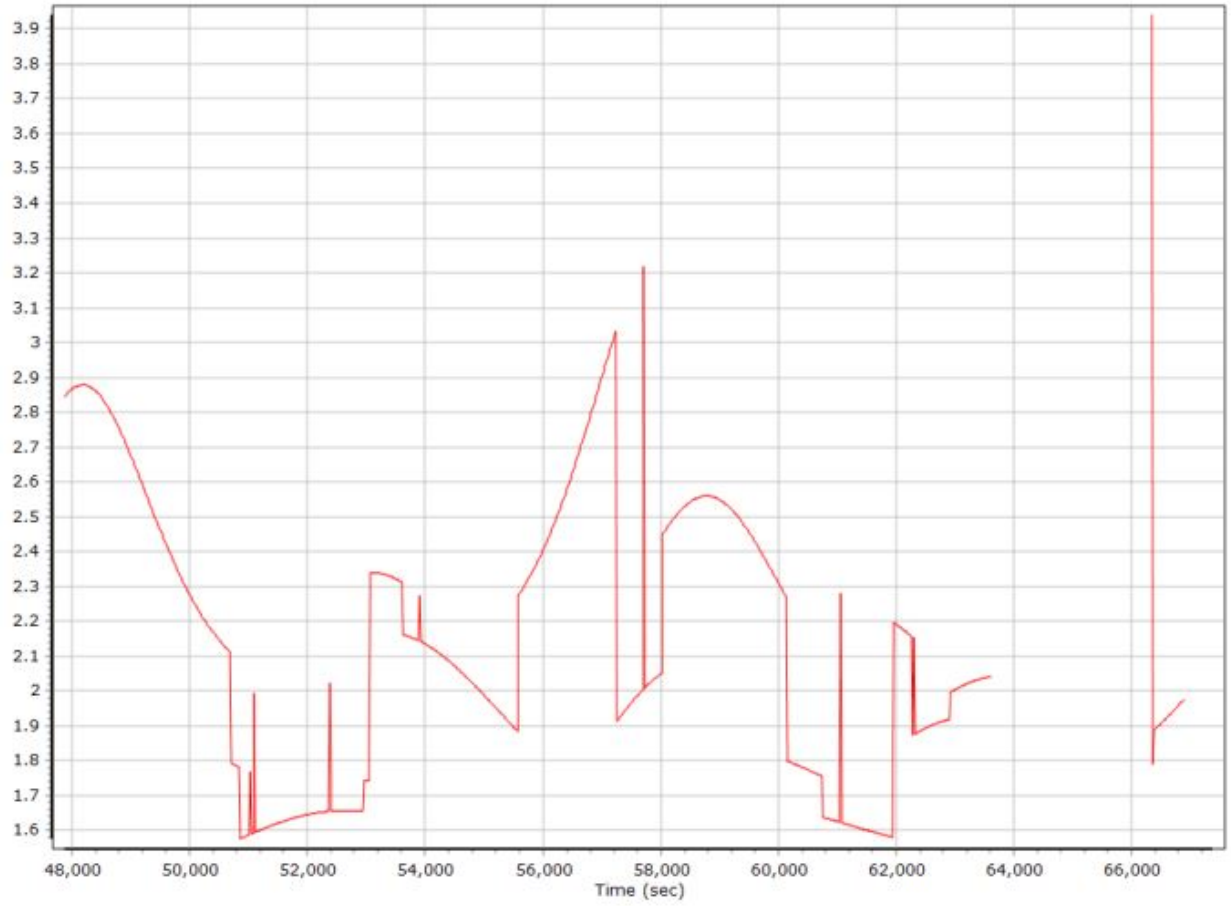
Number of Satellites



Forward/Reverse Separation

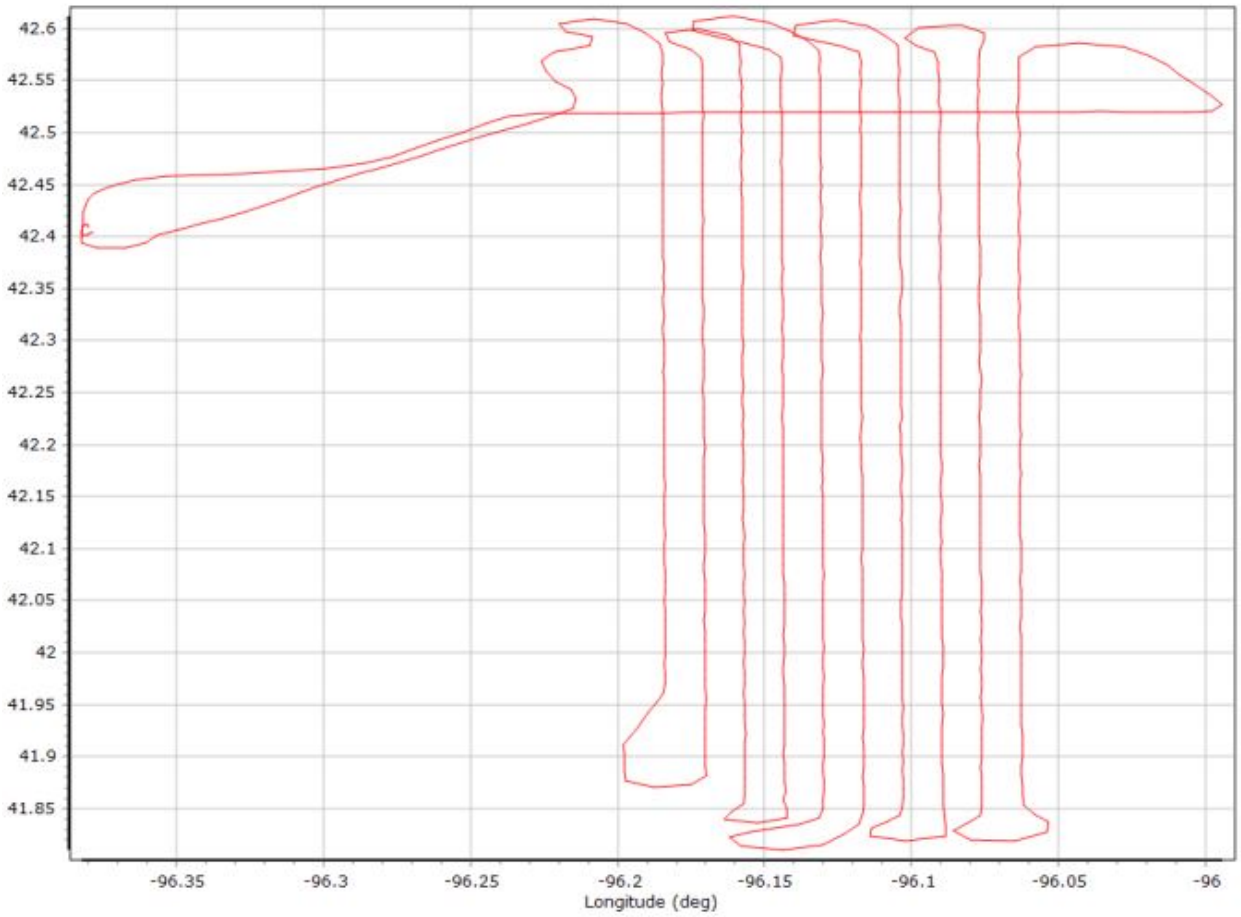


PDOP


3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
48,000
50,000
52,000
54,000
56,000
58,000
60,000
62,000
64,000
66,000
Time (sec)

20210328_2_QC Report.docx QC Report – 8/27/2021 09:58:33
Smoothed Trajectory Information

Top View

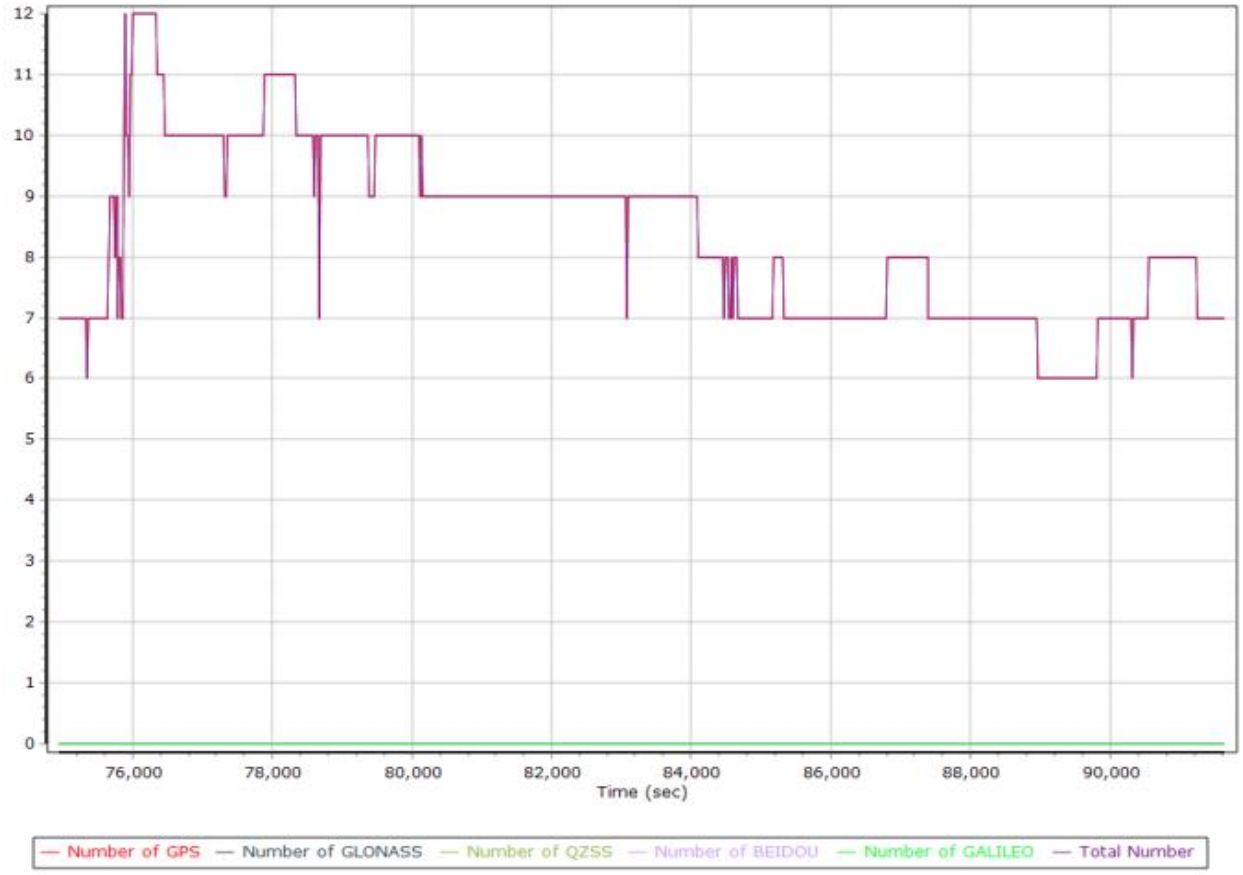


GNSS QC

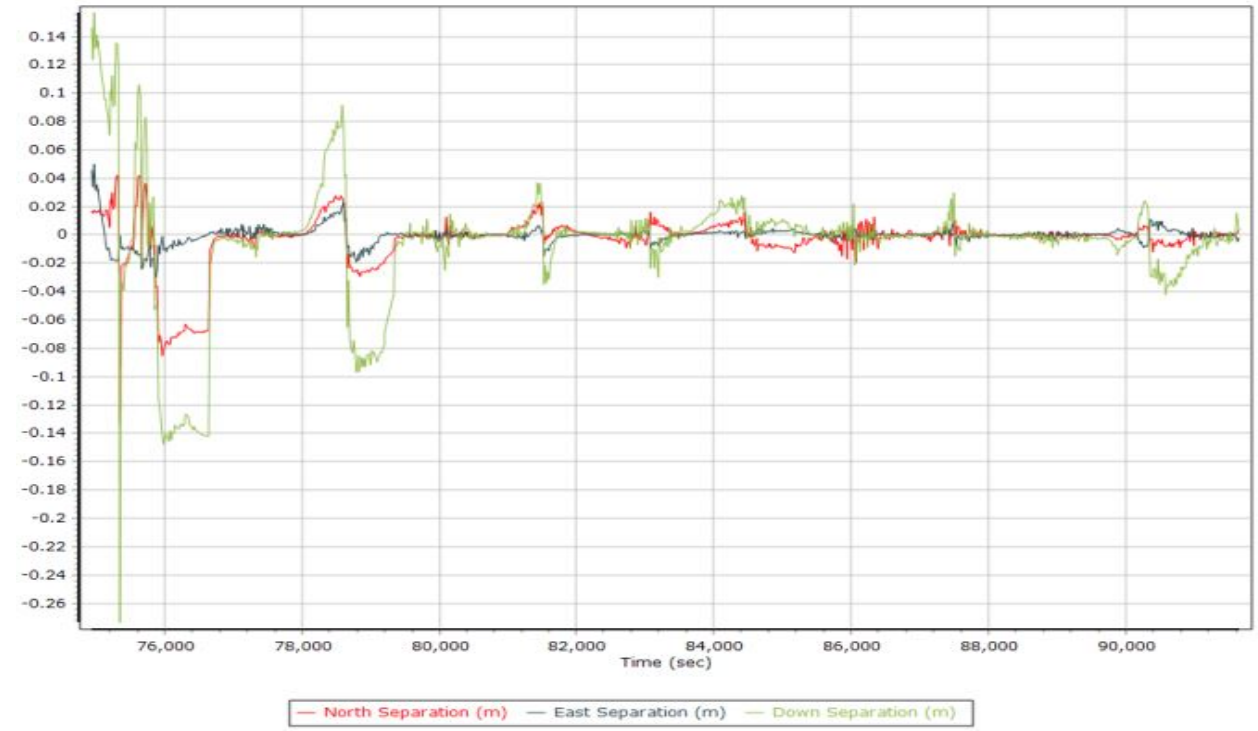
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.50	49.46	
Number of GPS SV	5	12	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	12	8
PDOP	1.26	6.23	1.88
QC Solution Gaps	1.00	4.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	17173.00	0.00	6.00
Percentage	99.97	0.00	0.03

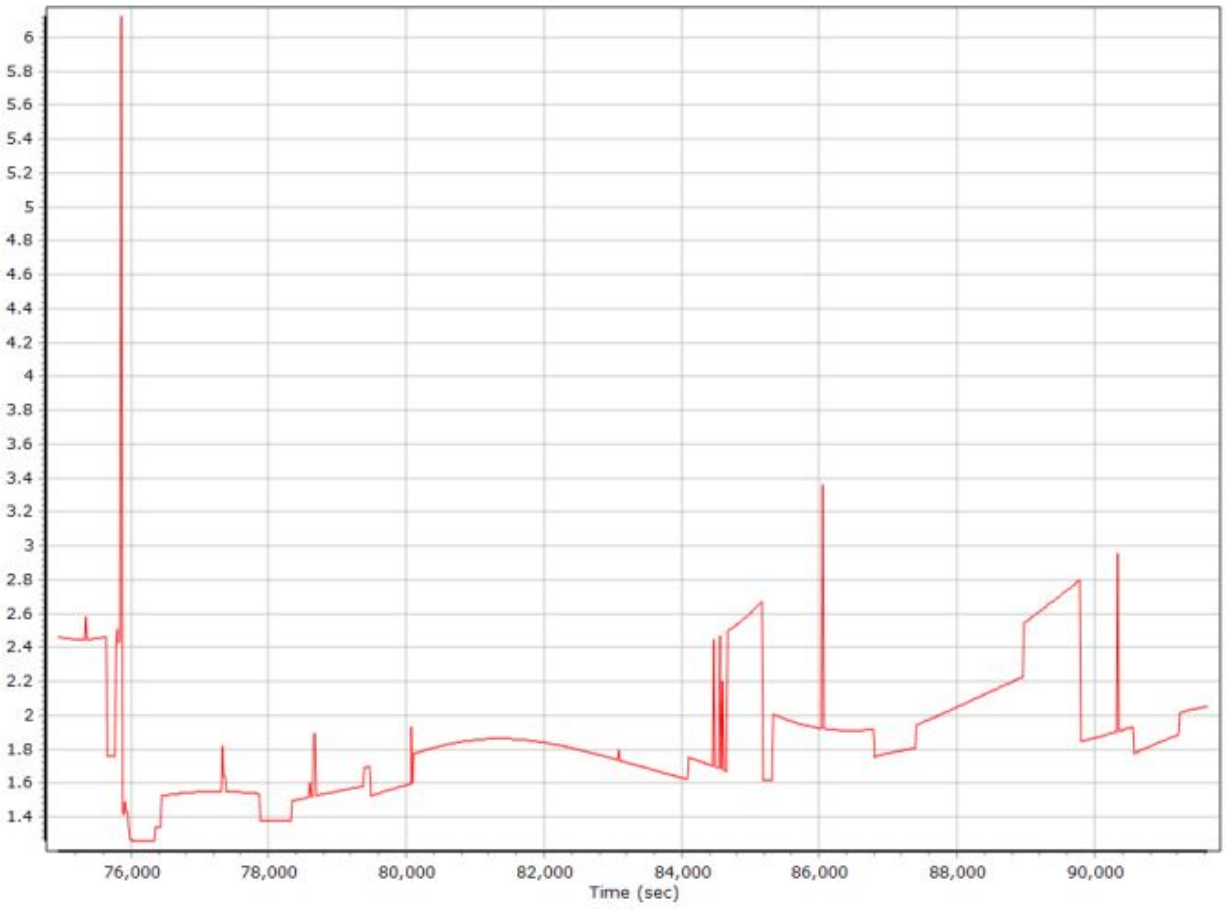
Number of Satellites



Forward/Reverse Separation

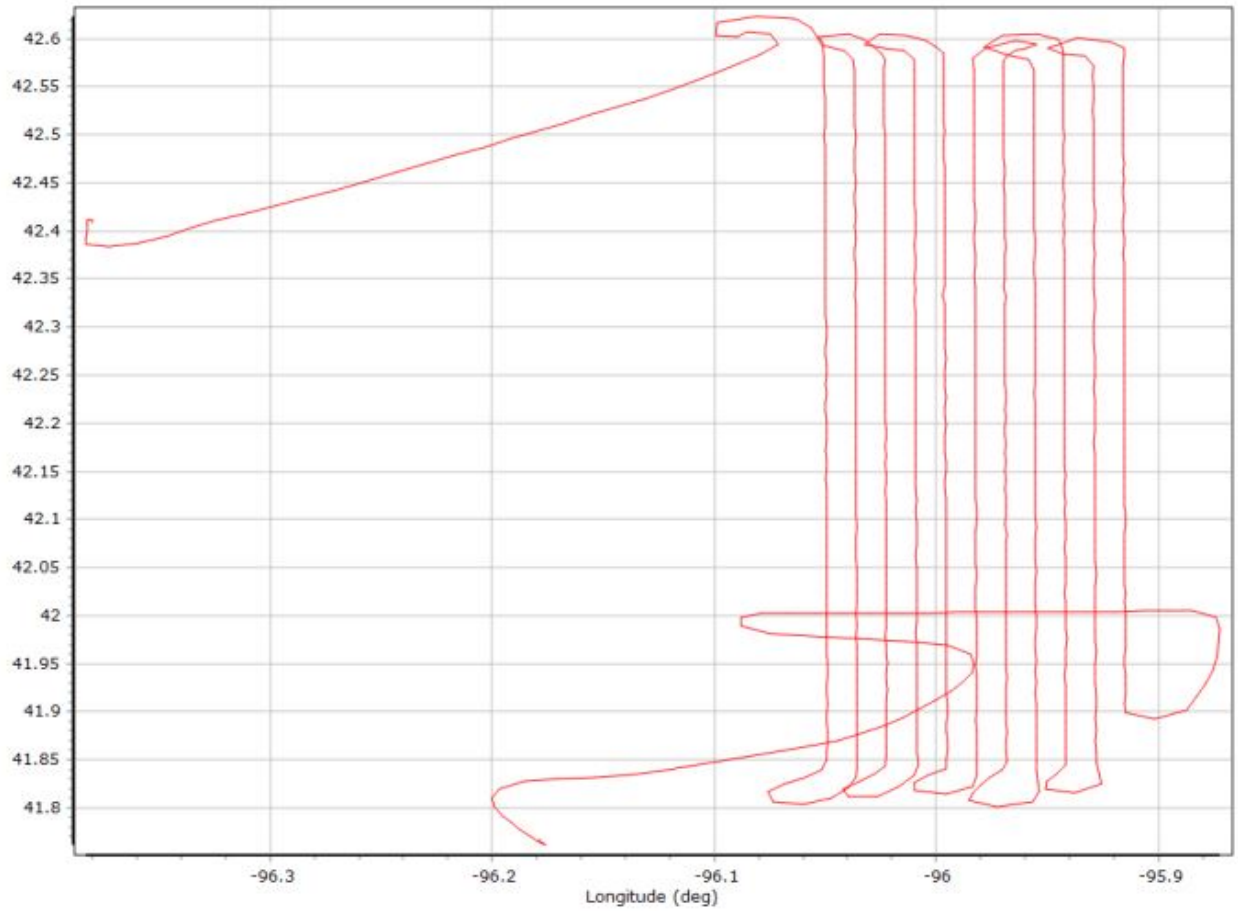


PDOP


6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
76,000
78,000
80,000
82,000
84,000
86,000
88,000
90,000
Time (sec)

20210329_1_QC Report.docx QC Report – 8/27/2021 10:07:14
Smoothed Trajectory Information

Top View



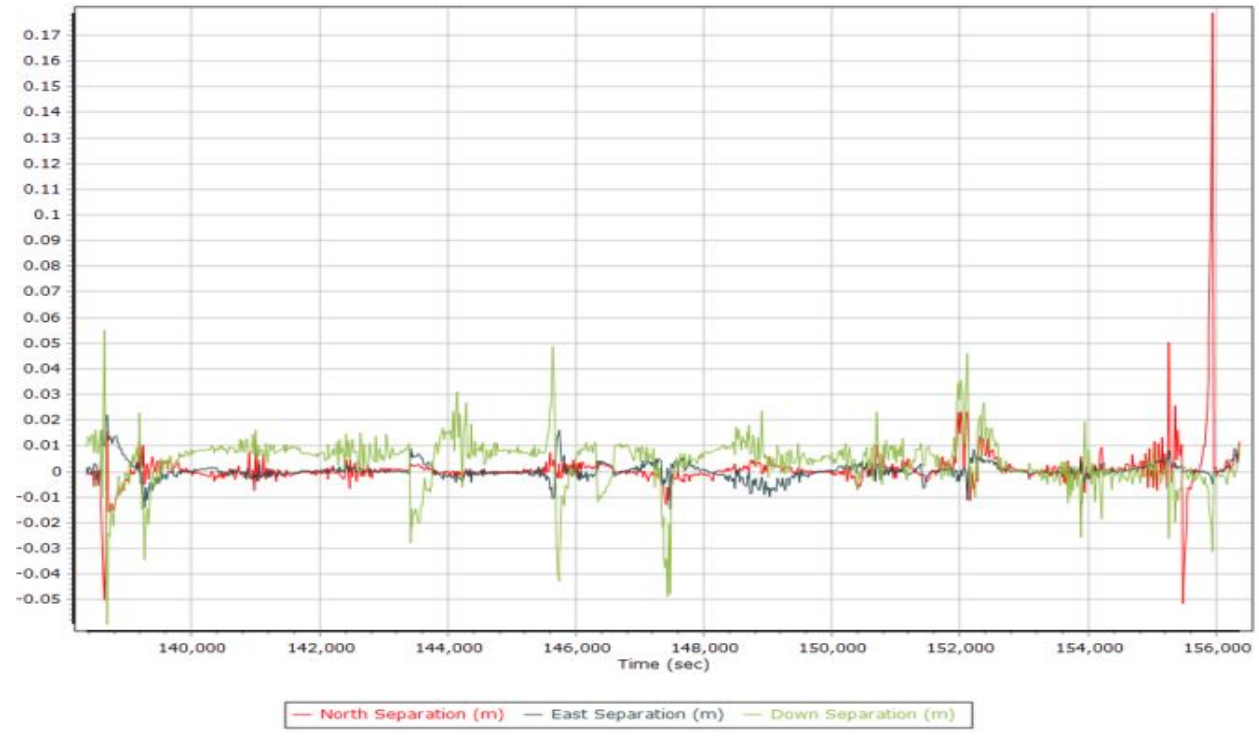
GNSS QC

GNSS QC Statistics

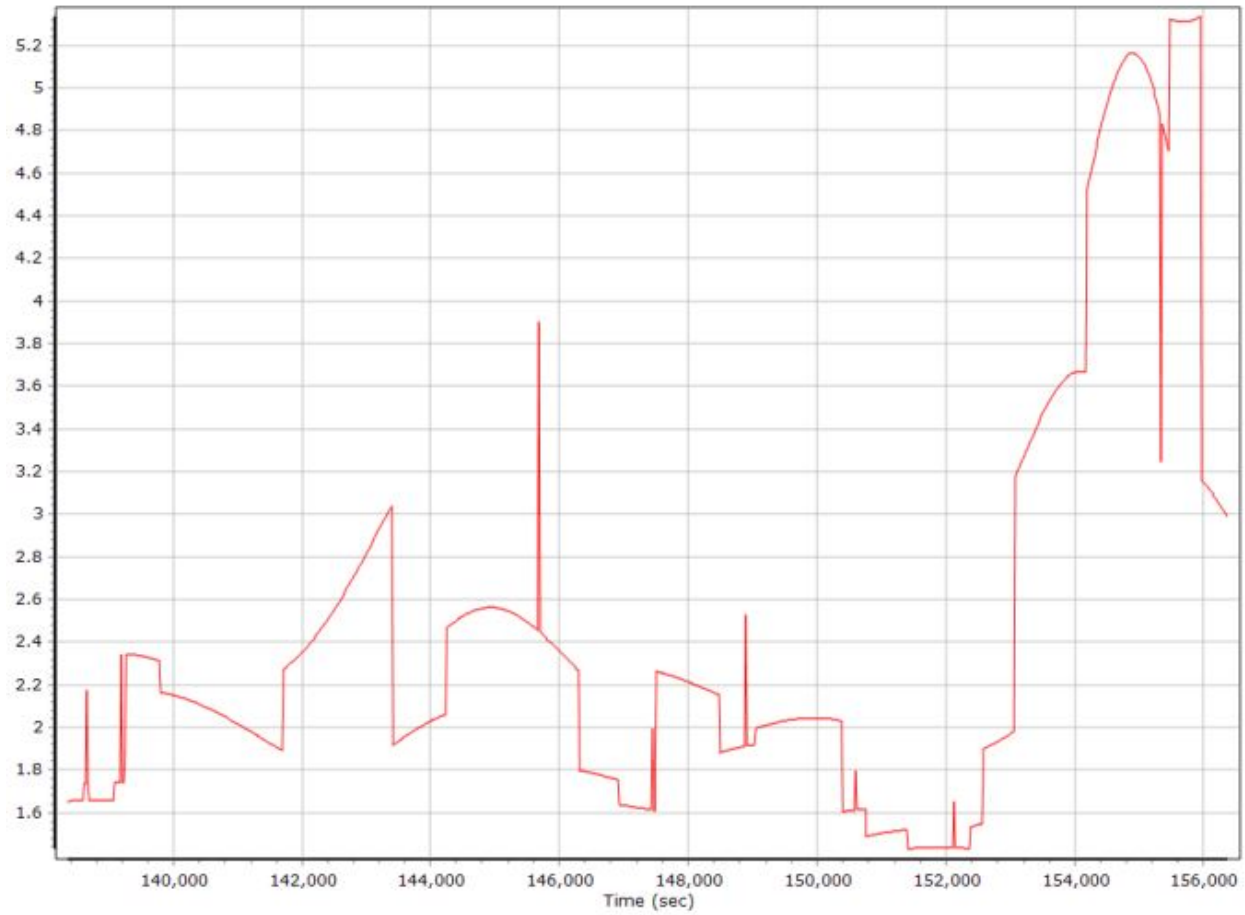
Statistics	Min	Max	Mean
Baseline length (km)	0.41	46.68	
Number of GPS SV	5	11	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	11	8
PDOP	1.43	5.34	2.43
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	18610.00	0.00	1.00
Percentage	99.99	0.00	0.01

Number of Satellites

Forward/Reverse Separation



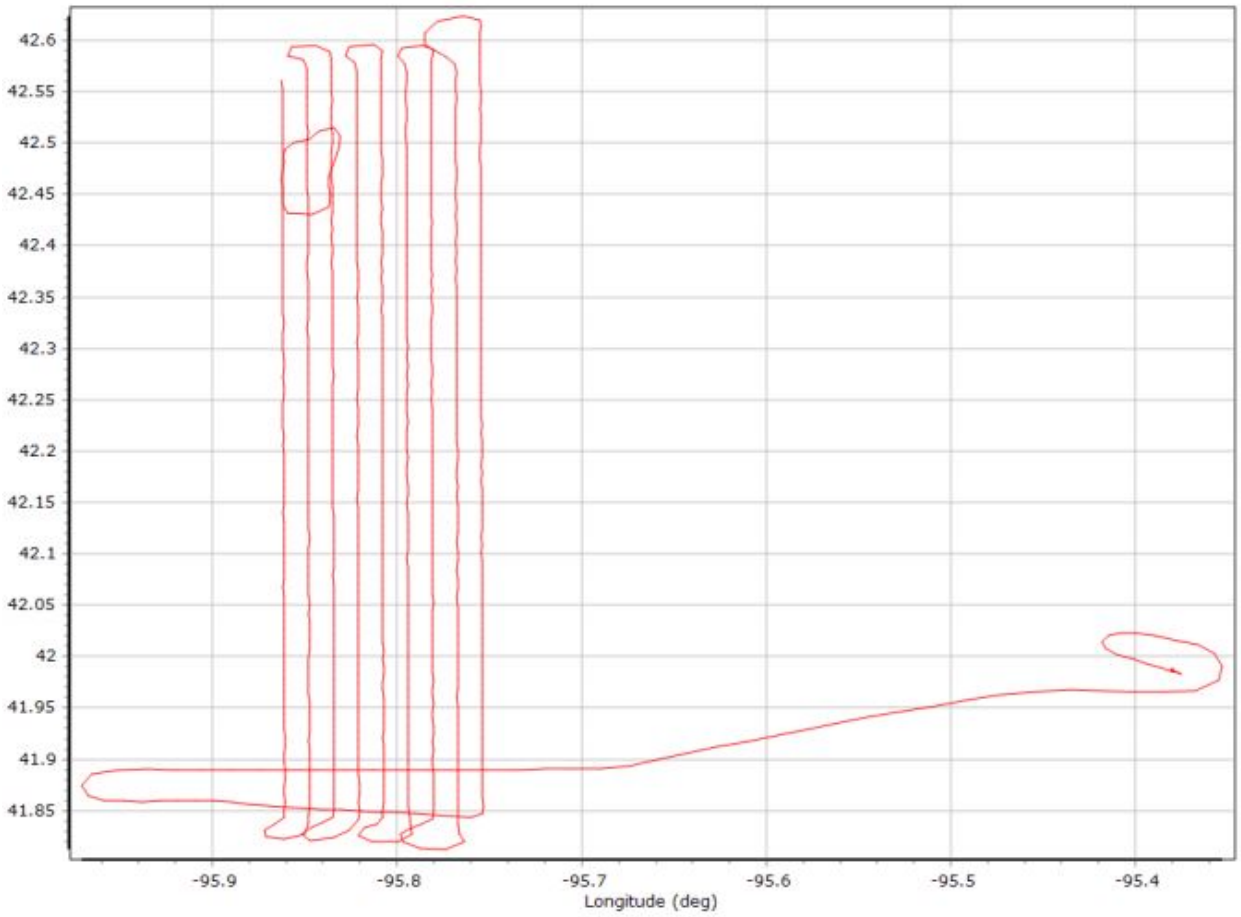
PDOP


5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
140,000
142,000
144,000
146,000
148,000
150,000
152,000
154,000
156,000
Time (sec)

