



# Precise Agriculture Lot Boundary Determined by Photogrammetric Modeling

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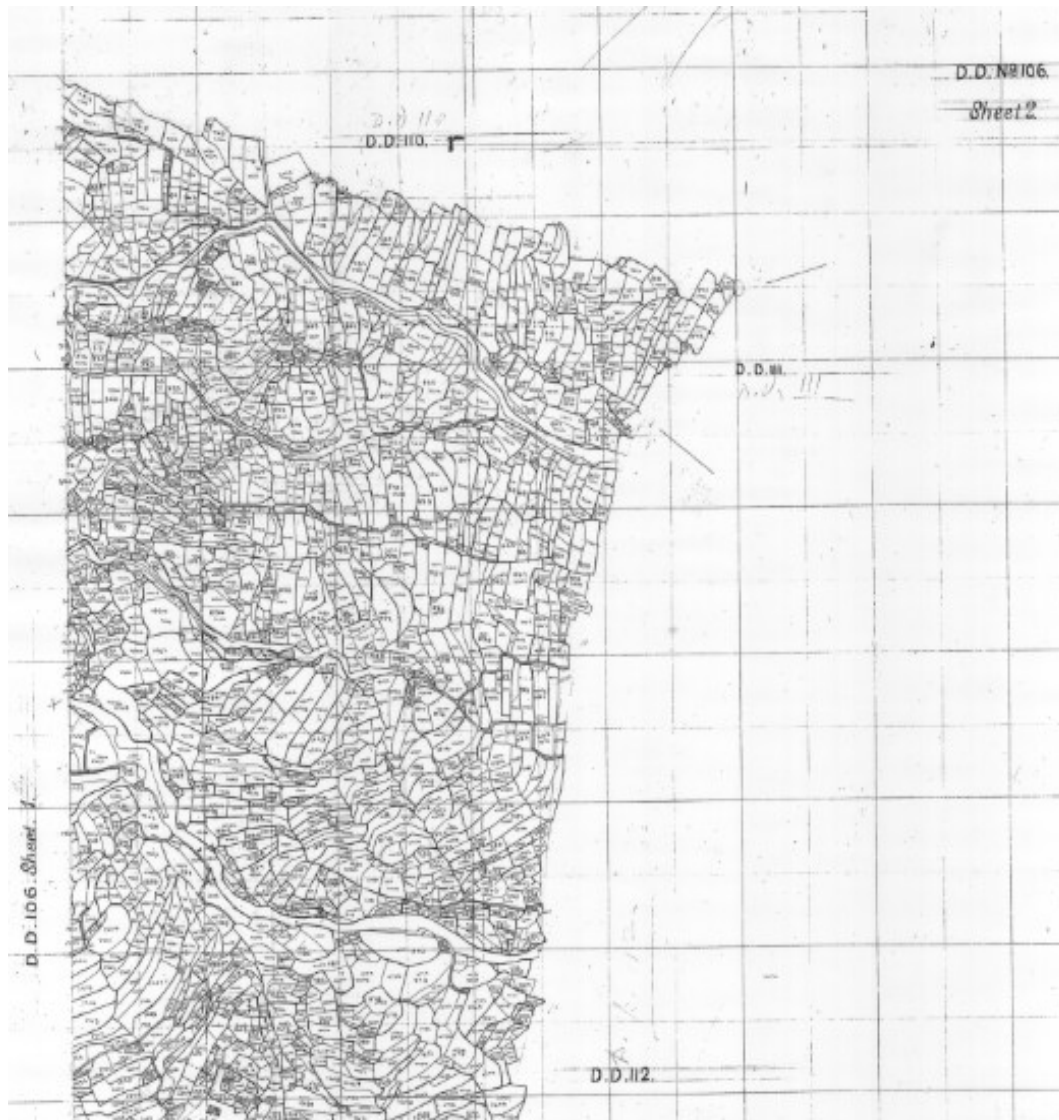
土地測量及地理資訊學系



