Satellite surveying

Presentation for ISCWSA

Over 550 global PhotoSat stereo satellite topographic mapping projects

Basic proposition

- ***Satellite surveying has improved to a level where it may be used as an alternative to ground surveying or airborne LiDAR for onshore oil and gas projects.***
- ***Satellite surveying is useful for detecting and correcting gross survey errors.***
- ***Uncertainty in surveying causes delays at many phases of oil and gas projects. A study of a typical onshore project shows that higher accuracy surveying earlier in the project greatly reduces delays.***

Agenda

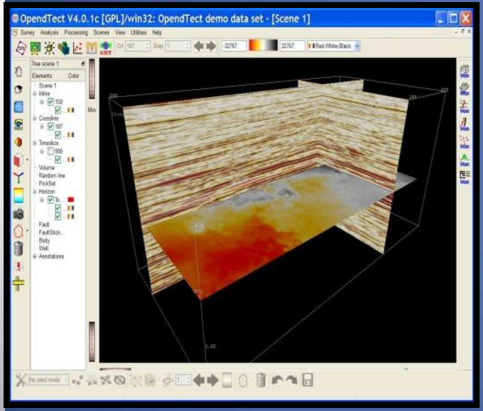
- Introduction to Satellite surveying
- Validating accuracy
- Real world examples
- Evaluating the value of surveying

Introduction to satellite surveying technology

Four key technical components enabling elevation mapping from space

High resolution stereo satellite photos

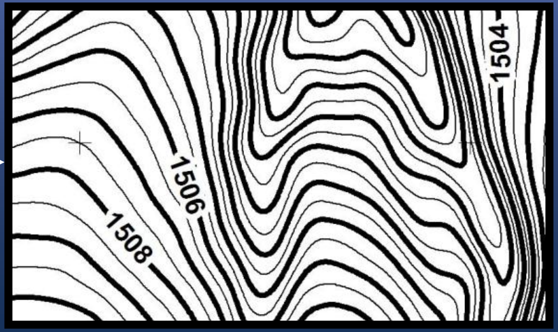
Adaptation of seismic processing systems



Graphics Processing Units (GPUs)

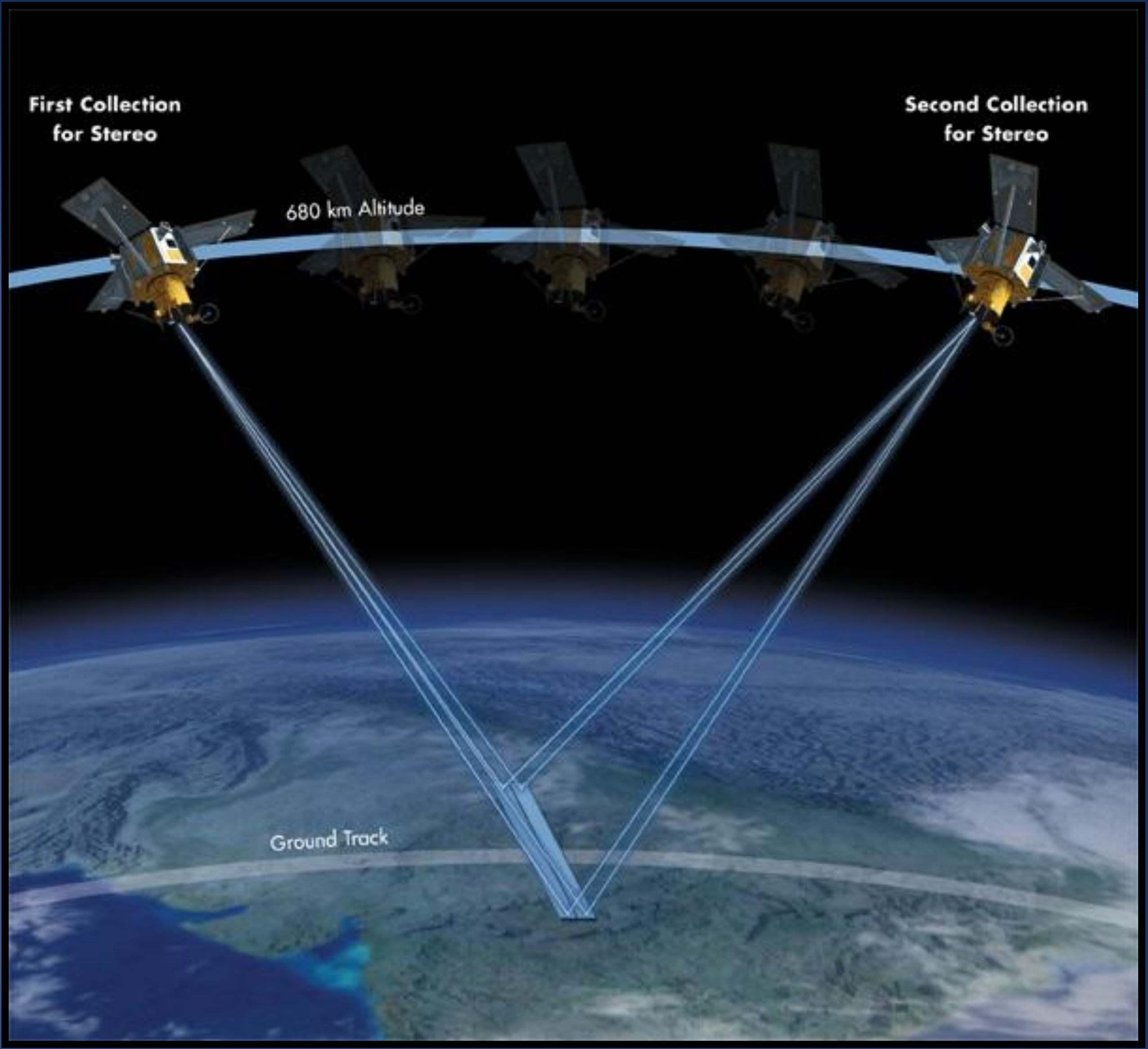
Oil Sands surveying

Characterize the satellites and optimize the process



PhotoSat Algorithms

- **Based on Seismic algorithms**
  - Achieve 4x better accuracy when compared to conventional photogrammetric algorithms
- **No image warping**
  - Can assess accuracy compared to ground control
- **Consistent throughout the area**
- **“Experience database” can be incorporated**
  - Ft McMurray and other projects have allowed us to identify systematic errors.
- **Ideal for GPU processing**
  - 20x better throughput
  - Allows iteration during QC

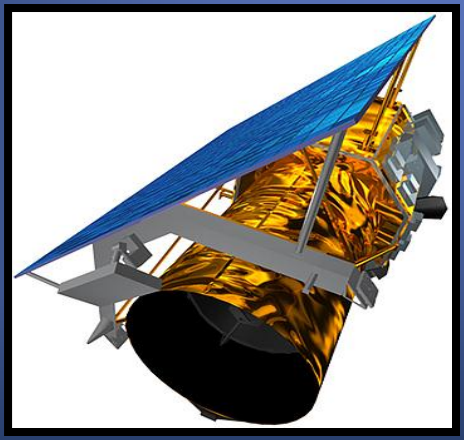


Stereo satellite photos used to map topography

High resolution stereo satellites

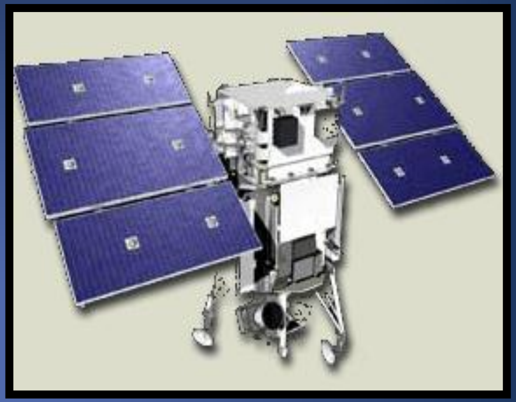
GeoEye Steeo Satellites

IKONOS 1m colour
2004

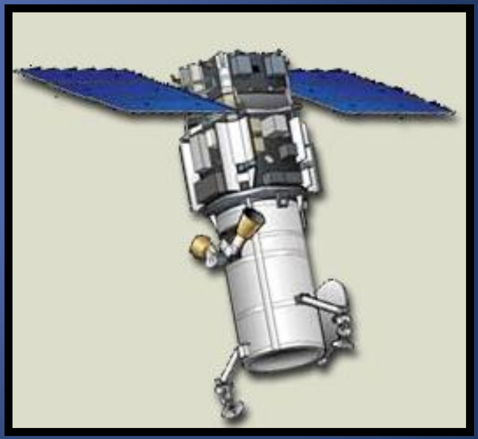


GeoEye-1 50cm colour
2009

DigitalGlobe Stereo Satellites



WorldView-1 50cm greyscale
2008



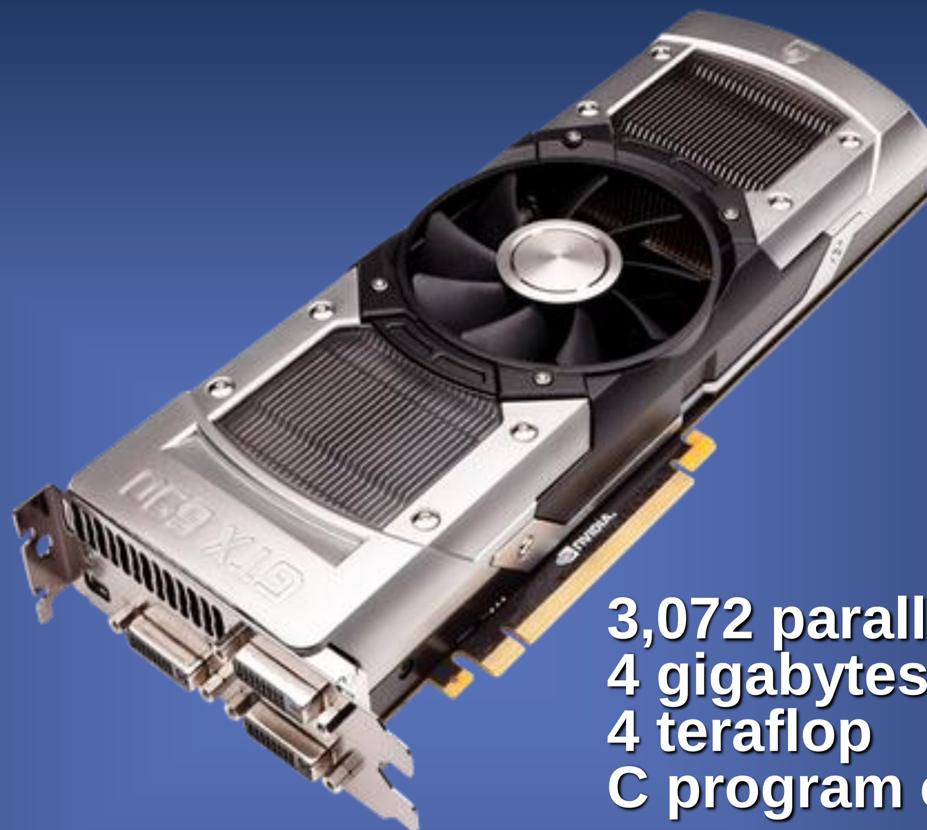
WorldView-2 50cm colour 2010
WorldView-3 30cm colour Aug 2014

High resolution stereo satellites

ASTRIUM Pleiades 1A
June 2012

ASTRIUM Pleiades 1B
February 2013

Graphic Processing Units (GPUs)



3,072 parallel processors
4 gigabytes RAM
4 teraflop
C program compiler

GPUs perform numerical processing up to 1000 times faster than CPUs. This enables us to do the hundreds of millions of 2D Fourier transforms necessary to automatically produce 1m Digital Surface Models from stereo satellite photos in reasonable times.

Testing the accuracy

- Two examples:
  - Comparison to DGPS ground survey points

    45,000 ground points in Eritrea

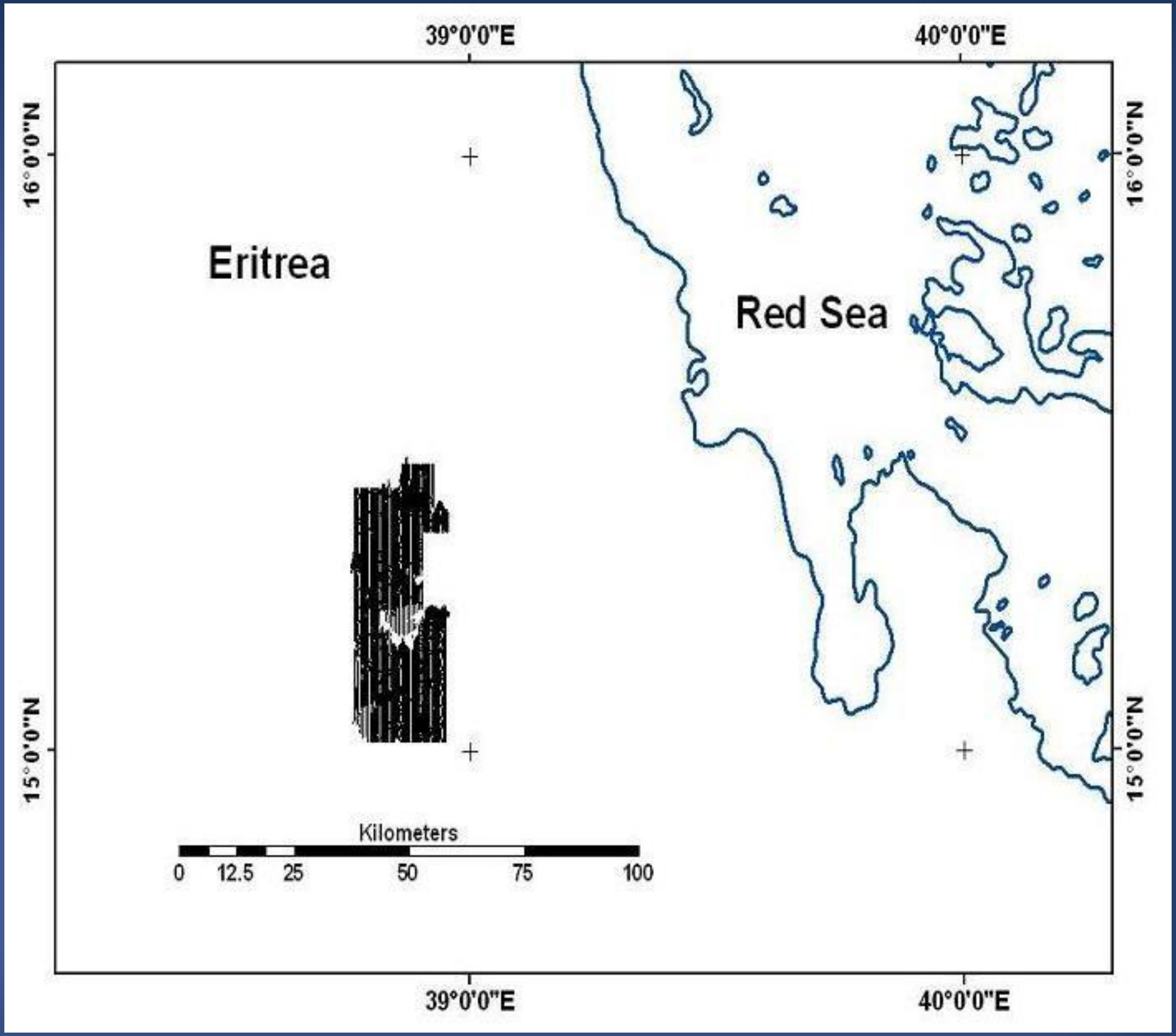
  - Comparison to airborne LiDAR

    Garlock Fault USA – NCALM data

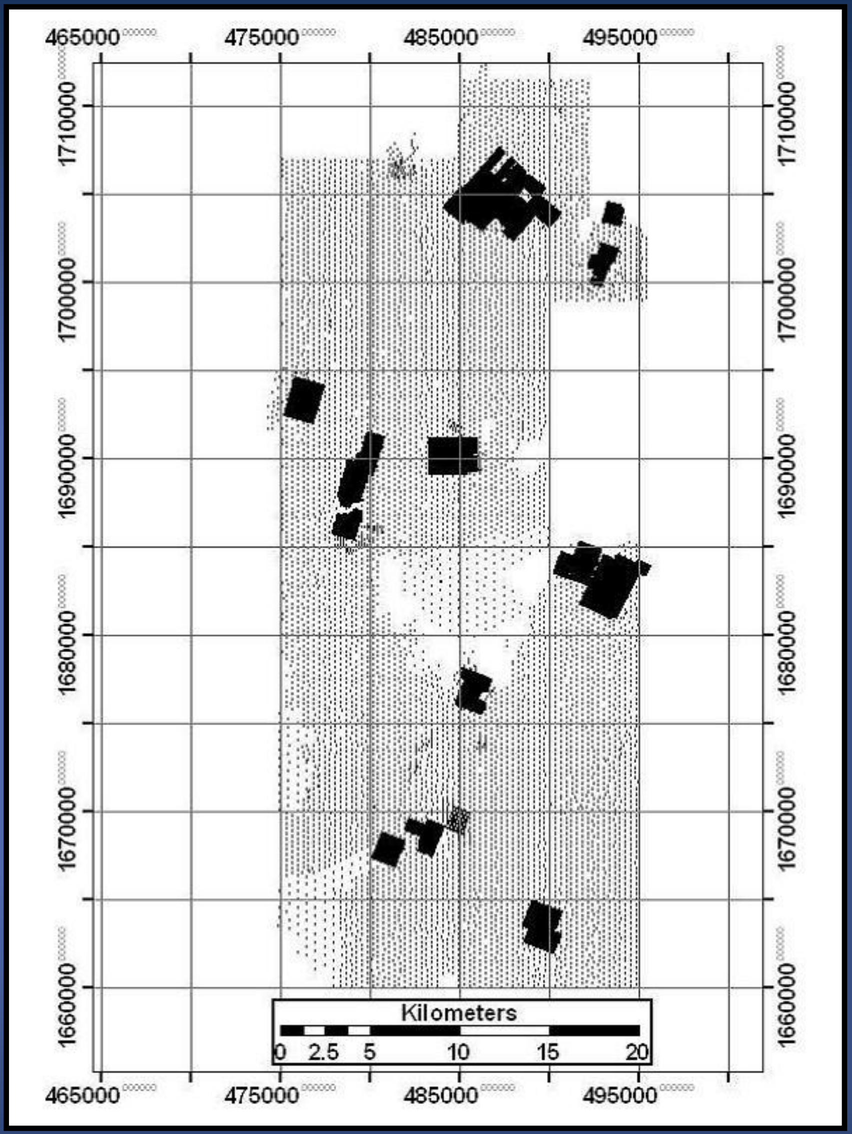
- US National Digital Elevation Program (NDEP)