20210329_2_QC Report.docx QC Report – 8/27/2021 1014:24

Smoothed Trajectory Information

Top View

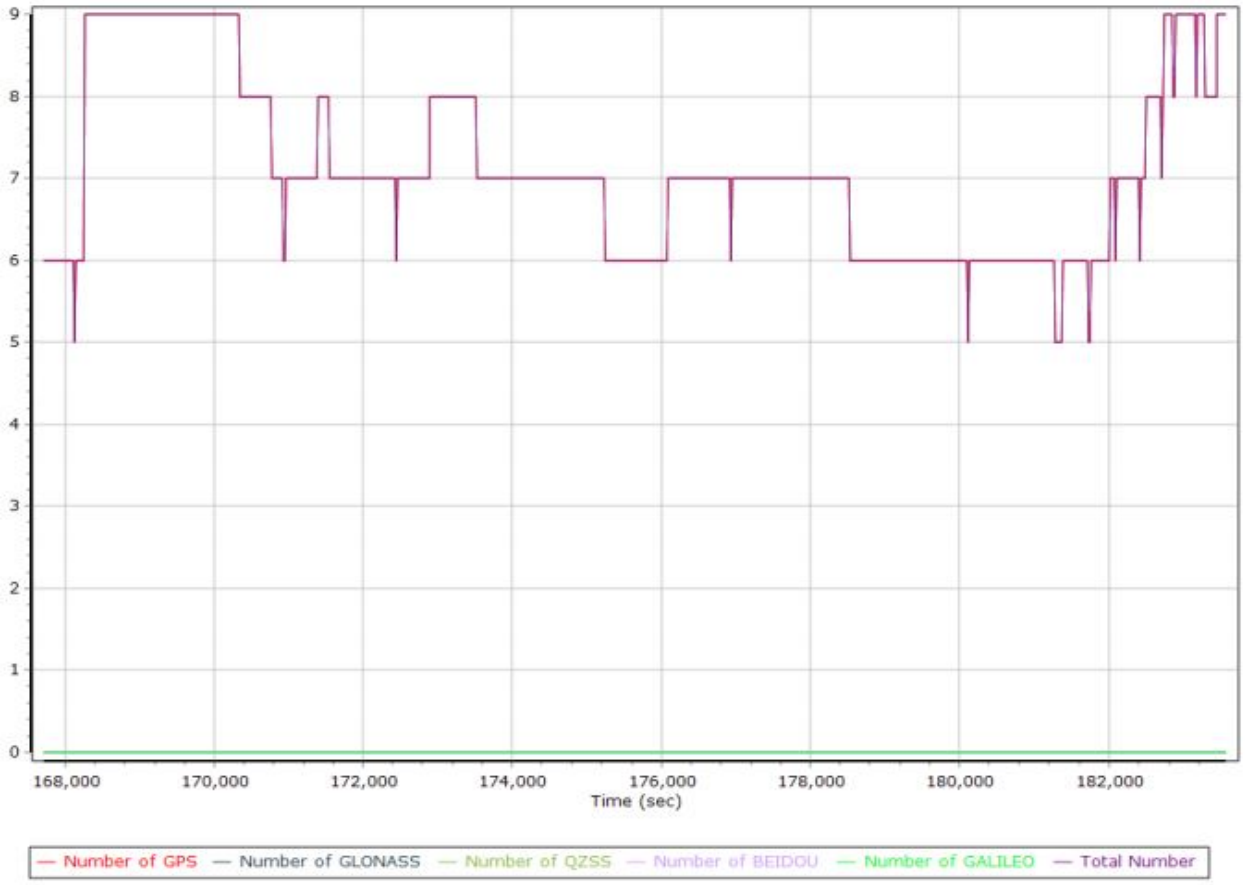


GNSS QC

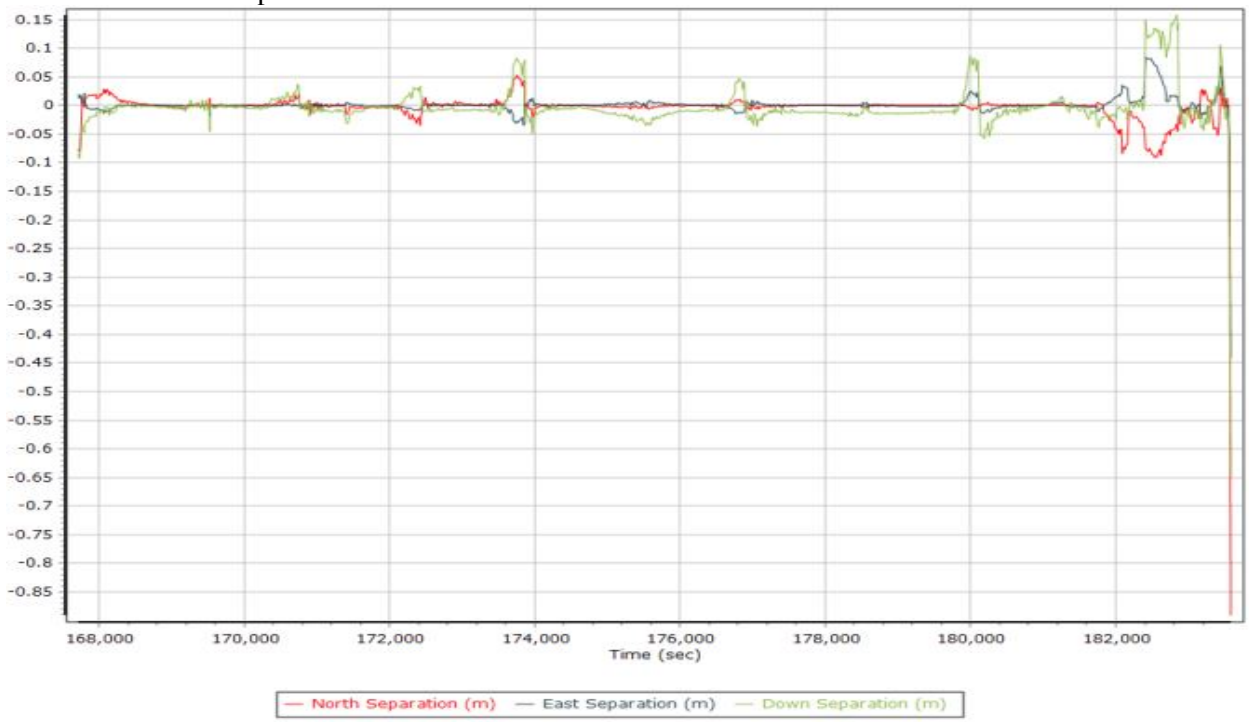
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.31	51.94	
Number of GPS SV	5	9	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	9	7
PDOP	1.61	6.96	2.26
QC Solution Gaps	3.00	9.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15914.00	0.00	12.00
Percentage	99.92	0.00	0.08

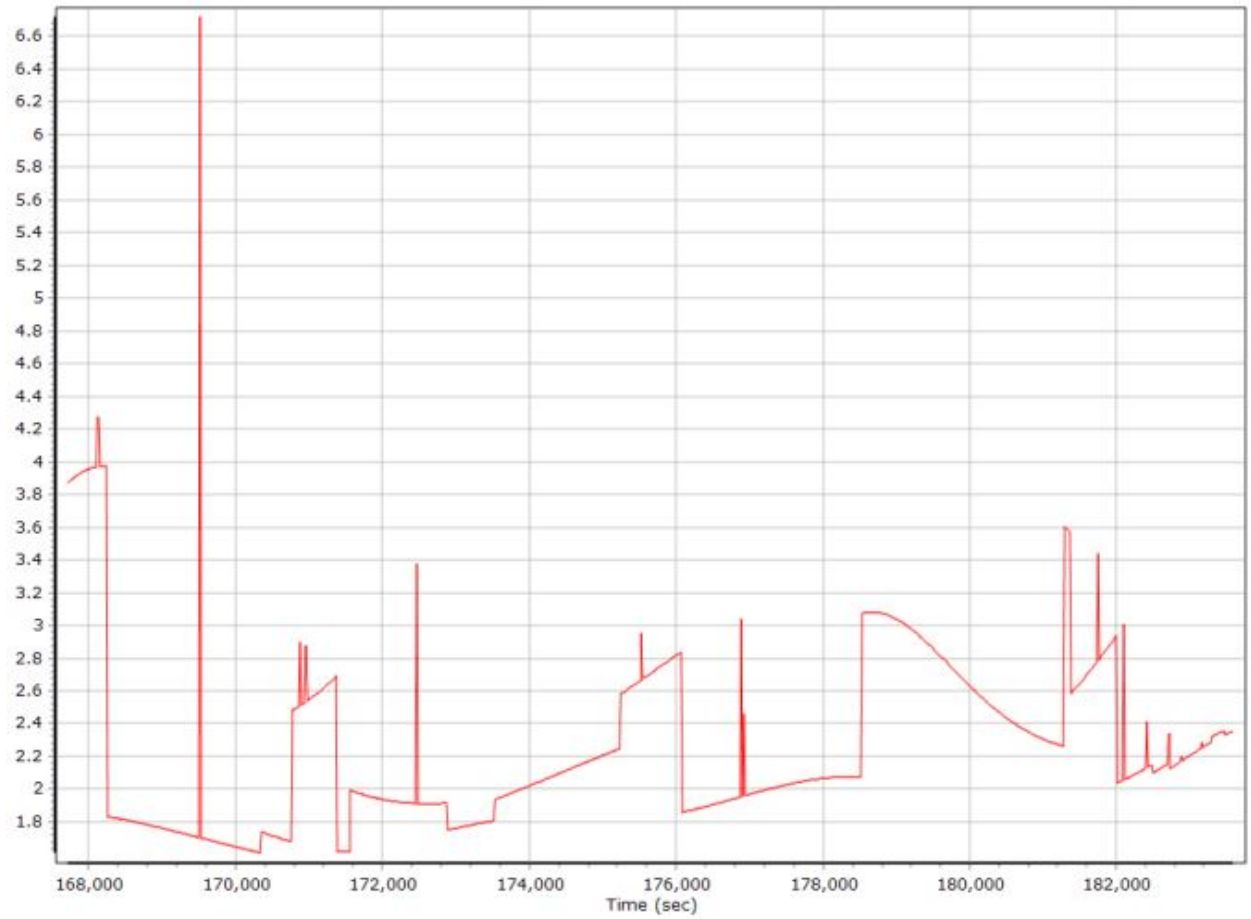
Number of Satellites



Forward/Reverse Separation

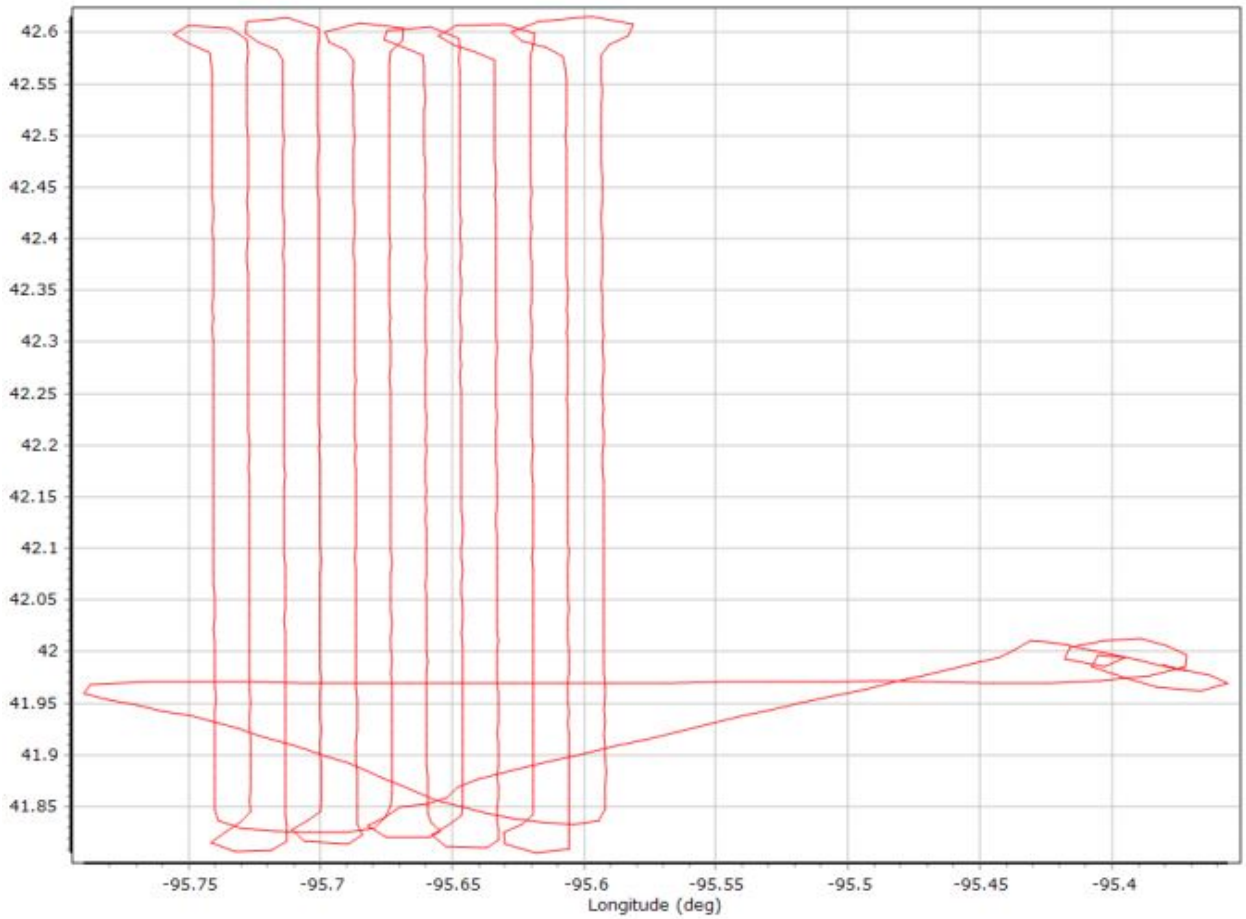


PDOP


6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
168,000
170,000
172,000
174,000
176,000
178,000
180,000
182,000
Time (sec)

20210330_1_QC Report.docx QC Report – 8/27/2021 10:20:22
Smoothed Trajectory Information

Top View

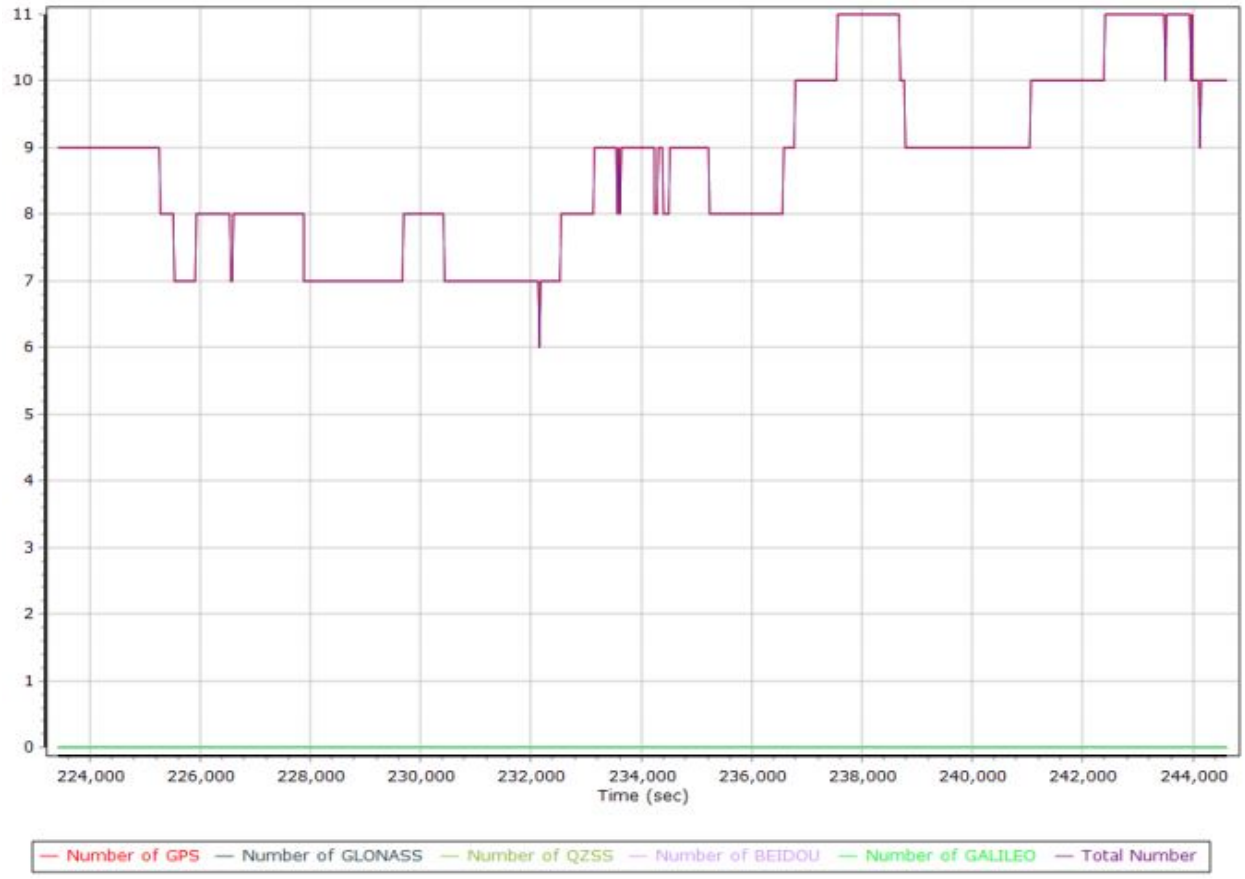


GNSS QC

GNSS QC Statistics

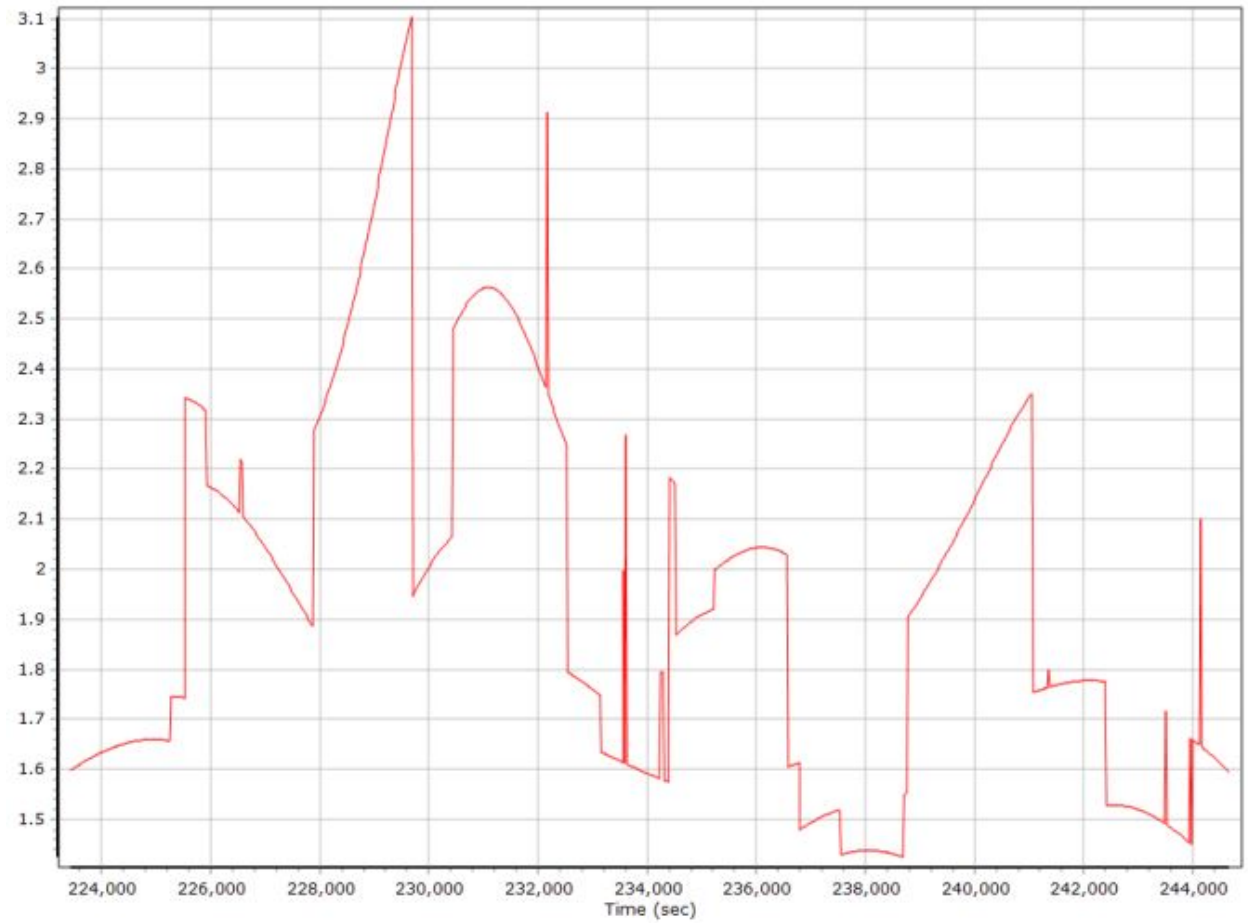
Statistics	Min	Max	Mean
Baseline length (km)	0.26	49.38	
Number of GPS SV	6	11	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	11	9
PDOP	1.42	3.95	1.94
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	21672.00	0.00	1.00
Percentage	100.00	0.00	0.00

Number of Satellites



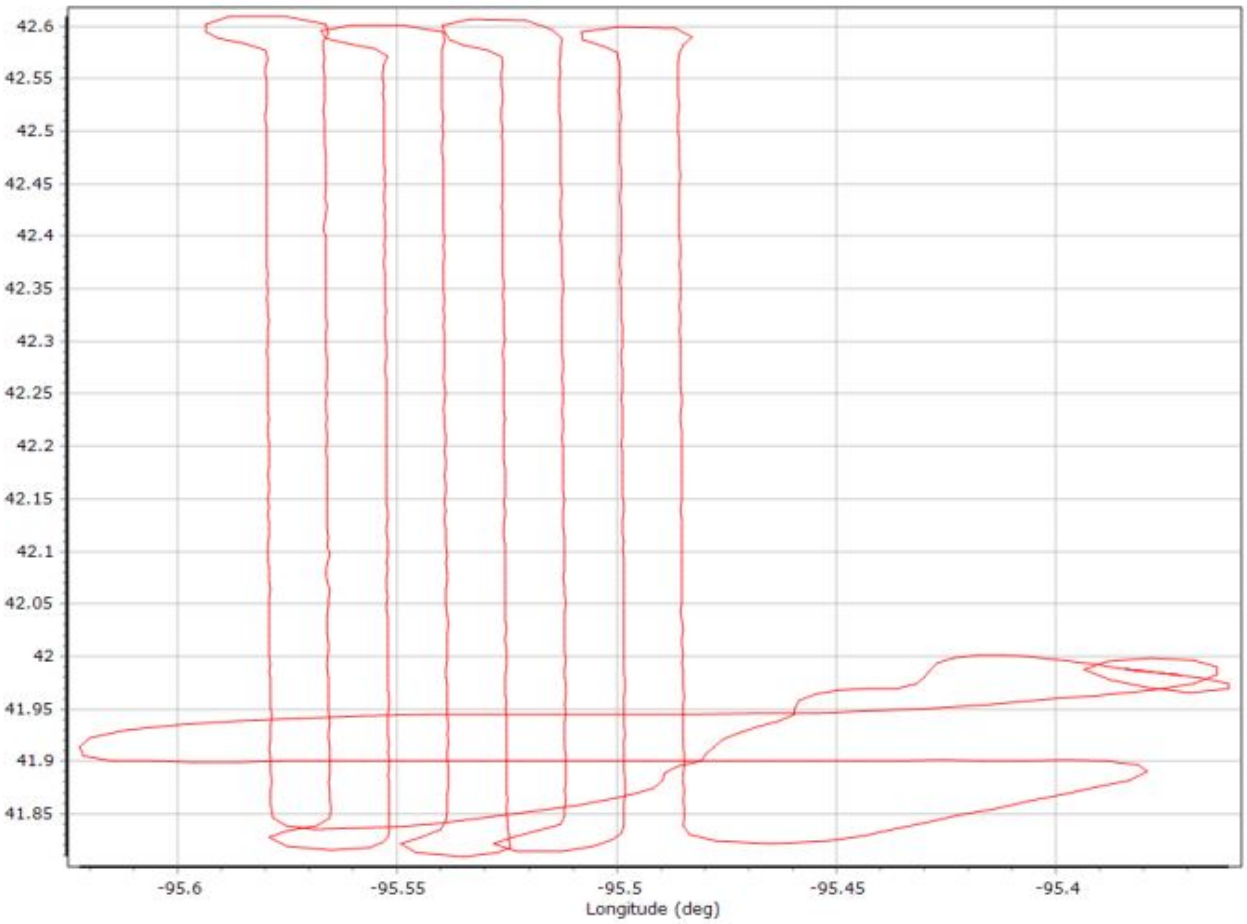
Forward/Reverse Separation

PDOP


3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
224,000
226,000
228,000
230,000
232,000
234,000
236,000
238,000
240,000
242,000
244,000
Time (sec)

20210330_2_QC Report.docx QC Report – 8/27/2021 10:26:41
Smoothed Trajectory Information

Top View

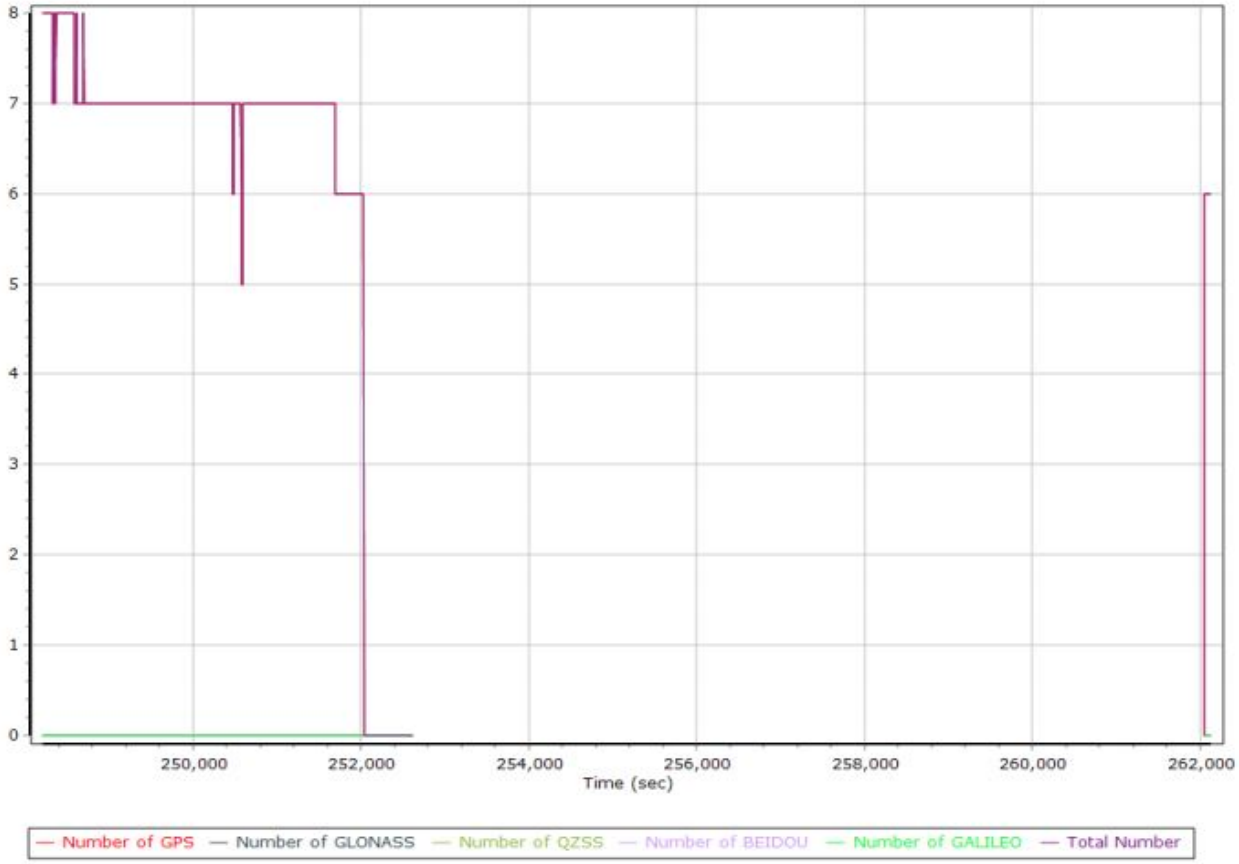


GNSS QC

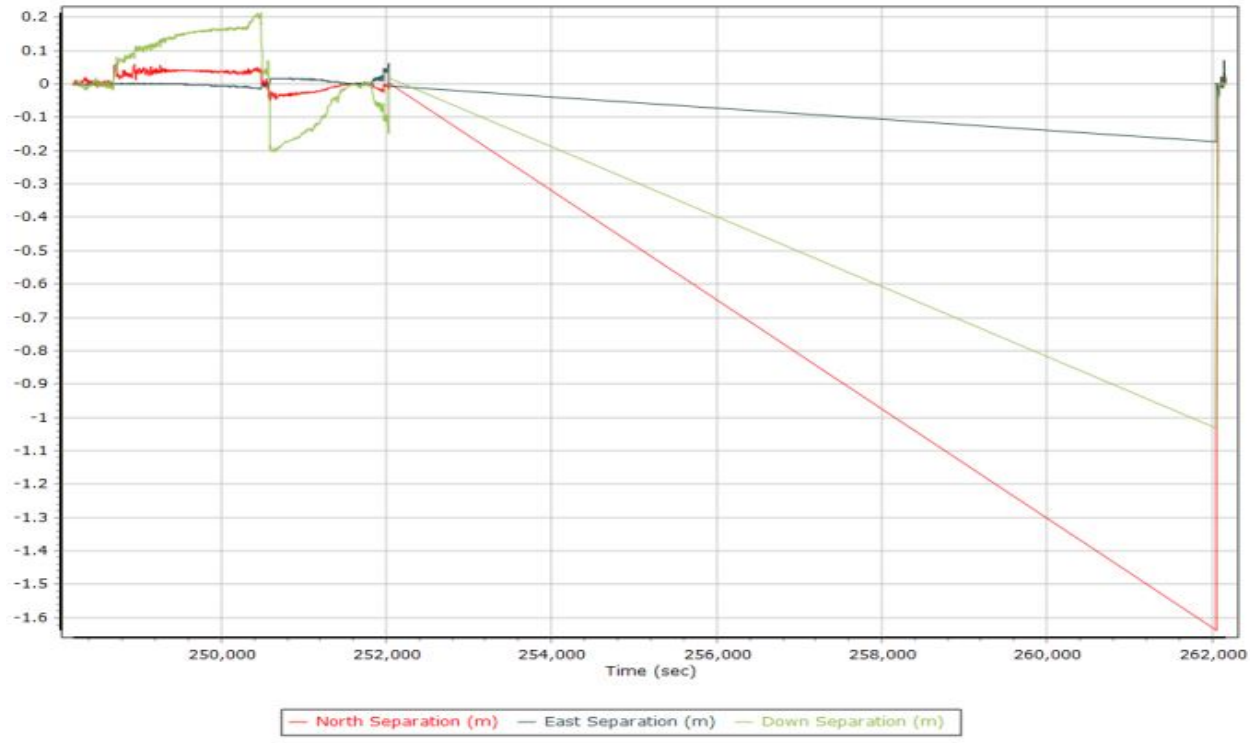
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	4.15	49.91	
Number of GPS SV	5	9	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	9	7
PDOP	1.80	6.99	4.07
QC Solution Gaps	1.00	9405.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	4270.00	39.00	10010.00
Percentage	29.82	0.27	69.91

Number of Satellites



Forward/Reverse Separation

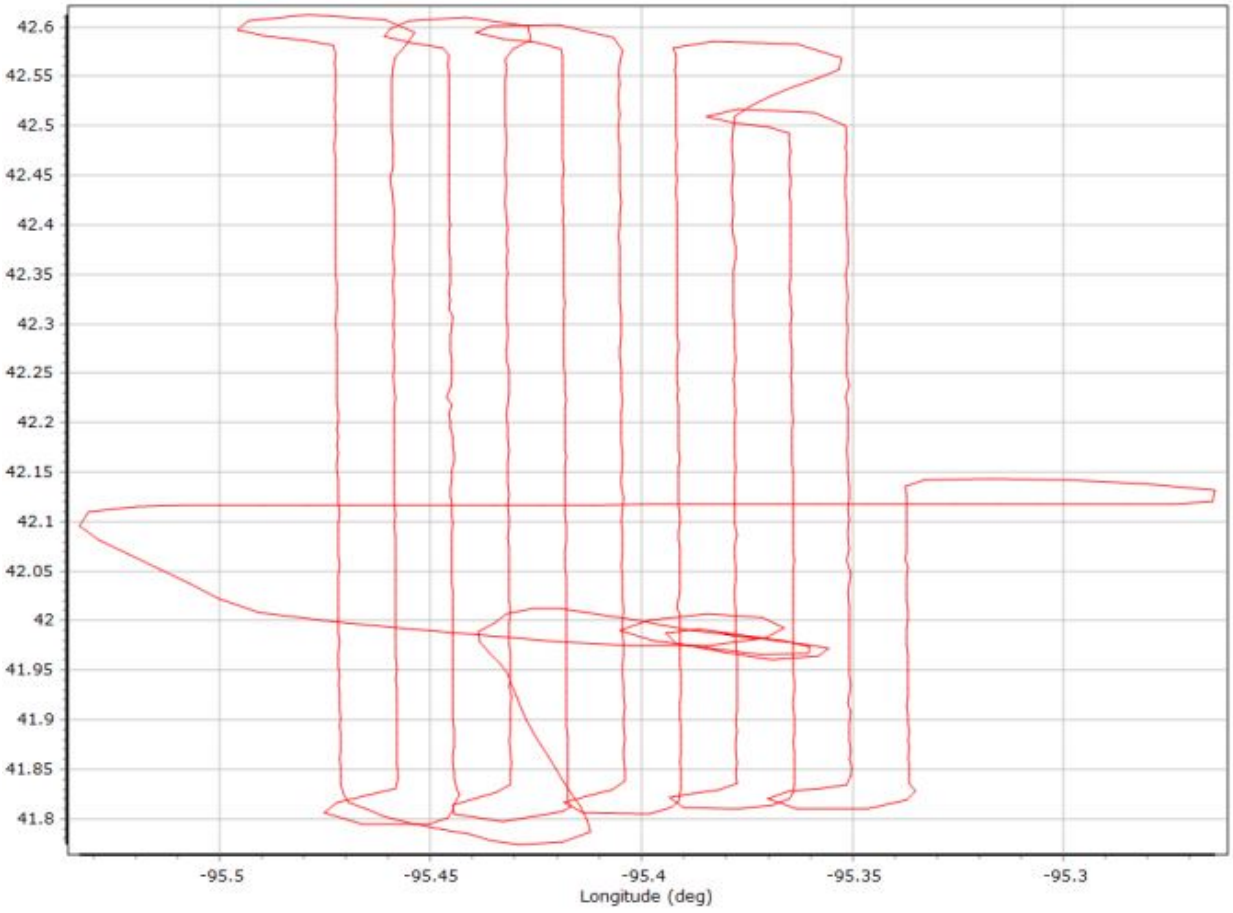


PDOP


5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
250,000
252,000
254,000
256,000
258,000
260,000
262,000
Time (sec)