## Introduction

### Land boundary determination in the New Territories of Hong Kong

- In the New Territories, the Demarcation District (DD) sheets are still in use as the legal record of land boundaries



- DD sheet: have no coordinates framework
- Limited by the graphic accuracy e.g. 16"DD with only a positional accuracy of 4 m by itself.
- Extrinsic evidence of aerial photos e.g. 1949 and 1963



- Aerial photo: show the features of the time.
- From the 60's photo, field bounds largely maintained as in 1905
- determine agricultural lot boundaries by digital photogrammetry



# Digital Photogrammetry

## Exterior Orientation

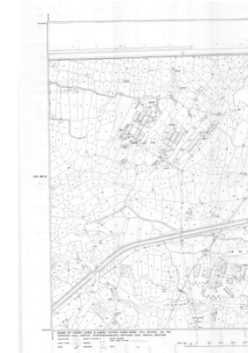
- 1) Geo-referencing old survey sheet, then collect control-point coordinate information
- 2) Field Survey using Kinematic GPS method, collect control-point coordinate information.



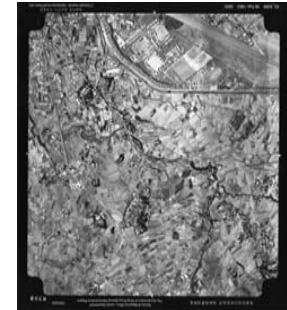


## Data resources

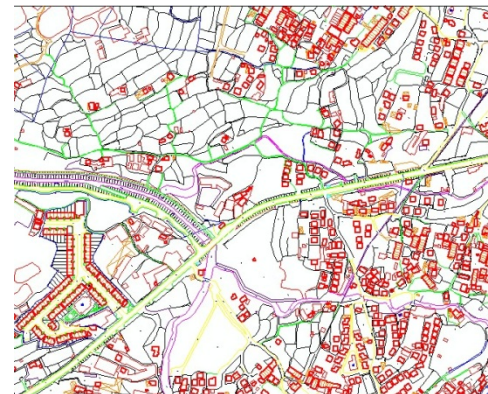
- 1960, 67, 73 old survey sheet (Yuen Long)



- 1963 aerial photo (Yuen Long, scanned with 1200dpi)



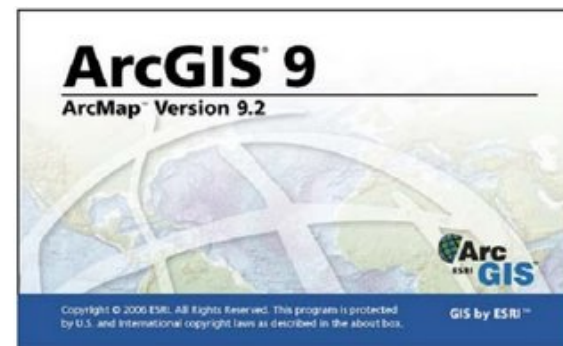
- 2008 Survey Sheet (Yuen Long)