  Choice of elevation check points

- USGS

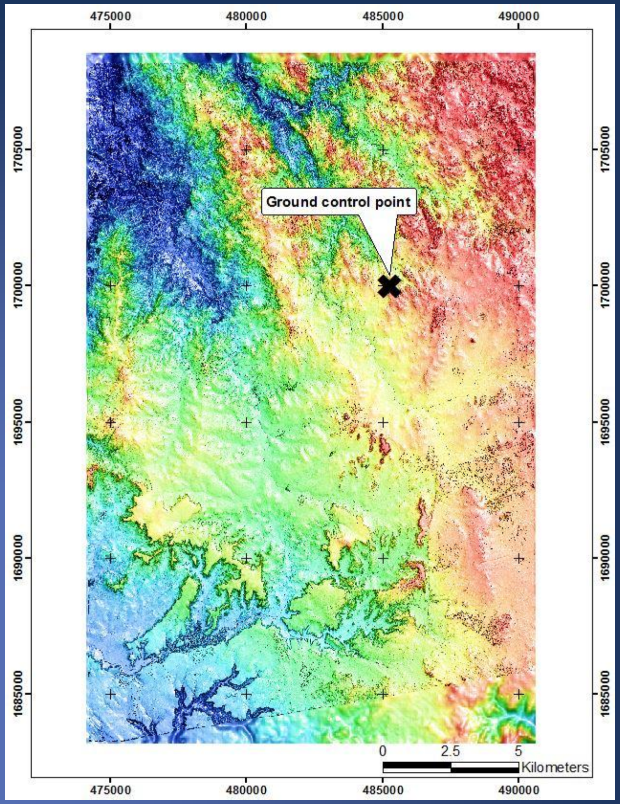


45,000 ground survey points in Asmara, Eritrea provided by Sunridge Gold.



45,000 ground survey points in Asmara, Eritrea provided by Sunridge Gold.

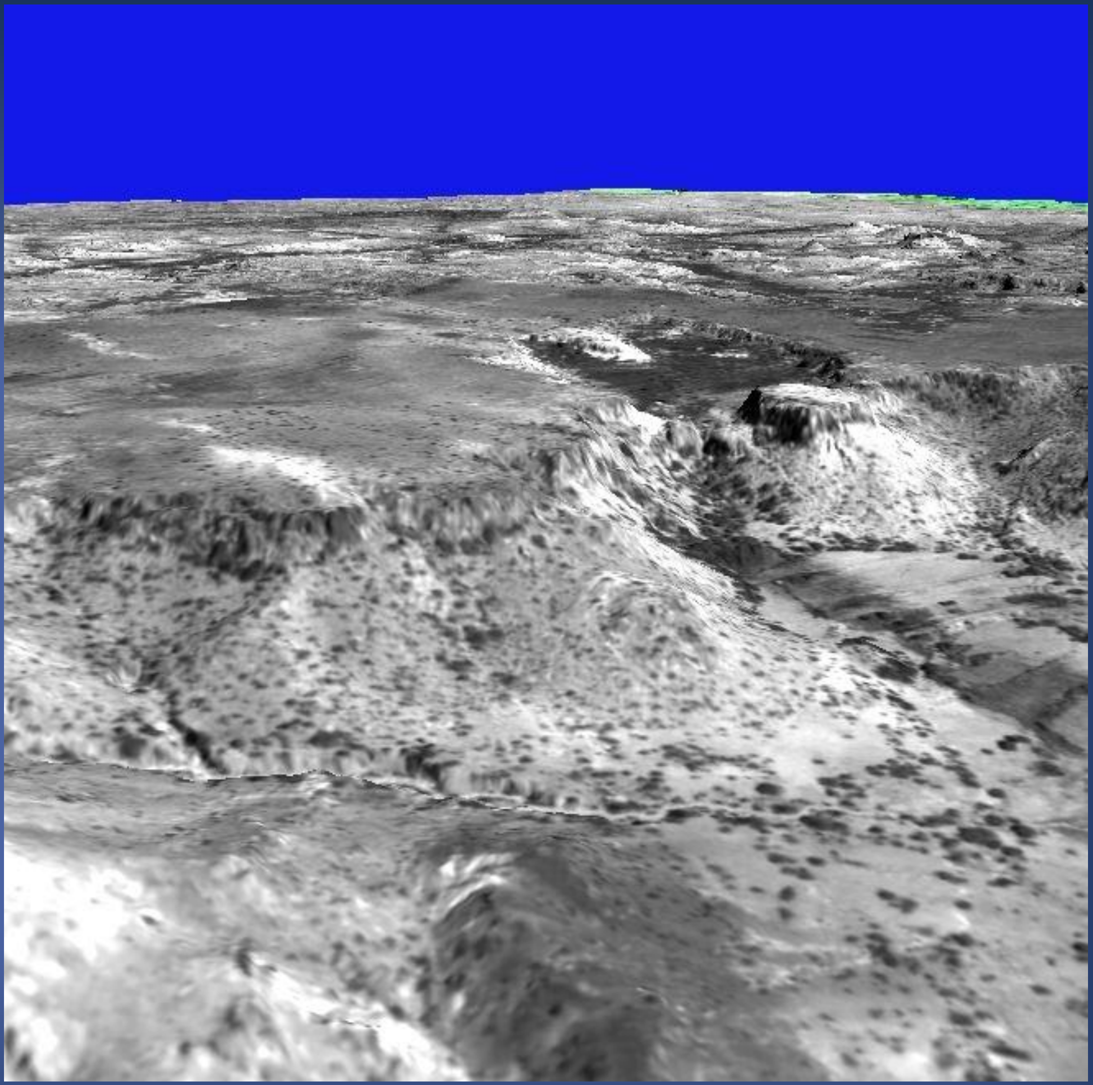
MWH Geophysics Survey Crew.