20210331_1_QC Report.docx QC Report – 8/27/2021 10:34:23
Smoothed Trajectory Information

Top View



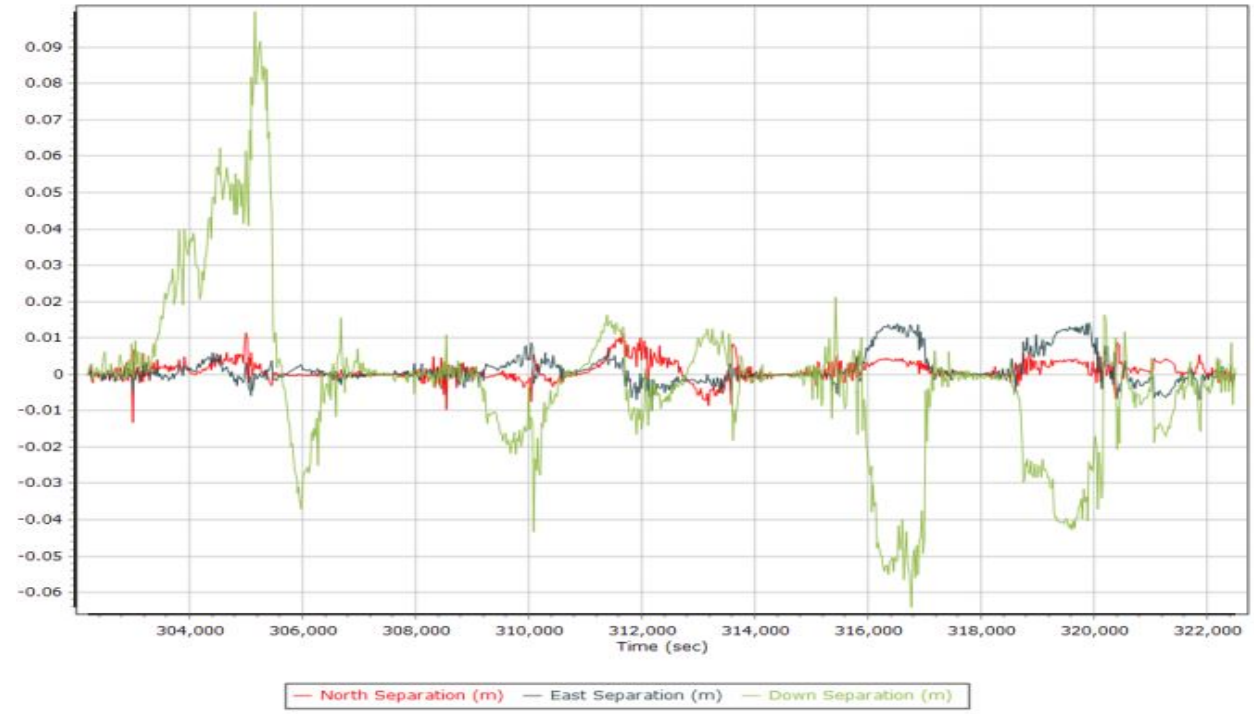
GNSS QC

GNSS QC Statistics

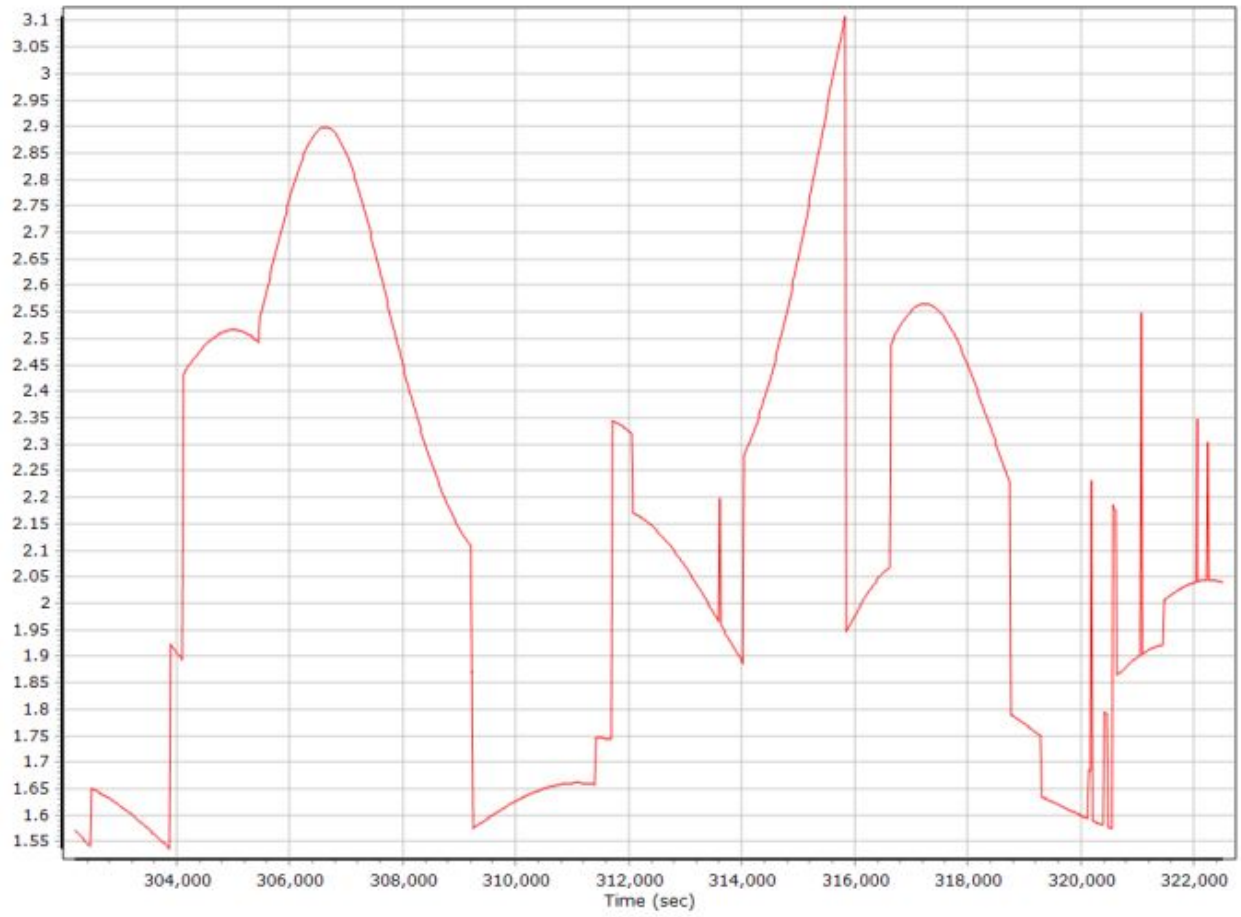
Statistics	Min	Max	Mean
Baseline length (km)	0.37	51.20	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	8
PDOP	1.53	5.50	2.14
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	20705.00	0.00	1.00
Percentage	100.00	0.00	0.00

Number of Satellites

Forward/Reverse Separation



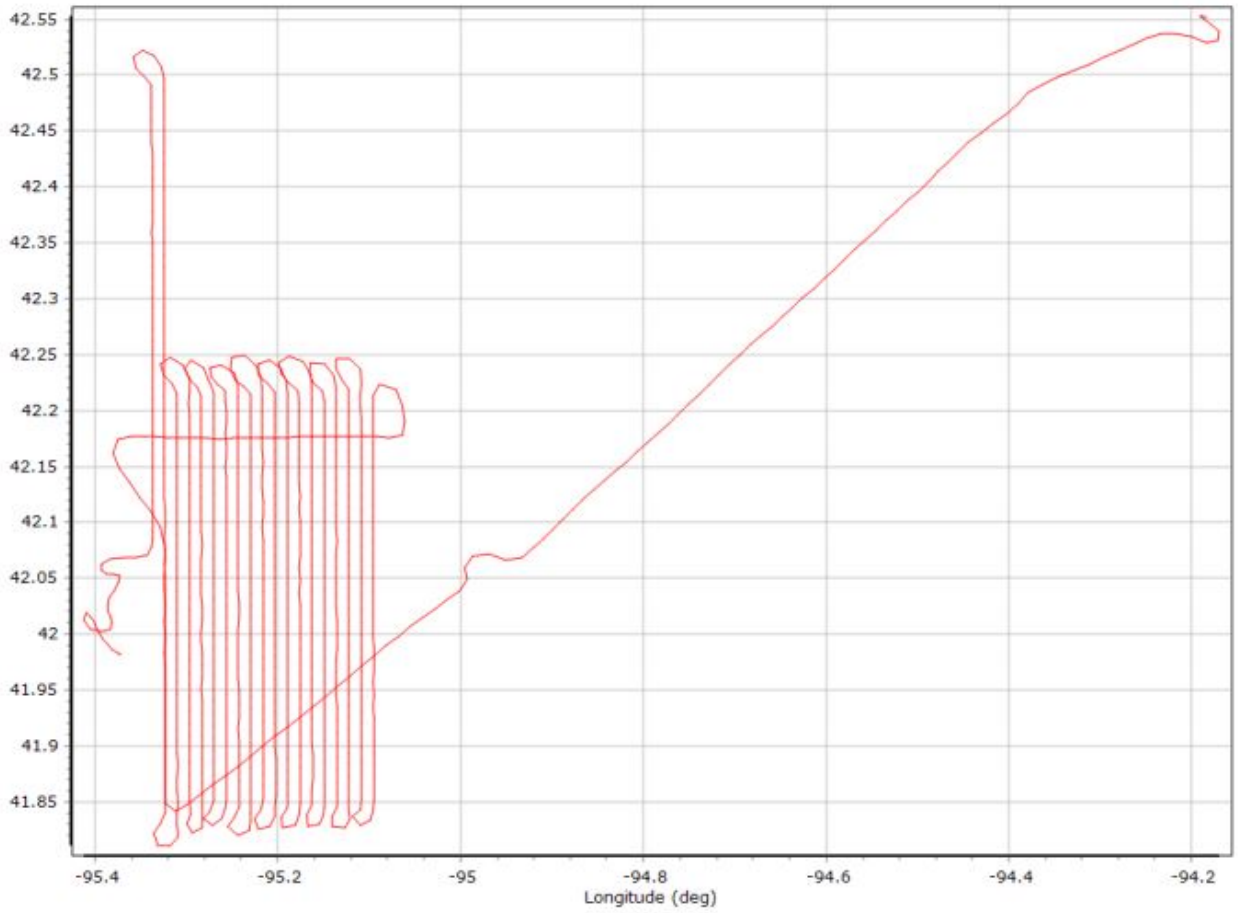
PDOP


3.1
3.05
3
2.95
2.9
2.85
2.8
2.75
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
304,000
306,000
308,000
310,000
312,000
314,000
316,000
318,000
320,000
322,000
Time (sec)

20210331_2_QC Report.docx QC Report – 8/27/2021 10:47:22

Smoothed Trajectory Information

Top View



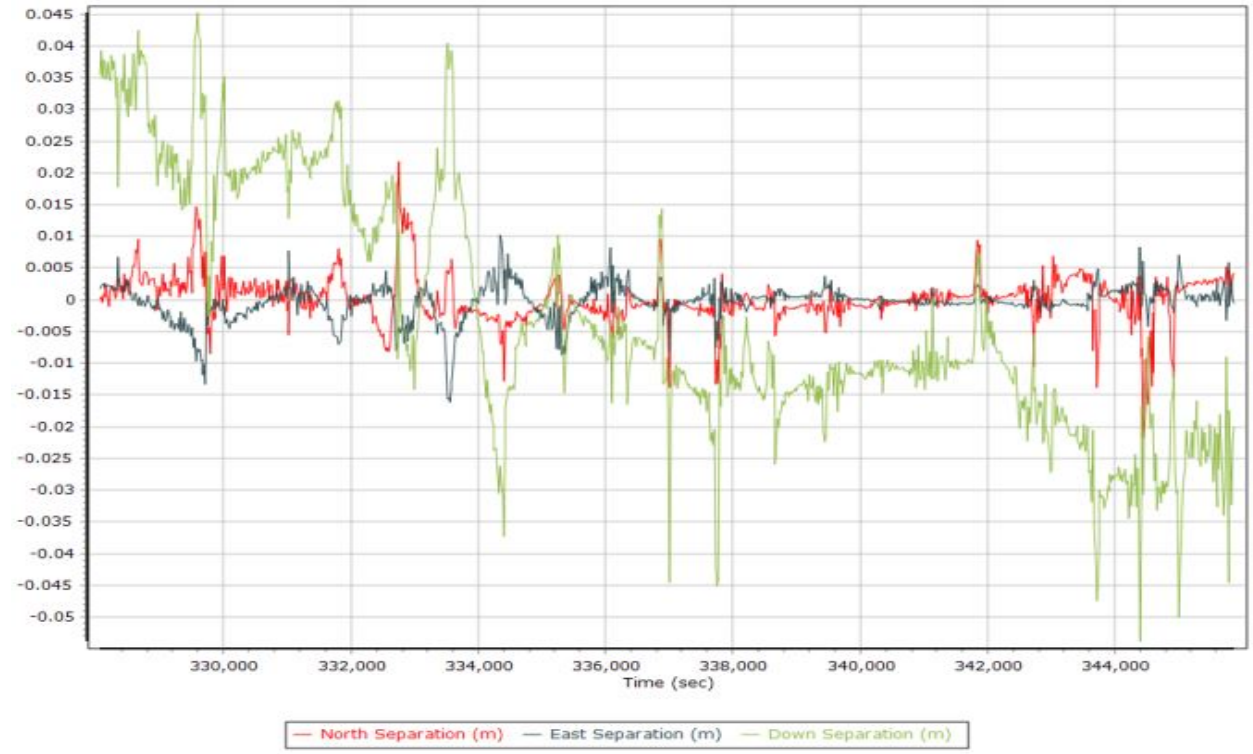
GNSS QC

GNSS QC Statistics

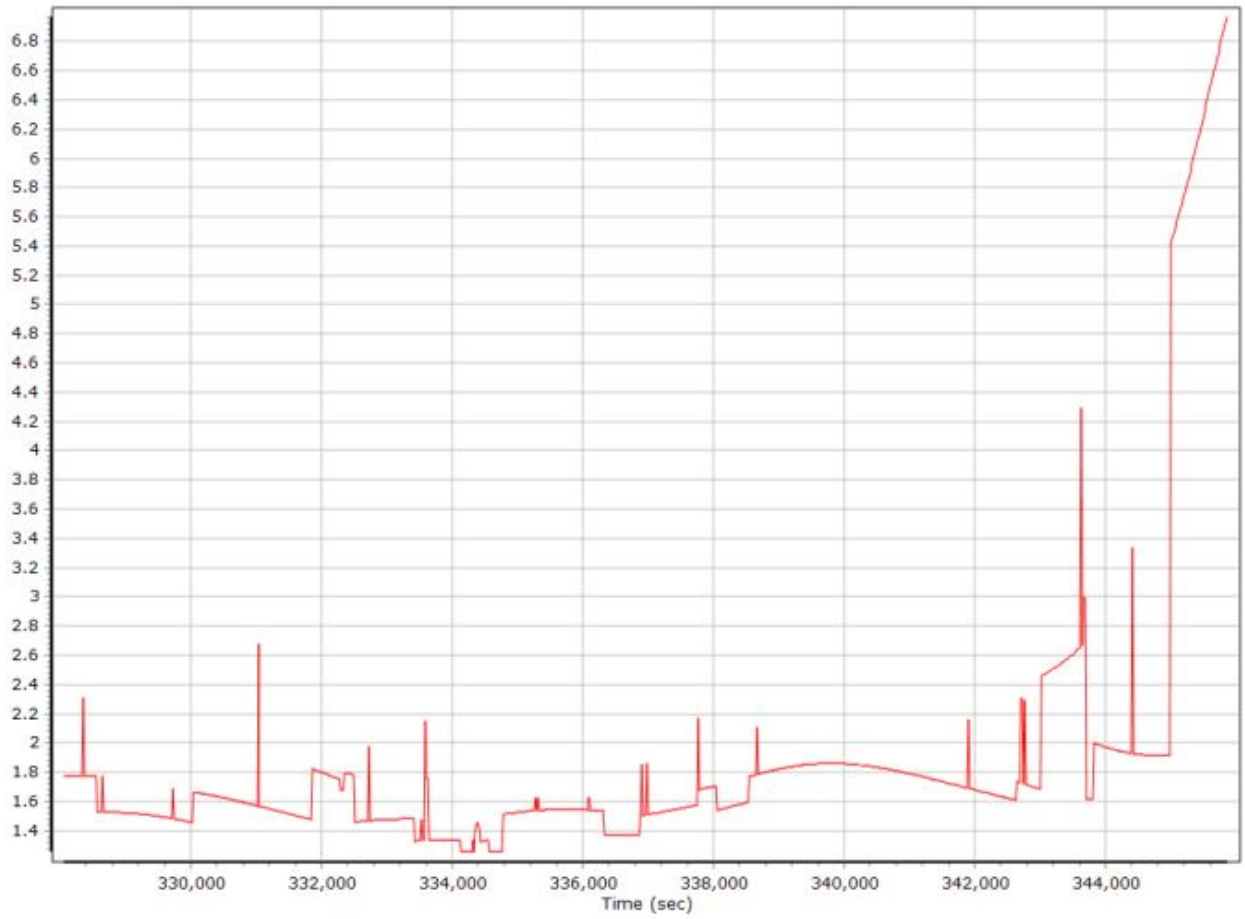
Statistics	Min	Max	Mean
Baseline length (km)	0.38	50.92	
Number of GPS SV	5	12	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	12	9
PDOP	1.26	7.00	1.90
QC Solution Gaps	1.00	20.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	18200.00	0.00	22.00
Percentage	99.88	0.00	0.12

Number of Satellites

Forward/Reverse Separation



PDOP

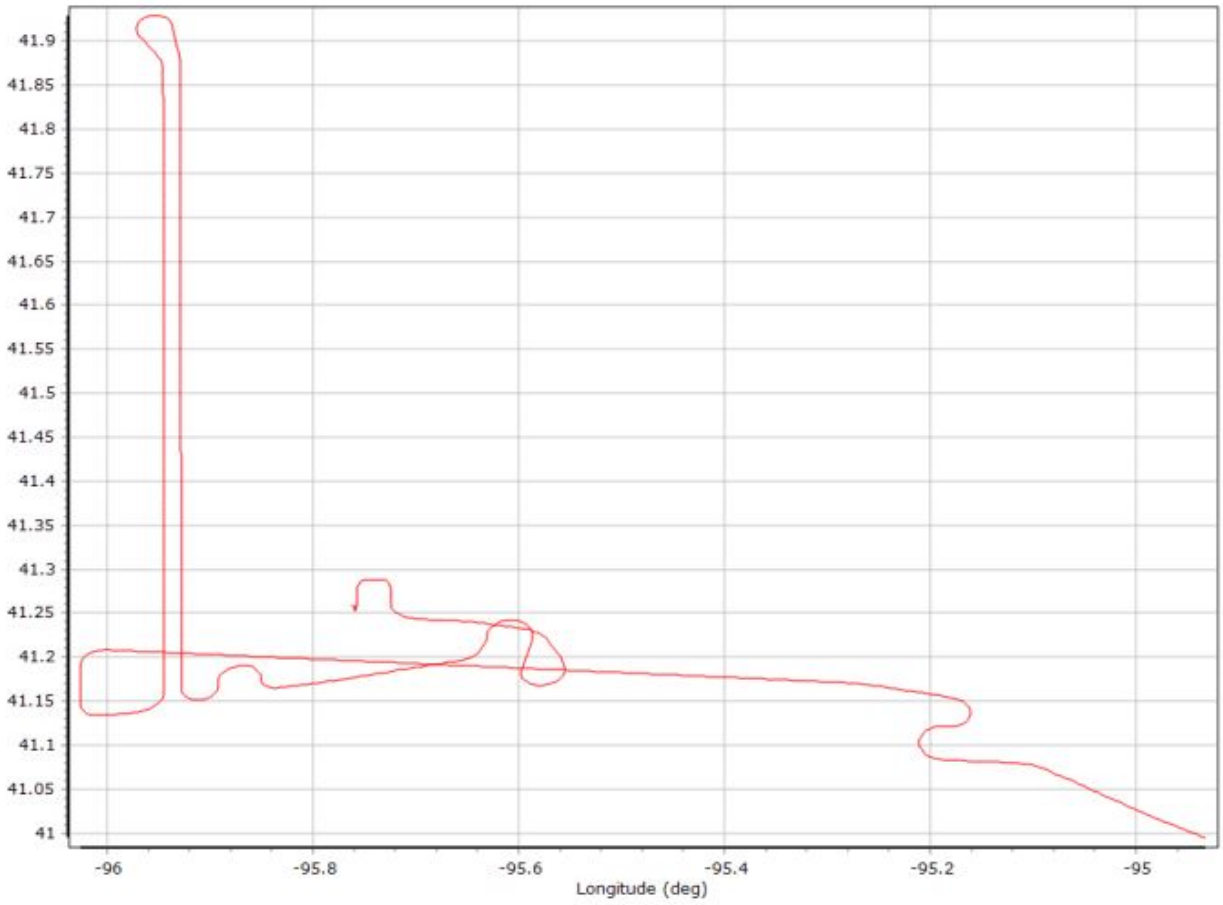

6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
330,000
332,000
334,000
336,000
338,000
340,000
342,000
344,000
Time (sec)

Aerial Services, Inc. QC Reports.

0319a448_QC Report.docx QC Report - 8/25/2021 14:45:25

Smoothed Trajectory Information

Top View



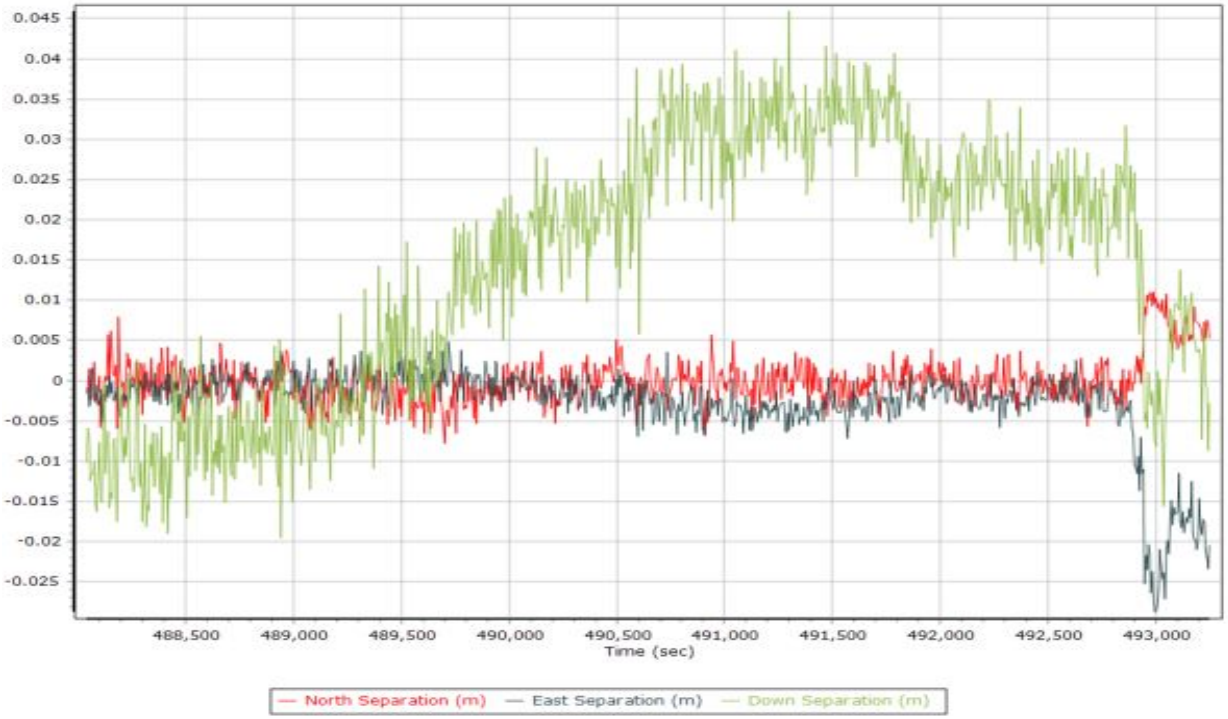
GNSS QC

GNSS QC Statistics

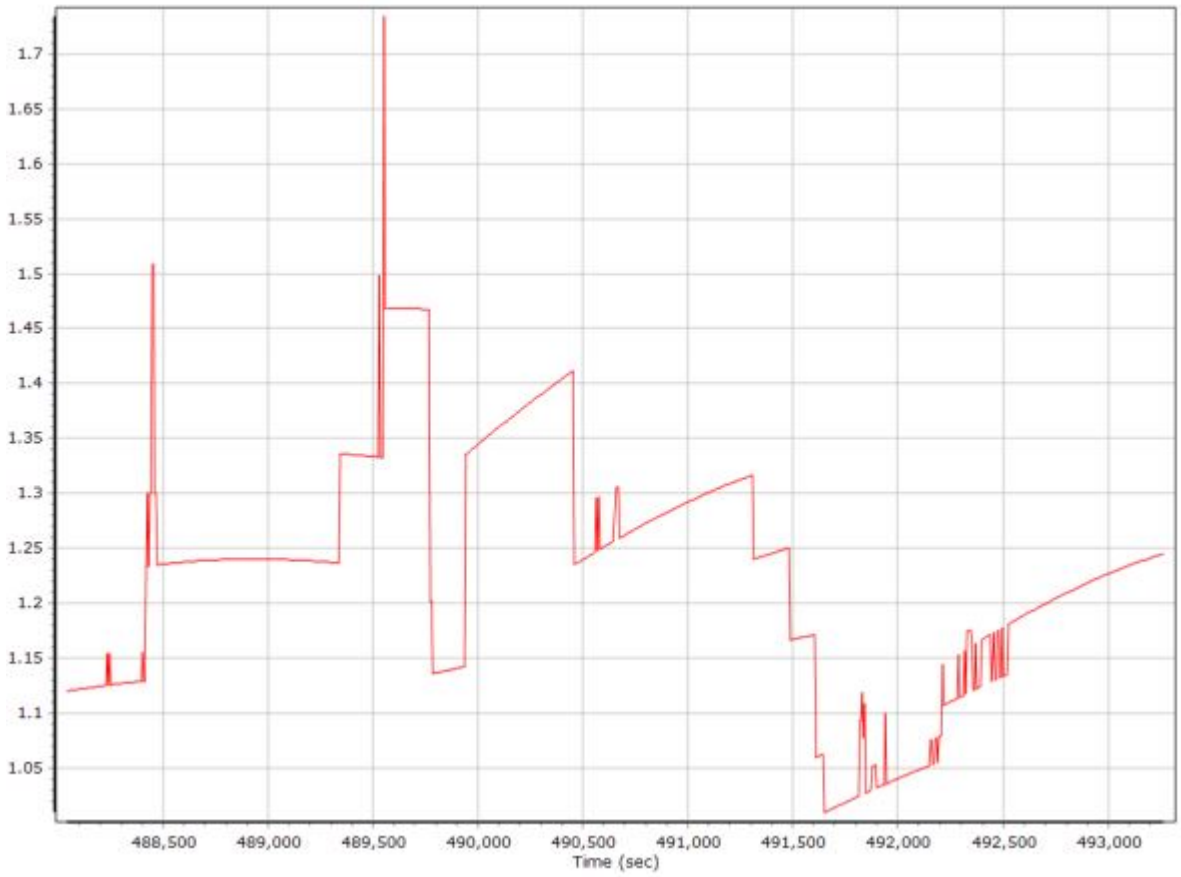
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	9	8
Number of GLONASS SV	4	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	7	6
Total number of SV	16	23	20
PDOP	1.01	1.73	1.20
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11088.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites

Forward/Reverse Separation



PDOP


1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
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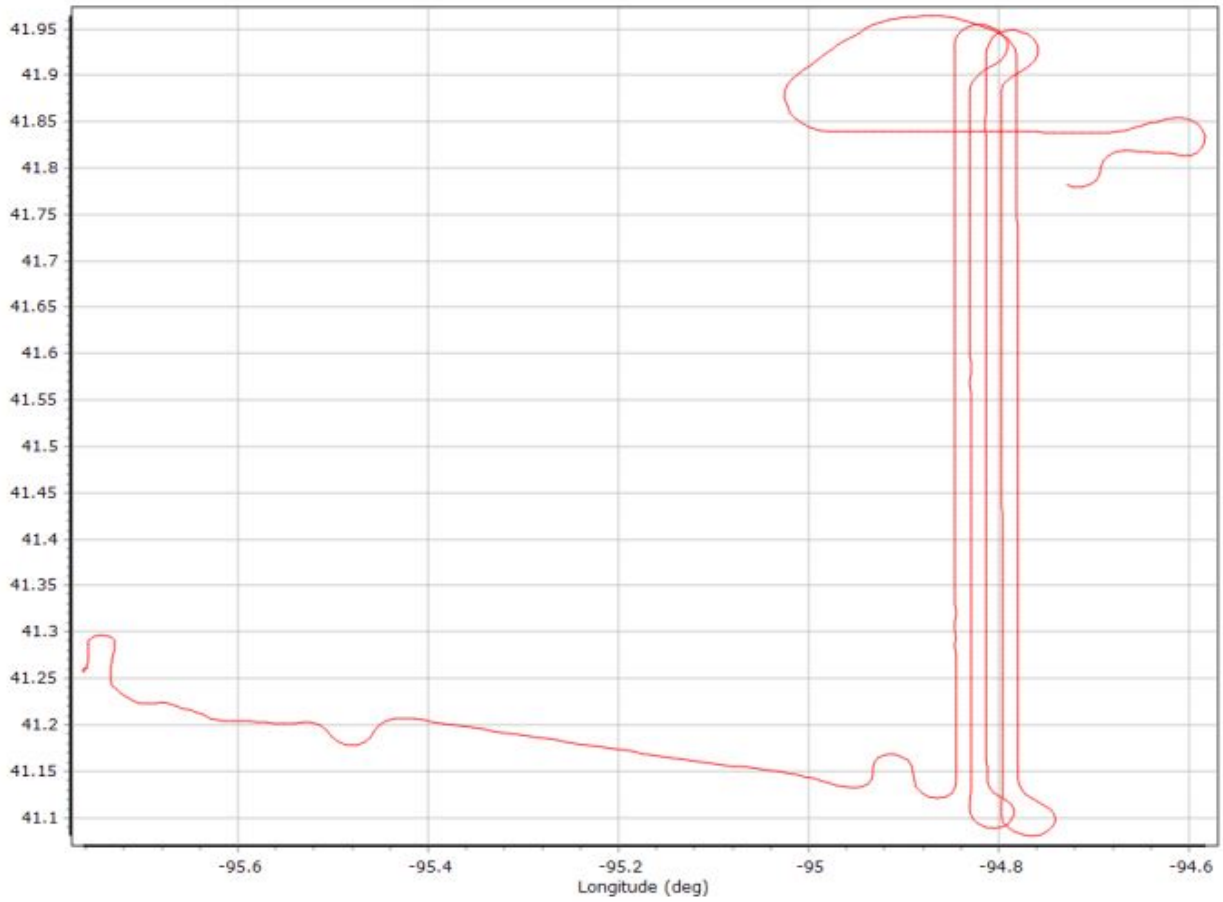
489,000
489,500
490,000
490,500
491,000
491,500
492,000
492,500
493,000
Time (sec)

0319b386_QC Report.docx QC Report – 8/25/2021 09:32:25
Smoothed Trajectory Information