## Software adopted

ArcGIS 9.2



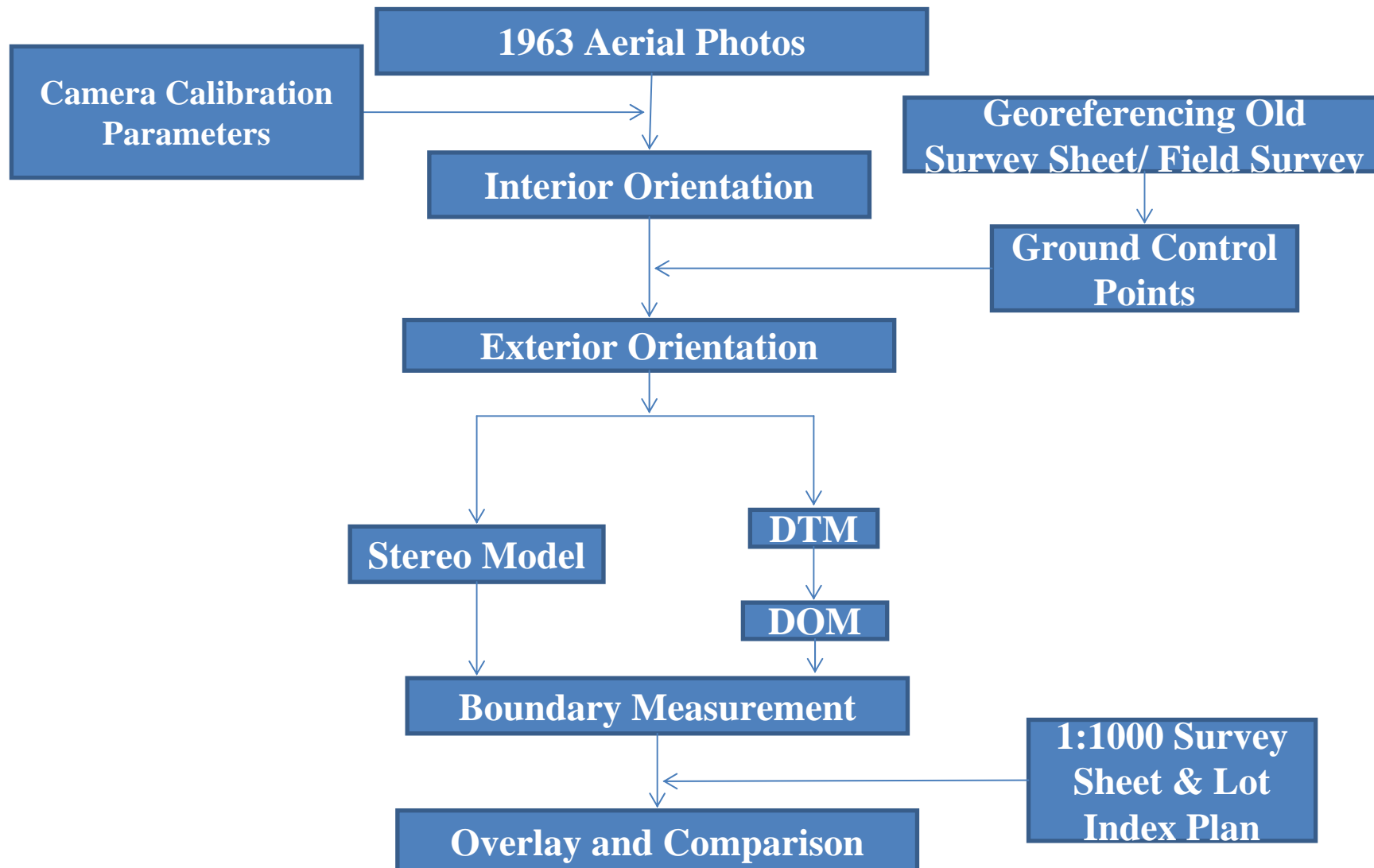
Leica Photogrammetry Suite 9.2



**In all these experiments, software processing:  
X means Easting;  
Y means Northing;**



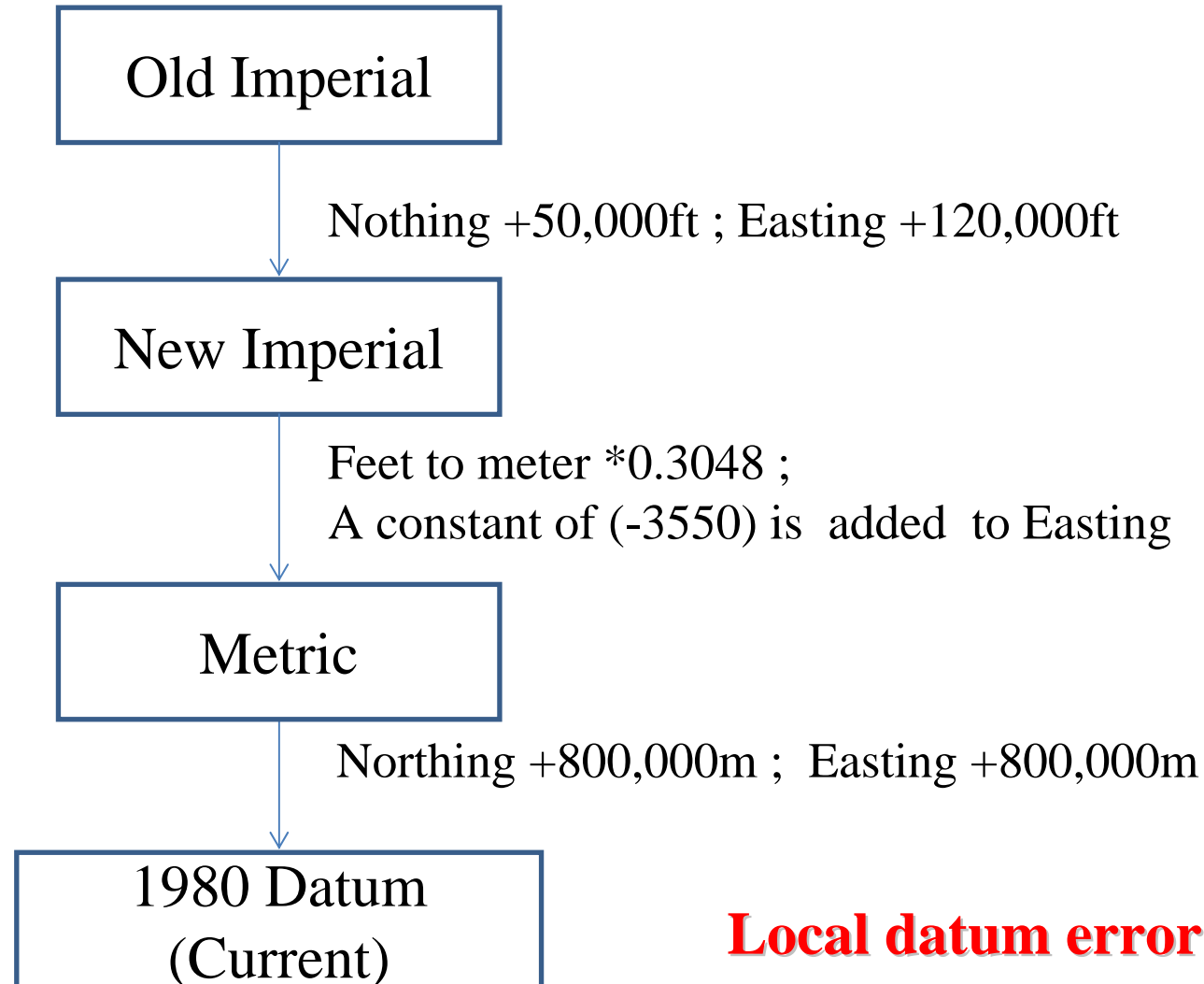
# Work Flowchart







# Coordinate Transformation

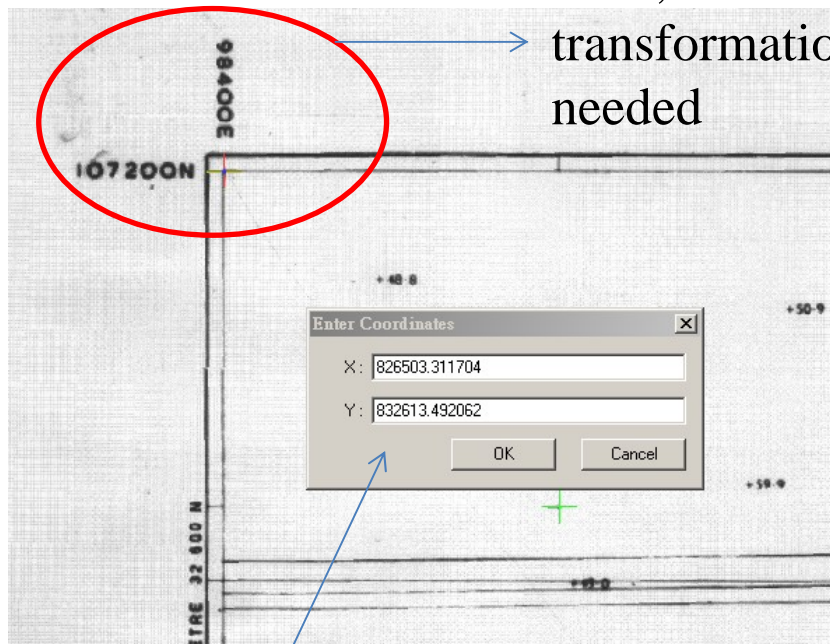