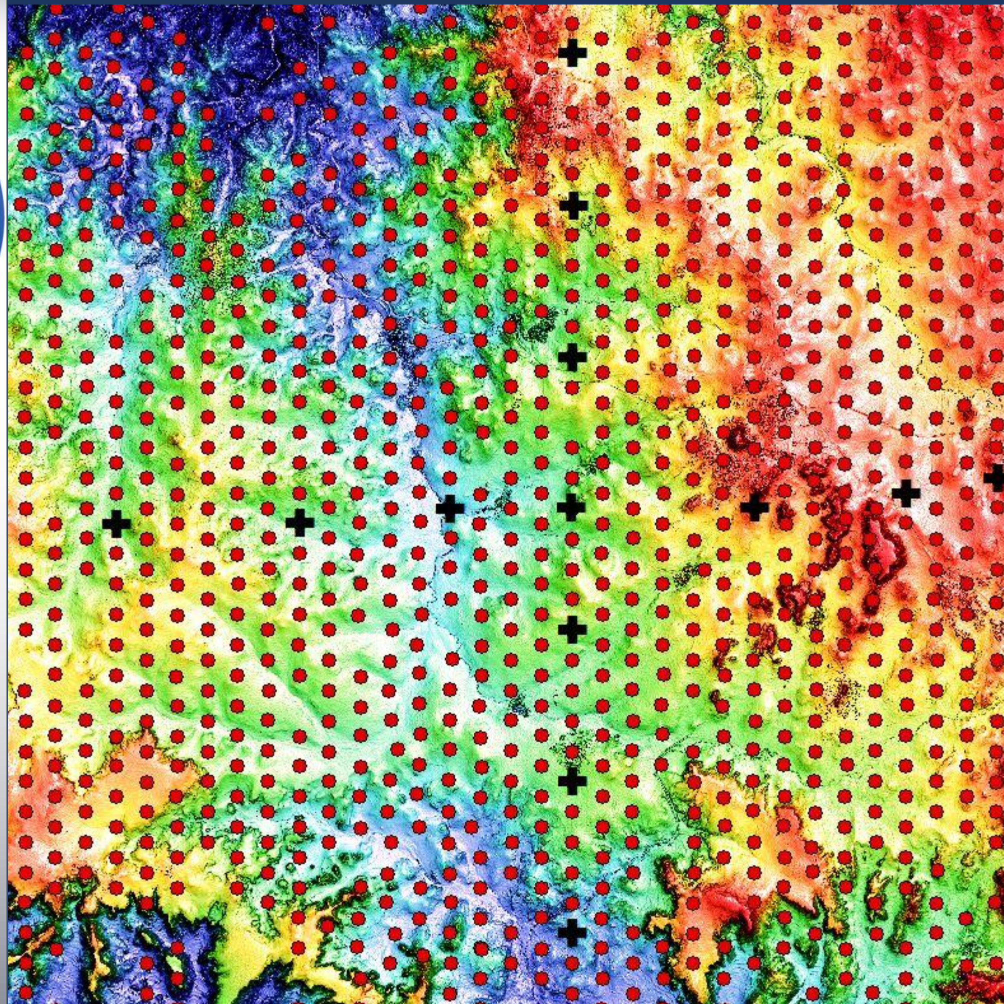
WorldView-2

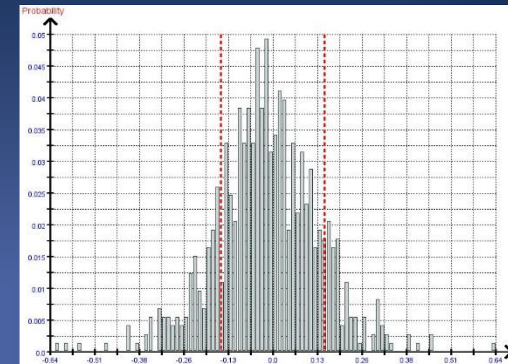
DEM

100 km² Stereo WorldView-2
Asmara, Eritrea, June 2014



3D Ortho view

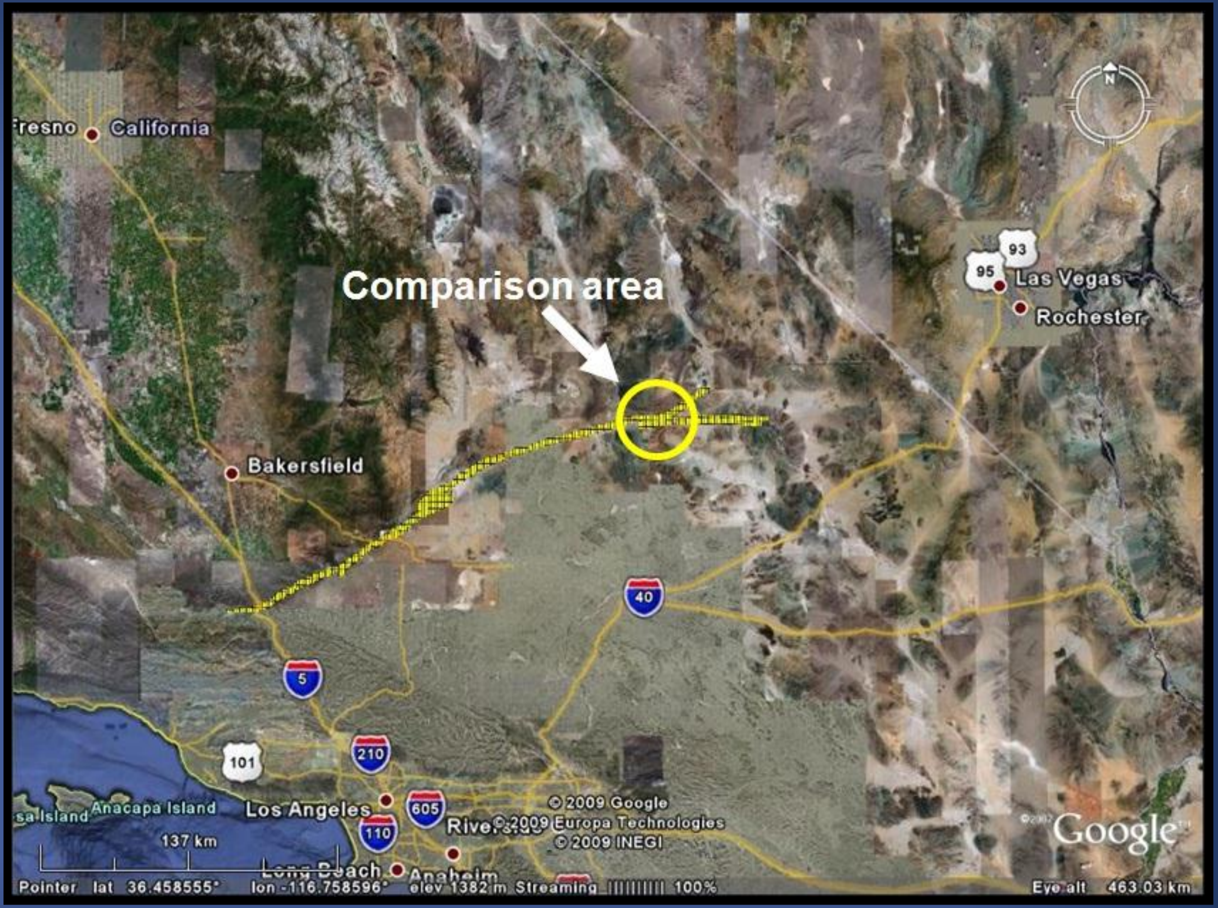




RMSE 15cm

10km x 10km area
14 ground control points
731 check points

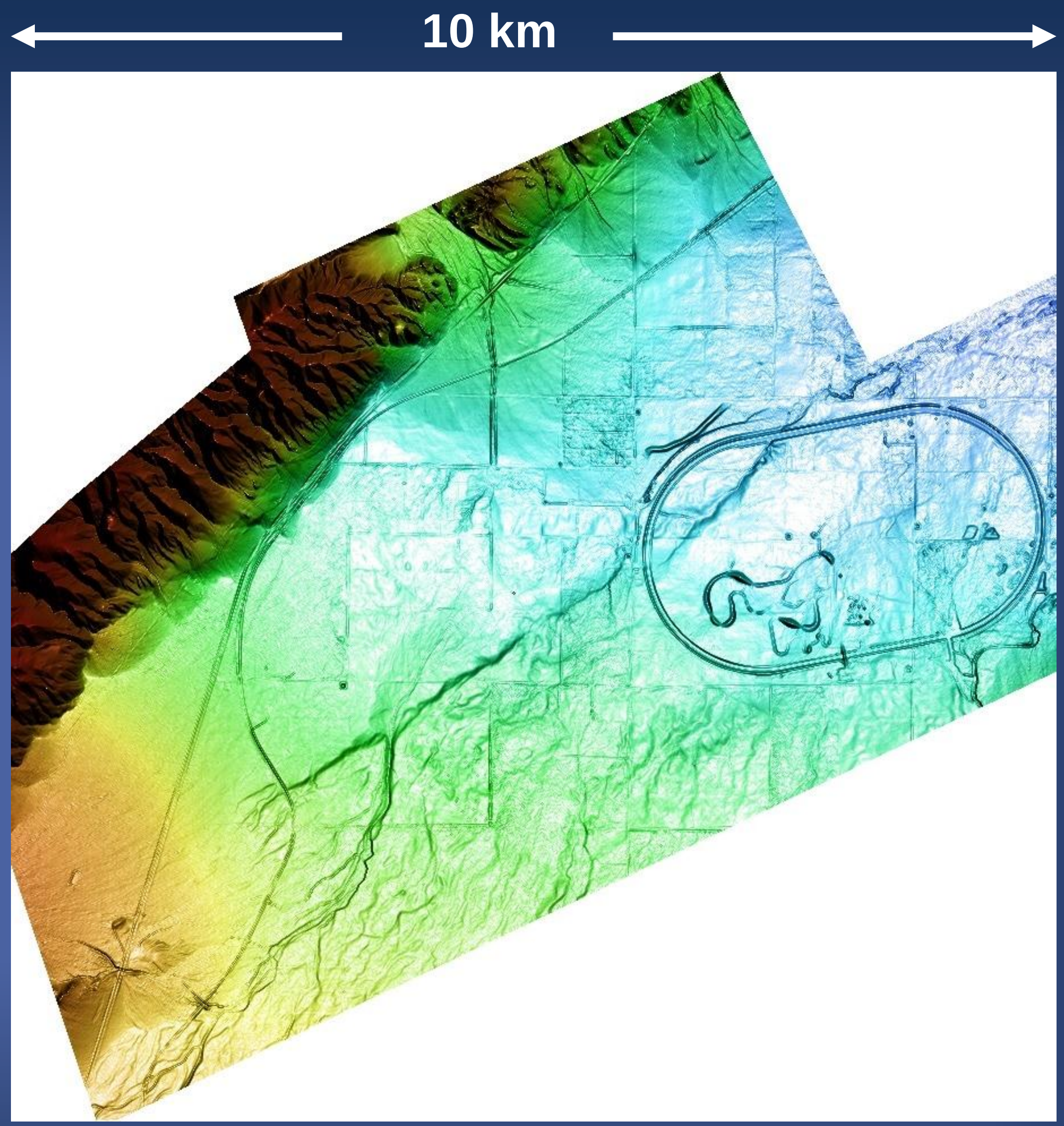
PhotoSat accuracy study



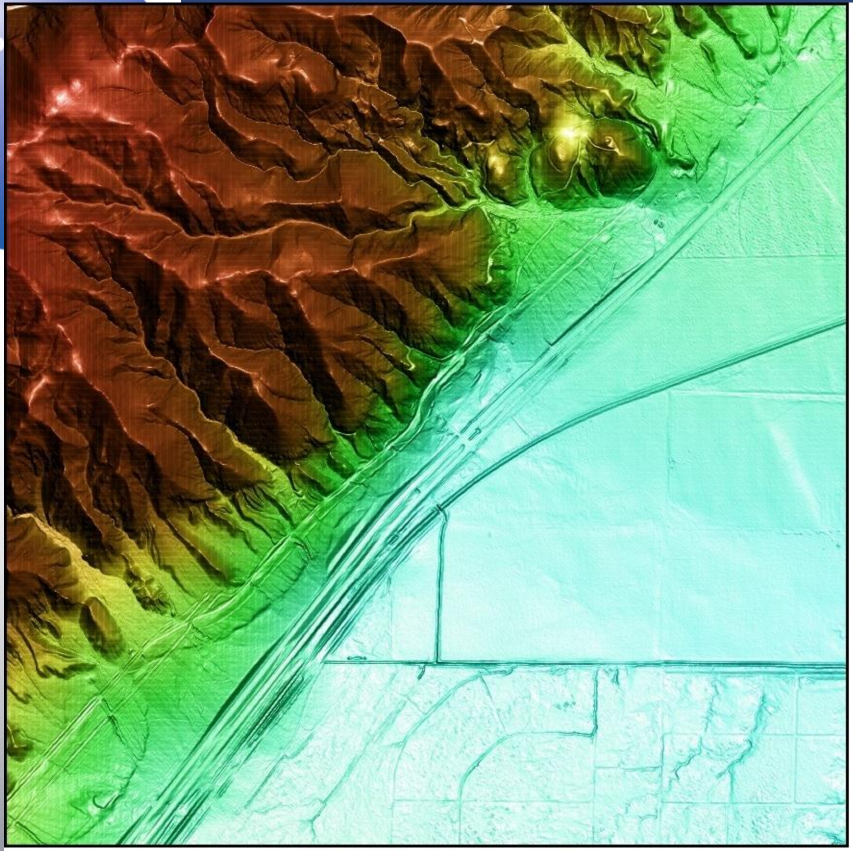
Location area of Open Topography LiDAR DEM.
Garlock Fault, California.

LiDAR mapping from aircraft

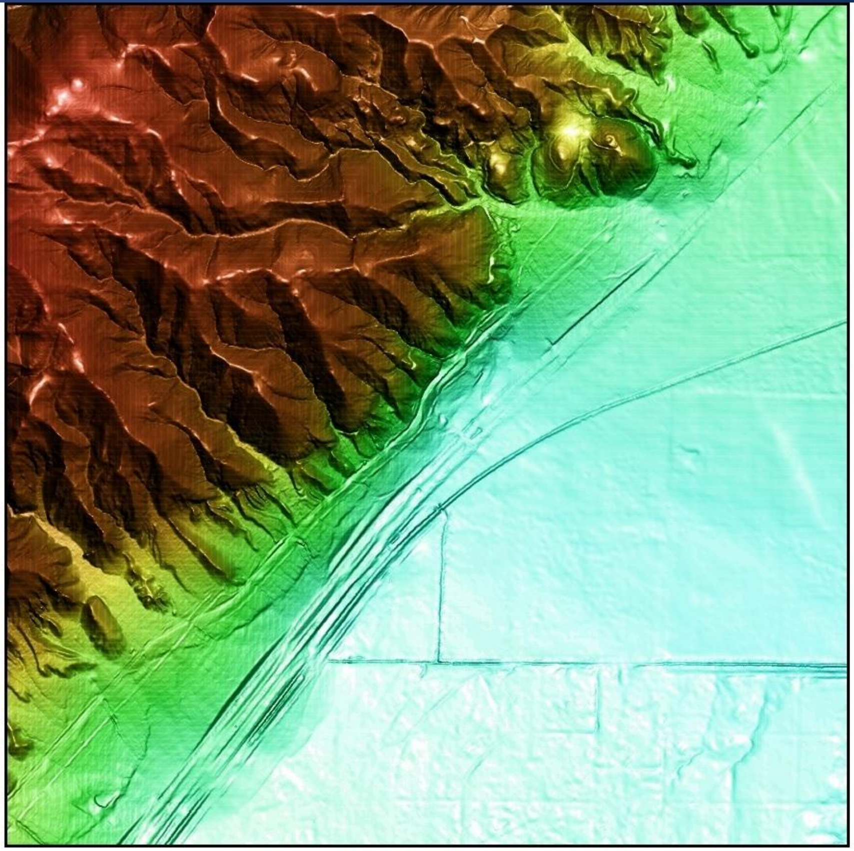
WV 3 stereo satellite photo



Open Topography LiDAR DTM.
5cm accuracy.

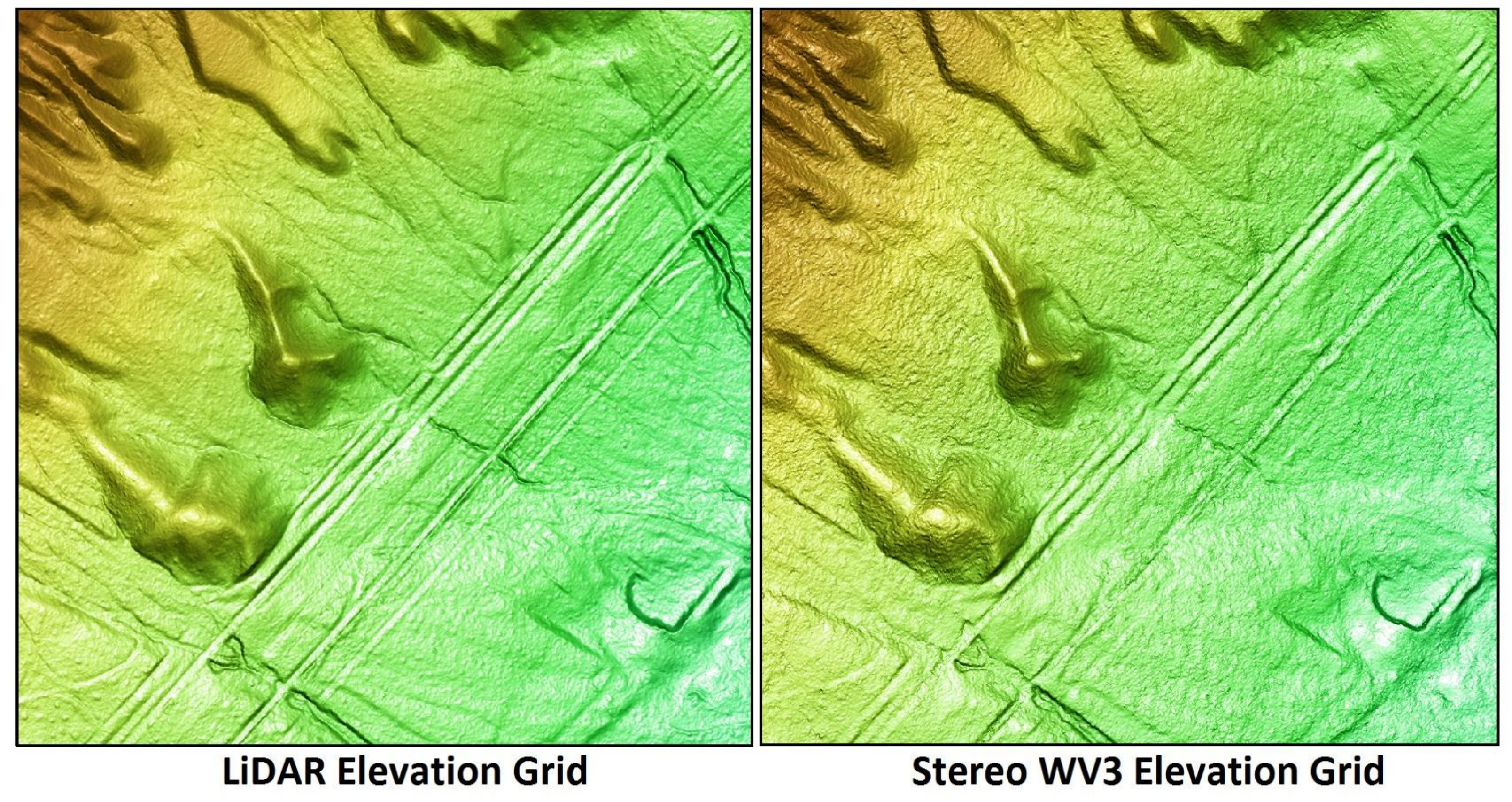


LiDAR Elevation Grid



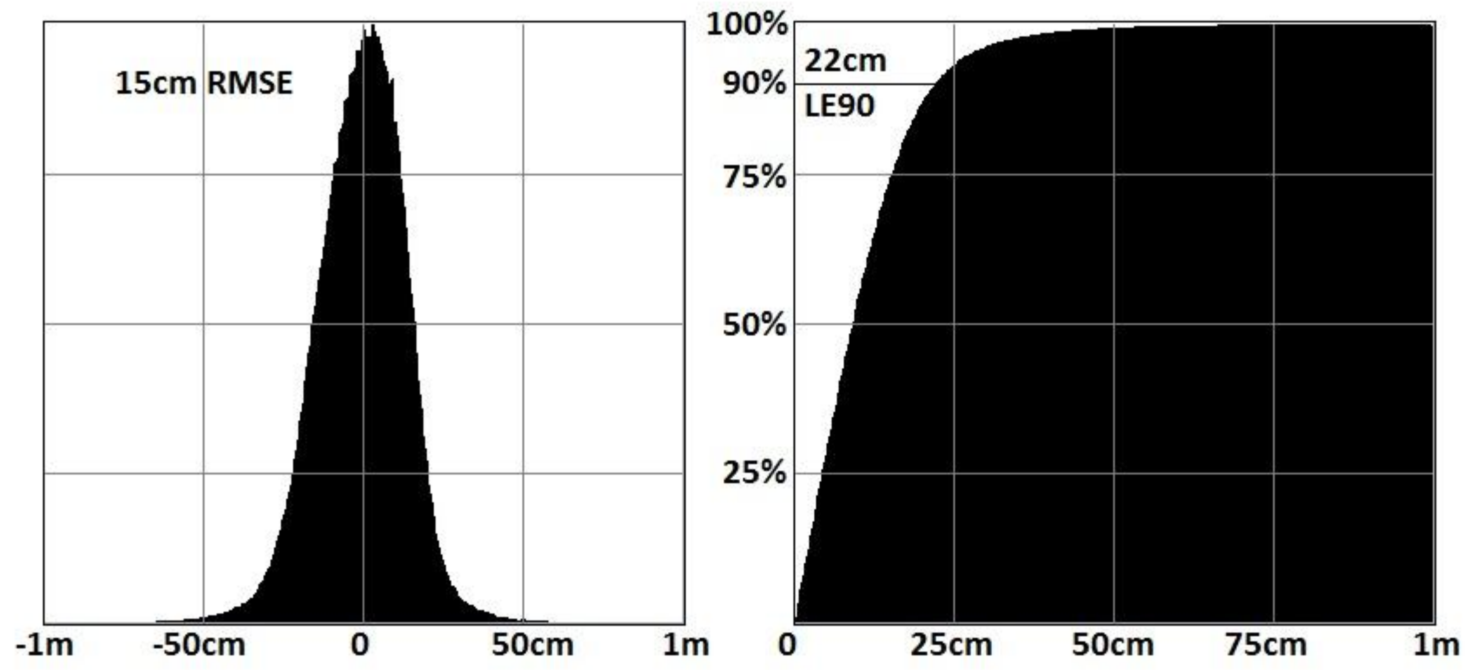
Stereo WV3 Elevation Grid

2.5km width CSH – Lidar vs PhotoSat



500m width CSH – Lidar vs PhotoSat

Garlock Fault, California



Elevation differences between the PhotoSat WV3 and LiDAR topography.

(in unchanged areas and slopes <20% grade)
If we assume that the LiDAR is perfect then the RMS Linear error is less than 22cm

Examples of real world projects

SADG Oil well heads – Alberta

Tobkana block, Kurdistan, Talisman Energy

Reconciling multiple surveys – Oil major – Kurdistan

Drillcollar mapping - Mexico

Pilot Program

SAGD well site in Alberta

Case study – SAGD well site in Alberta

Pilot program for
Producing SAGD well site
In Alberta Canada

Project started Jan 30th 2015

Satellite images acquired
February 4th 2015

Processing complete
February 6th 2015

SAGD well site in Alberta

- Deliverables
  - 100 sq km of satellite image data + orthophoto.
  - Location of 70 well heads (excel + vectors)
  - 1m elevation grid over well pad areas
  - 50 cm contours
  - Colour elevation image
  - $12k USD

- Well head locations compared to Government of Alberta certified RTK surveying – RMSE 11cm.