Top View
`

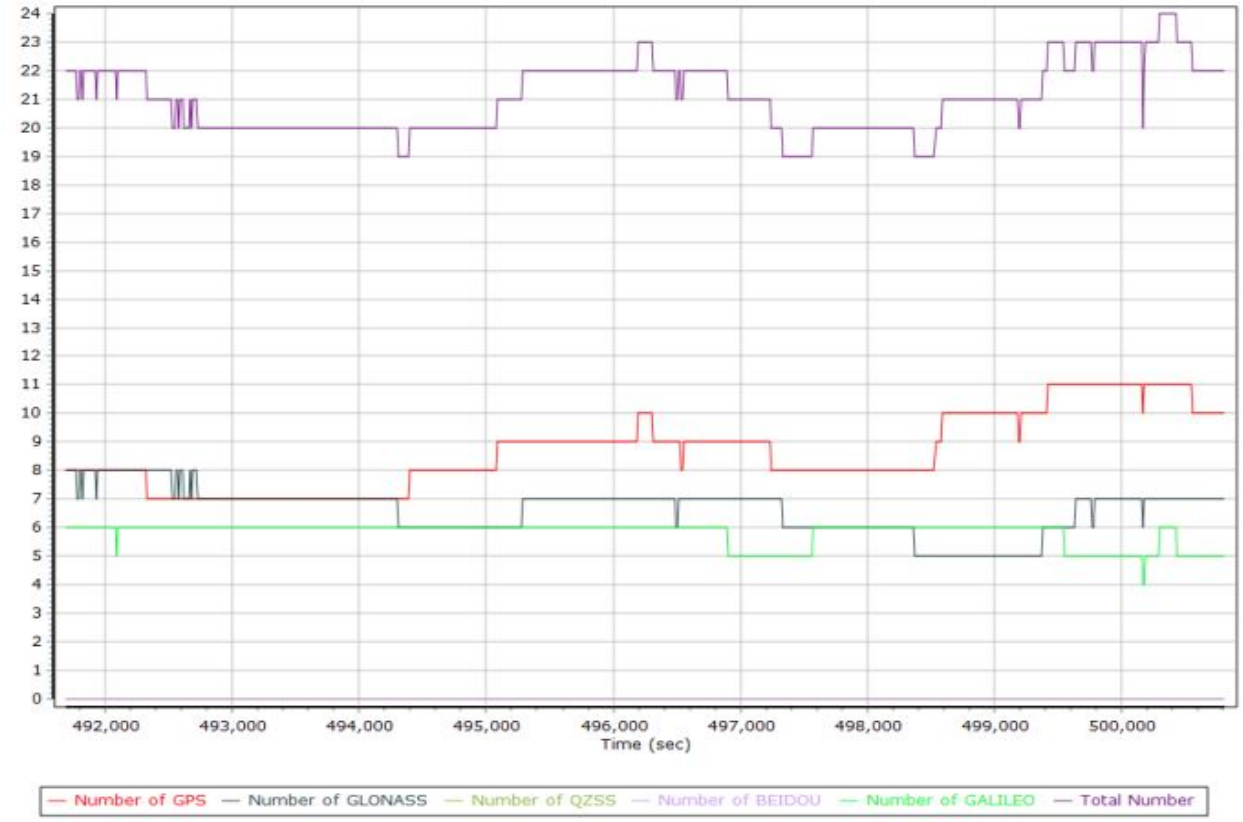


GNSS QC

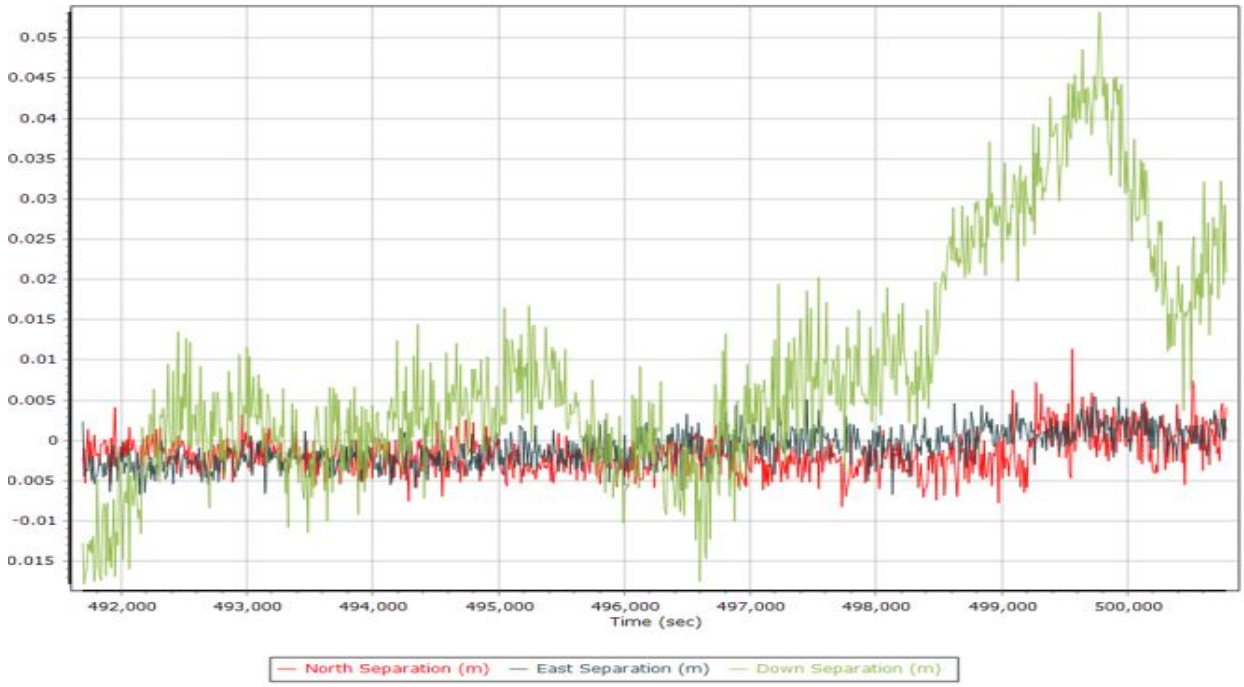
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	11	9
Number of GLONASS SV	5	8	7
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	6	6
Total number of SV	17	24	21
PDOP	0.98	1.52	1.23
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	9552.00	0.00	0.00
Percentage	100.00	0.00	0.00

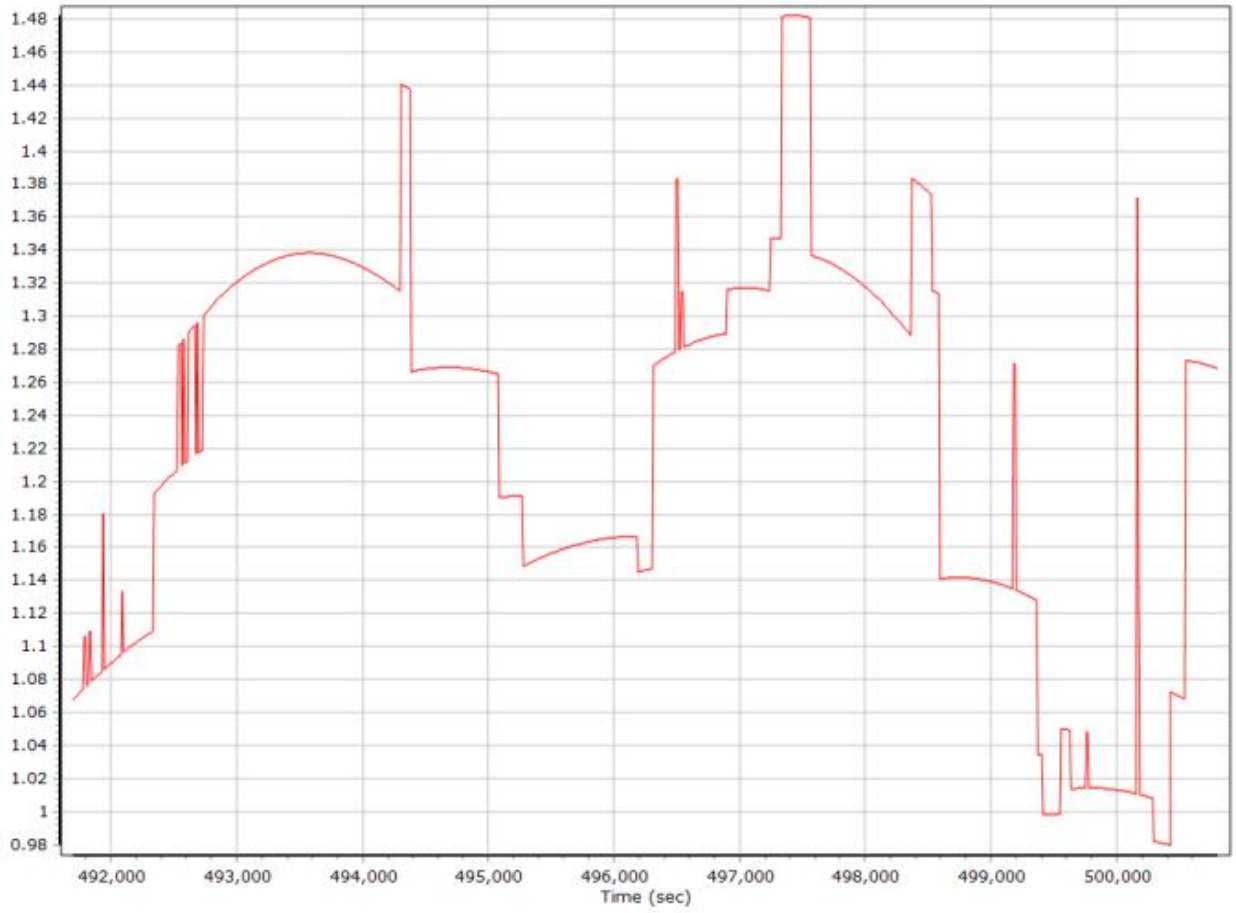
Number of Satellites



Forward/Reverse Separation



PDOP


1.48
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1.44
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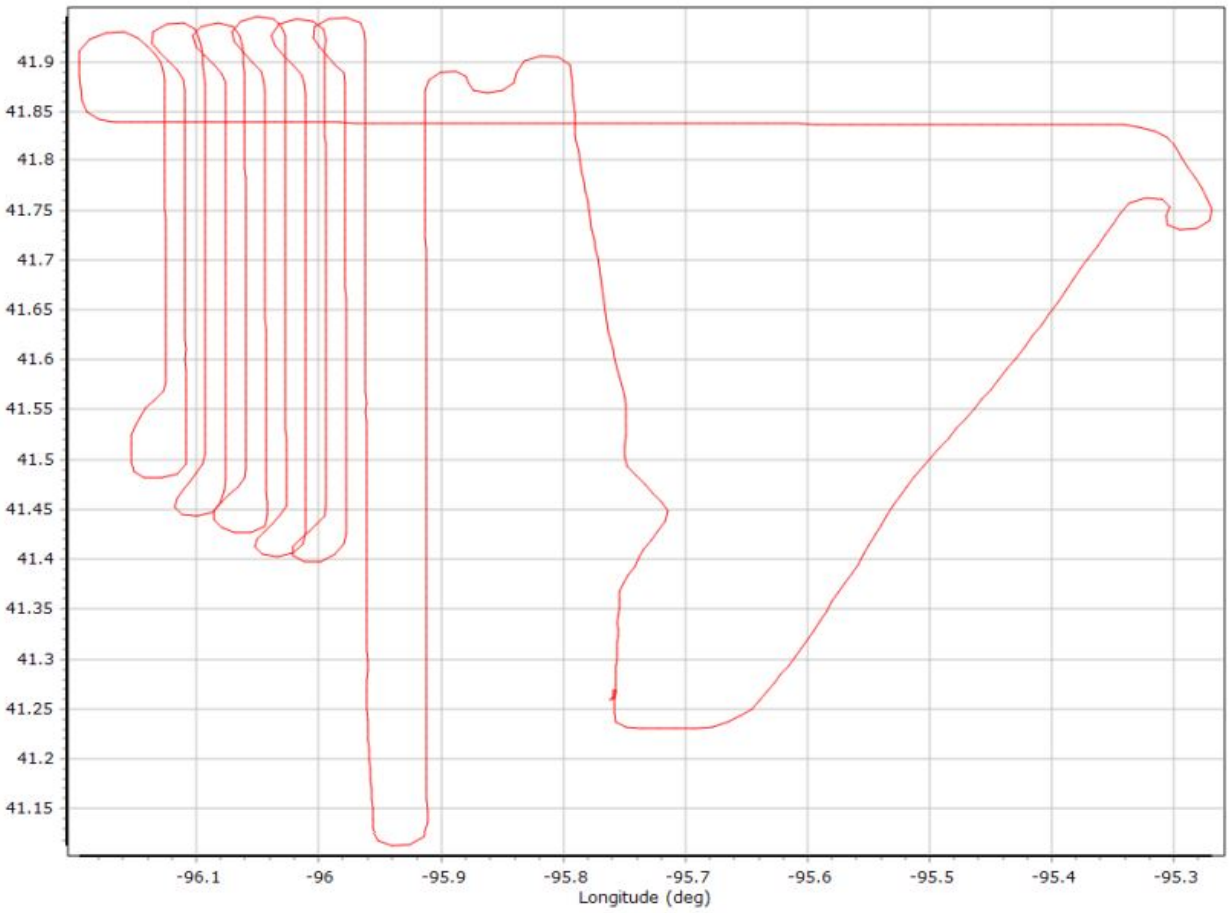
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
1.02
1
0.98
492,000
493,000
494,000
495,000
496,000
497,000
498,000
499,000
500,000
Time (sec)

0319b448_QC Report.docx QC Report – 8/25/2021 09:54:33
Smoothed Trajectory Information

Top View



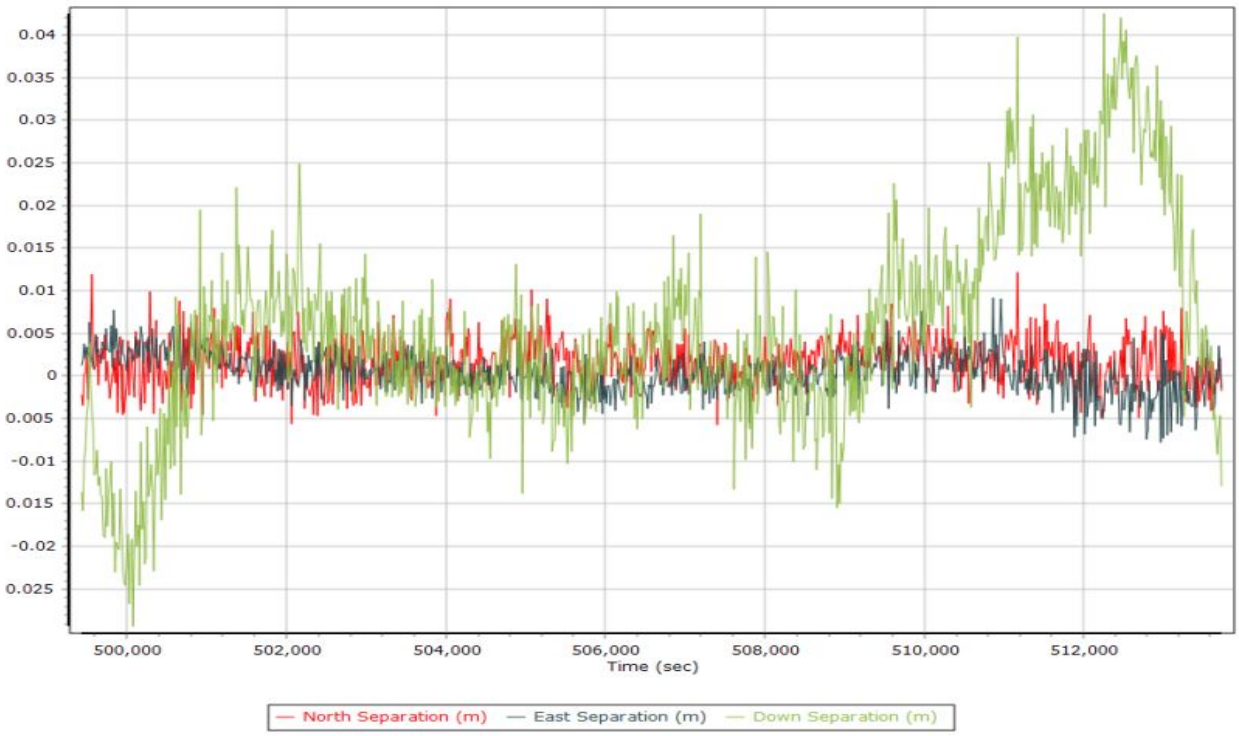
GNSS QC

GNSS QC Statistics

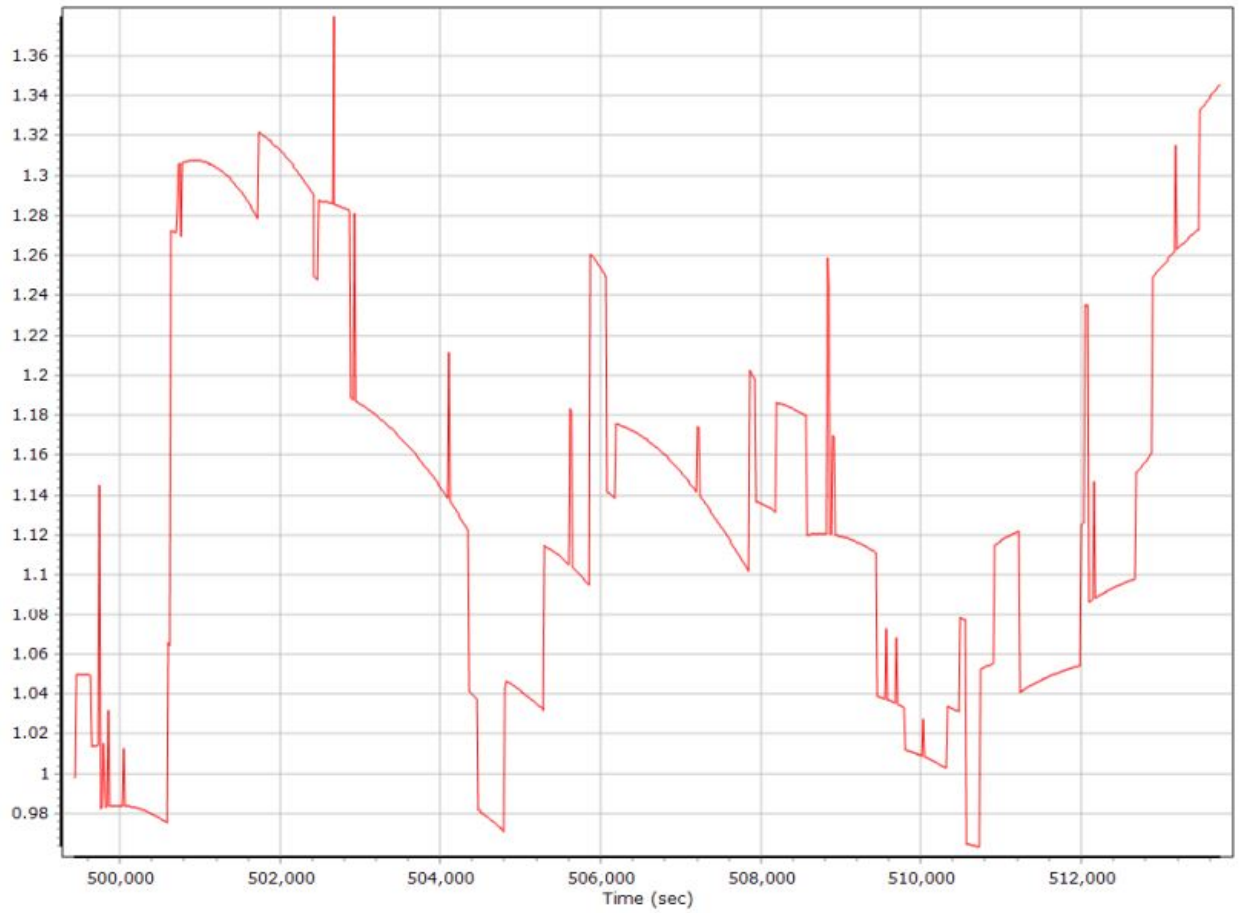
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	8	11	10
Number of GLONASS SV	3	7	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	6	5
Total number of SV	17	24	21
PDOP	0.96	1.41	1.14
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	14786.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites

Forward/Reverse Separation

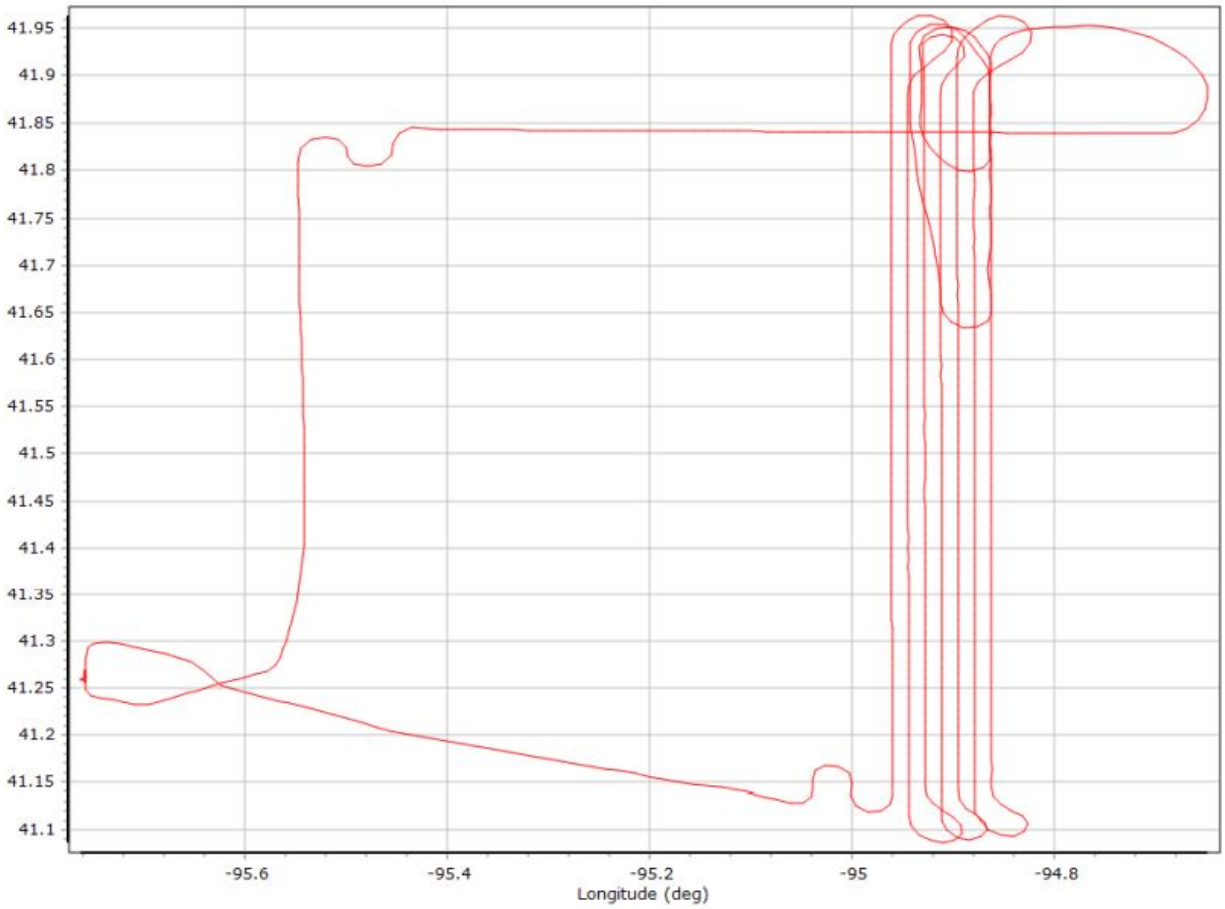


PDOP


1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
1.02
1
0.98
500,000
502,000
504,000
506,000
508,000
510,000
512,000
Time (sec)

0319c386_QC Report.docx QC Report – 8/25/2021 10:03:59
Smoothed Trajectory Information

Top View



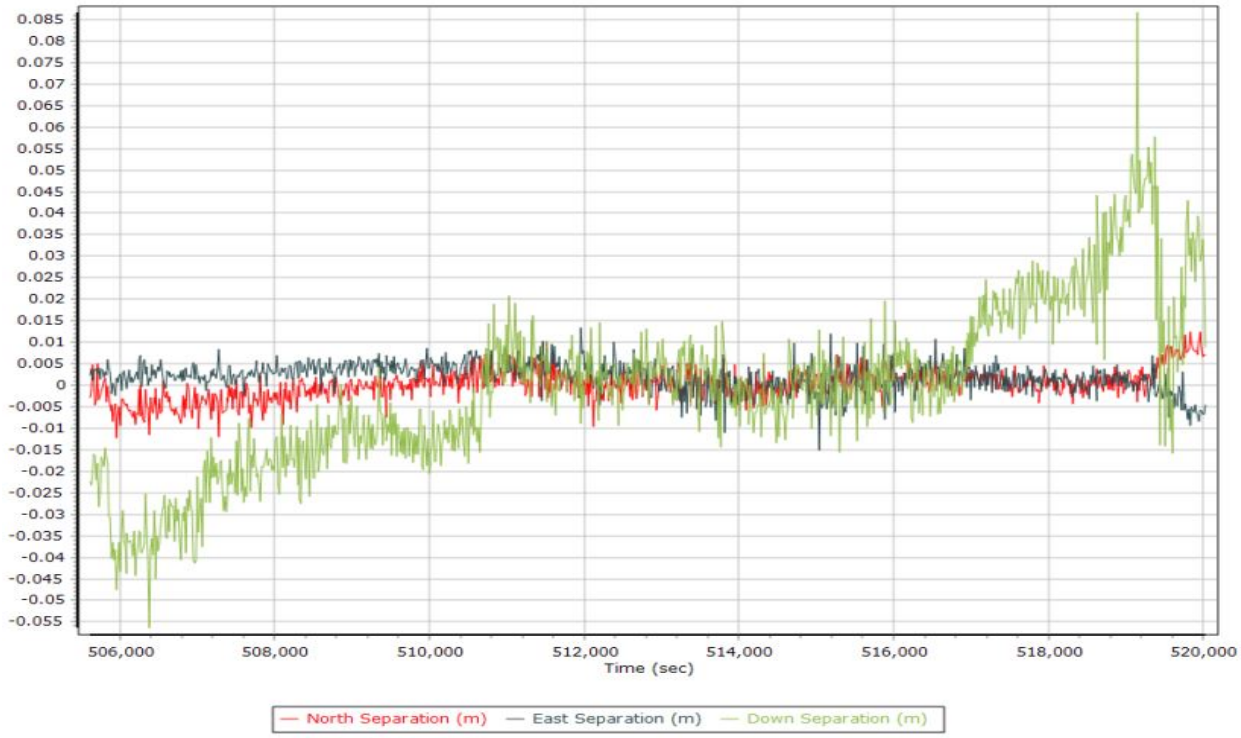
GNSS QC

GNSS QC Statistics

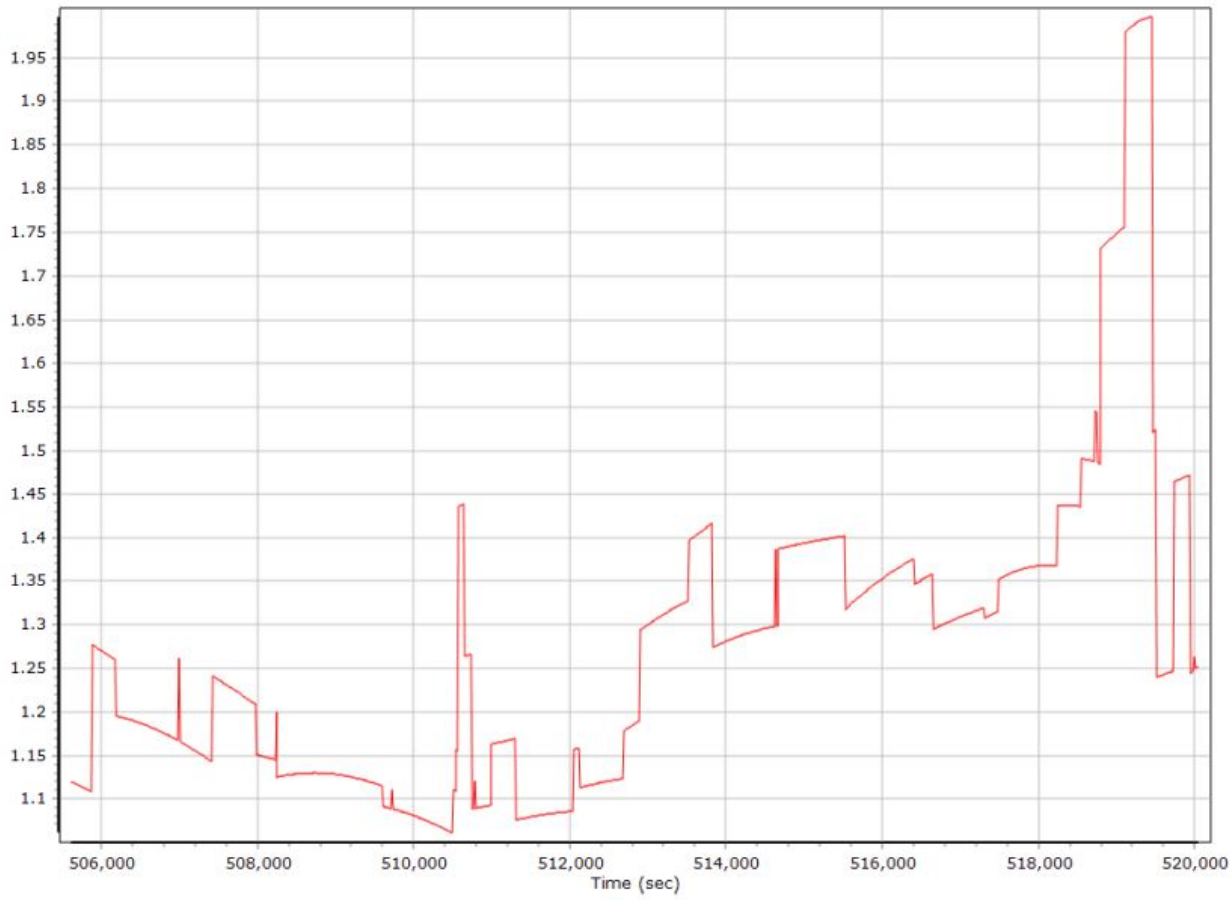
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	11	9
Number of GLONASS SV	0	7	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	0
Number of GALILEO SV	2	5	4
Total number of SV	14	21	18
PDOP	1.04	2.00	1.27
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	14843.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites

Forward/Reverse Separation



PDOP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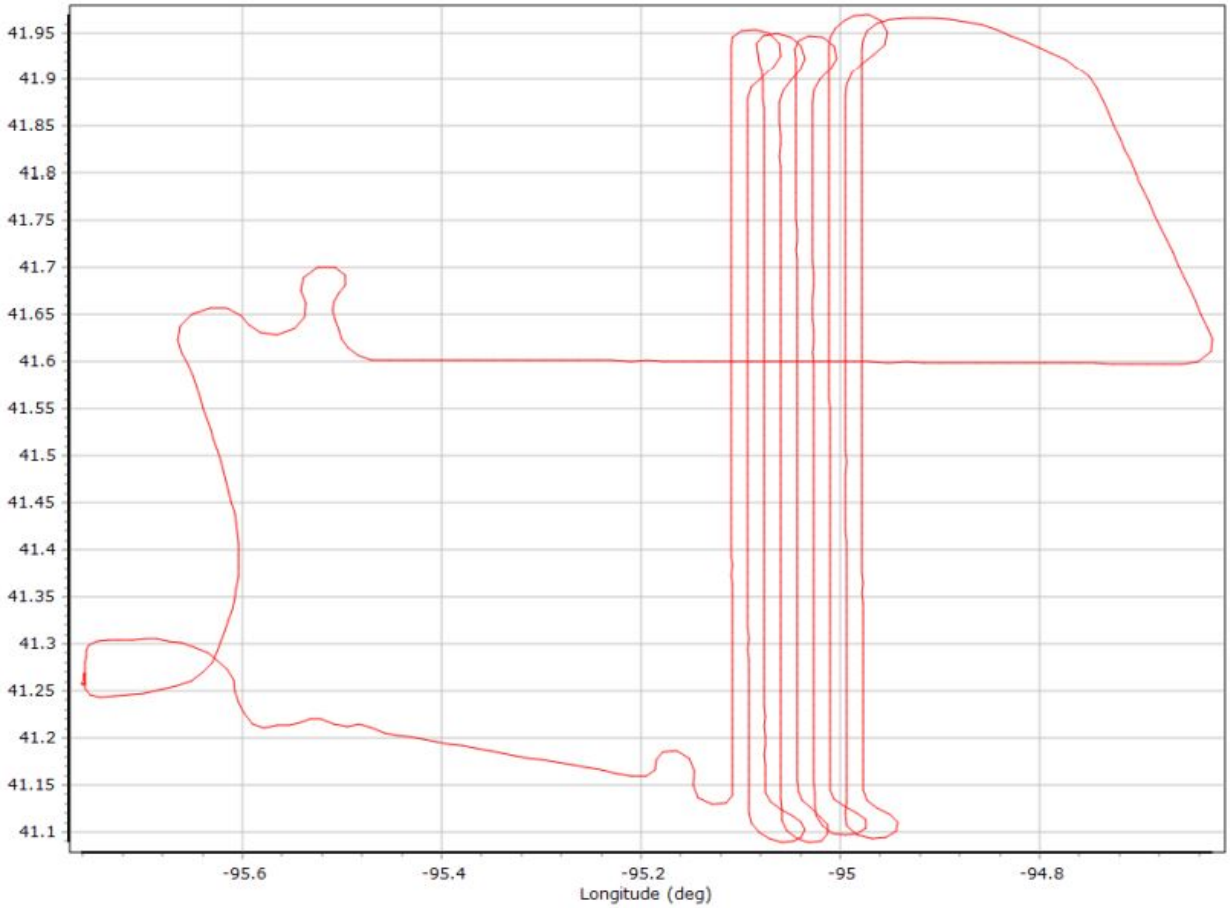
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
506,000
508,000
510,000
512,000
514,000
516,000
518,000
520,000
Time (sec)