**Local datum error may exist !**



# Georeferencing Old Survey Sheet

Here, coordinate transformation is needed

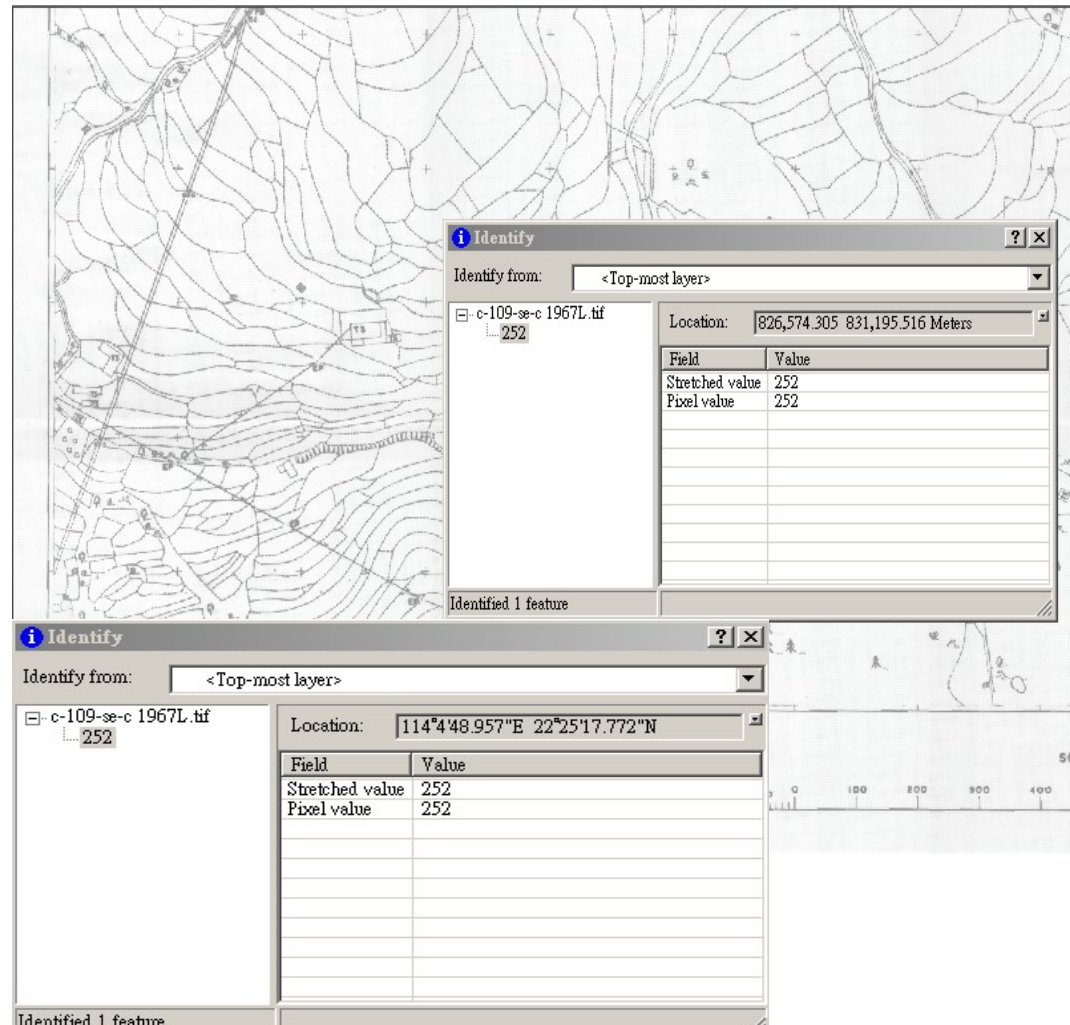


Add Control Point:  
Coordinate information should be inputted





Then, the old survey sheet can provide features' coordinate information