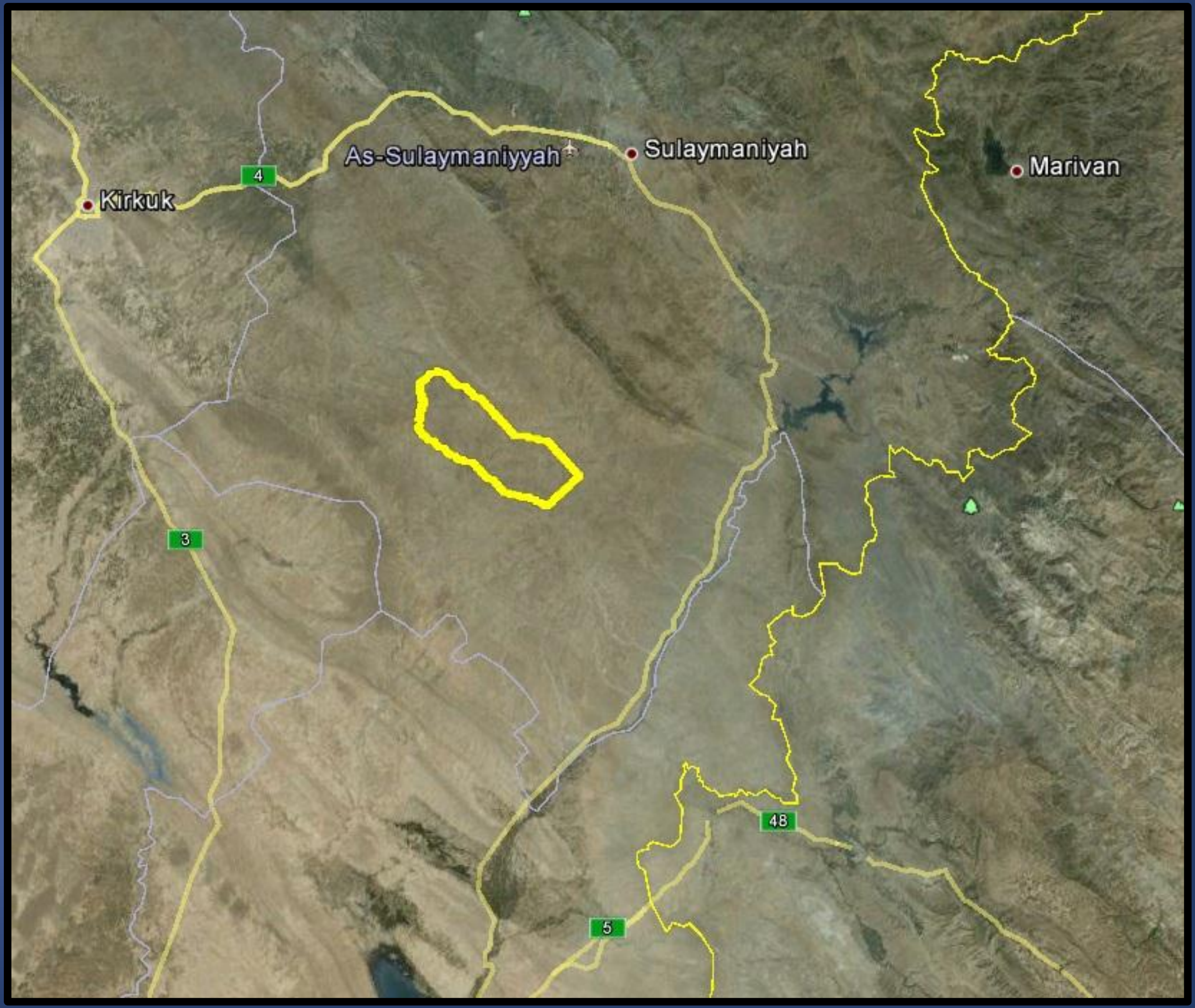
- Future program to compare this to low cost GPS surveying instrument.