0320a386_QC Report.docx QC Report – 8/25/2021 10:11:45

Smoothed Trajectory Information

Top View

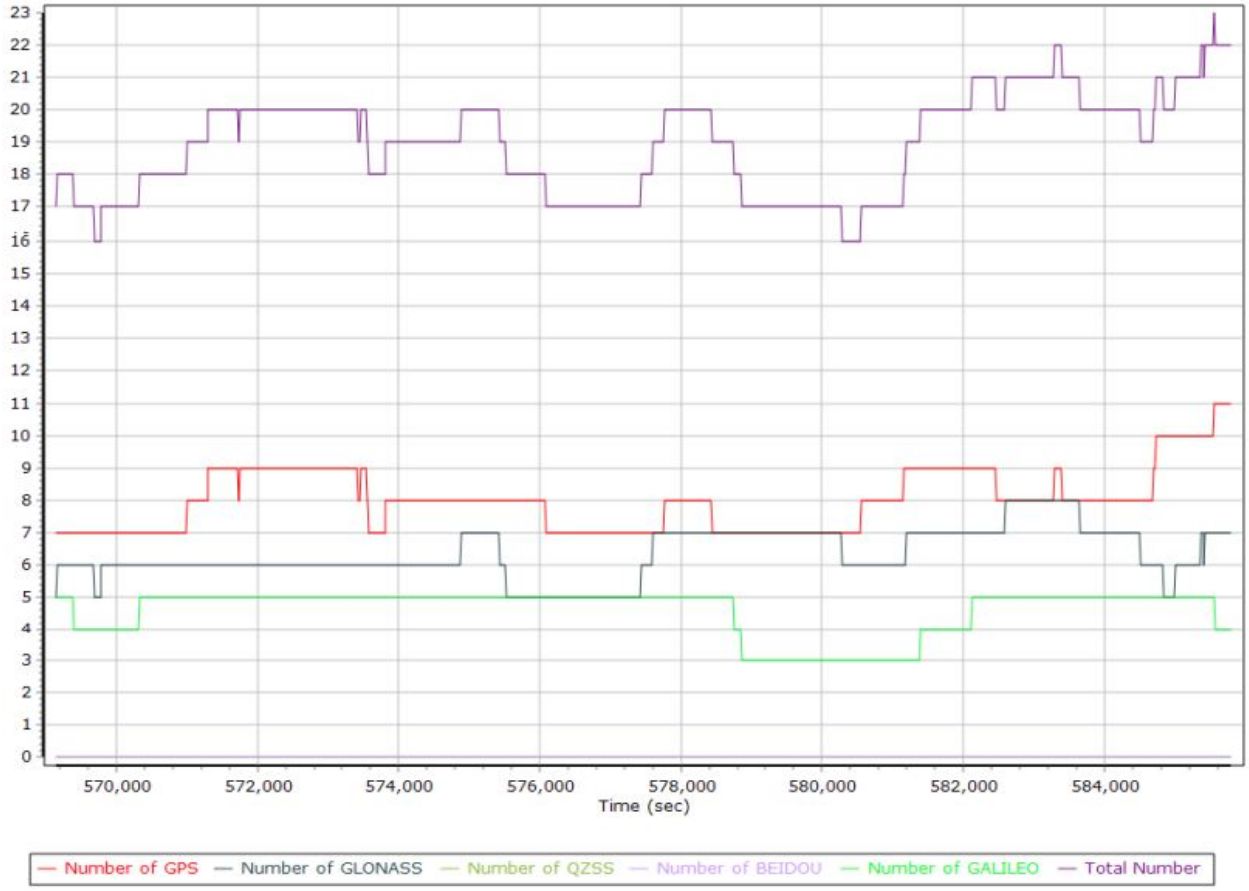


GNSS QC

GNSS QC Statistics

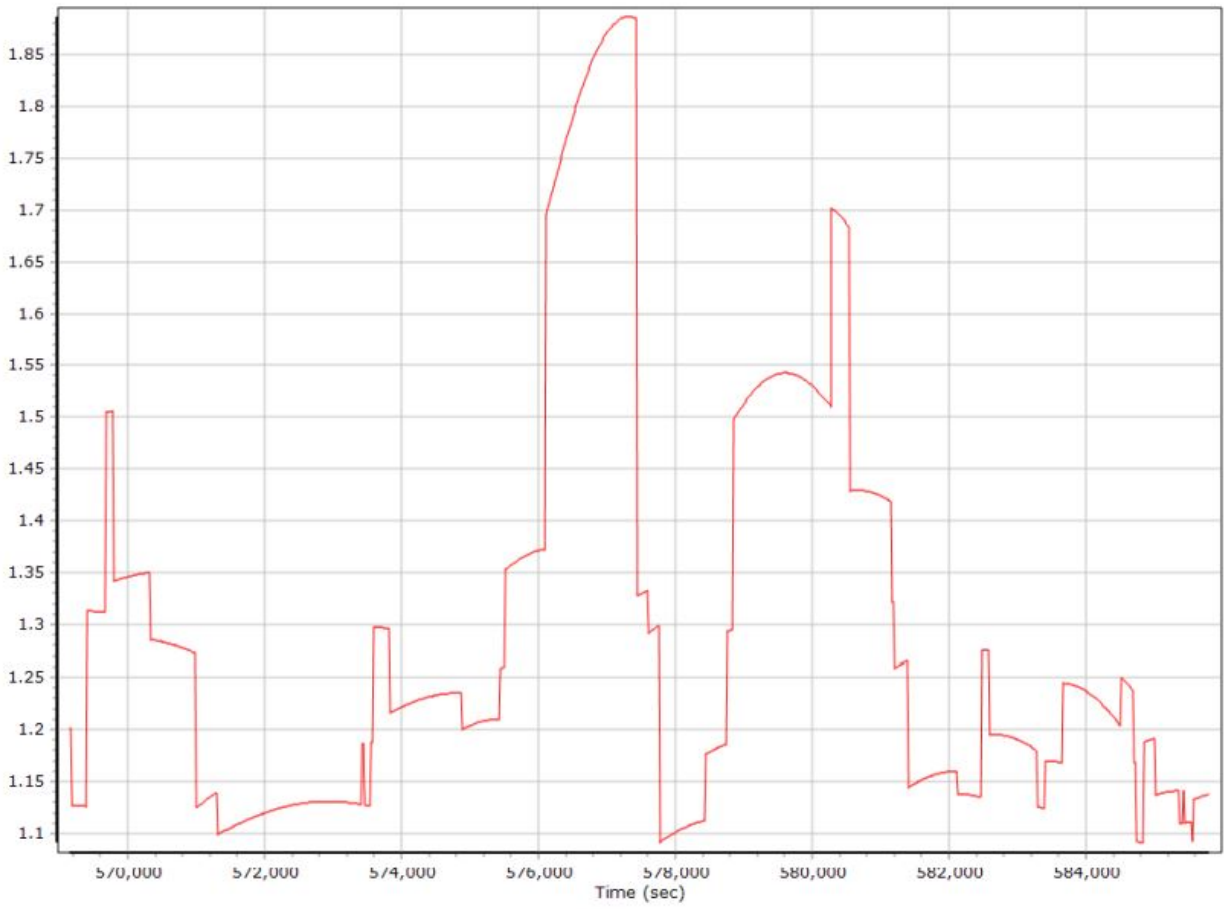
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	11	8
Number of GLONASS SV	0	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	5	5
Total number of SV	11	23	19
PDOP	1.09	1.89	1.30
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	17175.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



Forward/Reverse Separation

PDOP


1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
570,000
572,000
574,000
576,000
578,000
580,000
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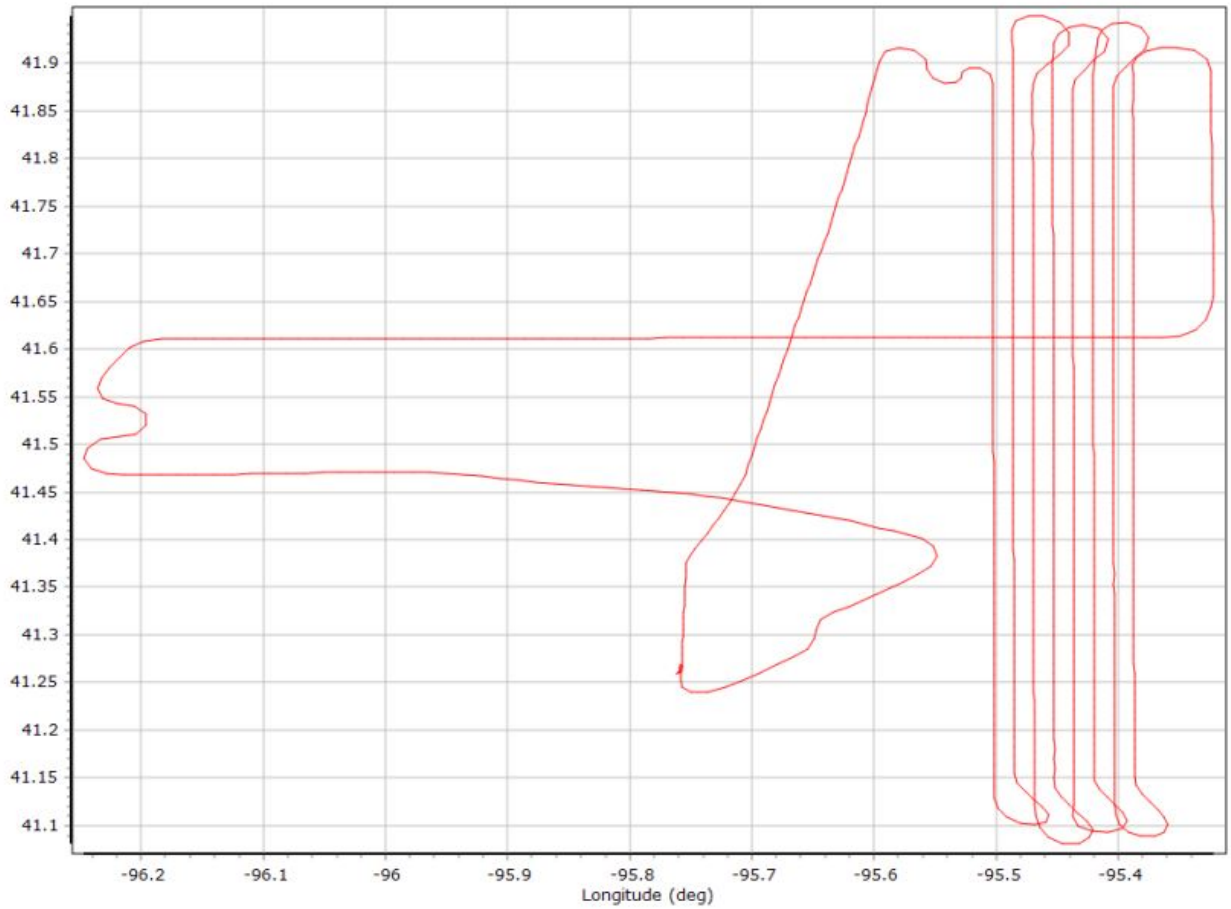
584,000
Time (sec)

0320a448_QC Report.docx QC Report – 8/25/2021 11:13:25
Smoothed Trajectory Information

Top View

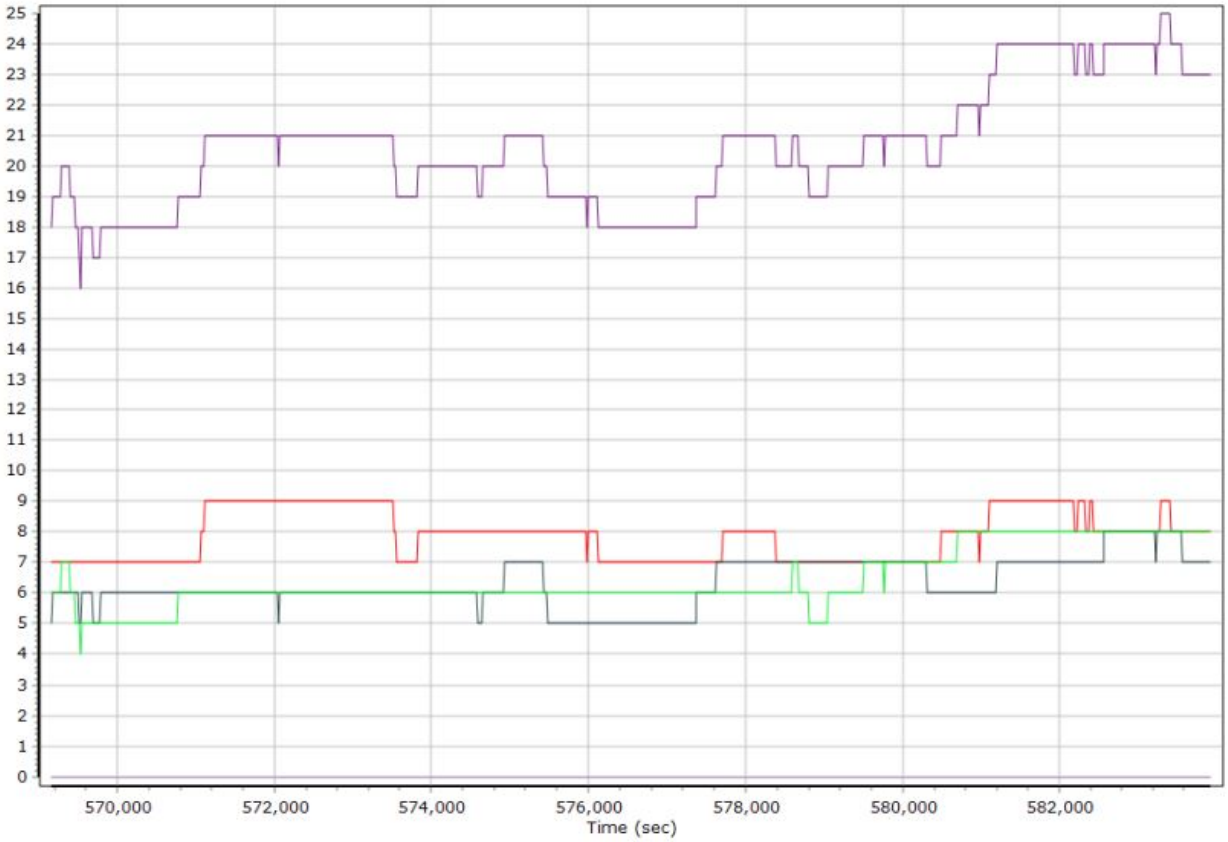


GNSS QC

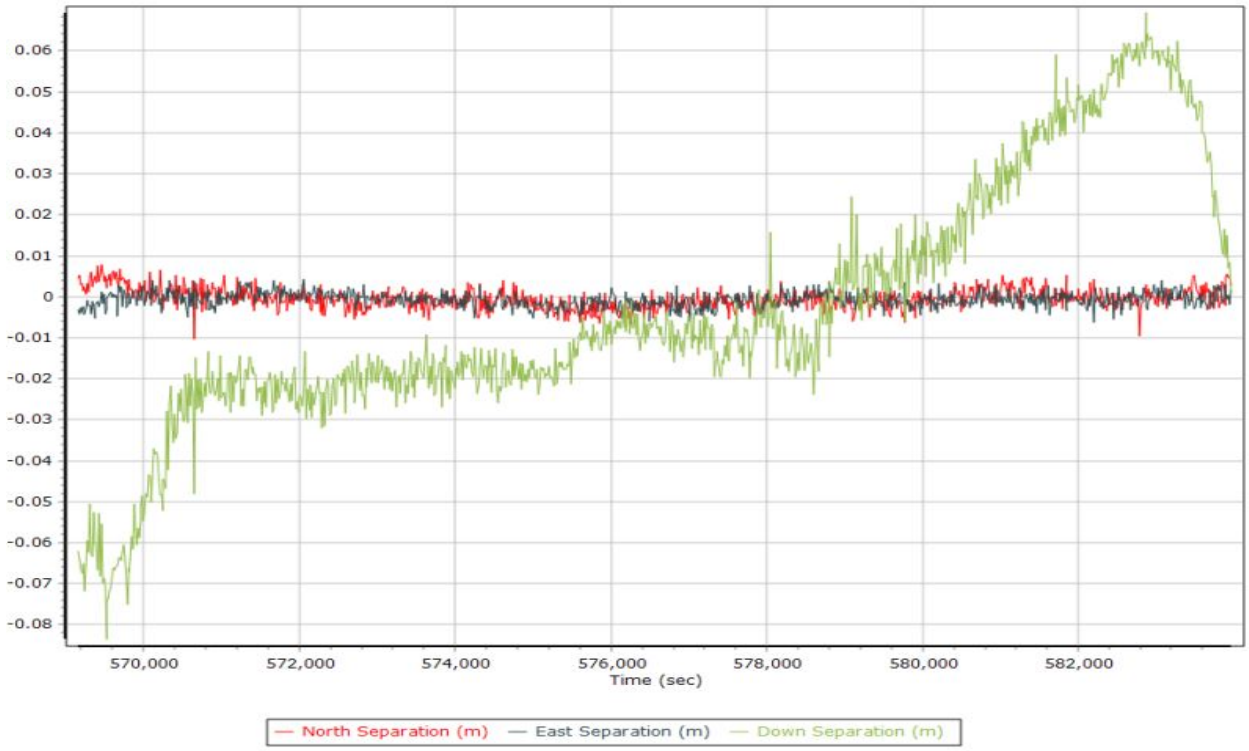
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	9	8
Number of GLONASS SV	4	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	8	6
Total number of SV	15	25	21
PDOP	1.03	1.77	1.20
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15298.00	0.00	0.00
Percentage	100.00	0.00	0.00

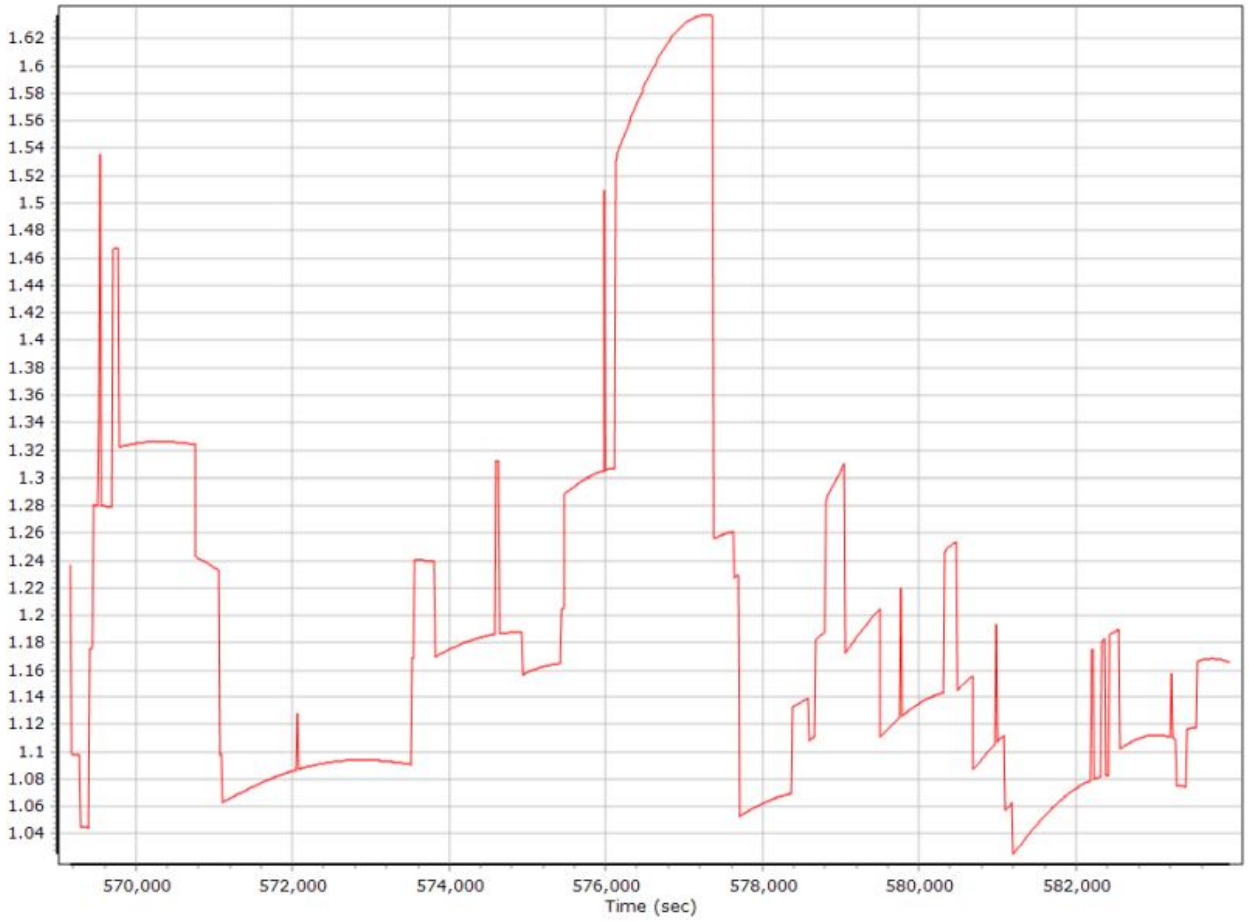
Number of Satellites



Forward/Reverse Separation



PDOP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1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
570,000
572,000
574,000
576,000
578,000
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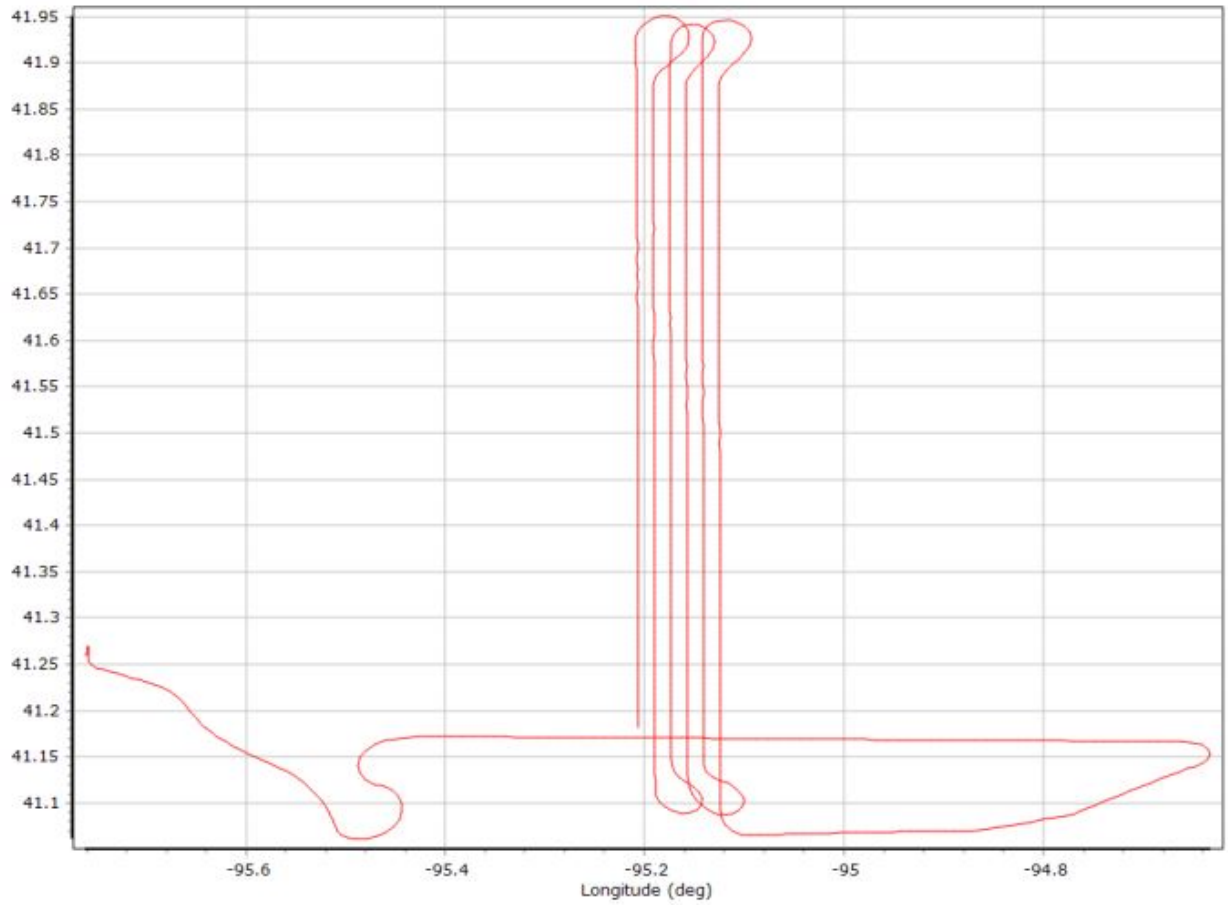
582,000
Time (sec)

0320b386_QC Report.docx QC Report – 8/25/2021 12:50:46

Smoothed Trajectory Information

Top View

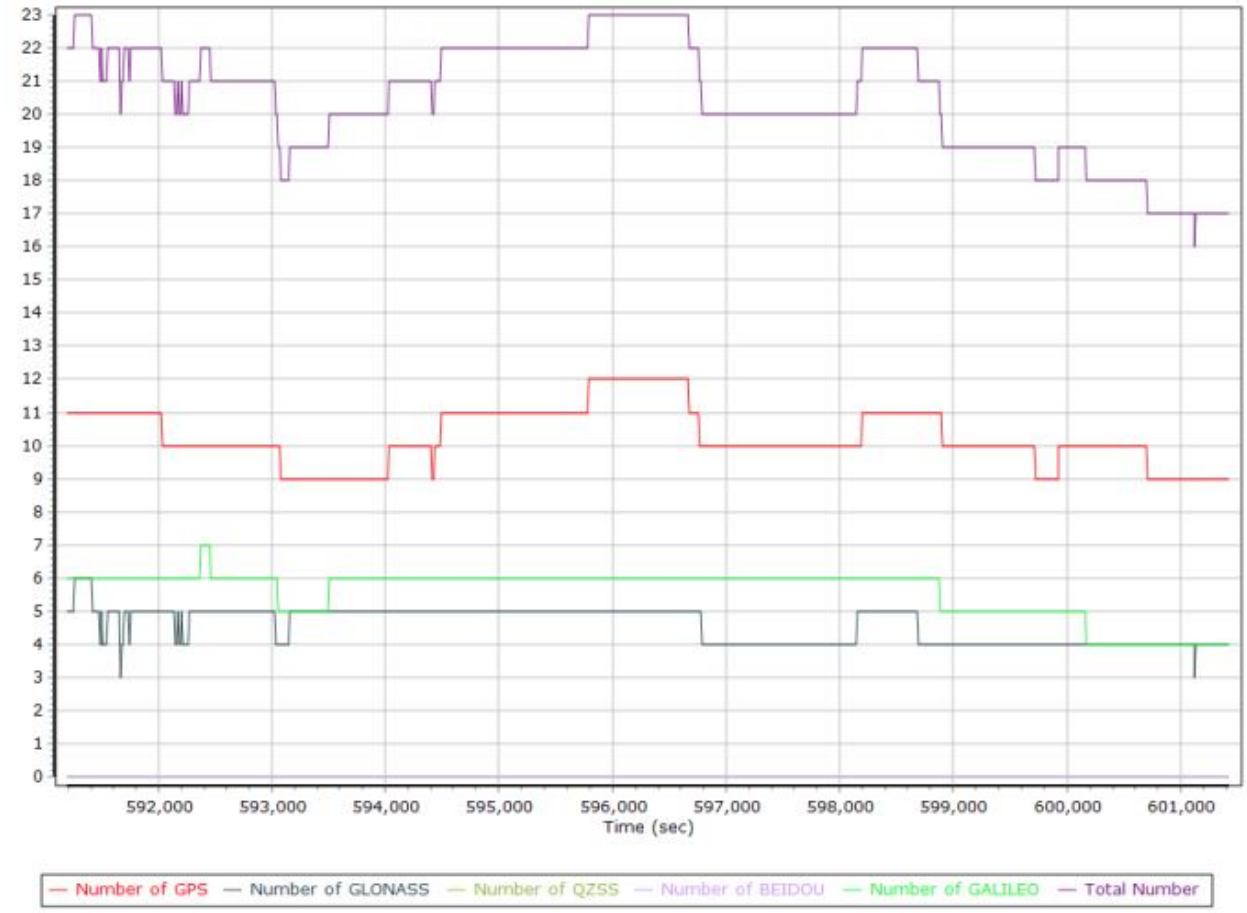


GNSS QC

GNSS QC Statistics

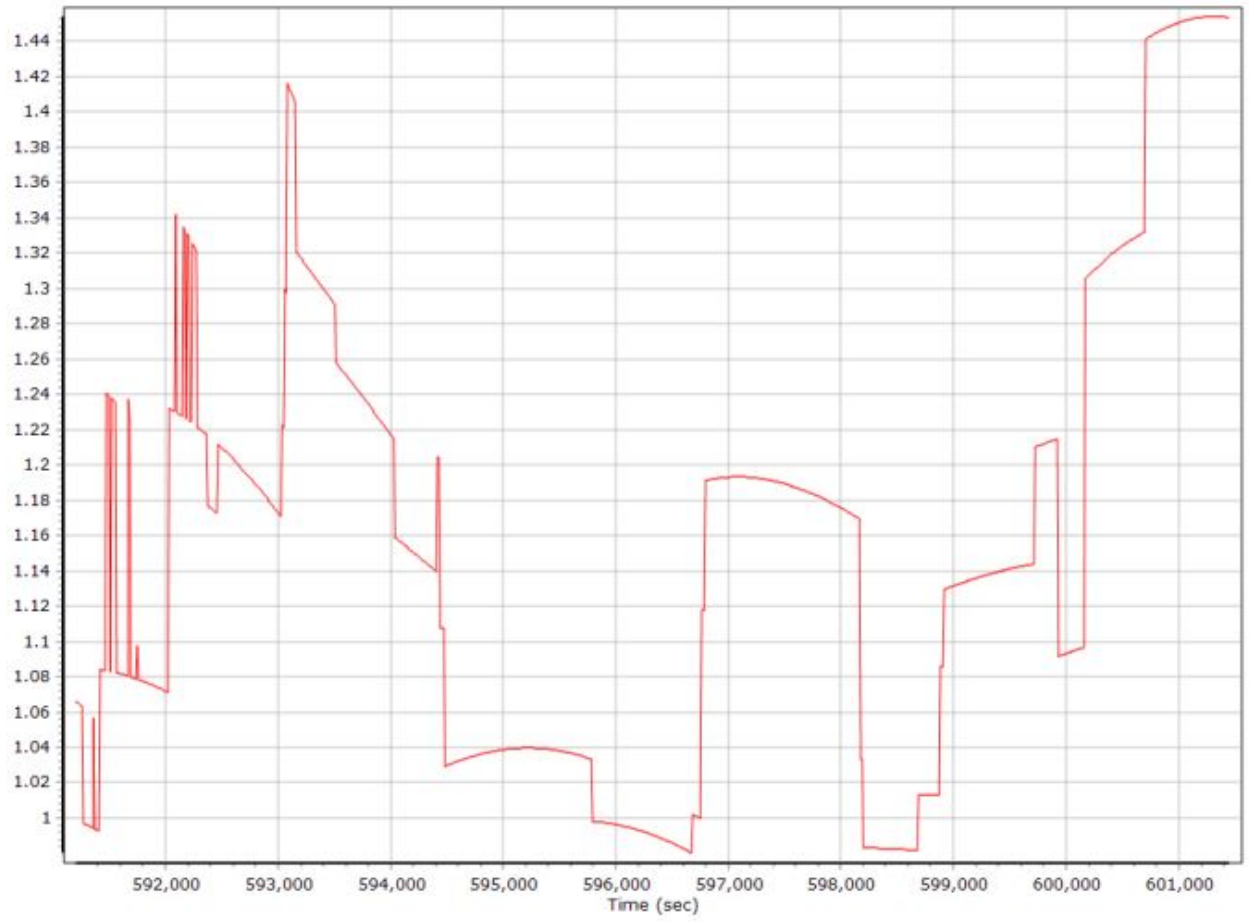
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	9	12	10
Number of GLONASS SV	0	6	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	7	6
Total number of SV	16	23	20
PDOP	0.98	1.55	1.15
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	10633.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