## Field Work for control points in exterior orientation

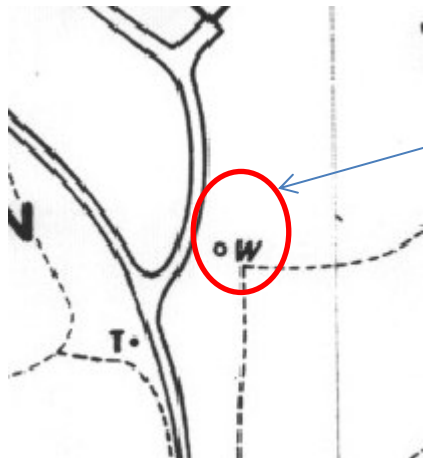
- Adopt wells as the top priority ground control point

Sensible to believe:

Old wells may be in-use, covered or filled,  
but their location can be determined accurately



Well in aerial  
photo(63)



Well in old  
survey  
sheet (73)



Well in lot index  
plan(2011)





- Kinematic GPS

- Centimeter level





## Models with Different Control Points

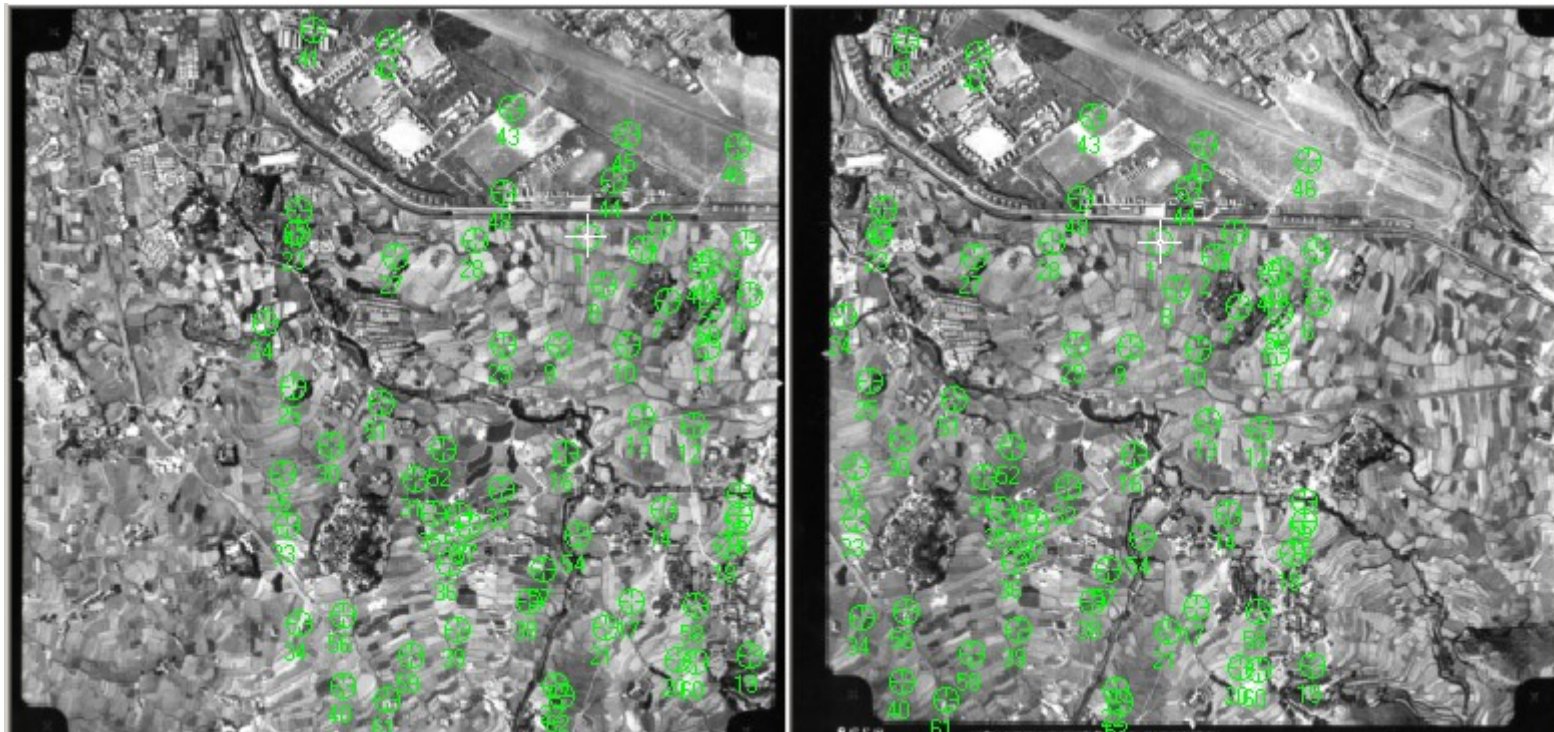
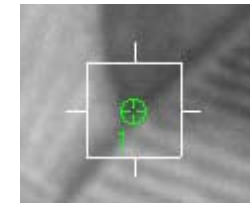
Model Name	GCP Period	GCP Coordinate Source	GCP Type	Number of Control
Model 60 field-bund	1960	Old Survey Sheet Capture	field-bund Crossing	27
Model 67 field-bund	1967	Old Survey Sheet Capture	field-bund Crossing	24
Model 73 field-bund	1973	Old Survey Sheet Capture	field-bund Crossing	25
Model 73 field-bund *	1973	Old Survey Sheet Capture	field-bund Crossing	5
Model 73 Well	1973	Old Survey Sheet Capture	Old Well	4
Model 2009 Well	2009	RTK Field Collection	Old Well	5