Tobkana and Kurdamir Blocks

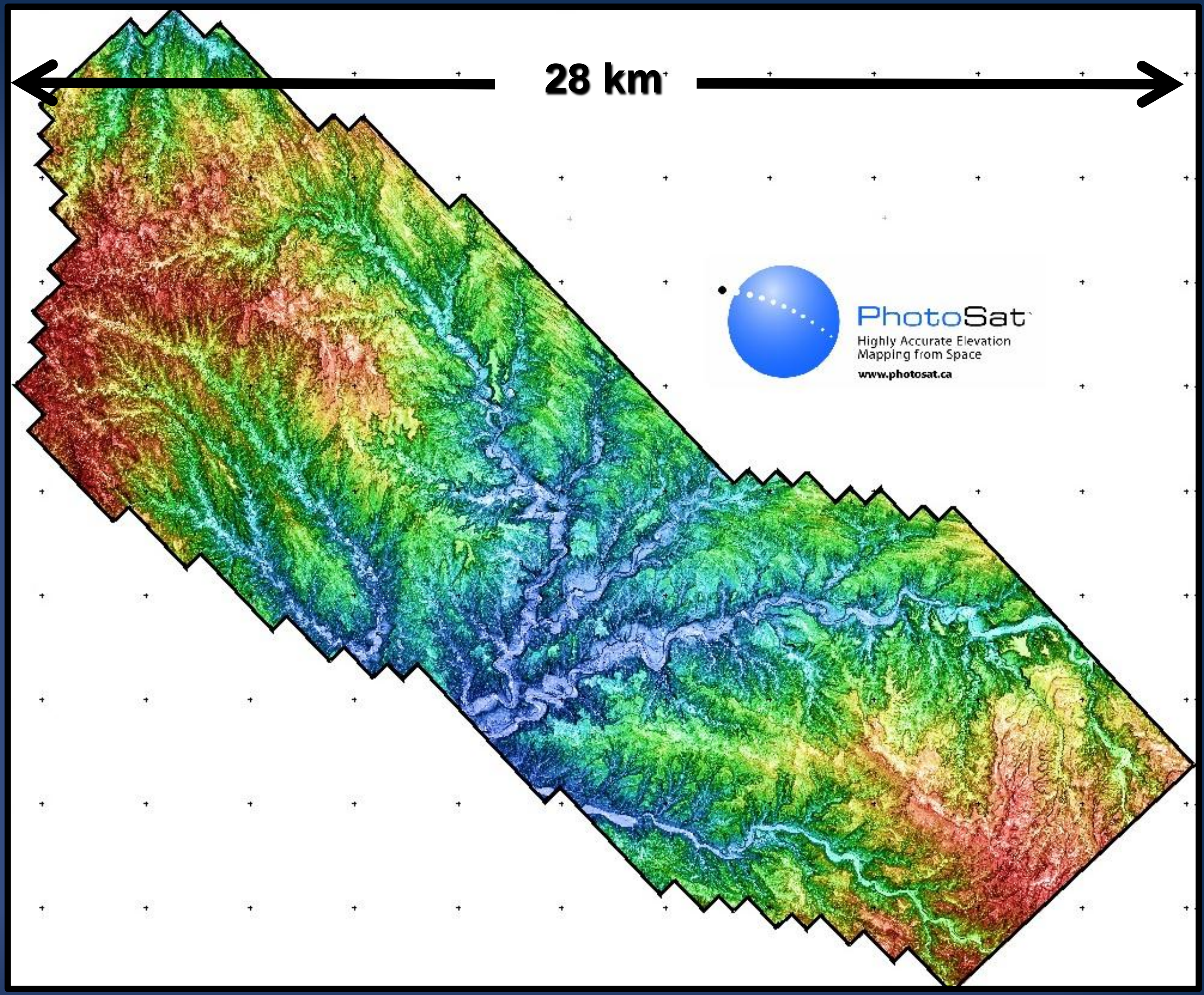
Talisman
Western Zagros

Seismic planning and point correction

Stereo Satellite Topographic Mapping
Tobkhana & Kurdamir Blocks

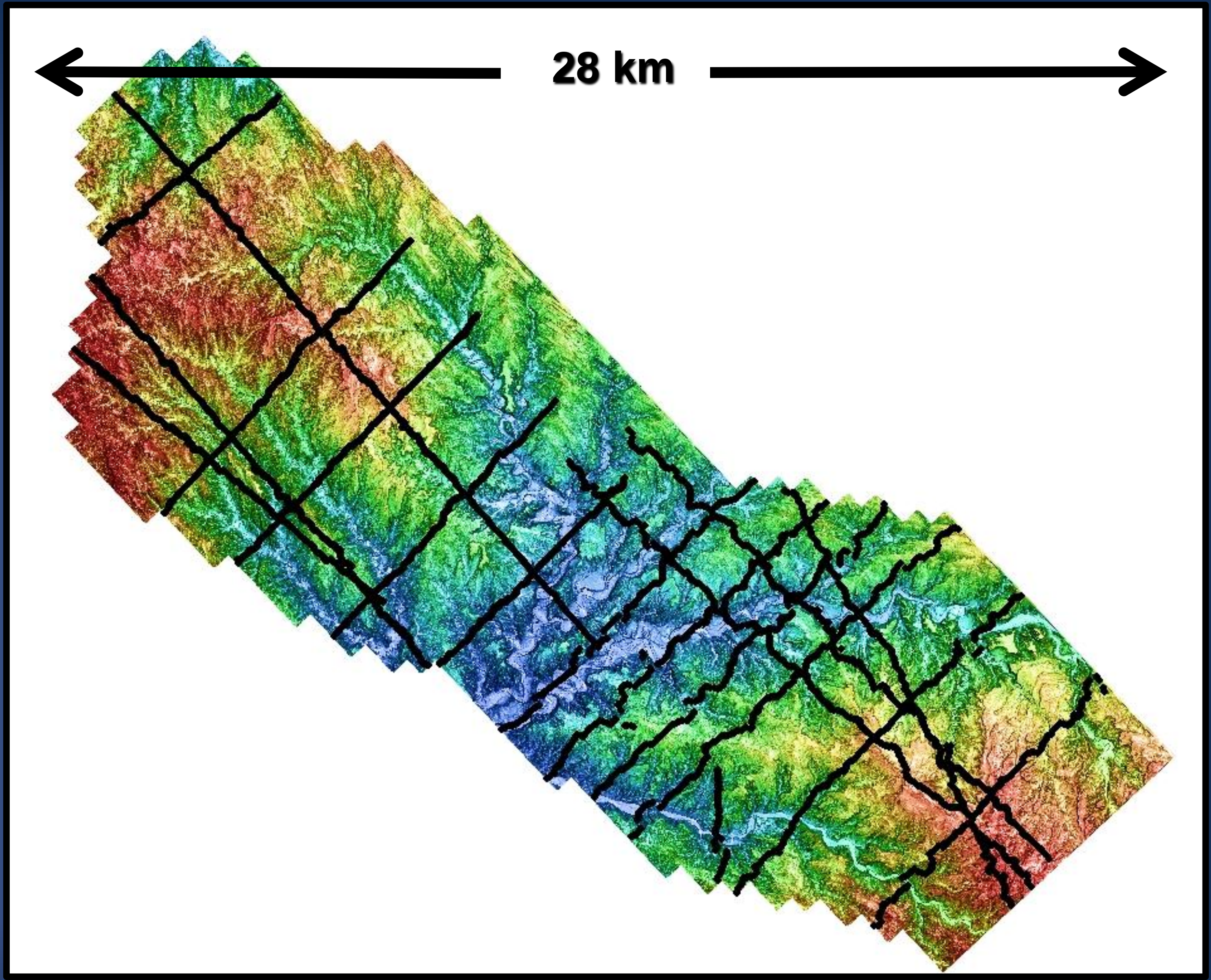


Talisman, WesternZagros

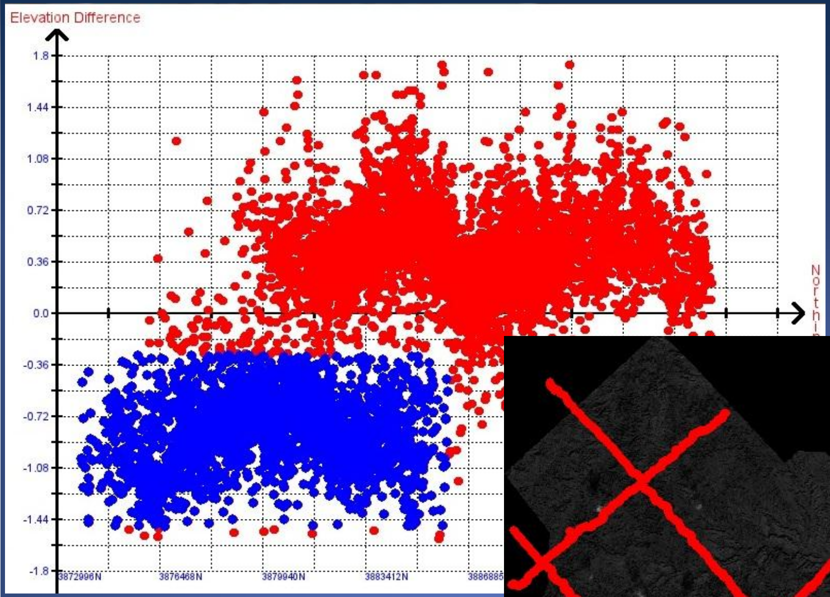


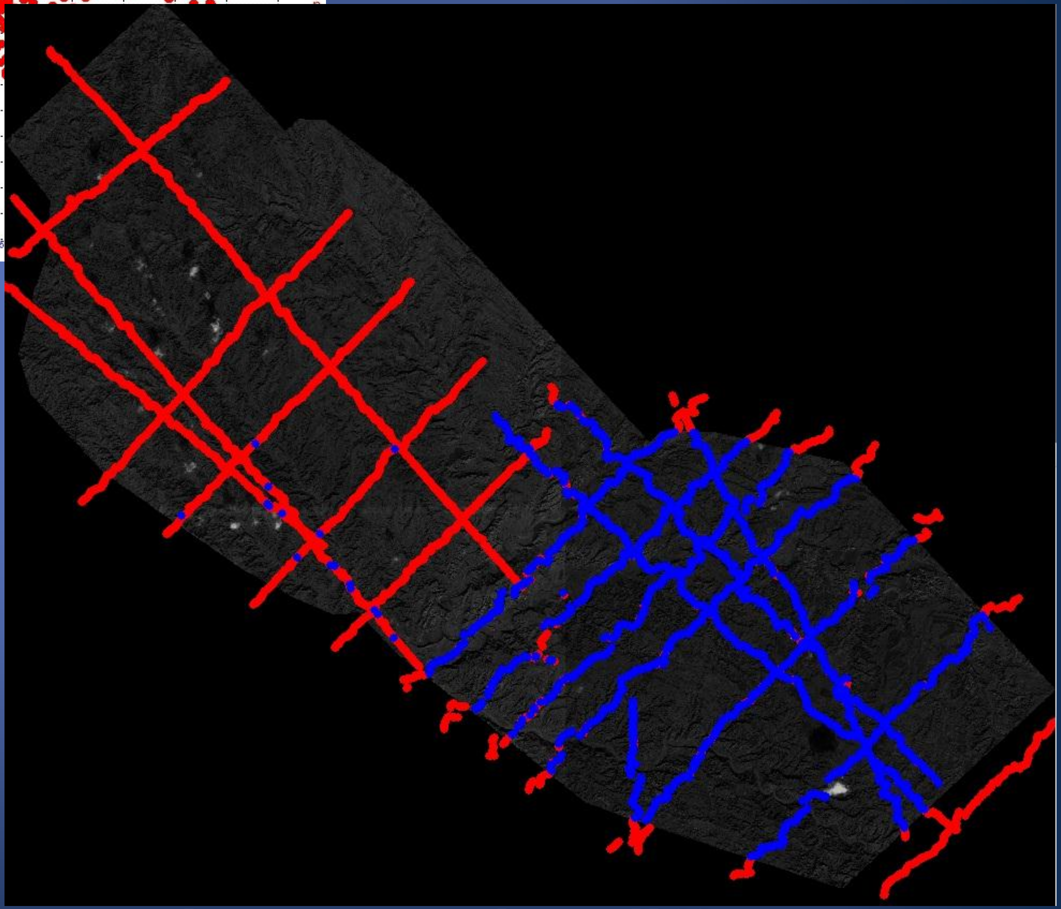
satellite topographic grid

www.photosat.ca

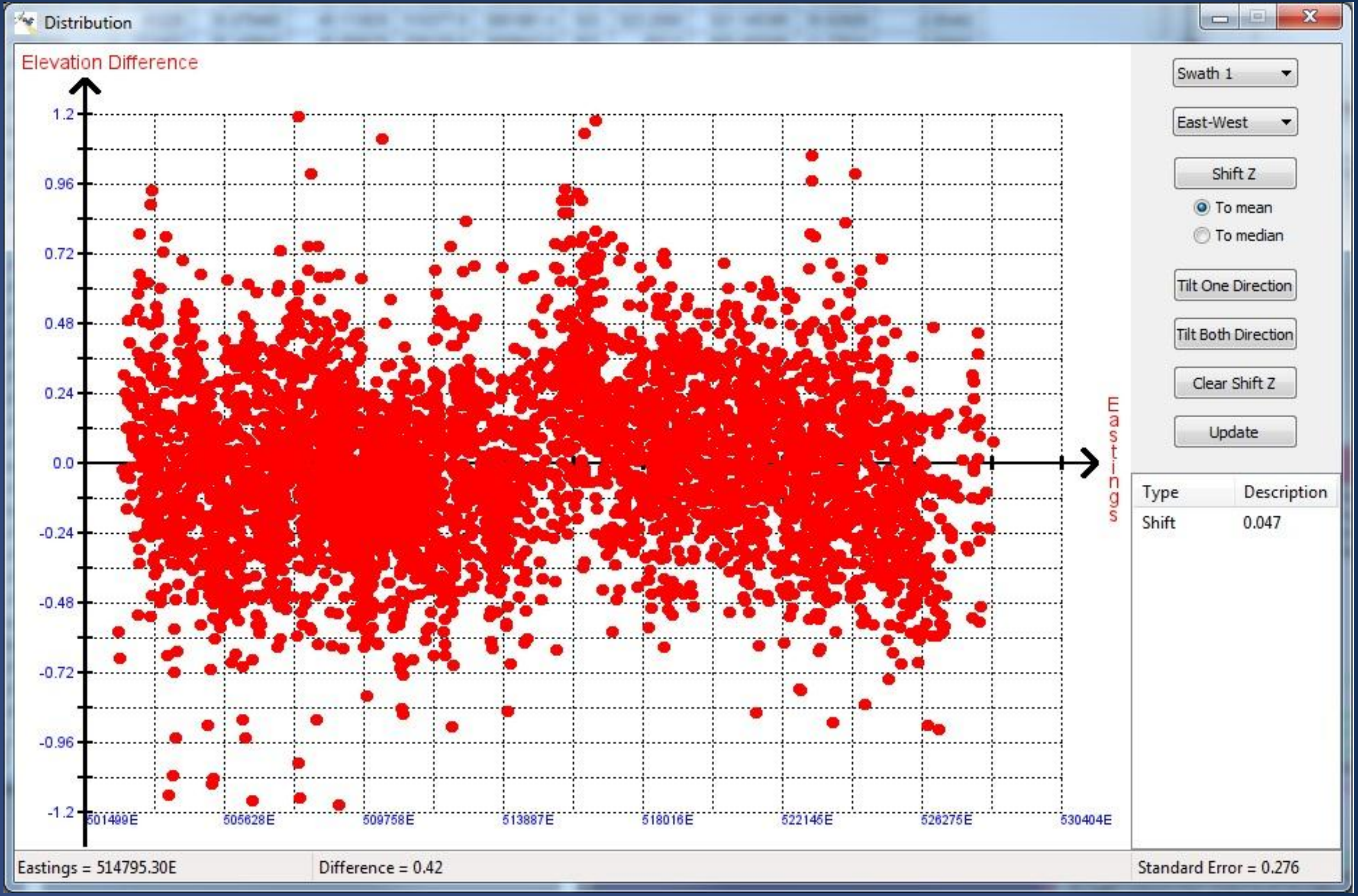


2D seismic source points



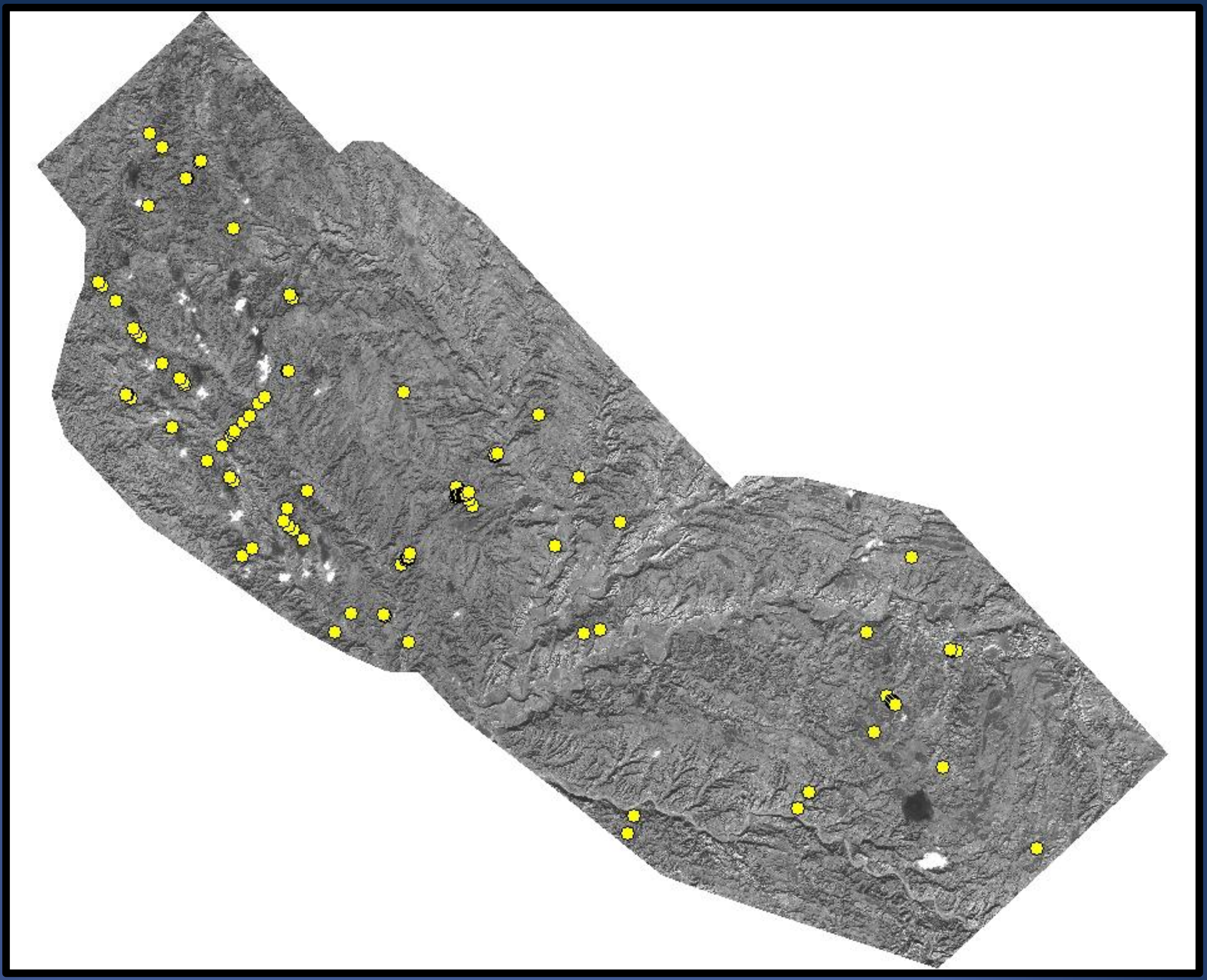


Seismic source points elevation differences to satellite elevations



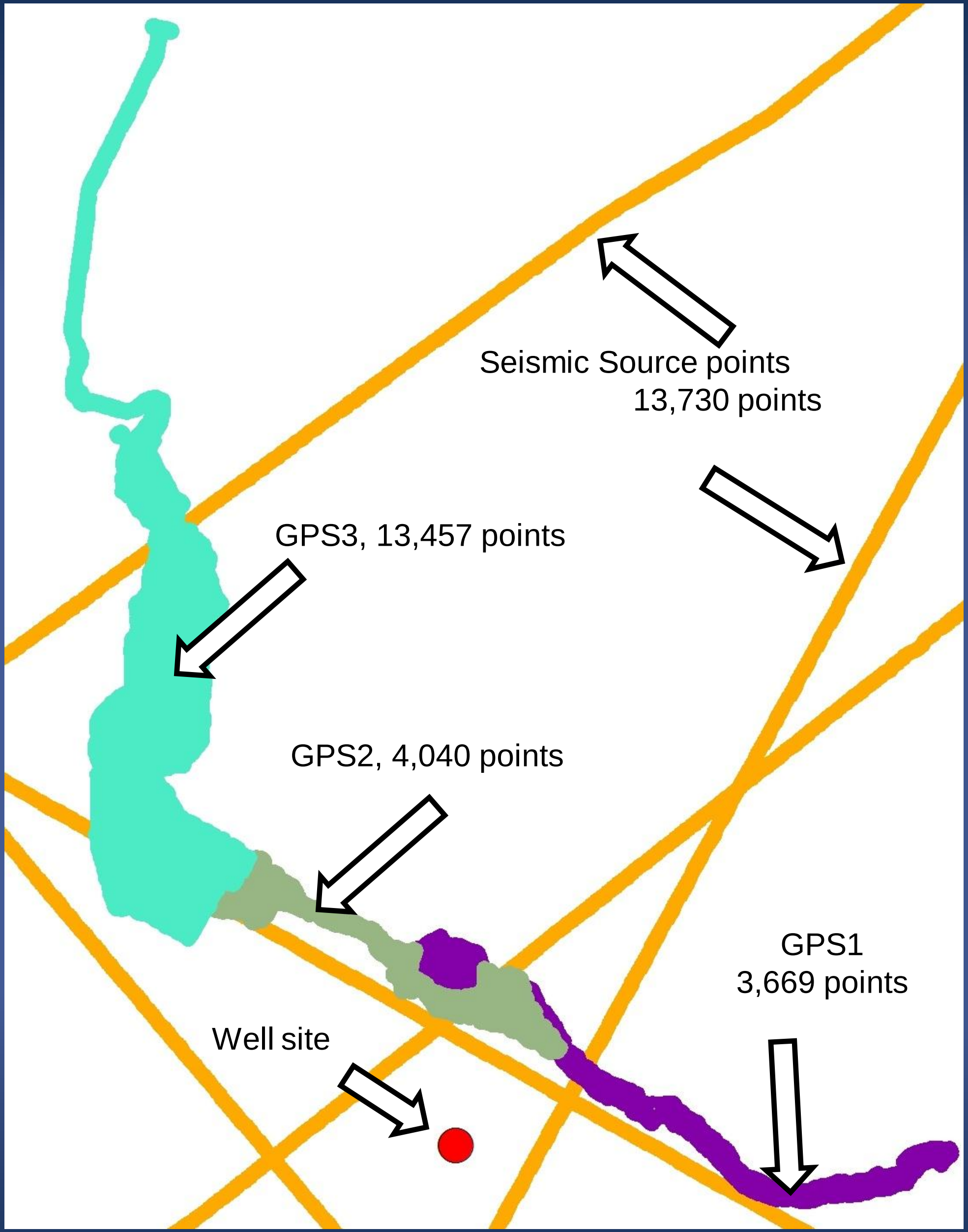
Kurdistan seismic source points differences to satellite elevations, SE points raised 1.3m Standard deviation 28cm.