Forward/Reverse Separation

PDOP


1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
1.02
1
592,000
593,000
594,000
595,000
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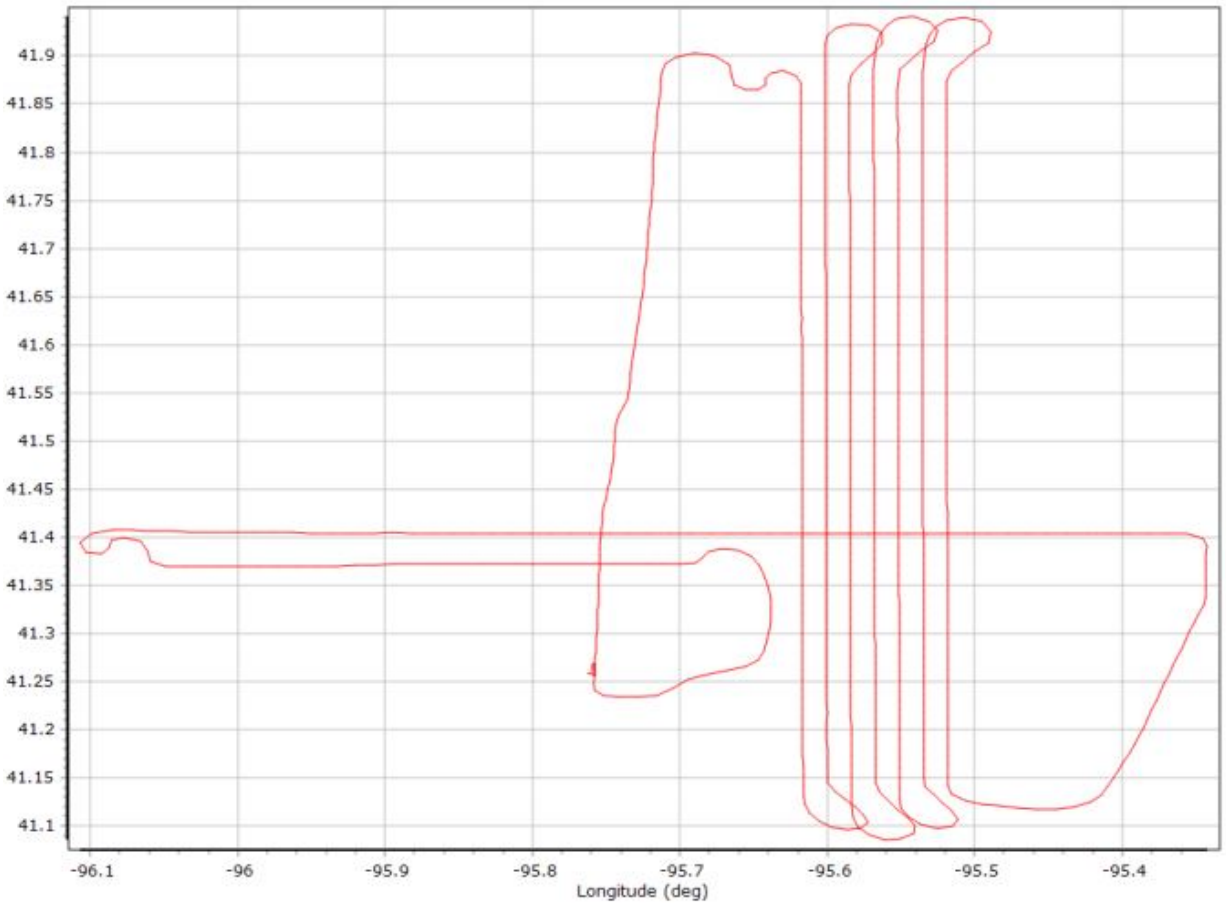
597,000
598,000
599,000
600,000
601,000
Time (sec)

0320b448_QC Report.docx QC Report – 8/25/2021 13:04:32

Smoothed Trajectory Information

Top View



GNSS QC

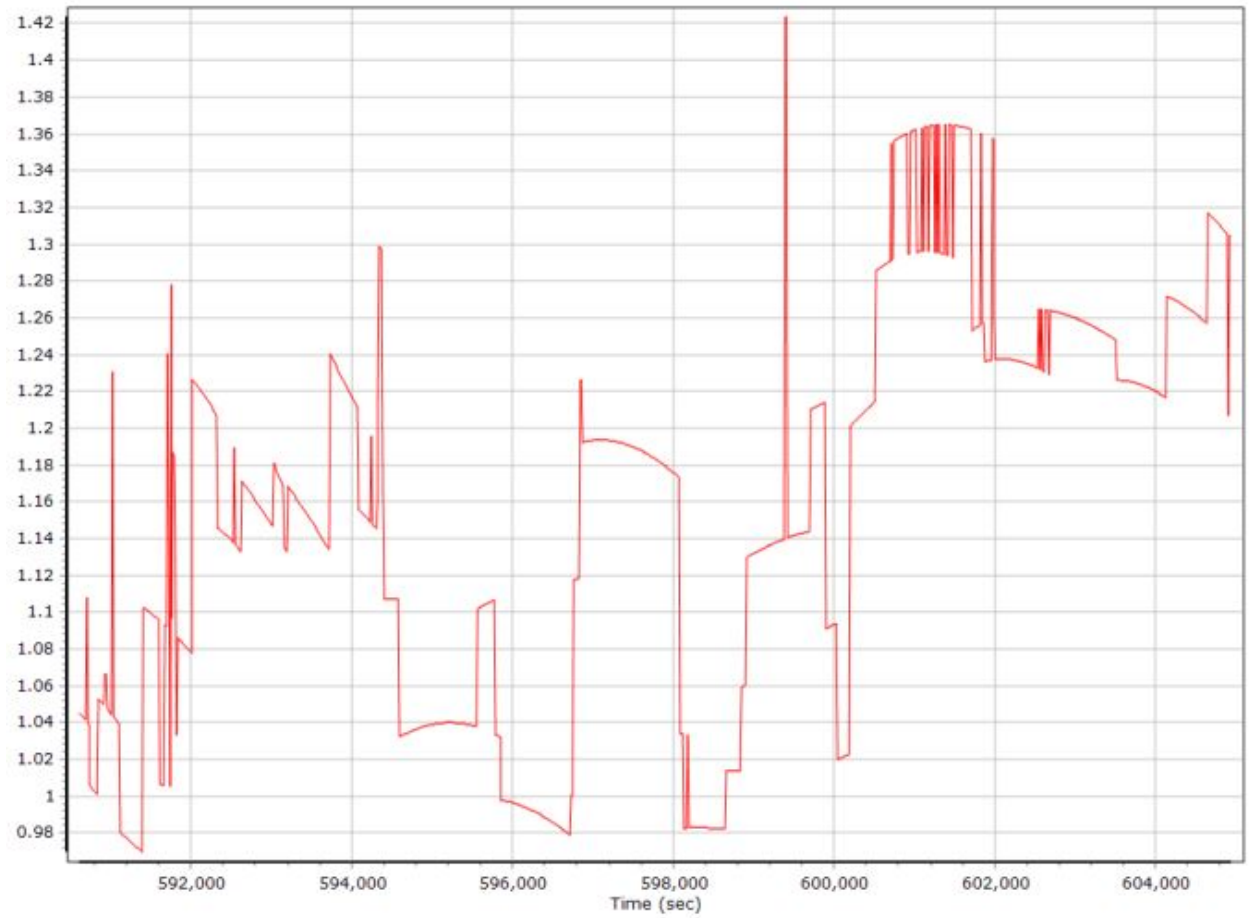
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	12	10
Number of GLONASS SV	2	8	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	5	8	6
Total number of SV	16	24	20
PDOP	0.96	1.51	1.15
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	14729.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites

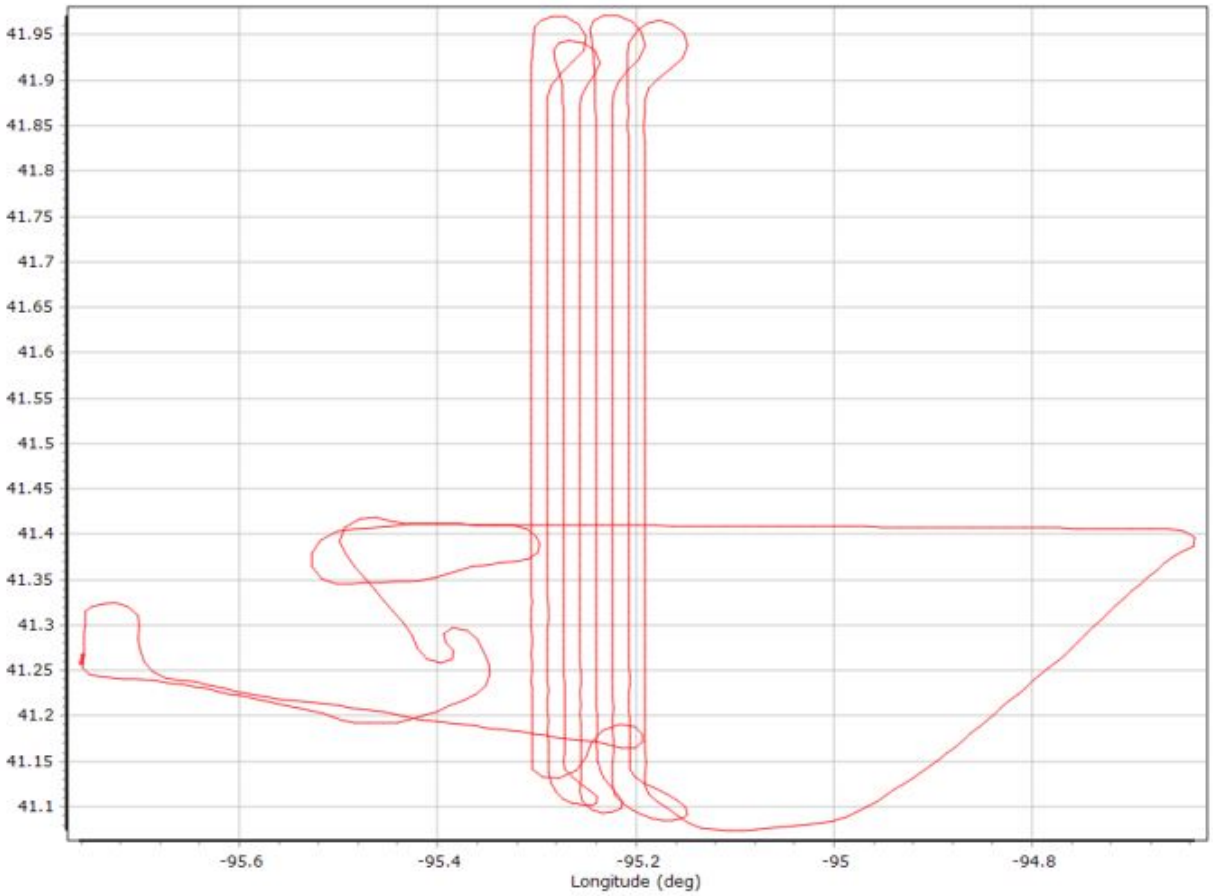
Forward/Reverse Separation

PDOP


1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
1.02
1
0.98
592,000
594,000
596,000
598,000
600,000
602,000
604,000
Time (sec)

0321a386_QC Report.docx QC Report – 8/25/2021 13:13:01
Smoothed Trajectory Information

Top View

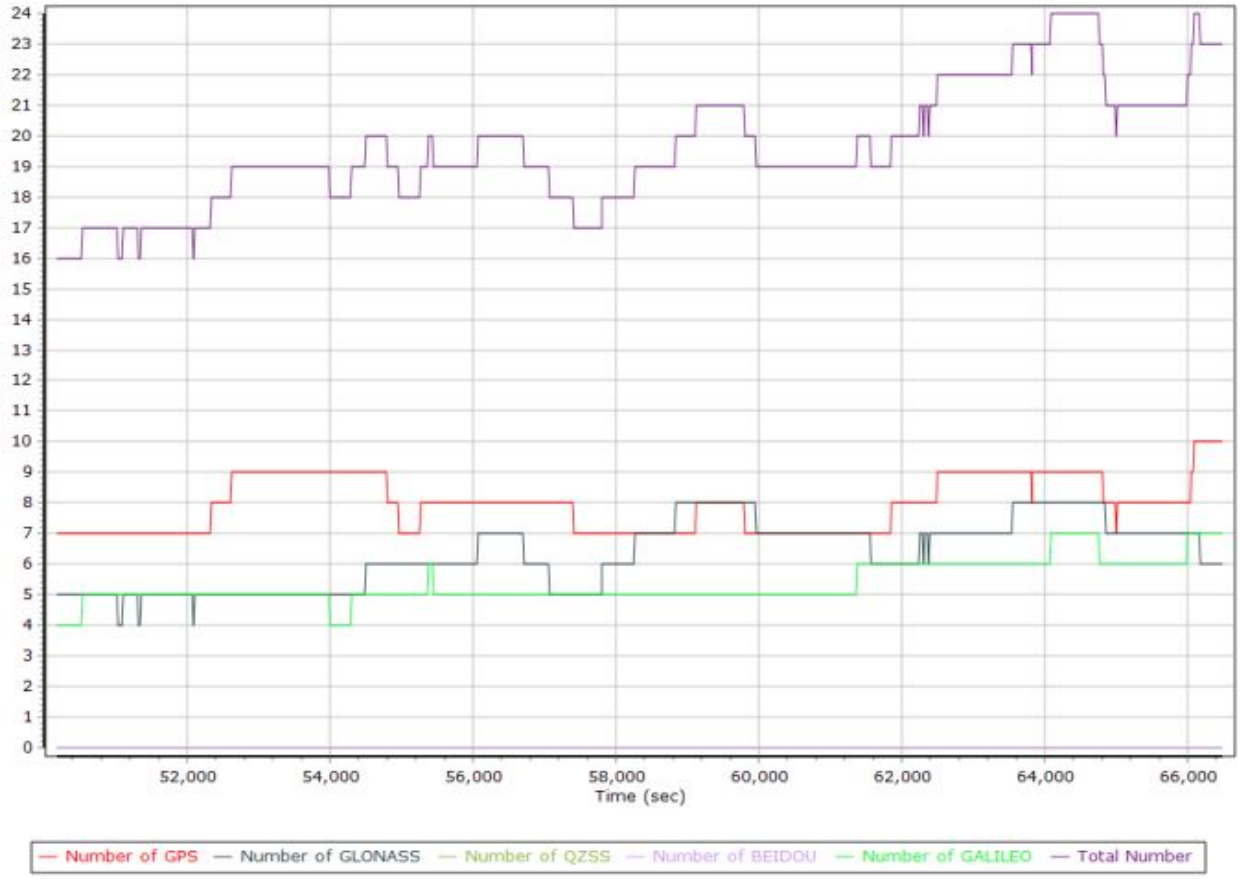


GNSS QC

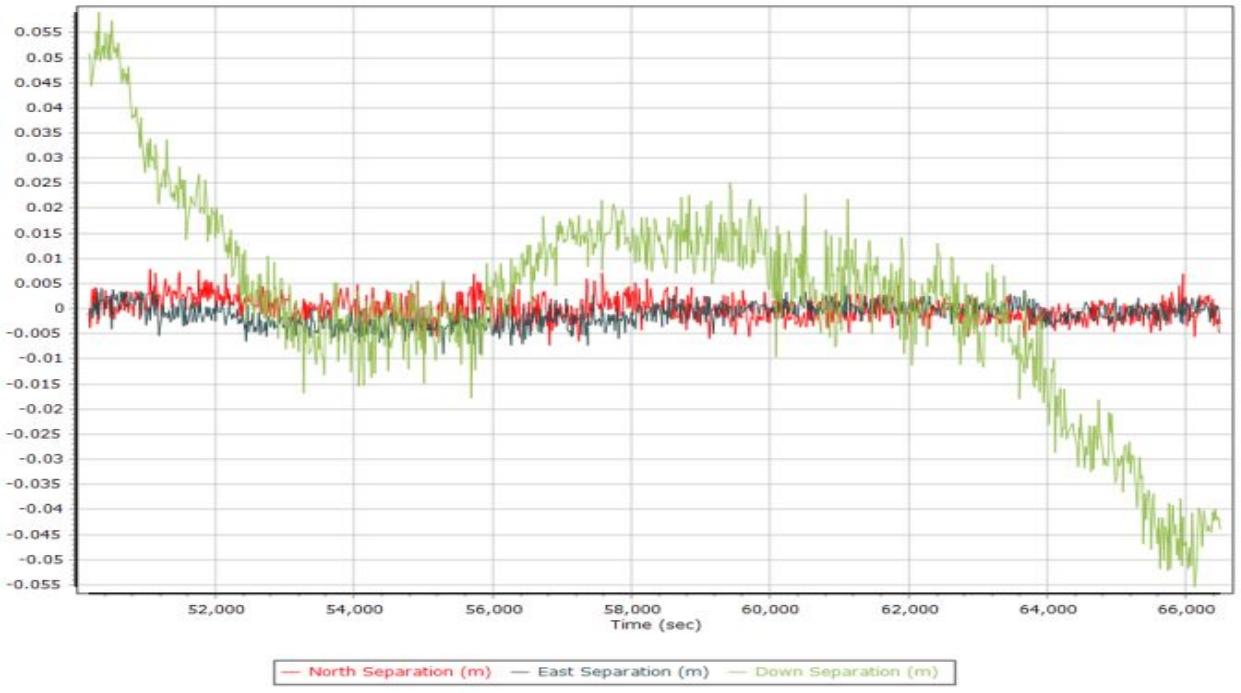
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	10	8
Number of GLONASS SV	0	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	7	5
Total number of SV	12	24	20
PDOP	1.02	1.93	1.24
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	16777.00	0.00	0.00
Percentage	100.00	0.00	0.00

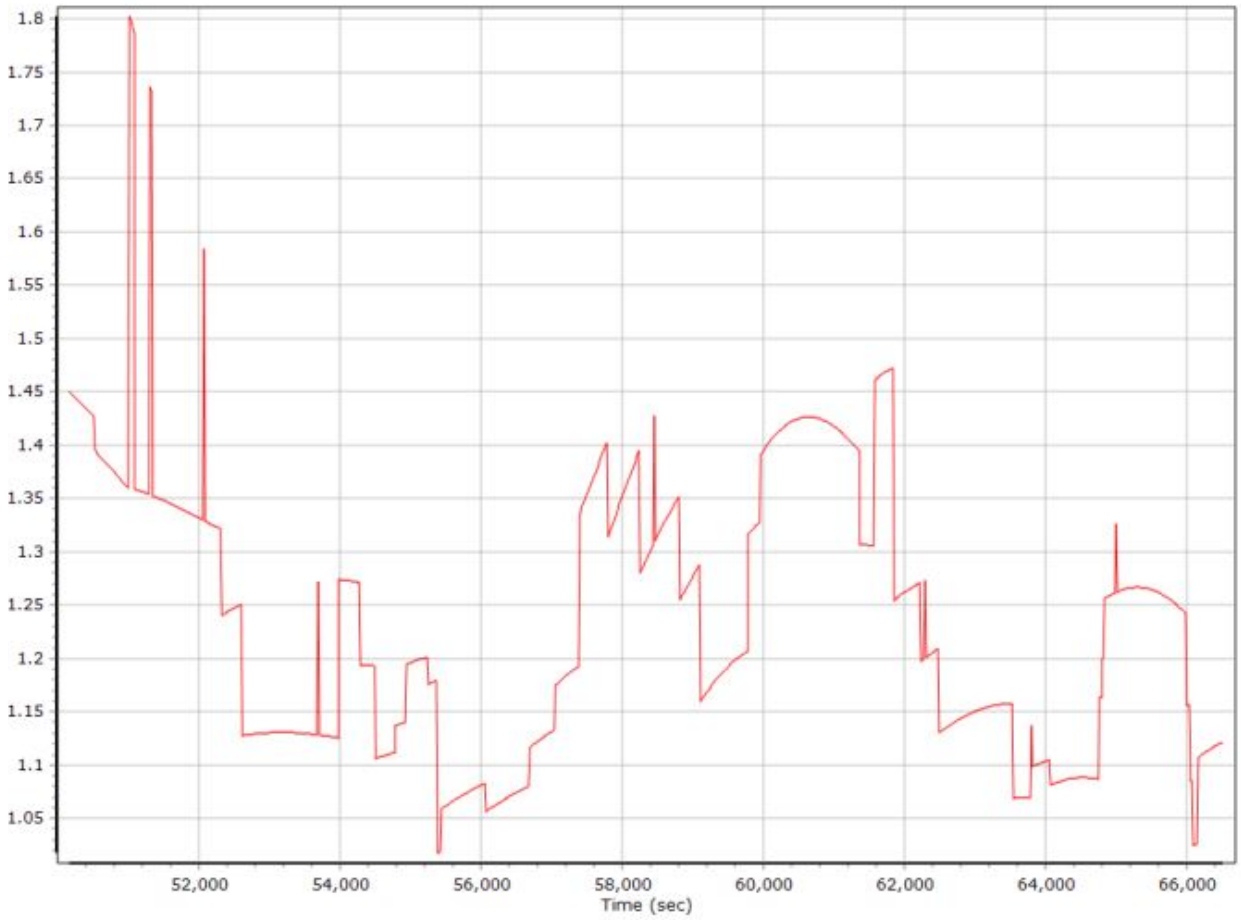
Number of Satellites



Forward/Reverse Separation



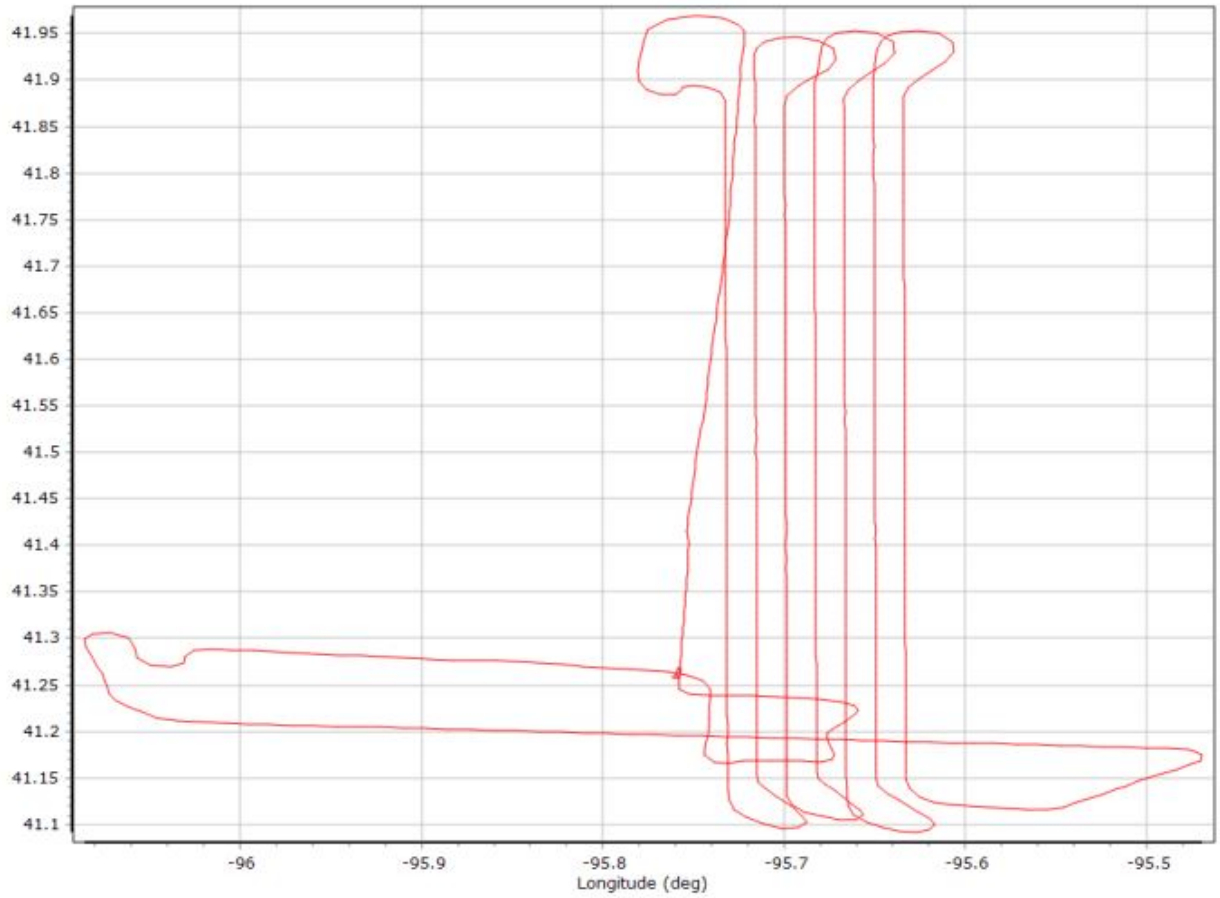
PDOP


1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
52,000
54,000
56,000
58,000
60,000
62,000
64,000
66,000
Time (sec)

0321a448_QC Report.docx QC Report -08/26/2021 13:27:25

Smoothed Trajectory Information

Top View

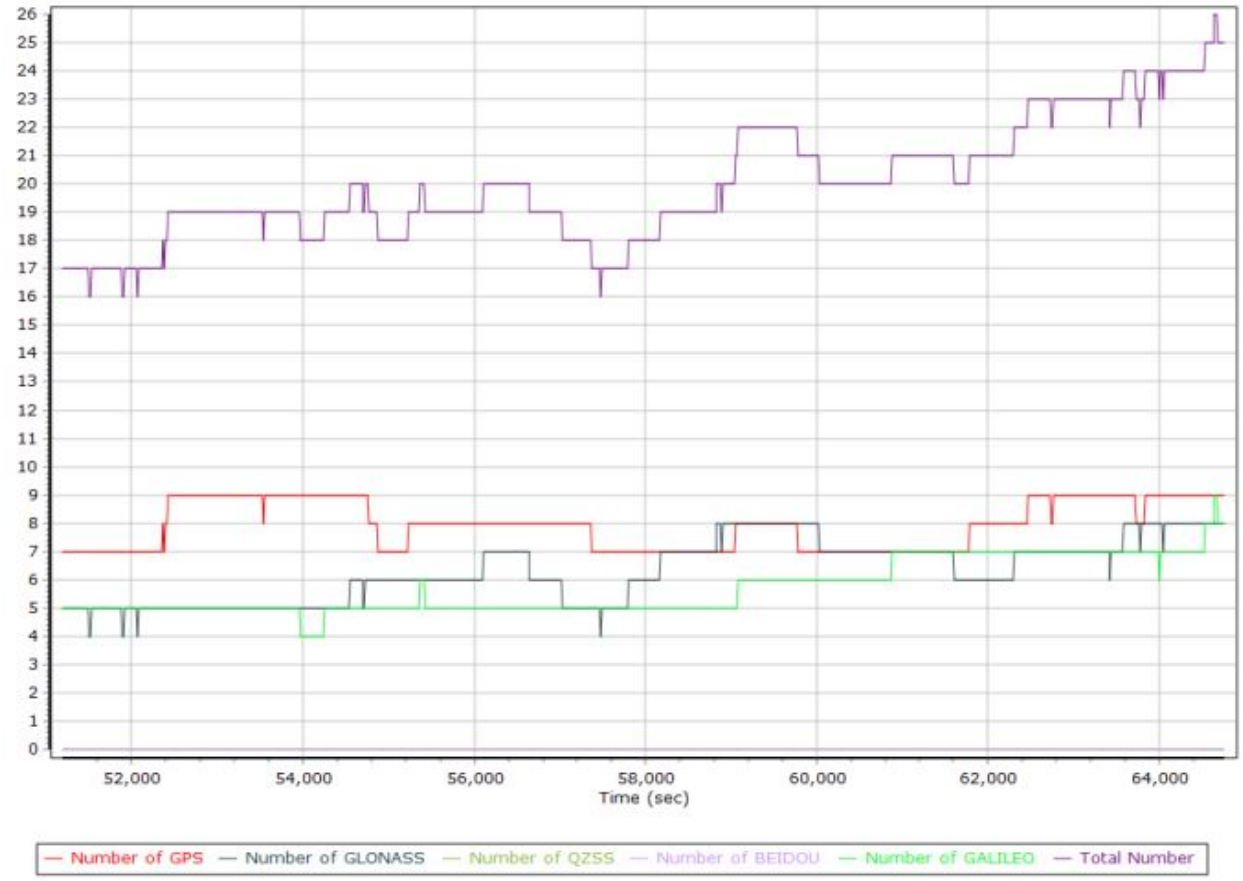


GNSS QC

GNSS QC Statistics

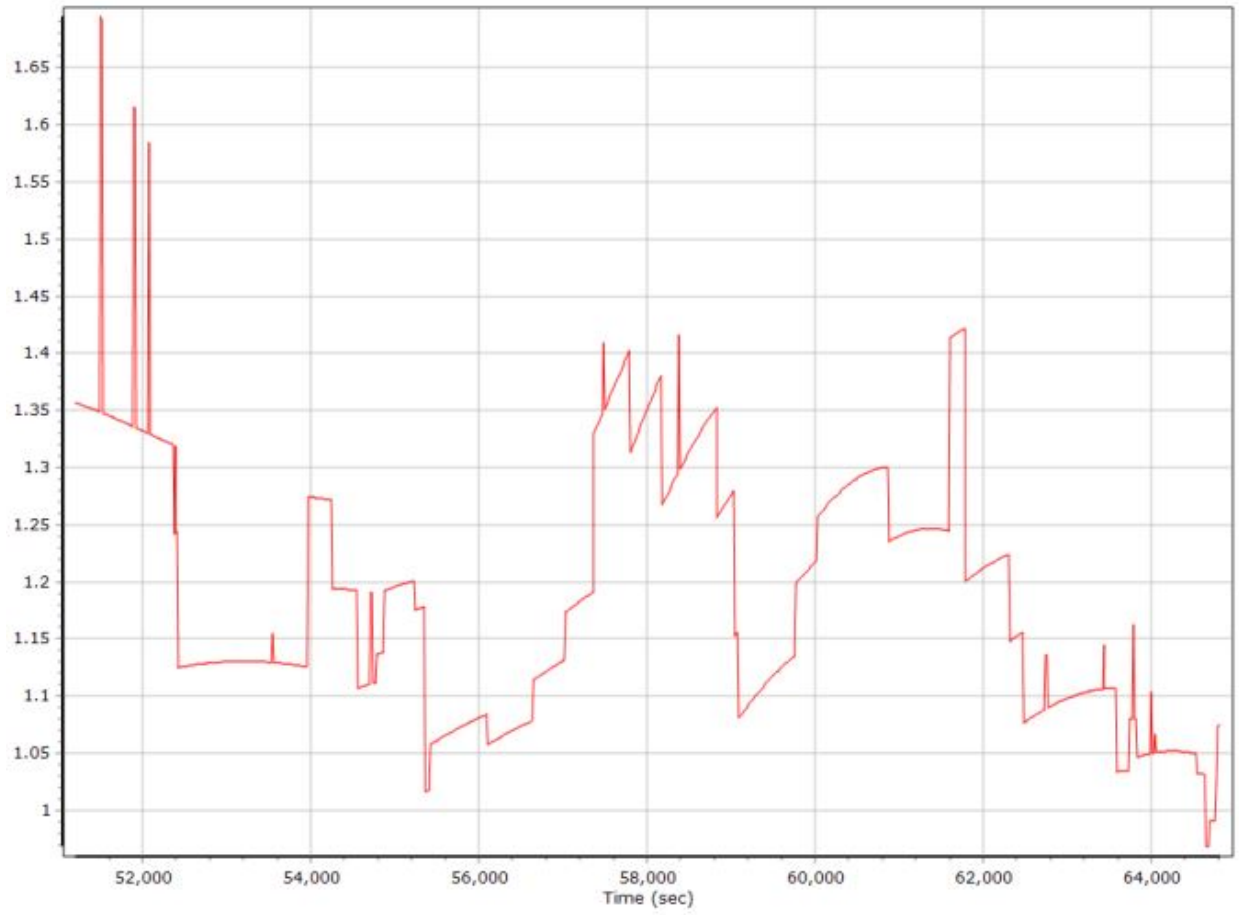
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	9	8
Number of GLONASS SV	3	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	9	6
Total number of SV	14	26	20
PDOP	0.97	1.98	1.20
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13989.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