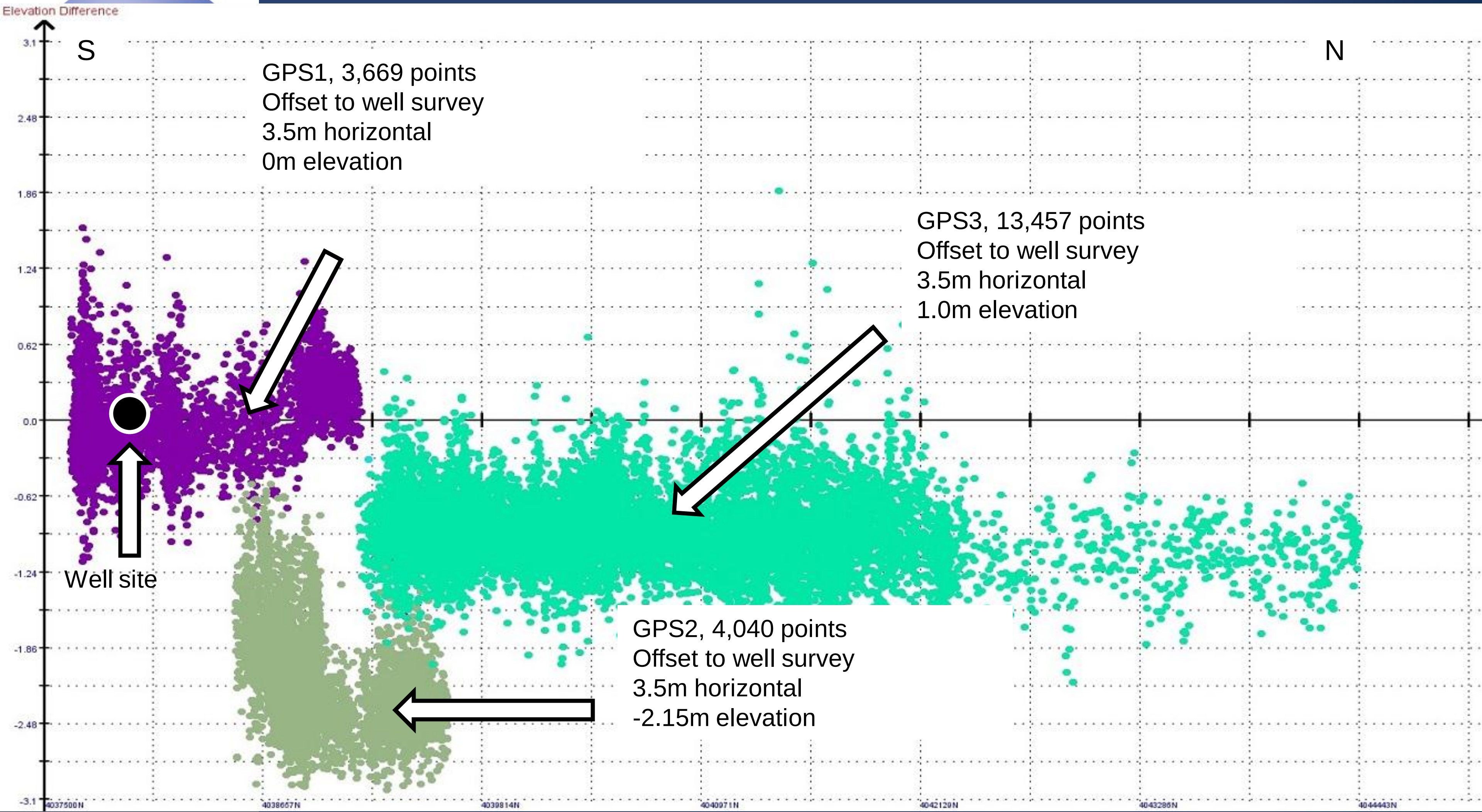
www.photosat.ca

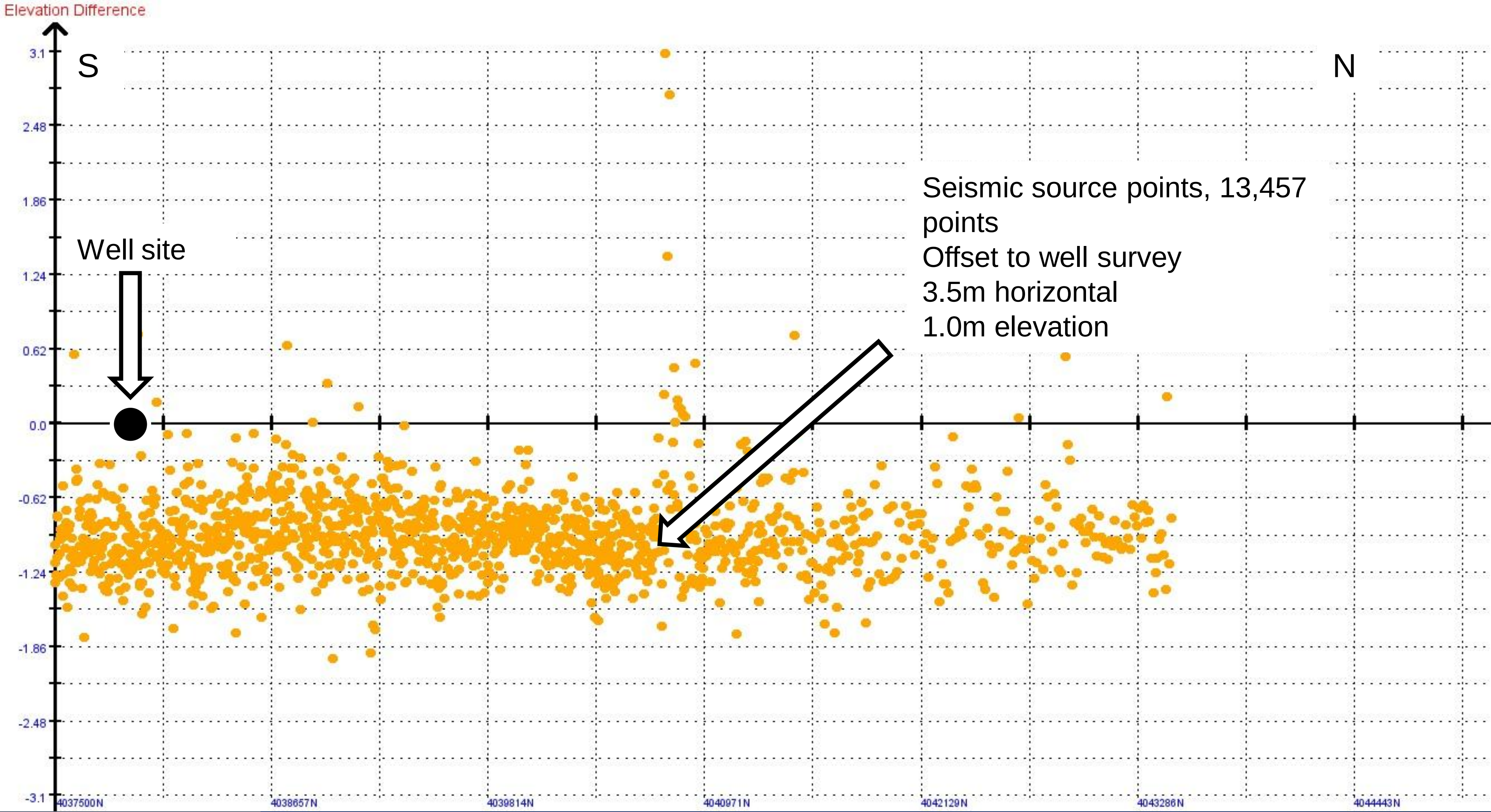


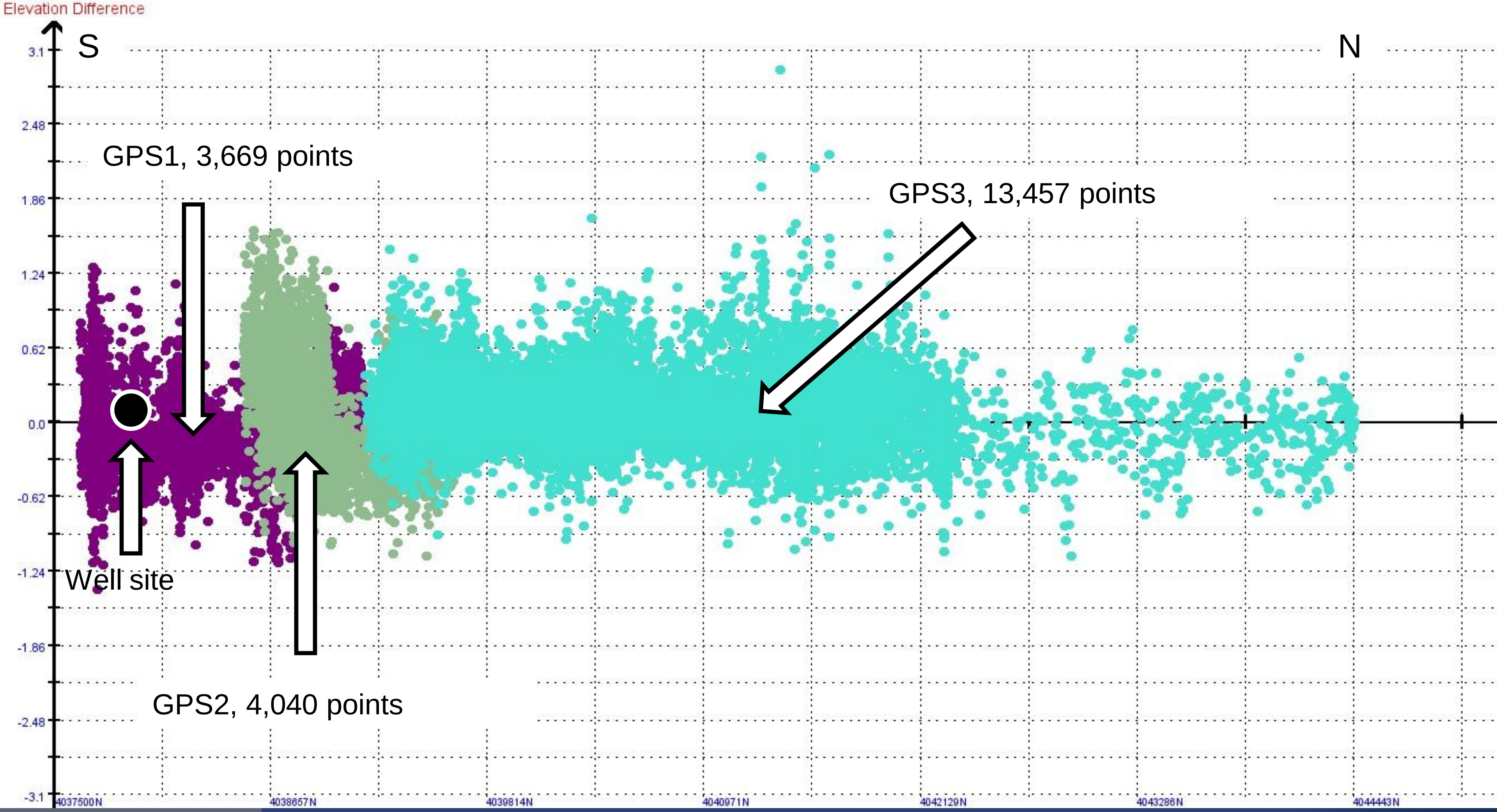
107 seismic source points with greater than 1m elevation difference to satellite elevations. These are probably survey errors due to too few GPS satellites in range. These source point elevations should be replaced by the stereo satellite elevations.

Reconciling multiple data sets


Seismic Source points
13,730 points
GPS3, 13,457 points
GPS2, 4,040 points
GPS1
3,669 points
Well site


Elevation Difference
S
N
GPS1, 3,669 points
Offset to well survey
3.5m horizontal
0m elevation
GPS3, 13,457 points
Offset to well survey
3.5m horizontal
1.0m elevation
GPS2, 4,040 points
Offset to well survey
3.5m horizontal
-2.15m elevation
Well site
3.1
2.48
1.86
1.24
0.62
0.0
-0.62
-1.24
-1.86
-2.48
-3.1
4037500N
4038657N
4039814N
4040971N
4042129N
4043286N
4044443N


Elevation Difference
3.1
2.48
1.86
1.24
0.62
0.0
-0.62
-1.24
-1.86
-2.48
-3.1
S
N
Well site
Seismic source points, 13,457 points
Offset to well survey
3.5m horizontal
1.0m elevation
4037500N
4038657N
4039814N
4040971N
4042129N
4043286N
4044443N


Elevation Difference
S
N
3.1
2.48
1.86
1.24
0.62
0.0
-0.62
-1.24
-1.86
-2.48
-3.1
GPS1, 3,669 points
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Well site
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4037500N
4038657N
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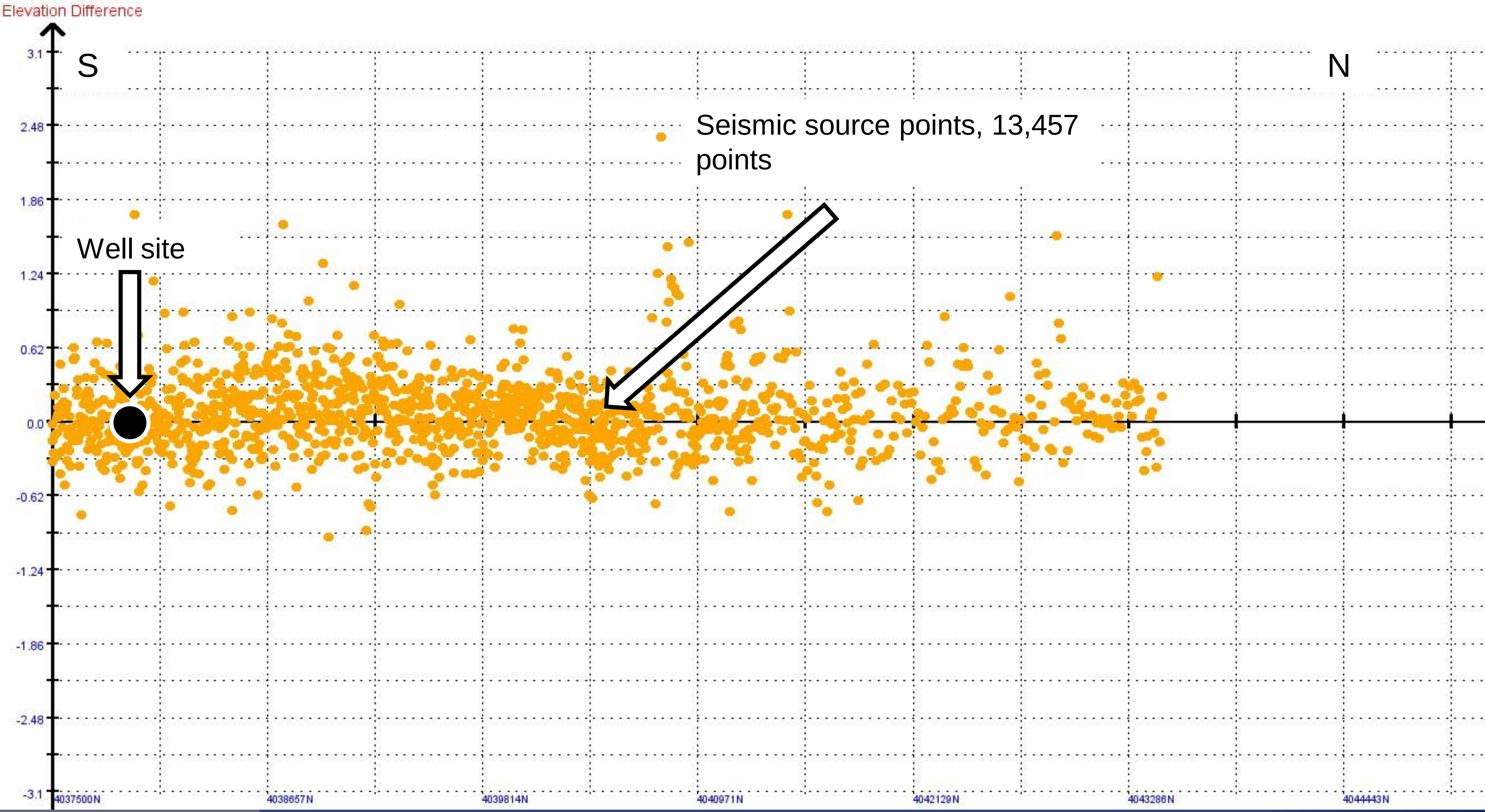
4040971N
4042129N
4043286N
4044443N


Elevation Difference
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3.1
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0.0
-0.62
-1.24
-1.86
-2.48
-3.1
4037500N
4038657N
4039814N
4040971N
4042129N
4043286N
4044443N

Assessing the impact of Surveying delays on Oil and Gas projects

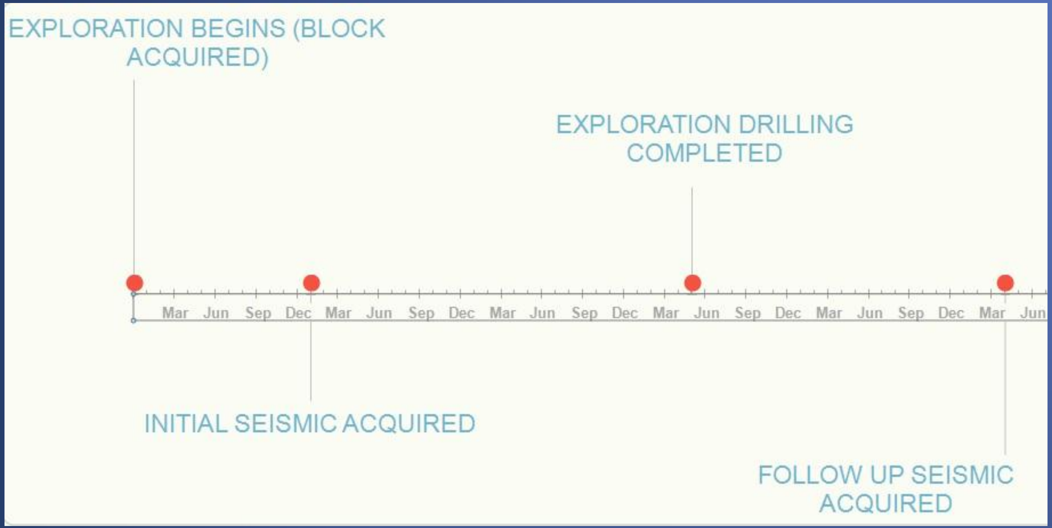
Most engineers agree that having accurate topographic survey data early in an Oil and Gas project reduces delays through-out the project.

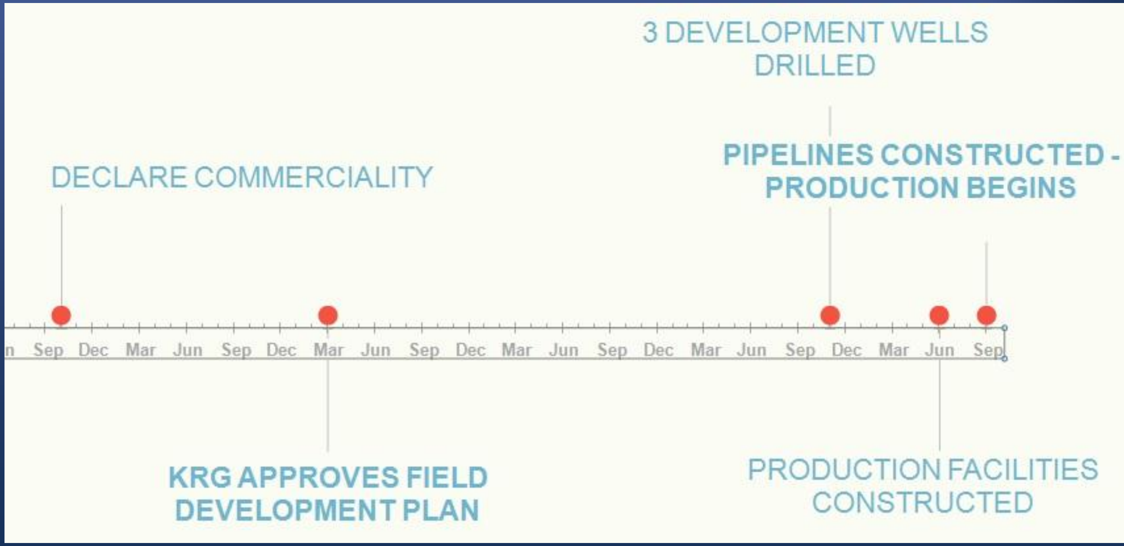
Despite this most projects commission multiple surveys with increasing levels of accuracy through-out the project life.

PhotoSat has commissioned the development of a critical path model of a typical Oil and Gas project with the objective of quantifying delays caused by the "multiple survey" approach.

This model was calibrated using actual client data for projects in Kurdistan.

Timeline for Kurdistan onshore Oil and Gas project





Detailed model

Program Evaluation and Review: Kurdistan Oil and Gas Project

Time = Months

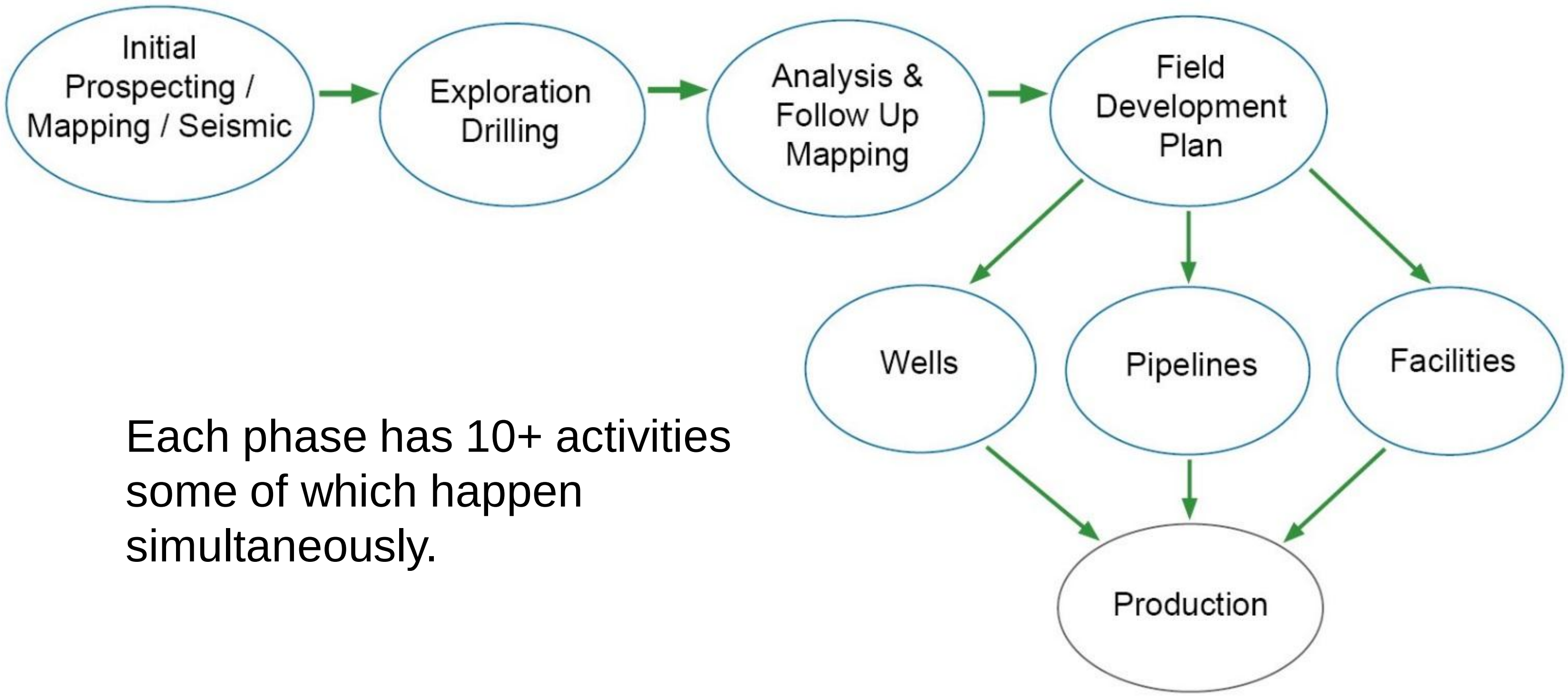
Activity	Description	Minimum Immediate Precedent Required	Quality Improvement Precedent Opportunity	Optimistic Time	Most Likely Time	Pessimistic Time	Expected Time	Variance	Std. Dev	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	Mean	Std Dev
				Without Improvement Step												
A	Acquire Block	-		1	2	4	2.167	0.25	0.50	0	2	0	2	0	2.2	0.5
B	Tender De-Mining and Surveying for Seismic Area	A		1	2	4	2.167	0.25	0.50	2	4	2	4	0	2.2	0.5
C	De-Mine Seismic Area	B		1	2	3	2.000	0.11	0.33	4	6	4	6	0	2.0	0.4
D	Survey Seismic Area for Acquisition	C		0.5	1	2	1.083	0.06	0.25	6	7	6	7	0	1.1	0.3
E	Tender Seismic Acquisition	A	D	2	4	6	4.000	0.44	0.67	2	6	3	7	1	4.0	0.7
F	Acquire Seismic Data	D,E		2	3	6	3.333	0.44	0.67	7	10	7	10	0	3.3	0.7
G	Tender Seismic Processing	A	F	1	3	6	3.167	0.69	0.83	2	5	7	10	5	3.2	0.8
H	Process Seismic Data	F,G		1	2	3	2.000	0.11	0.33	10	12	10	12	0	2.0	0.3
I	Scout Exploration Well Location(s) (May Require De-Mining)	H		3	5	7	5.000	0.44	0.67	12	17	12	17	0	5.0	0.7
J	Conduct Environmental Assessment of Lease(s) (May Require De-Mining)	I		1	2	3	2.000	0.11	0.33	17	19	18	20	1	2.0	0.3
K	Conduct Public Consulttation for Lease Approval(s)	I		2	3	12	4.333	2.78	1.67	17	20	17	20	0	4.3	1.7
L	Tender De-Mining and Surveying for Driling	I		1	2	4	2.167	0.25	0.50	17	19	18	20	1	2.2	0.5
M	De-Mine Lease(s) and Access Road(s)	J,K,L		1	2	3	2.000	0.11	0.33	20	22	20	22	0	2.0	0.3
N	Survey Lease(s) and Access Road(s)	M		0.5	1	2	1.083	0.06	0.25	22	23	22	23	0	1.1	0.2
O	Tender Lease and Access Construction Contract(s)	J,K	N	2	3	6	3.333	0.44	0.67	20	23	20	23	0	3.4	0.7
P	Construct Lease(s) and Access Road(s)	N,O		4	6	8	6.000	0.44	0.67	23	29	23	29	0	6.0	0.7
Q	Tender Drilling & Completion Contract	J,K	N	2	4	6	4.000	0.44	0.67	20	24	25	29	5	4.0	0.6
R	Drill & Complete 3 Exploration Wells	P,Q		6	9	12	9.000	1.00	1.00	29	38	29	38	0	9.0	1.0
S	Analyze Results and Plan Follow Up Seismic	R		4	8	12	8.000	1.78	1.33	38	46	38	46	0	8.0	1.4
T	Tender De-Mining and Surveying for Seismic	S		1	2	4	2.167	0.25	0.50	46	48	46	48	0	2.2	0.5
U	De-Mine Seismic Area	T		2	3	4	3.000	0.11	0.33	48	51	48	51	0	3.0	0.3
V	Survey Seismic Area	U		1	2	4	2.167	0.25	0.50	51	53	51	53	0	2.1	0.5
W	Tender Seismic Data Acquisition	S	V	1	3	6	3.167	0.69	0.83	46	49	50	53	4	3.2	0.9
X	Acquire Seismic Data	V,W		2	4	8	4.333	1.00	1.00	53	57	53	57	0	4.3	1.0
Y	Tender Seismic Processing	S	X	1	3	6	3.167	0.69	0.83	46	49	54	57	8	3.1	0.8
Z	Process Seismic Data	X,Y		2	3	4	3.000	0.11	0.33	57	60	57	60	0	3.0	0.3
AA	Analyze Results and Declare Commerciality	Z		4	6	12	6.667	1.78	1.33	60	66	60	66	0	6.6	1.3
AB	Scout Development Well and Facilty Locations (May Required De-Mining)	AA		3	6	12	6.500	2.25	1.50	66	72	66	72	0	6.6	1.5
AC	Public Consultation of Well and Facility Locations	AB		4	6	12	6.667	1.78	1.33	72	78	72	78	0	6.7	1.3
AD	Environmental Assessment of Well and Facility Locations	AB		2	3	4	3.000	0.11	0.33	72	75	75	78	3	3.0	0.3
AE	Field Development Plan Approval by KRG	AA,AC,AD		1	3	6	3.167	0.69	0.83	78	81	78	81	0	3.2	0.9
AF	Tender Contracts for De-Mining and Surveying for Development Drilling	AE		2	4	6	4.000	0.44	0.67	81	85	90	94	9	4.0	0.7
AG	De-Mine Drilling Leases and Access Roads	AF		4	8	12	8.000	1.78	1.33	85	93	94	102	9	8.0	1.3
AH	Survey Drilling Leases and Access Roads	AG		2	4	6	4.000	0.44	0.67	93	97	102	106	9	4.0	0.7
AI	Tender Contracts for Lease and Access Construction	AE	AH	2	4	6	4.000	0.44	0.67	81	85	102	106	21	4.0	0.7
AJ	Construct Drilling Leases and Access Roads	AH,AI		4	8	12	8.000	1.78	1.33	97	105	106	114	9	8.0	1.4
AK	Tender Contract for Drilling & Completion	AE	AH	4	6	8	6.000	0.44	0.67	81	87	108	114	27	6.0	0.7

Activity	A	B	C	D	E	F	G	H	I	J	K	L	M
Mean	##	##	##	1.1	##	##	##	##	##	##	4.3	##	##
Std Dev	##	##	##	##	##	##	##	##	##	##	1.7	##	##
1	2.8	2.3	1.8	1.0	4.8	4.0	3.3	1.7	4.8	2.3	3.8	1.9	2.3
2	0.8	2.3	2.4	1.2	2.9	4.6	3.0	2.3	6.1	1.6	3.4	2.7	1.9
3	1.6	2.2	2.4	0.4	4.2	3.7	3.0	2.4	4.0	1.4	2.1	2.1	2.5
4	1.9	2.3	2.3	0.9	3.8	4.1	4.7	2.0	6.8	1.8	6.7	2.7	1.9
5	1.5	2.1	2.4	1.2	3.0	3.0	2.3	1.7	3.9	2.0	3.9	3.0	2.1
6	3.1	2.4	1.8	1.4	4.3	2.0	2.0	2.2	4.8	1.3	3.9	3.3	2.0
7	1.9	1.4	2.1	1.0	4.1	3.3	3.6	2.3	5.4	2.2	4.3	1.9	1.7
8	2.7	1.7	2.2	1.3	4.2	3.4	2.5	2.0	4.4	1.7	2.7	1.5	2.0
9	2.3	2.2	1.8	1.3	4.1	3.4	3.2	1.5	3.2	2.1	5.4	2.3	1.3
10	3.0	2.2	1.4	1.2	4.5	2.7	3.4	1.7	4.5	2.1	5.6	1.0	2.1
11	2.6	1.8	2.3	0.8	3.0	3.7	1.7	2.2	4.1	2.0	3.1	1.5	2.4
12	2.2	1.2	2.1	1.4	4.2	3.6	2.2	2.3	5.2	2.1	2.3	1.3	2.2
13	2.8	1.7	1.5	1.2	3.9	3.8	3.3	2.3	3.7	1.2	6.2	1.4	2.3
14	1.6	1.7	1.9	1.0	4.6	4.0	2.6	1.8	4.5	1.7	2.9	2.2	2.5
15	1.8	1.6	1.8	0.9	3.9	4.5	2.1	1.7	5.4	2.1	4.2	1.9	2.6
16	1.9	1.9	1.9	0.9	5.3	3.4	3.6	2.4	5.5	2.2	4.3	2.4	1.5
17	2.4	2.6	2.3	1.4	4.6	3.2	2.3	1.3	5.0	1.7	4.1	2.3	2.2
18	1.9	2.2	2.5	1.2	3.4	4.0	3.4	1.6	5.9	2.3	4.2	2.6	1.8
19	1.9	2.6	2.4	1.2	3.6	4.1	2.8	2.4	5.2	2.2	6.2	2.5	2.3
20	2.8	1.9	2.4	1.4	4.7	3.8	2.0	2.0	5.0	1.6	3.6	2.1	2.4
21	1.7	2.5	2.0	0.9	5.2	3.4	4.1	1.7	5.6	2.1	3.0	2.3	1.3
22	2.1	2.0	2.5	0.8	4.5	4.5	3.9	1.5	5.6	2.0	3.4	2.1	2.0
23	2.3	2.6	2.0	0.7	3.9	3.0	4.2	2.0	5.0	1.7	1.5	1.4	1.6
24	2.7	2.0	2.0	1.0	3.3	2.8	3.3	2.3	5.4	1.4	4.2	2.8	2.4
25	2.2	2.3	2.0	1.3	3.4	4.1	4.2	2.0	5.3	2.3	3.7	1.5	2.2
26	1.7	1.3	1.8	1.0	3.9	3.7	3.6	2.1	5.0	2.0	3.2	2.2	1.8
27	2.5	2.5	2.0	1.5	3.6	2.6	4.0	1.8	4.1	1.8	1.3	1.9	1.8
28	2.9	1.6	2.4	1.1	3.8	3.0	2.6	1.9	5.8	1.7	2.2	2.5	2.0
29	2.4	2.1	2.2	1.2	4.1	2.7	3.4	2.2	5.3	2.0	7.1	2.6	1.7
30	2.6	1.8	2.3	1.2	4.0	3.8	2.8	2.4	5.5	1.9	3.2	1.7	2.2
31	1.6	1.5	2.4	1.1	4.0	3.8	3.2	2.3	5.2	2.4	4.8	2.5	1.9
32	2.0	1.9	2.1	1.3	3.7	3.7	3.2	1.8	4.7	1.9	6.5	2.8	1.7
33	2.4	3.2	2.8	1.2	3.4	3.2	3.7	1.8	5.4	1.4	4.2	2.1	1.7
34	1.6	2.6	2.2	1.1	3.8	3.3	4.0	2.1	5.2	1.5	2.3	1.9	2.2
35	3.4	2.5	1.9	1.2	2.9	3.0	4.2	2.5	4.7	1.7	6.4	2.0	2.0
36	2.4	2.6	2.3	0.9	4.4	2.6	2.4	1.6	4.3	2.2	2.5	2.5	2.5
37	2.3	2.1	2.5	0.6	5.1	4.3	3.6	2.0	4.2	2.0	4.7	2.5	2.0

50+ activities identified, calibrated using projects in Kurdistan
1000 iteration Monte Carlo analysis to include effect of random errors
Does not include “catastrophic delays” caused by errors in data

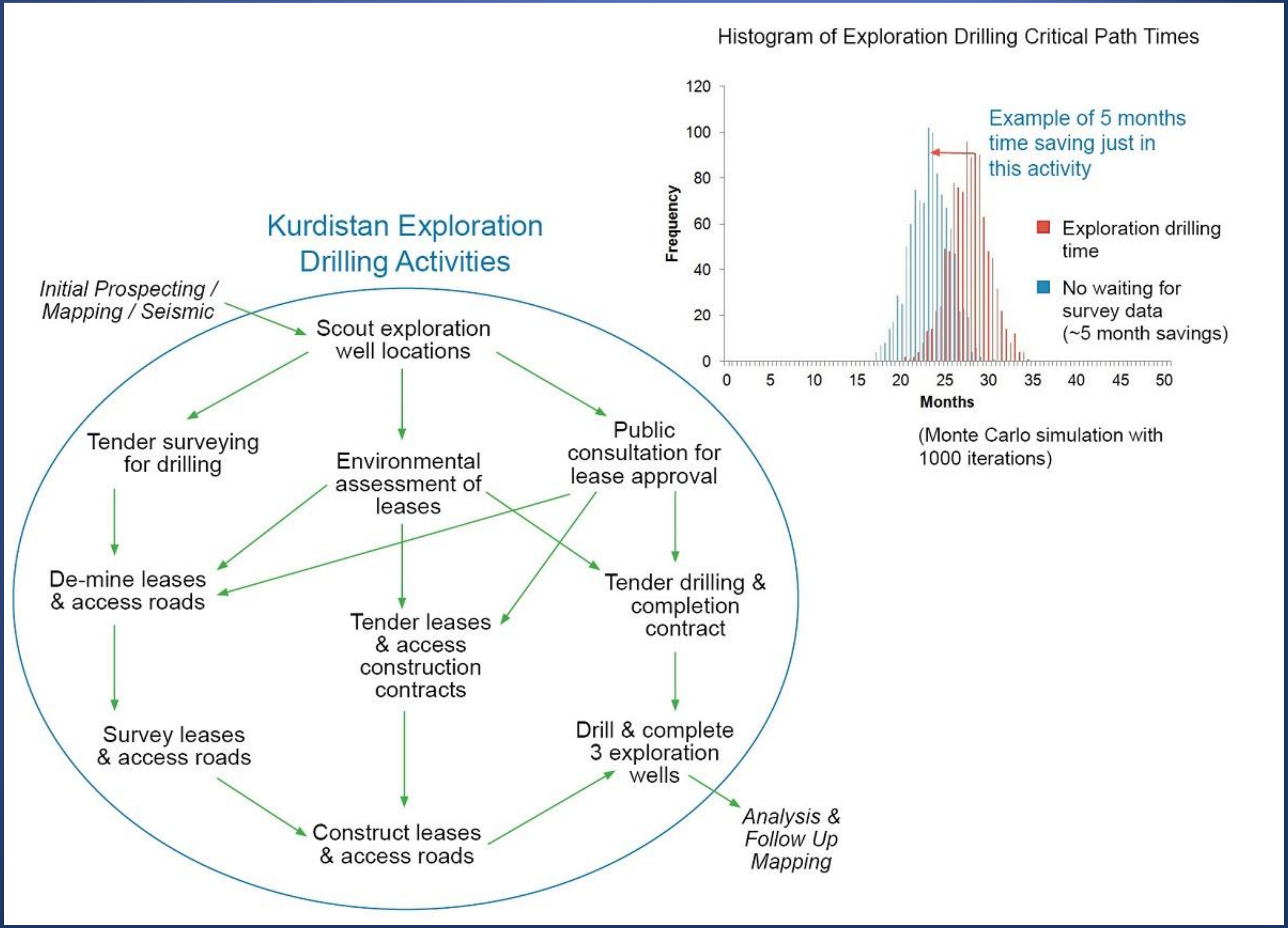
Calculates delays – does not quantify these into $

Phases of an onshore Oil and Gas project



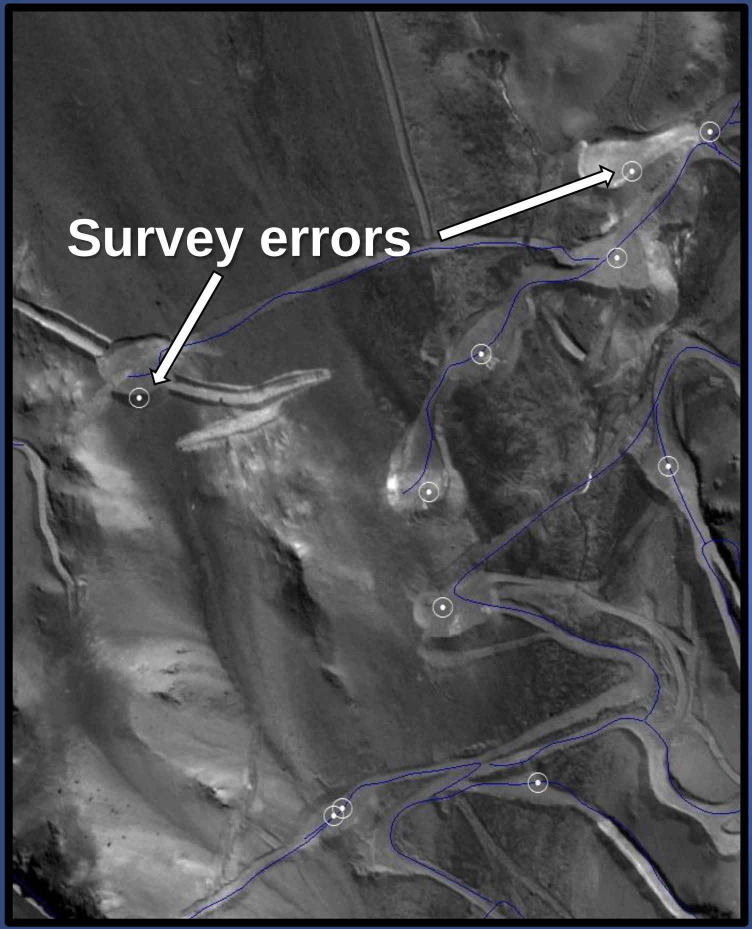
Each phase has 10+ activities some of which happen simultaneously.