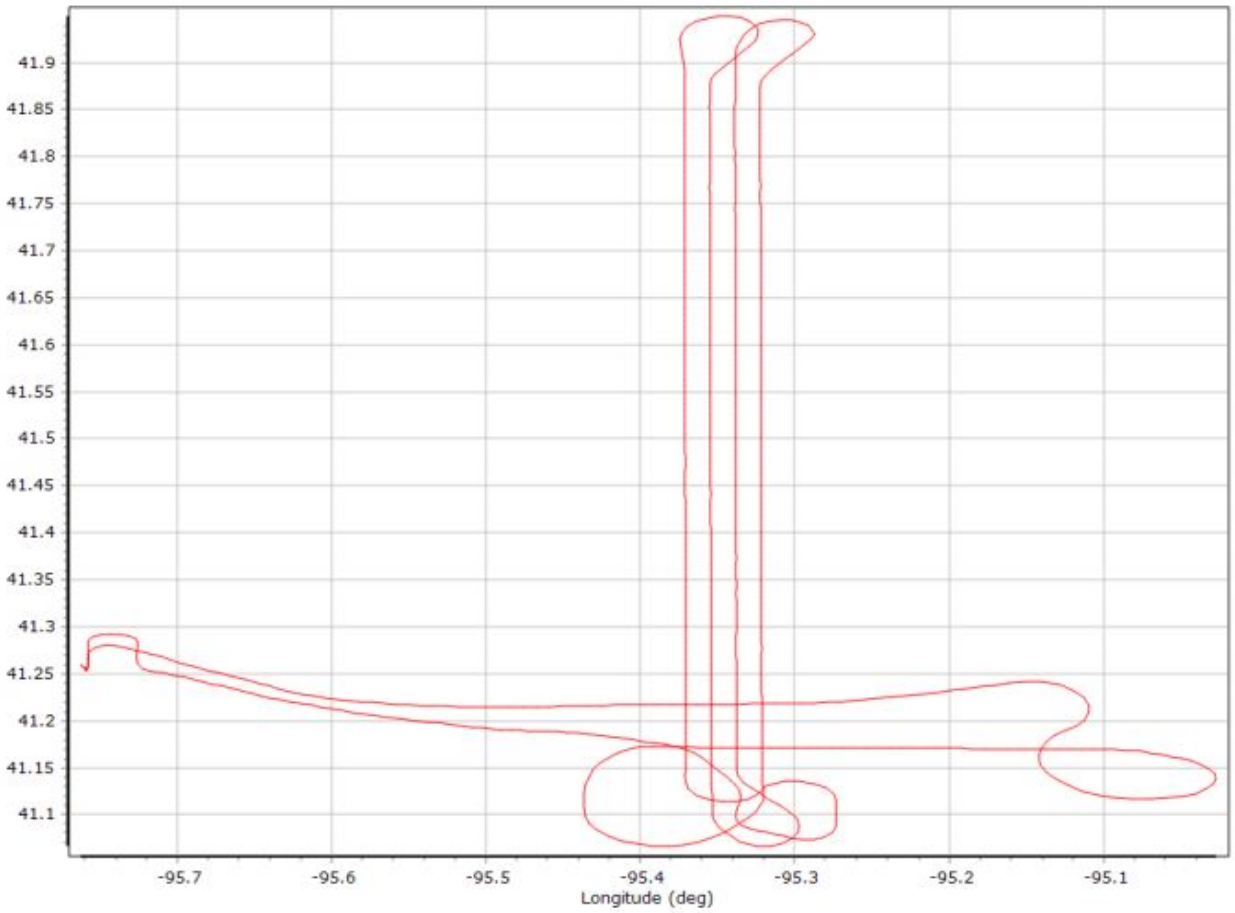
Forward/Reverse Separation

PDOP


1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
52,000
54,000
56,000
58,000
60,000
62,000
64,000
Time (sec)

0328a386_QC Report.docx QC Report – 8/26/2021 13:35:30
Smoothed Trajectory Information

Top View

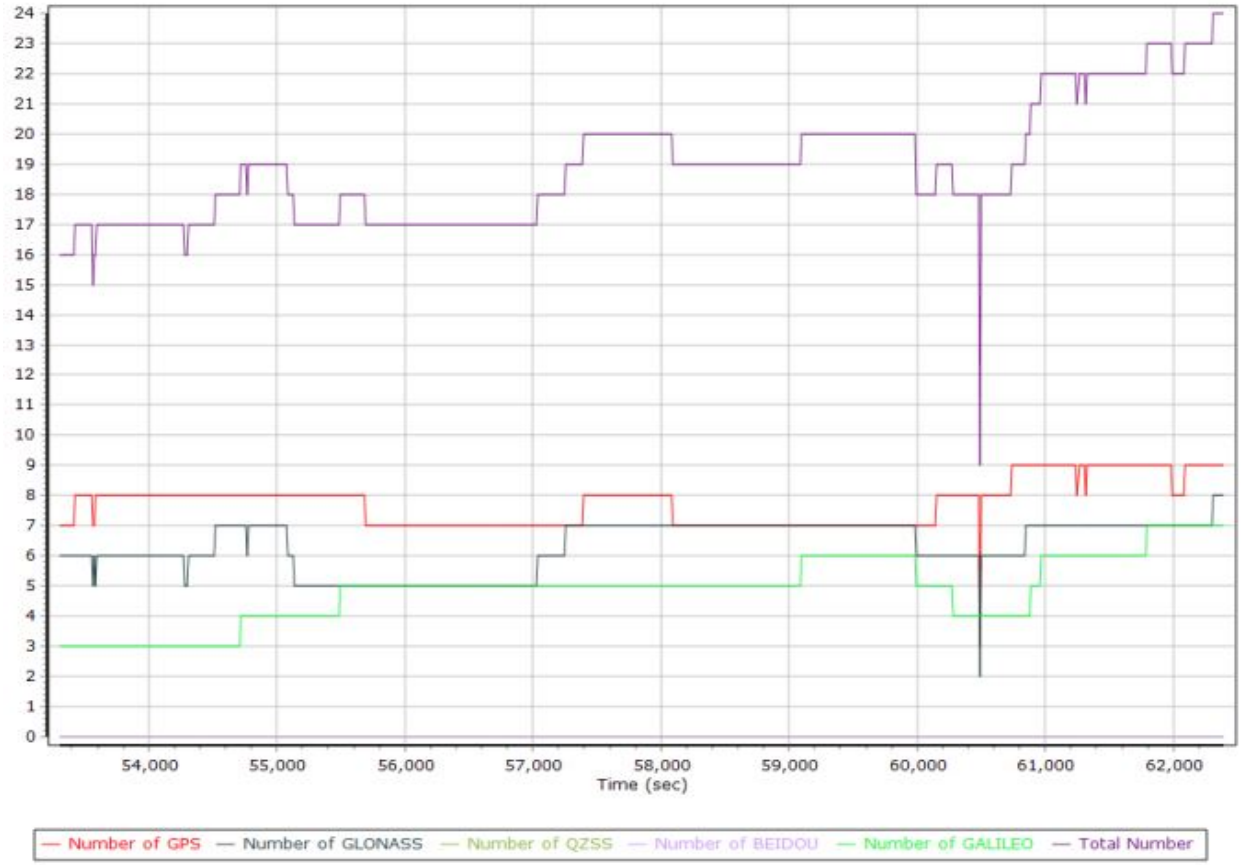


GNSS QC

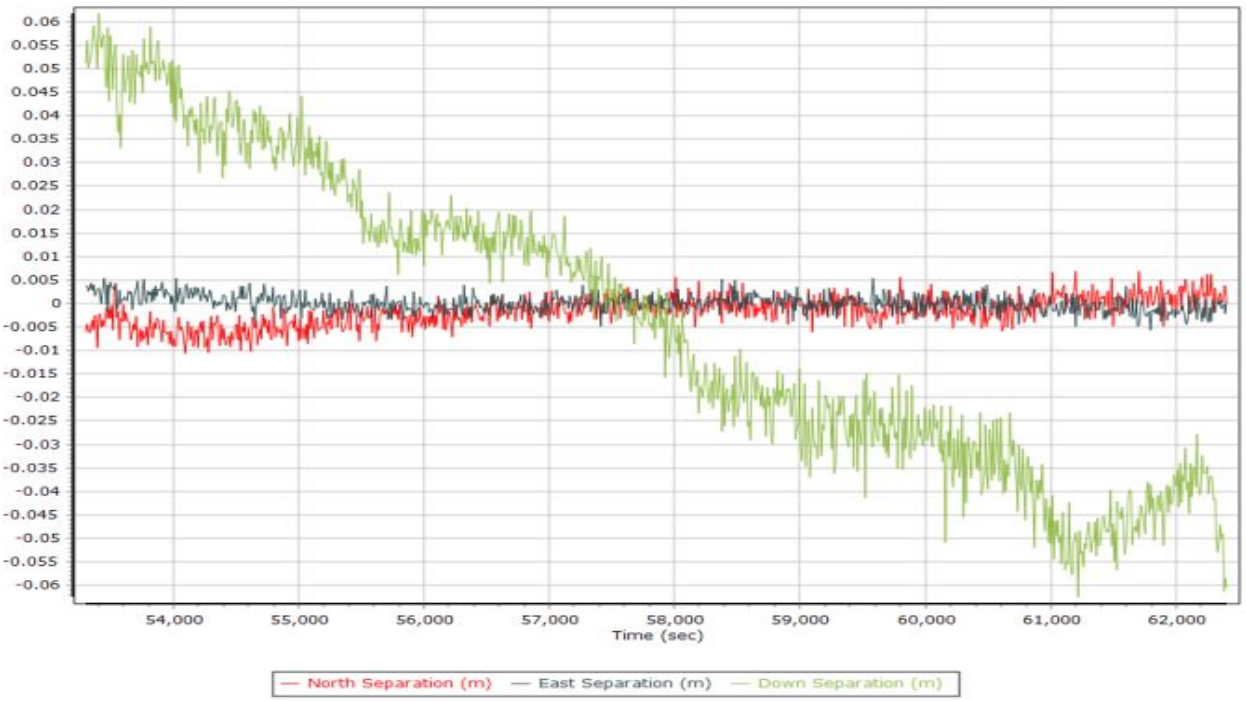
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	3	9	8
Number of GLONASS SV	0	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	7	5
Total number of SV	9	24	19
PDOP	1.03	3.58	1.31
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	9609.00	0.00	0.00
Percentage	100.00	0.00	0.00

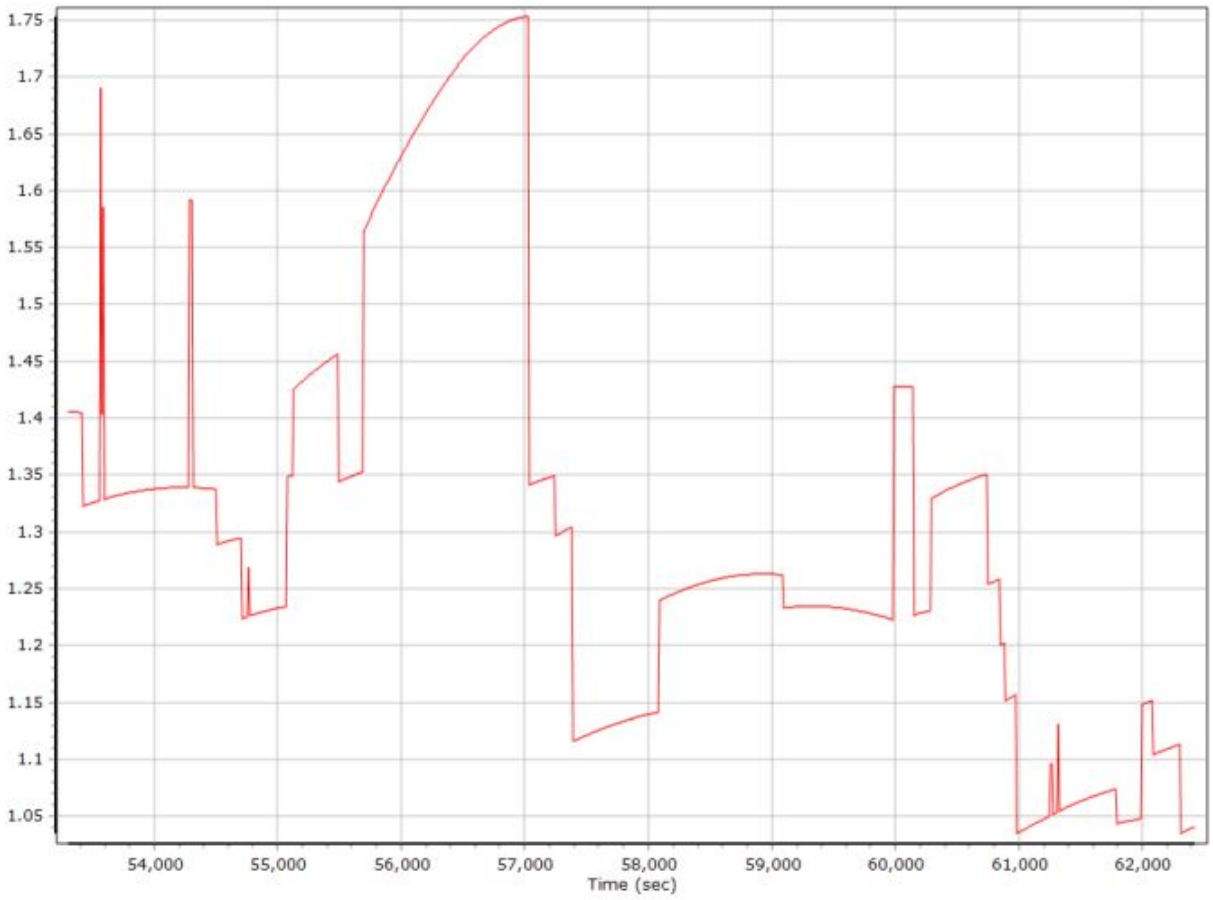
Number of Satellites



Forward/Reverse Separation



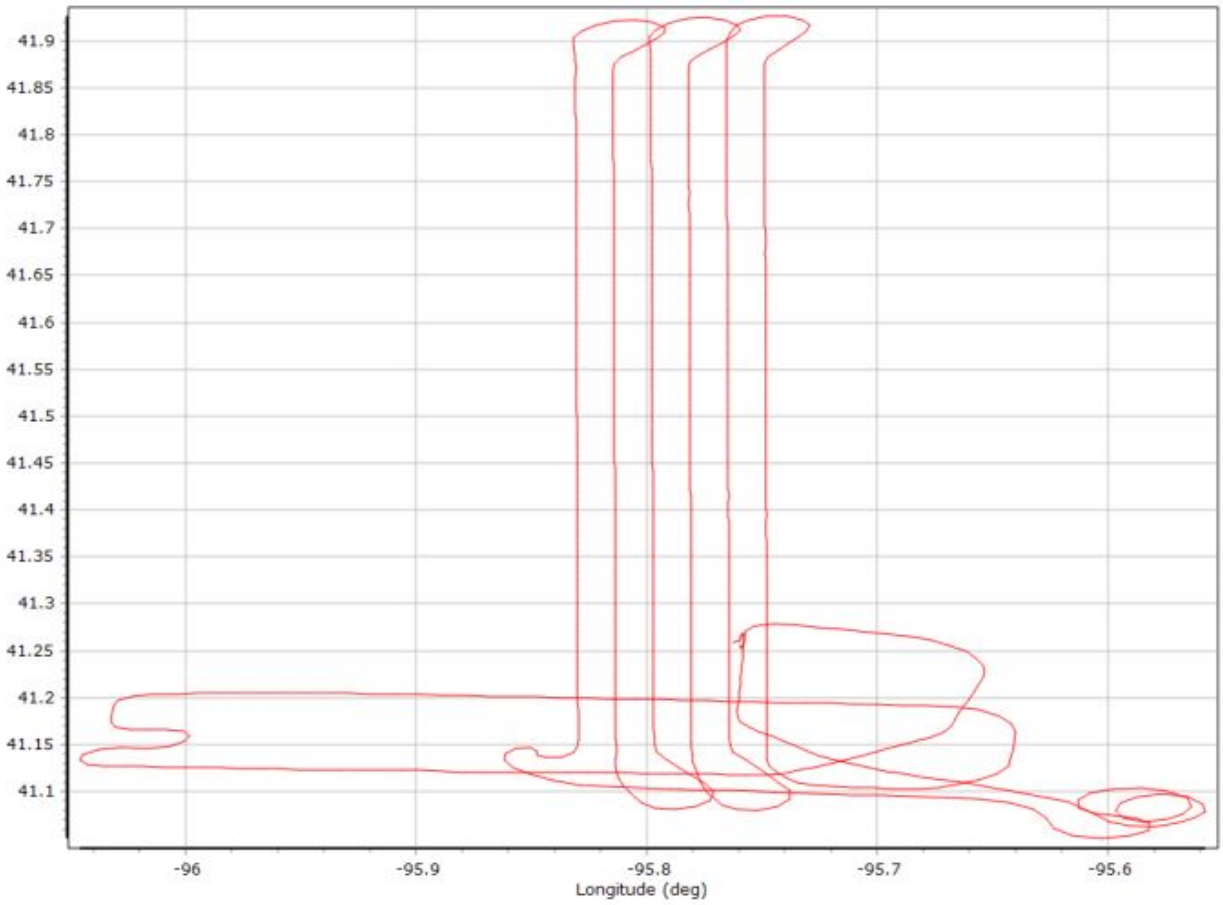
PDOP


1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
Time (sec)

0328a448_QC Report.docx QC Report – 8/26/2021 13:43:38

Smoothed Trajectory Information

Top View



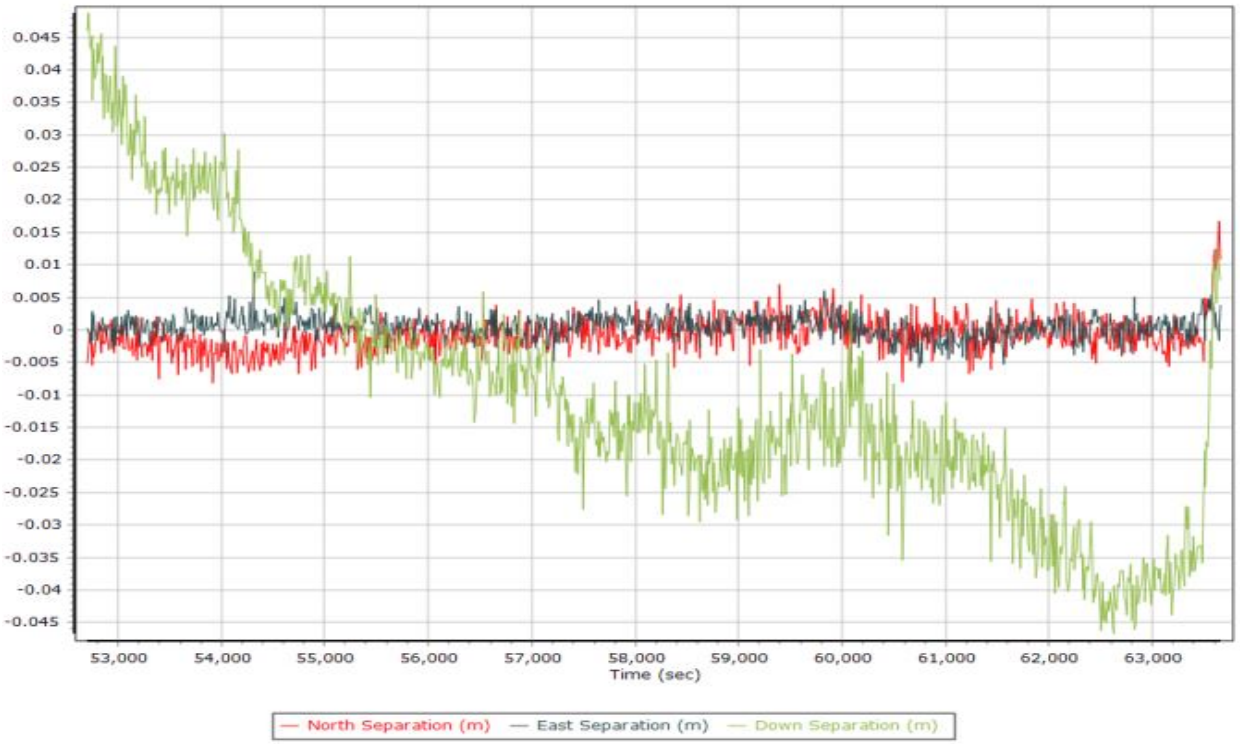
GNSS QC

GNSS QC Statistics

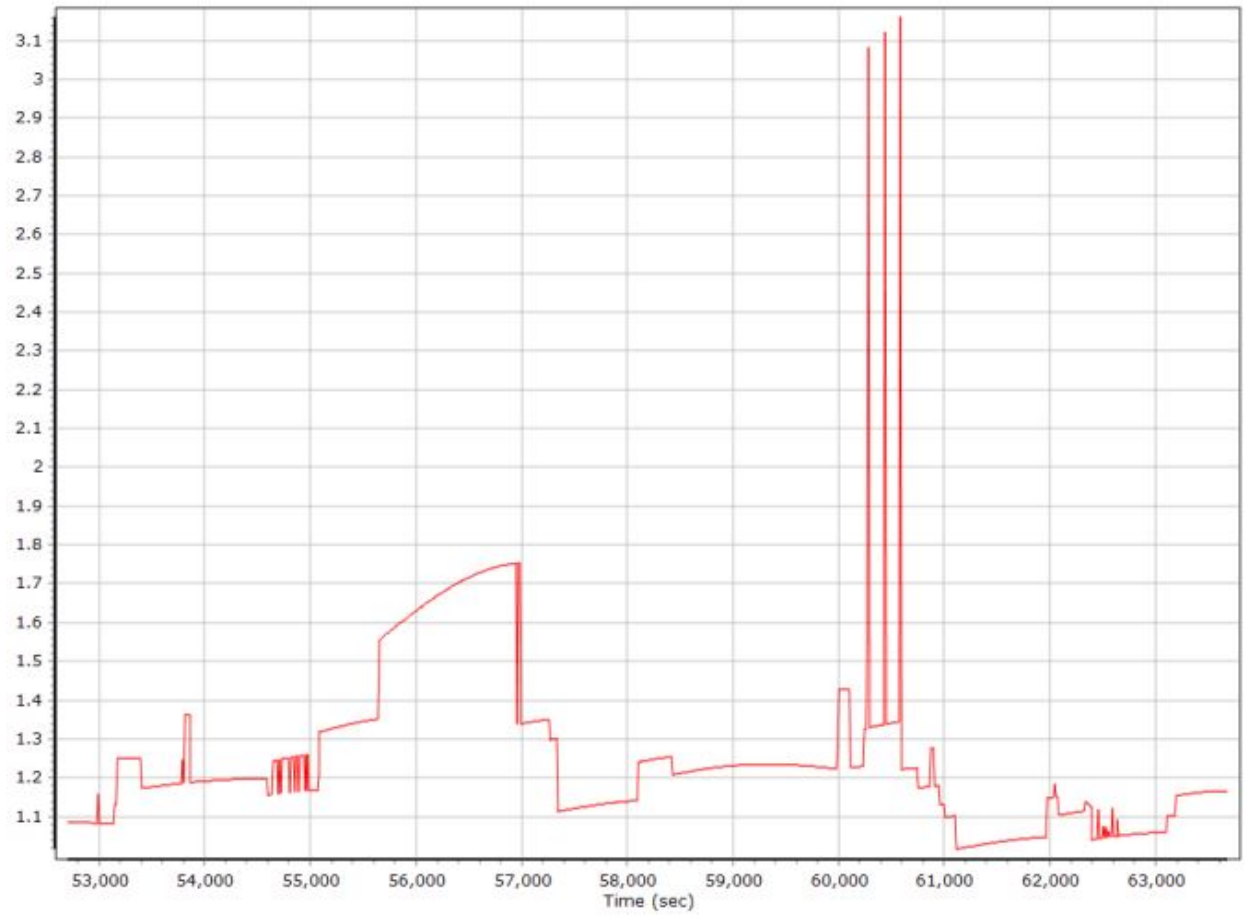
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	3	9	8
Number of GLONASS SV	2	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	7	6
Total number of SV	9	24	20
PDOP	1.02	3.16	1.24
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11372.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites

Forward/Reverse Separation

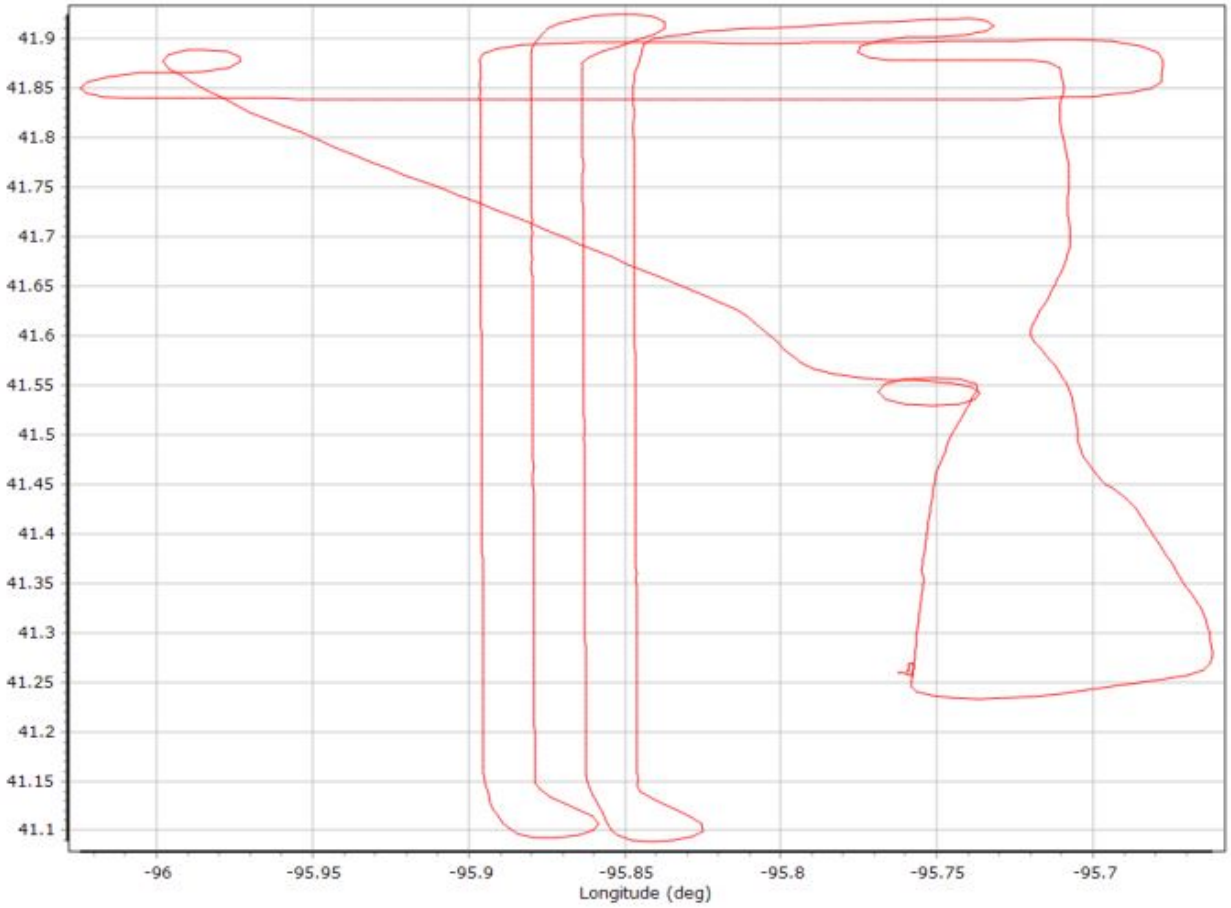


PDOP


3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
53,000
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
Time (sec)

0328c448_QC Report.docx QC Report – 8/25/2021 13:52:41
Smoothed Trajectory Information

Top View

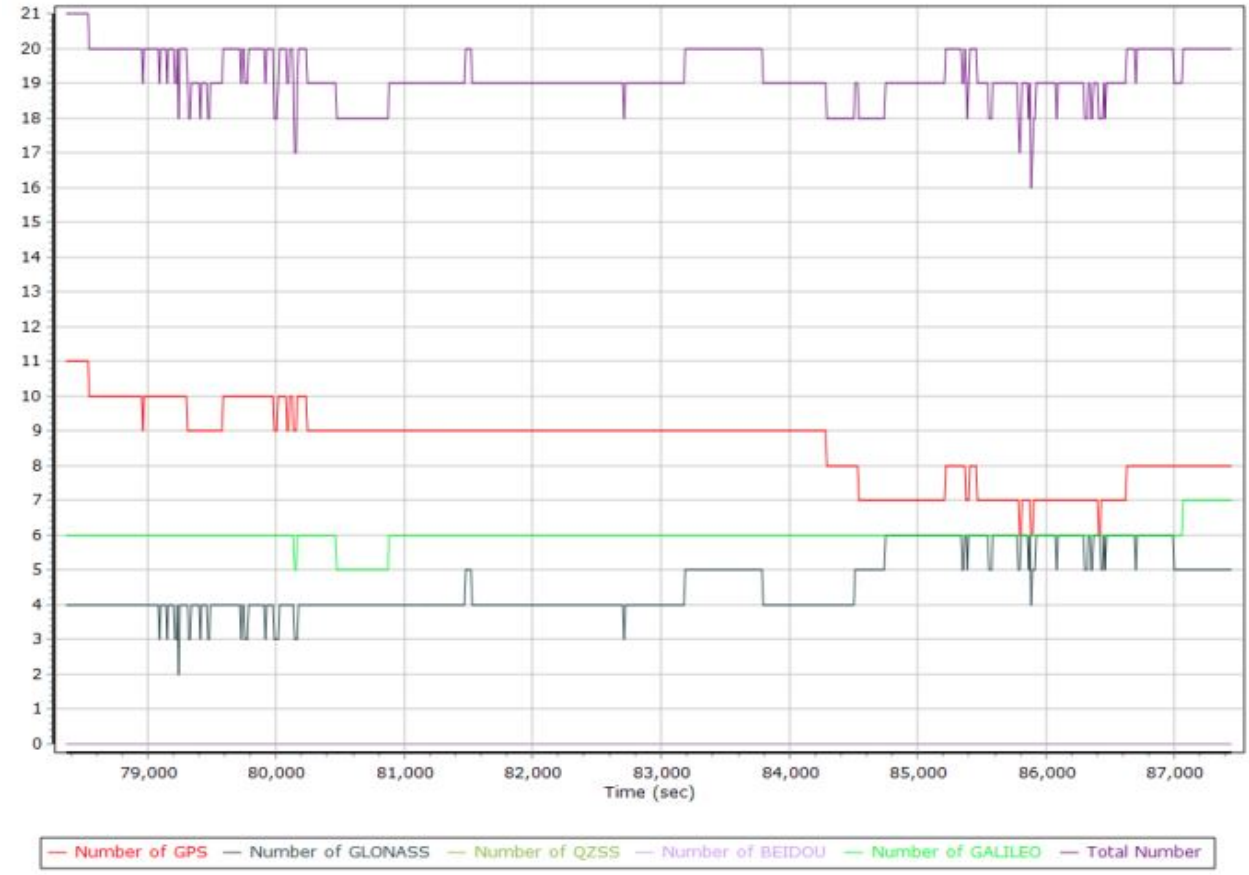


GNSS QC

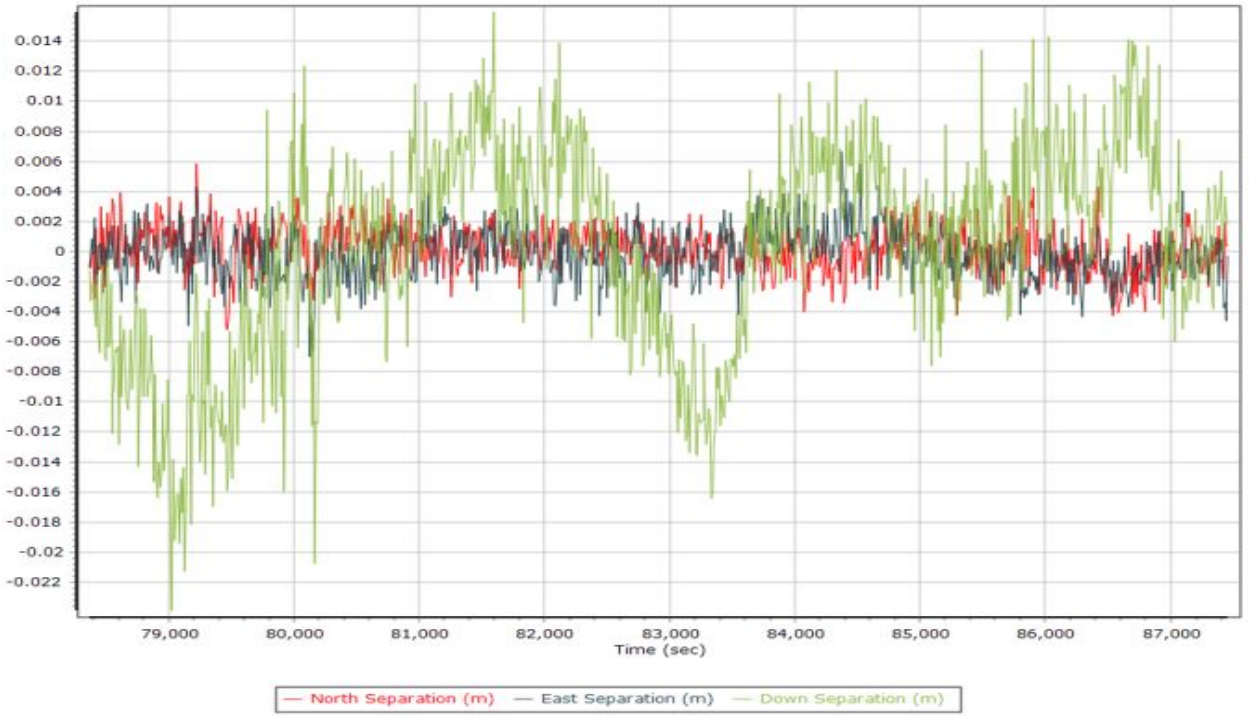
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	11	9
Number of GLONASS SV	2	6	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	5	7	6
Total number of SV	16	22	19
PDOP	1.00	1.54	1.16
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	9495.00	0.00	0.00
Percentage	100.00	0.00	0.00

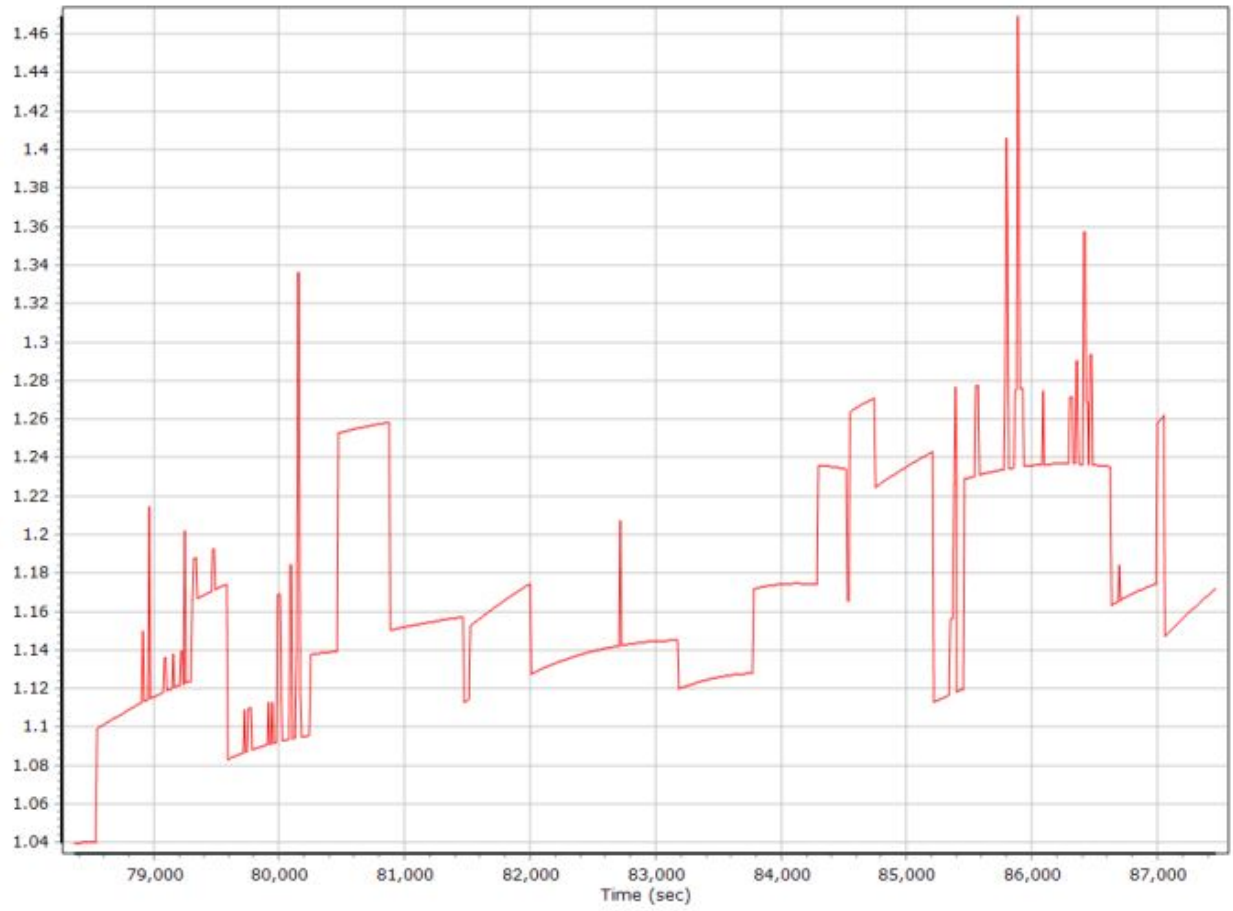
Number of Satellites



Forward/Reverse Separation

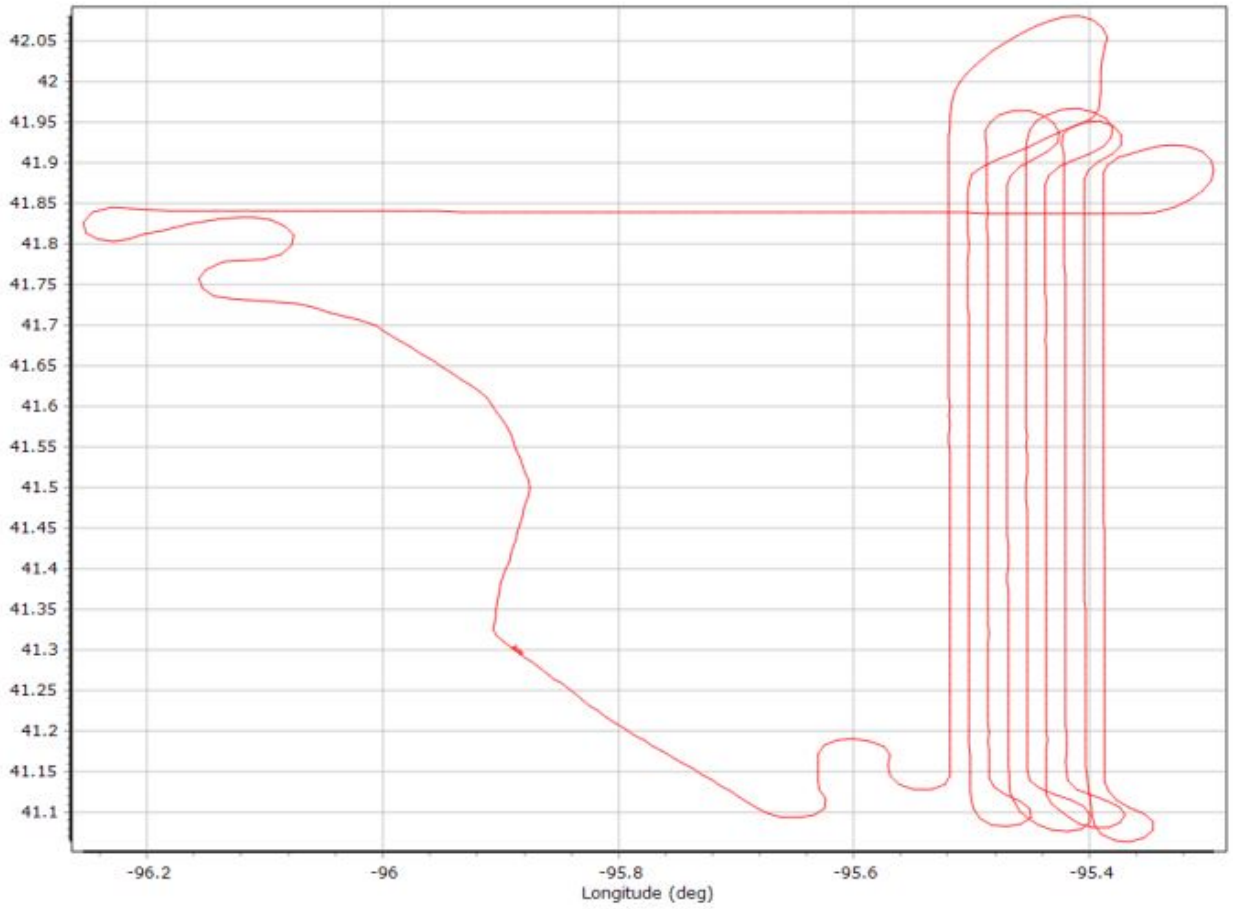


PDOP


1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
79,000
80,000
81,000
82,000
83,000
84,000
85,000
86,000
87,000
Time (sec)

1210a386_QC Report.docx QC Report – 8/26/2021 14:00:11
Smoothed Trajectory Information

Top View

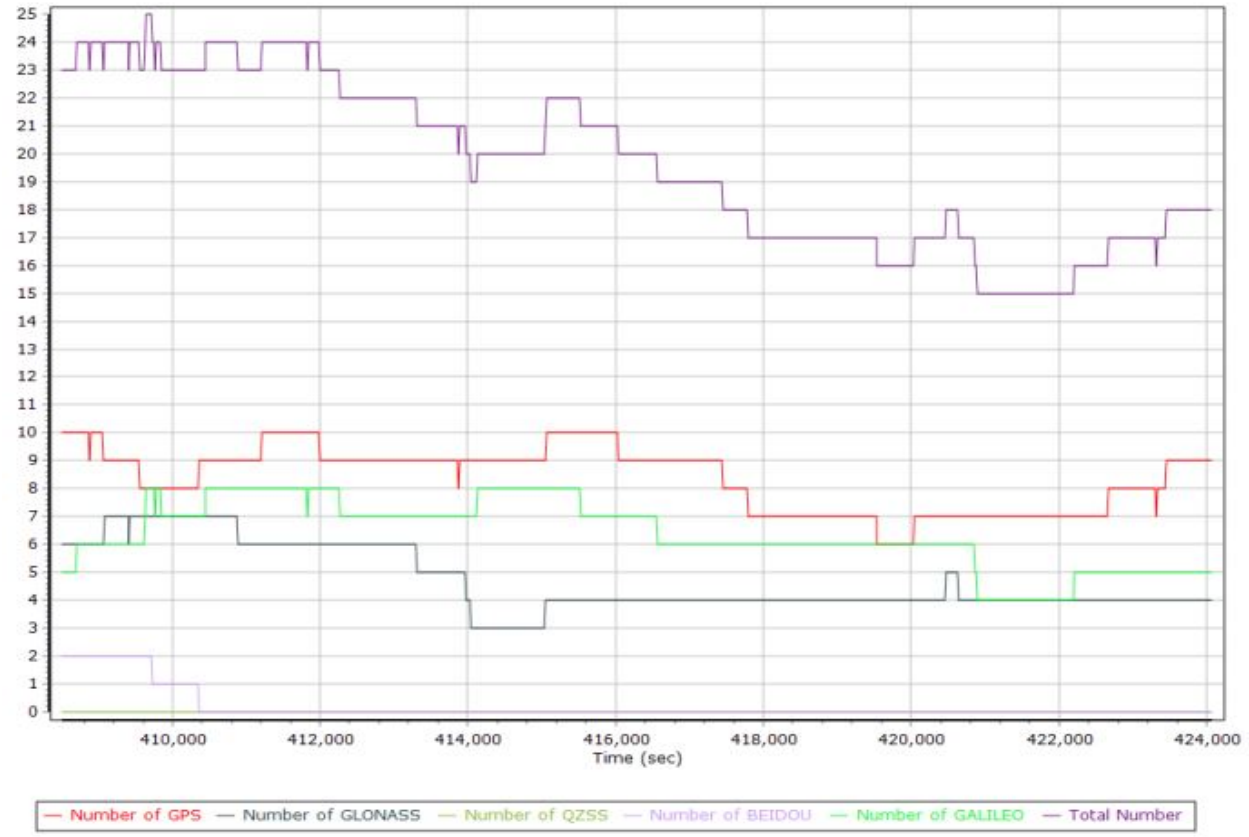


GNSS QC

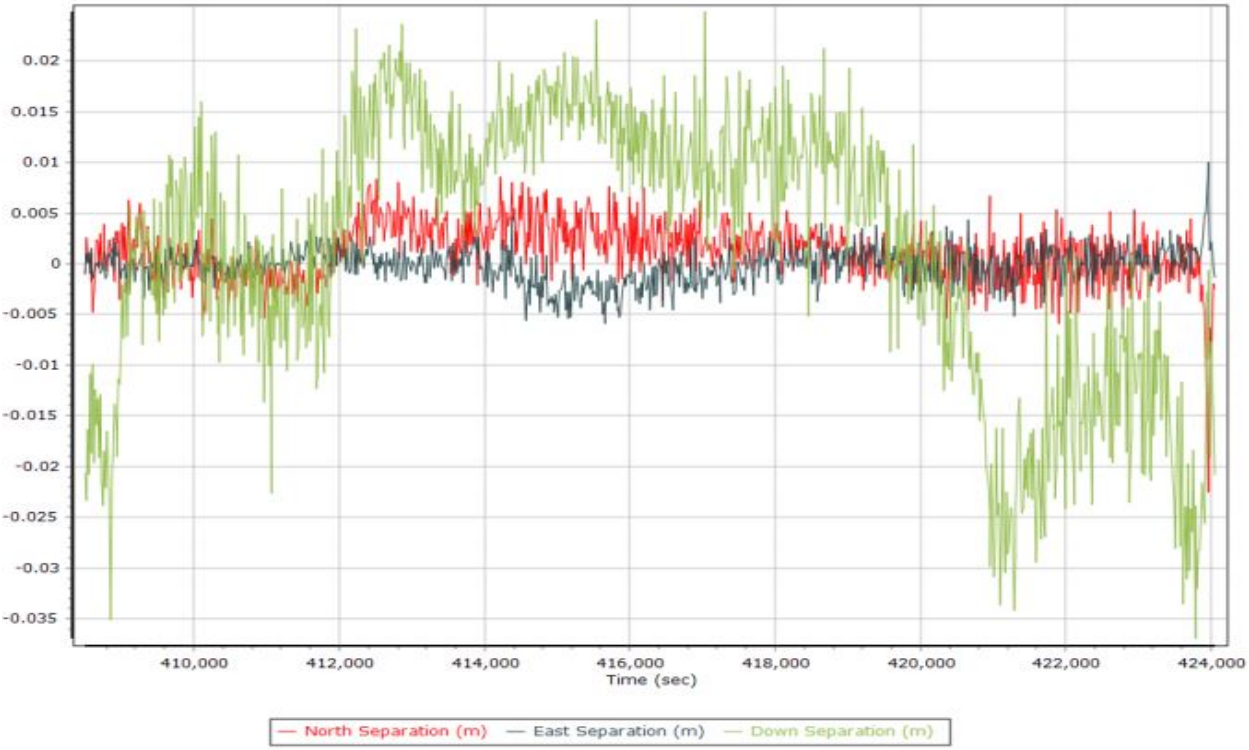
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	7	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	0
Number of GALILEO SV	0	8	6
Total number of SV	15	25	20
PDOP	1.02	1.97	1.30
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	16265.00	0.00	0.00
Percentage	100.00	0.00	0.00

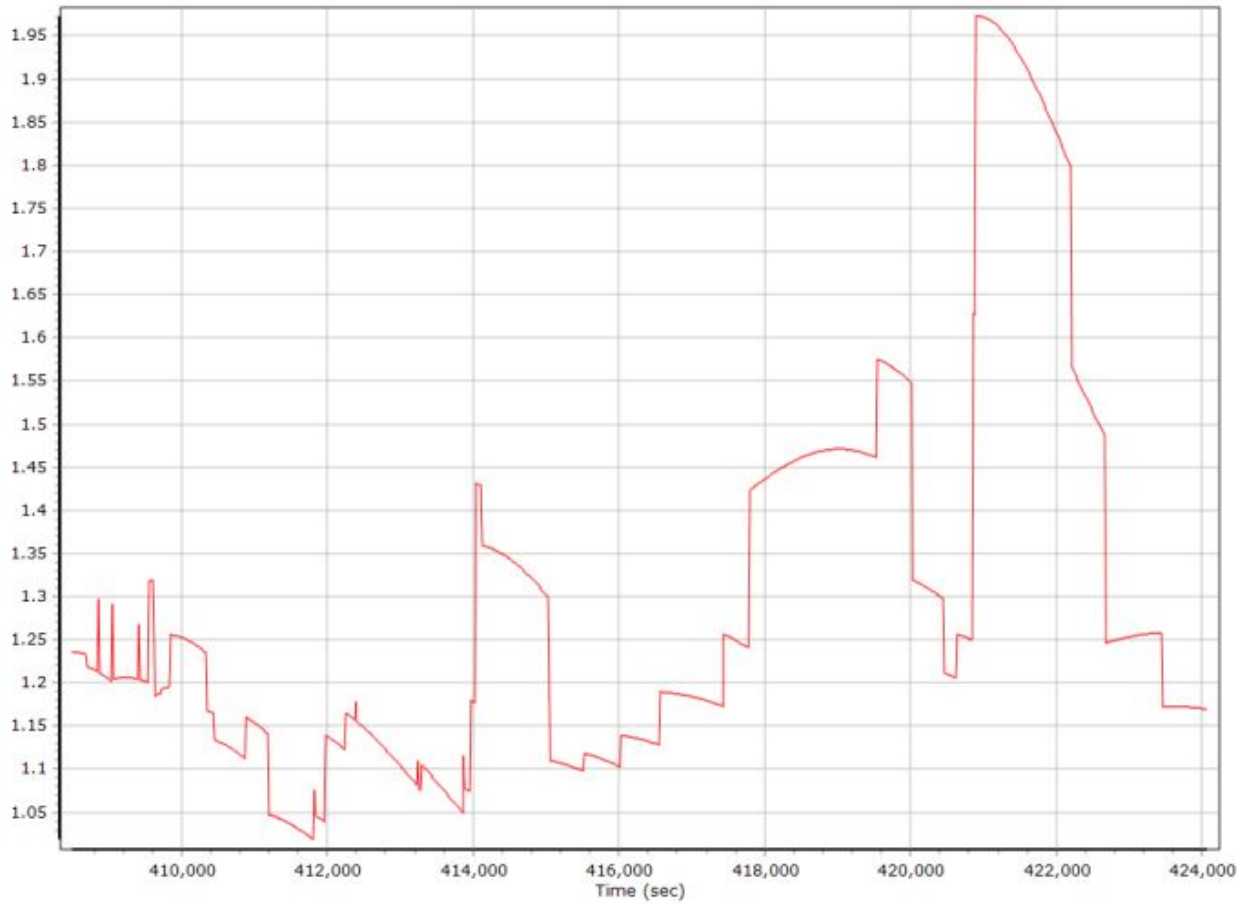
Number of Satellites



Forward/Reverse Separation

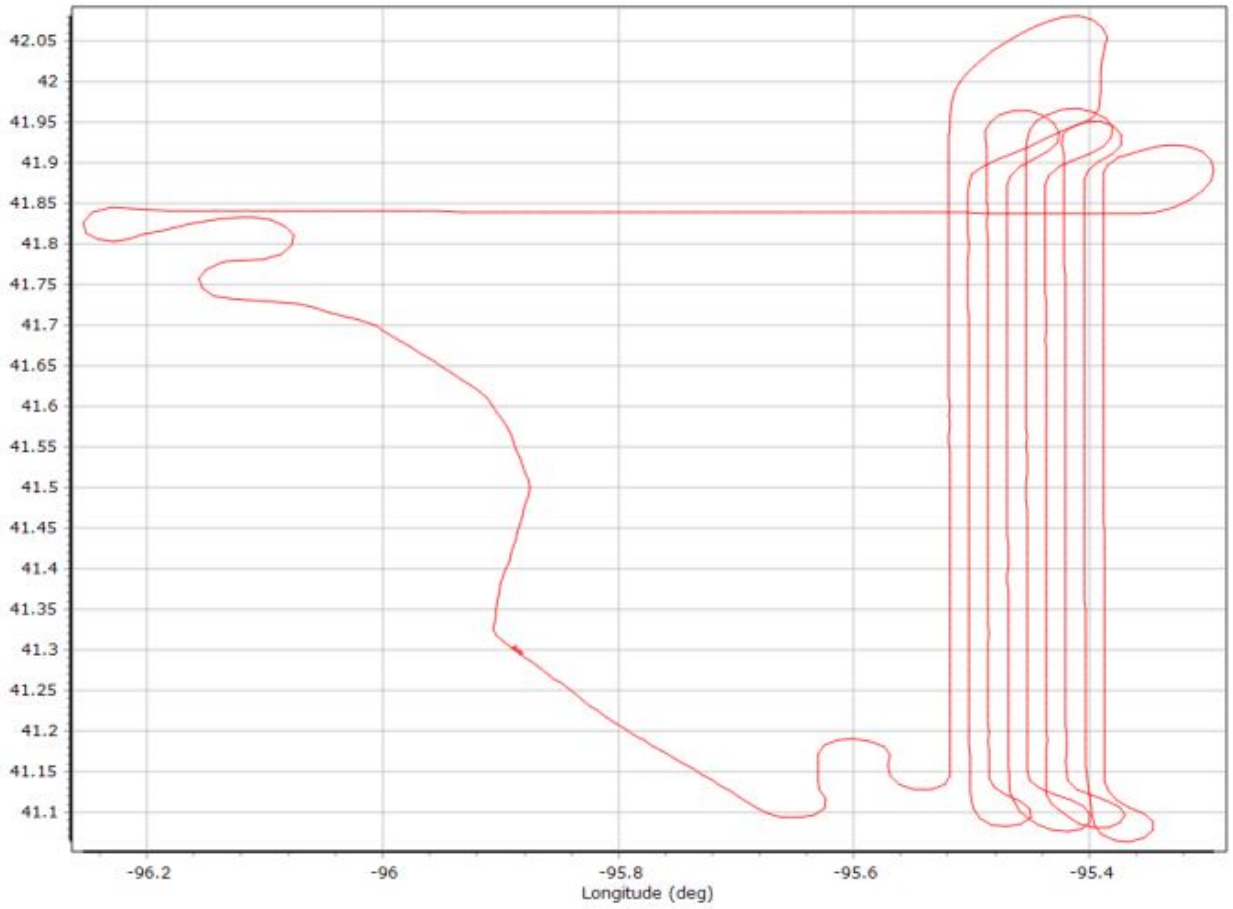


PDOP


1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
410,000
412,000
414,000
416,000
418,000
420,000
422,000
424,000
Time (sec)

1210a448_QC Report.docx QC Report - 8/26/2021 14:10:44
Smoothed Trajectory Information

Top View

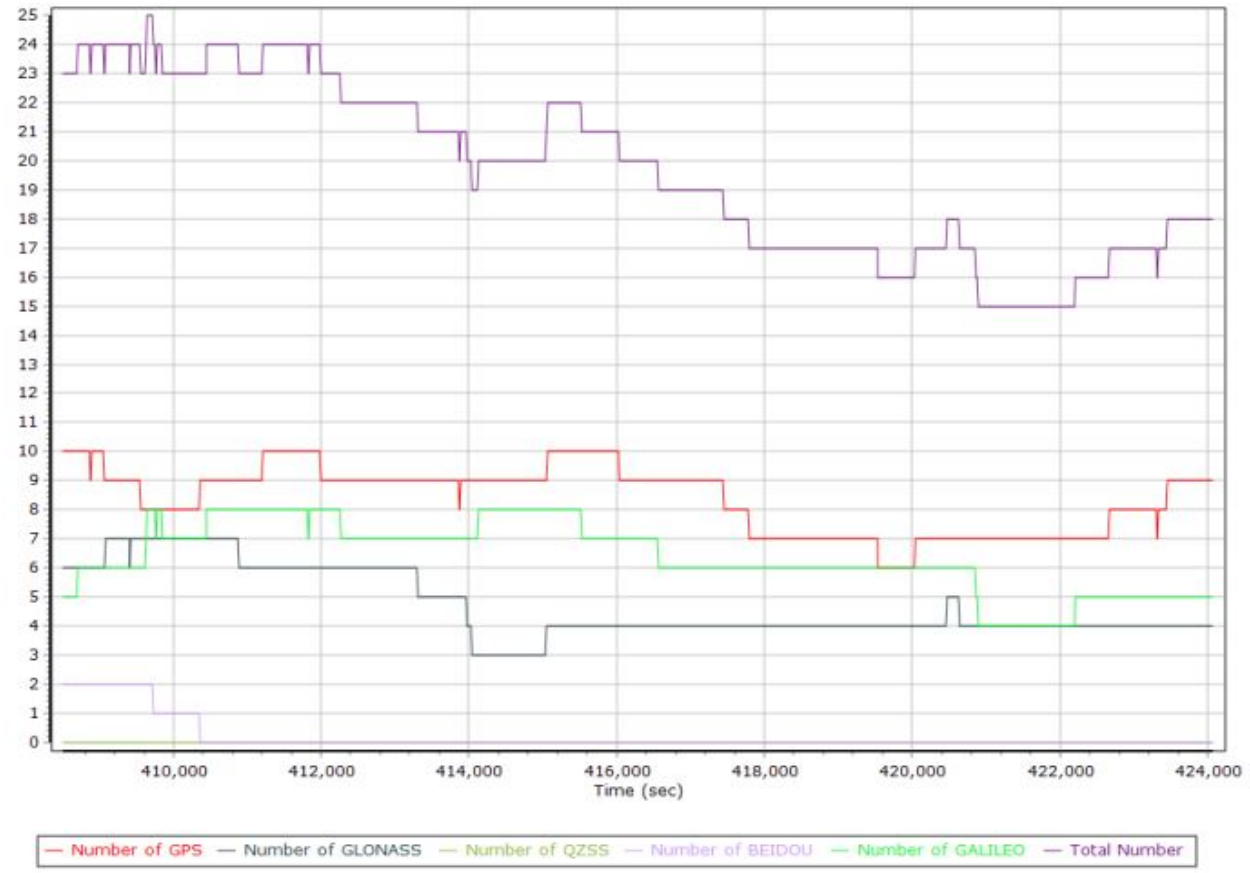


GNSS QC

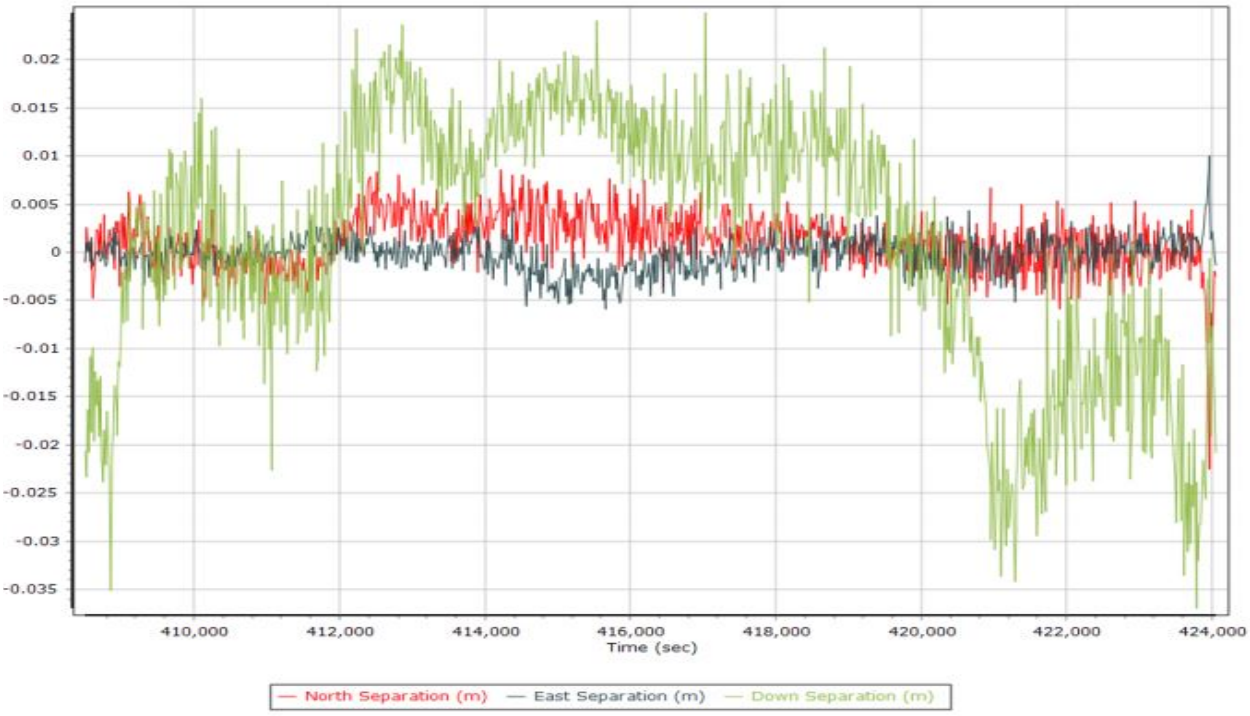
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	7	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	0
Number of GALILEO SV	0	8	6
Total number of SV	15	25	20
PDOP	1.02	1.97	1.30
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	16265.00	0.00	0.00
Percentage	100.00	0.00	0.00

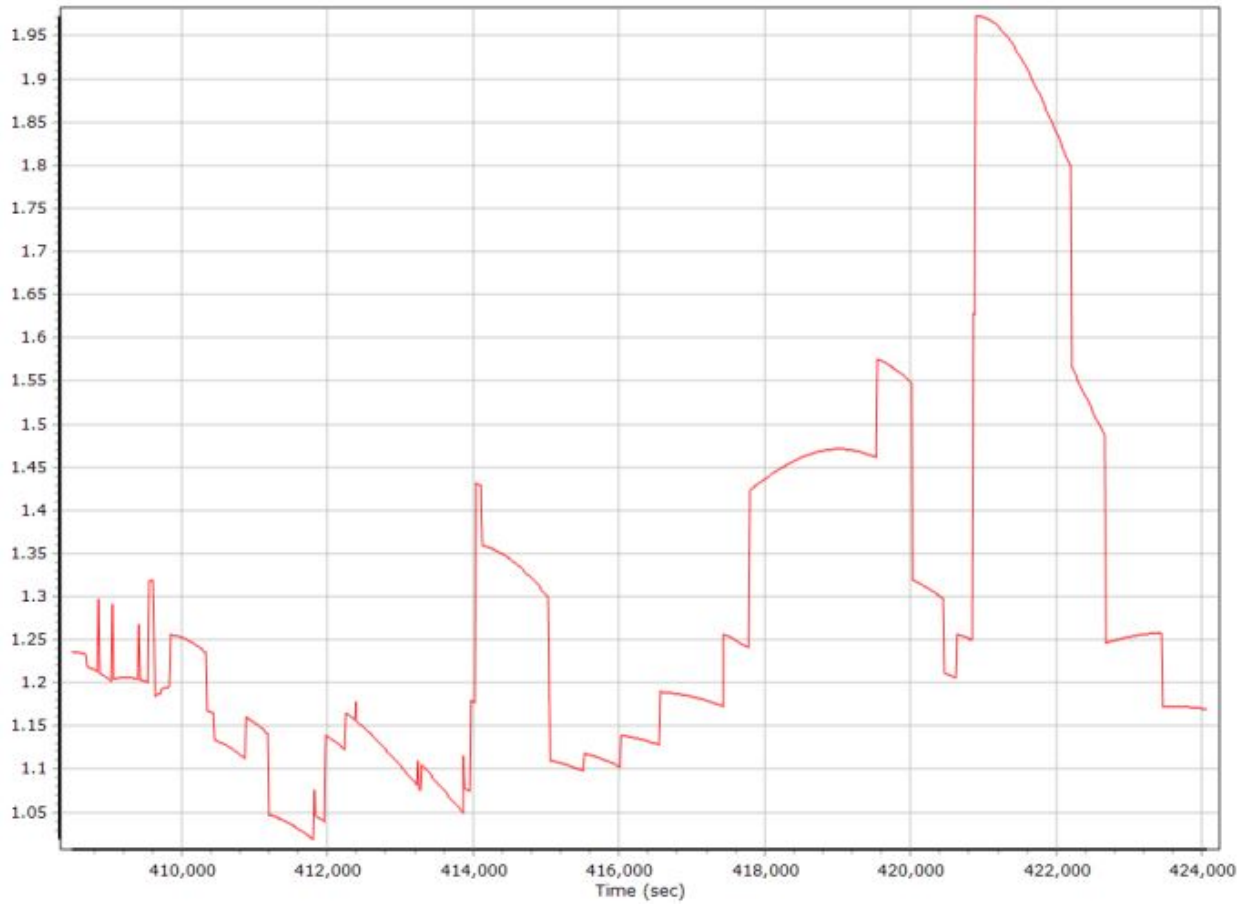
Number of Satellites



Forward/Reverse Separation



PDOP


1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
410,000
412,000
414,000
416,000
418,000
420,000
422,000
424,000
Time (sec)