Exploration drilling critical path

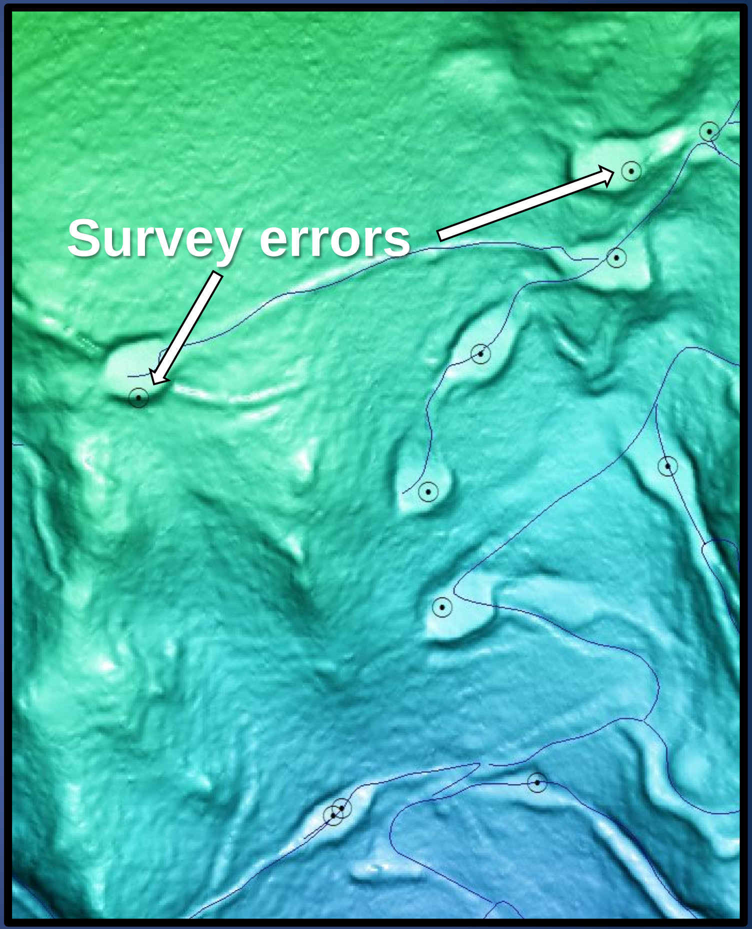


Drill collar location examples from Mining applications

Drill hole collar location errors identified with satellite mapping



Drill holes on WV1 photo



Drill holes on WV2 DEM

Drill hole collar coordinate mapping

750 Drill holes surveyed by three different survey contractors

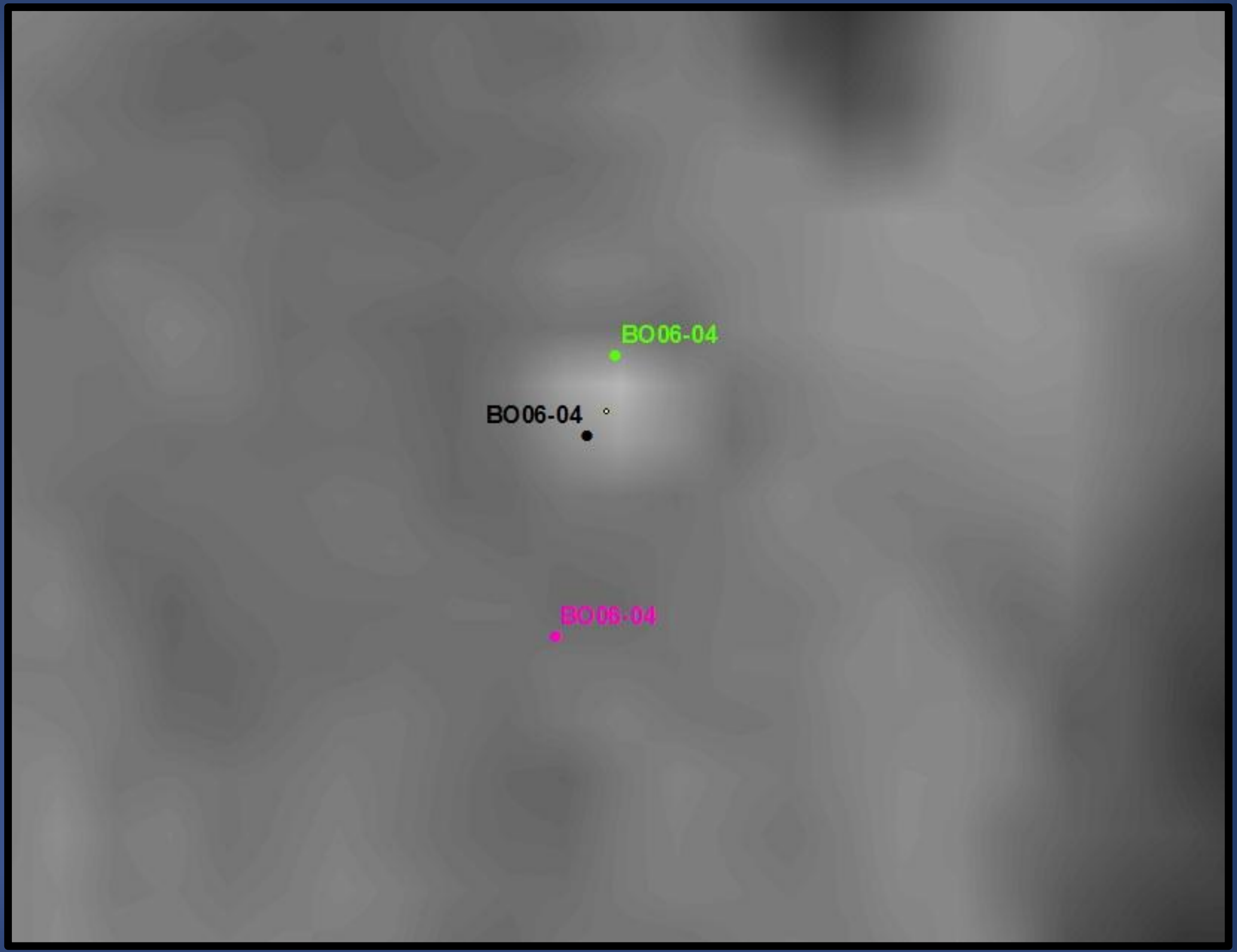
Drill hole collar locations determined directly from stereo satellite mapping

Drill hole collar

40cm x 40cm white concrete block

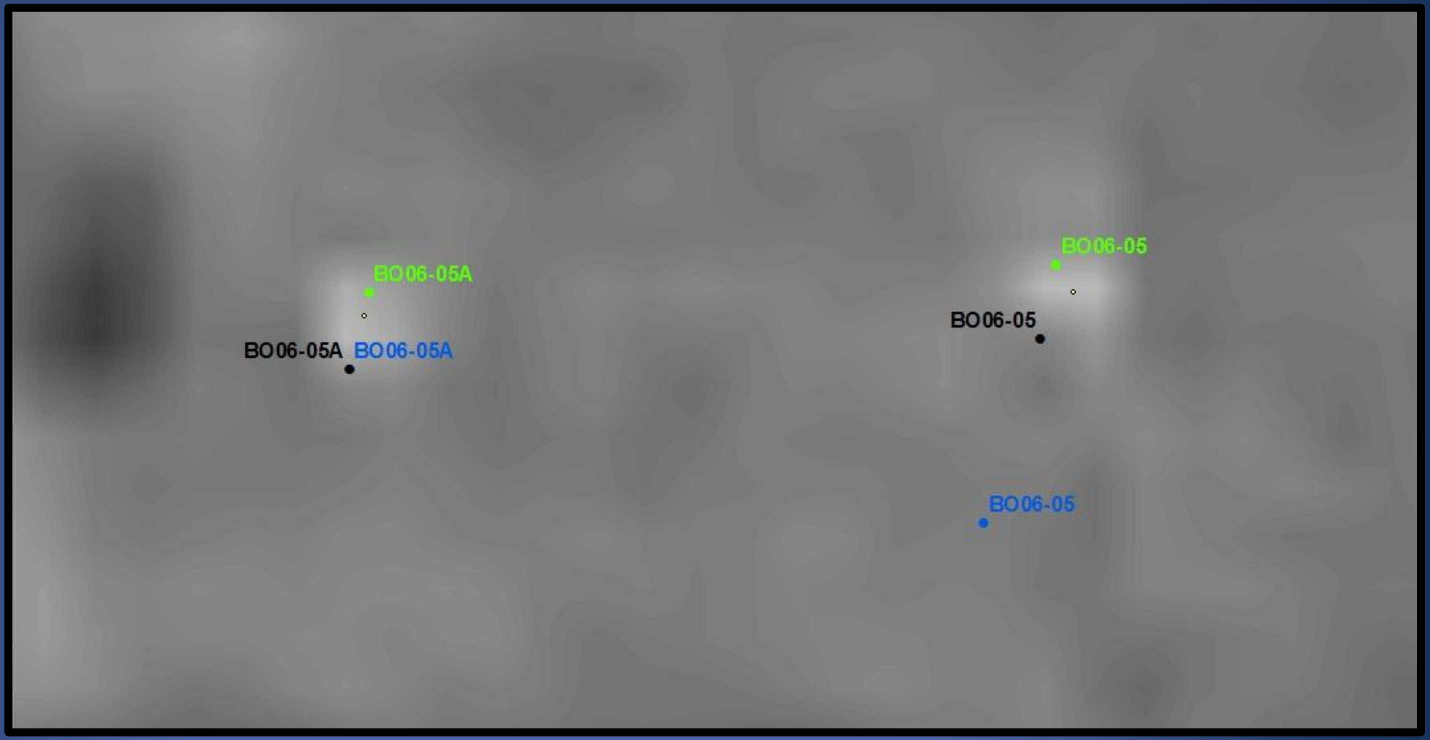
White drill hole collar blocks on WV precision ortho

Drill hole collar coordinate mapping



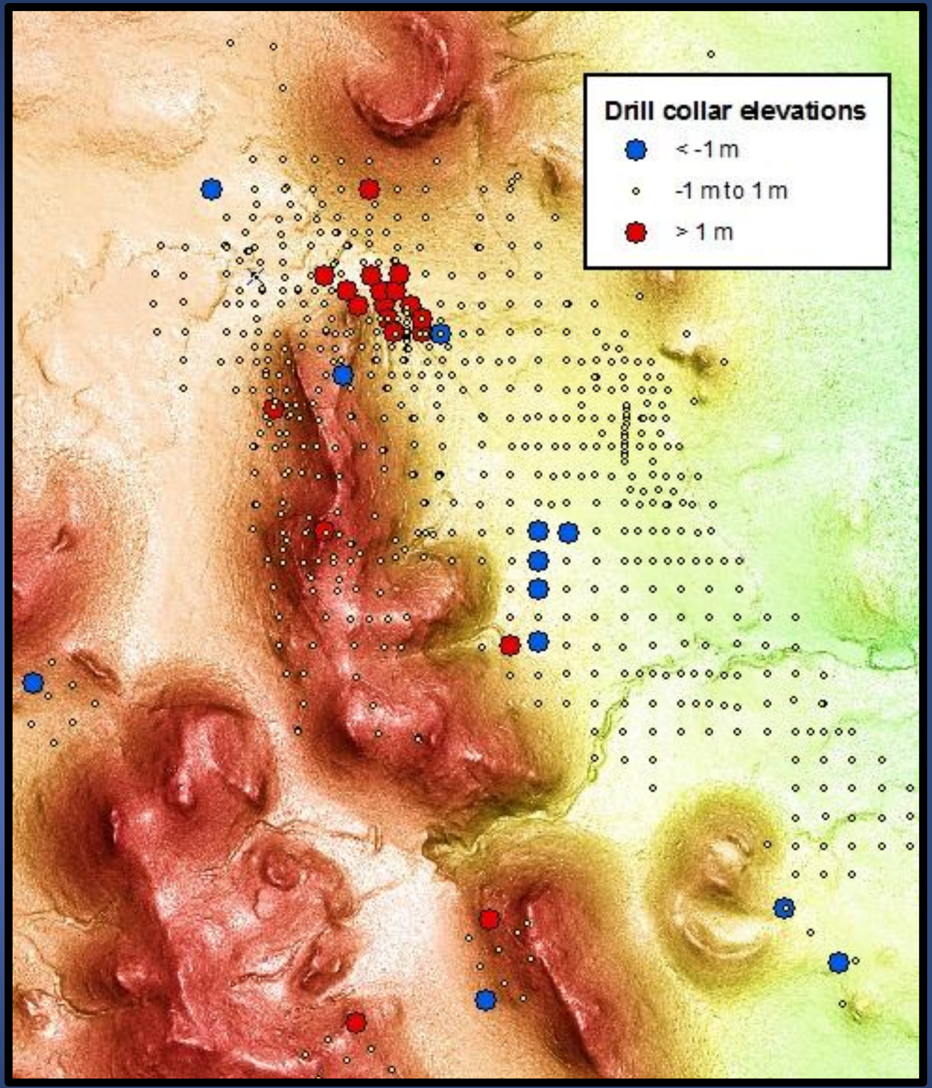
40cm x 40cm white concrete block on satellite photo and the coordinates from the three GPS surveys

Drill hole collar coordinate mapping



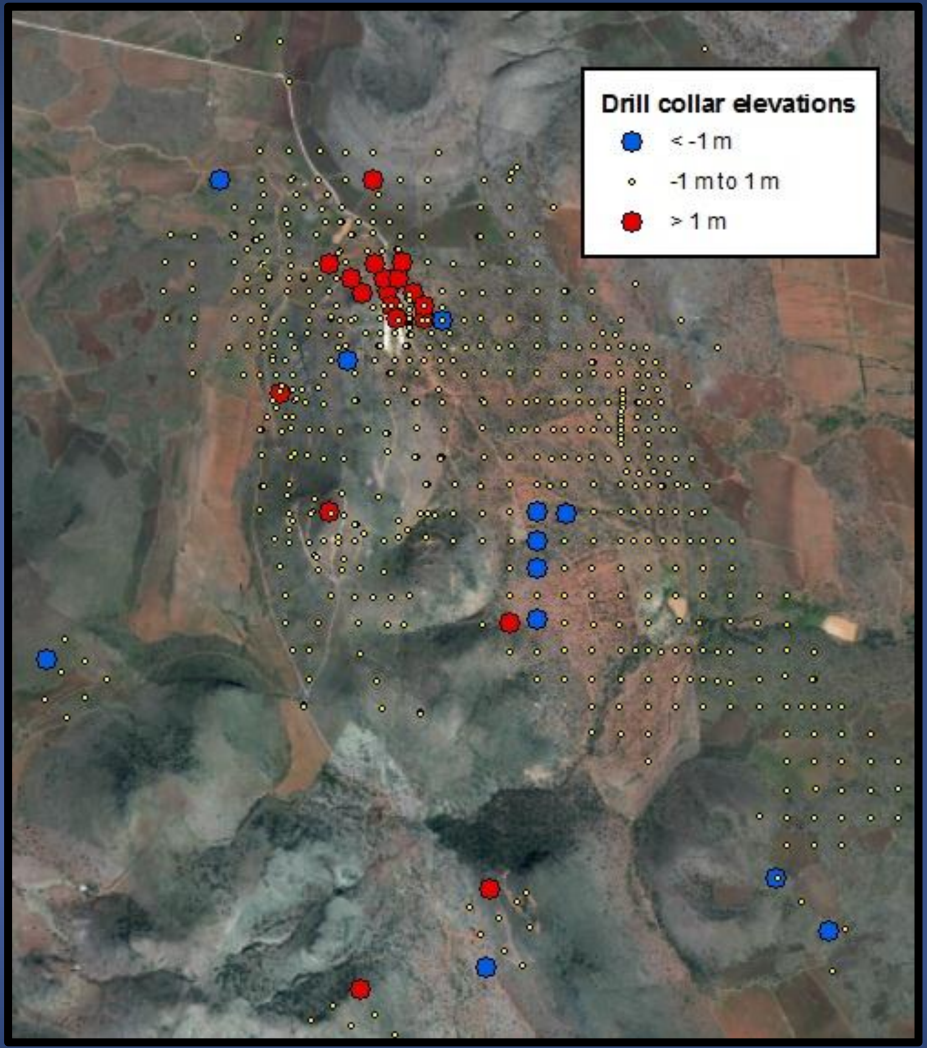
40cm x 40cm white concrete blocks on satellite photo and the coordinates from the three GPS surveys.

Drill hole collar coordinate mapping



Drill hole collar elevation differences between the GPS survey and the stereo satellite mapping

Drill hole collar coordinate mapping



Drill hole collar elevation differences between the GPS survey and the stereo satellite mapping

Conclusions

- *Satellite surveying has improved to a level where it may be used as an alternative to ground surveying or airborne LiDAR for onshore oil and gas projects.*
- *Satellite surveying is useful for detecting and correcting gross survey errors.*
- *Uncertainty in surveying causes delays in many phases of oil and gas projects. A study of a typical onshore project shows that higher accuracy surveying earlier in the project greatly reduces delays.*