# Control Point Distribution

Exterior Orientation using field-bund crossings

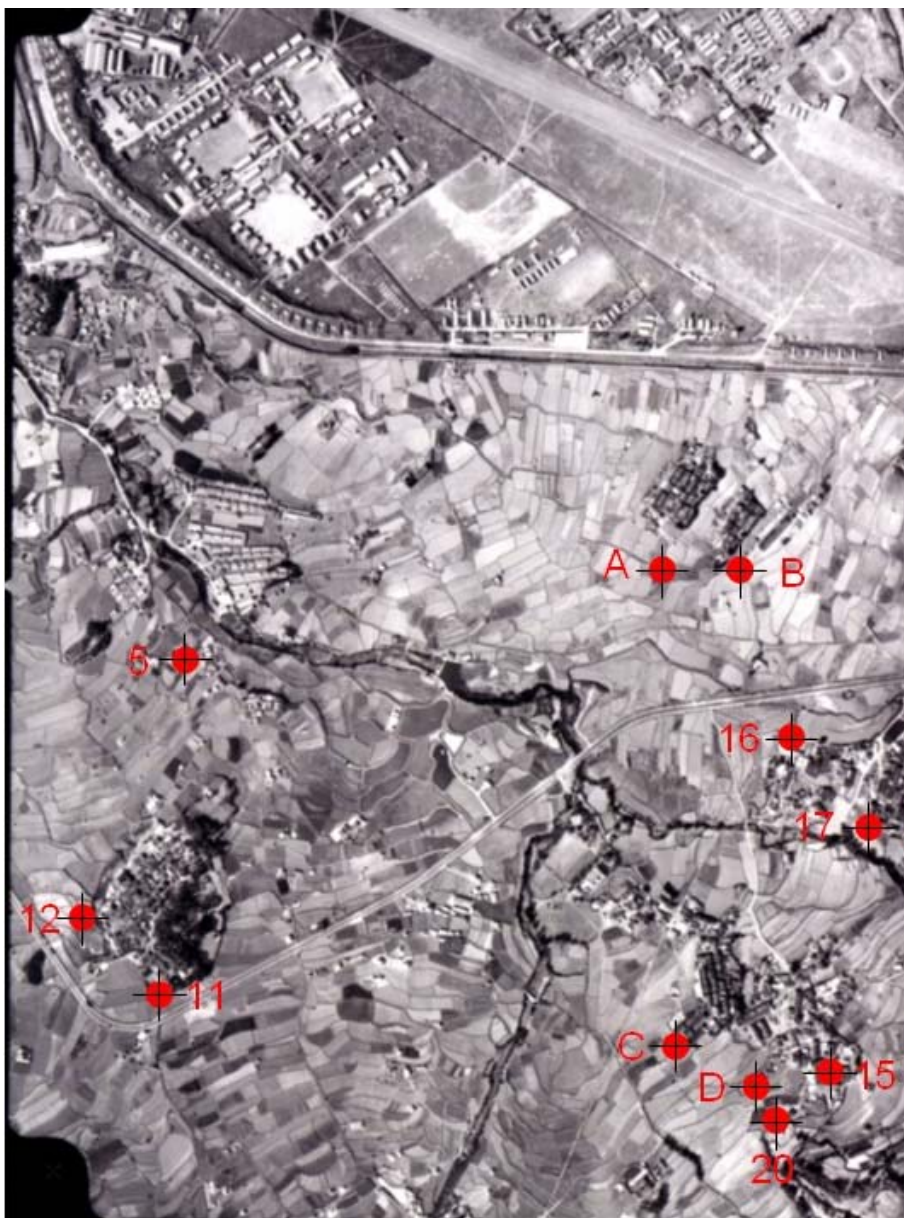
Field-bund







# Control Point Distribution



Exterior Orientation  
using old wells (still  
exist, 2009)

Model 73 Well

Model 09 Well



## Exterior Orientation in LPS

**Model 60 field-bund**

-- Triangulation Summary (60)

Based on the 60' survey sheet

Control/Check Point

Type: "Y"/"T" field-bund crossing

Unit: Meter —Ground

Unit: Pixel —Image

Triangulation Summary	
Triangulation Iteration Convergence:	Yes
Total Image Unit-Weight RMSE:	4.1521
Control Point RMSE:	Check Point RMSE:
Ground X: 0.9332 (27)	Ground X: 0.7036 (12)
Ground Y: 0.7996 (27)	Ground Y: 0.9054 (12)
Ground Z: 1.9194 (27)	Ground Z: 1.0224 (12)
Image X: 5.0712 (52)	Image X: 0.0242 (24)
Image Y: 3.7859 (52)	Image Y: 0.8628 (24)
RMSE Significant Digits:	4

$$M_{\text{horizontal}} = 1.15\text{m}$$





Product : DOM 1960 field-bund

Accuracy can  
achieved





Application:

Overlap comparison:  
1960DOM(field-bund) &  
2008SurveySheet(1:1000)



Overlap comparison:  
1960DOM(field-bund) &  
1960SurveySheet(1:1200)



## Exterior Orientation in LPS

**Model 67 field-bund**

-- Triangulation Summary (67)

Based on the 67' survey sheet

Control/Check Point

Type: "Y"/"T" field-bund crossing

Unit: Meter —Ground

Unit: Pixel —Image

Triangulation Iteration Convergence:		Yes	
Total Image Unit-Weight RMSE:		3.6448	
Control Point RMSE:		Check Point RMSE:	
Ground X:	0.9936 (24)	Ground X:	0.7799 (10)
Ground Y:	0.9862 (24)	Ground Y:	1.0092 (10)
Ground Z:	1.4218 (24)	Ground Z:	0.9568 (10)
Image X:	4.6746 (46)	Image X:	0.0271 (20)
Image Y:	2.9845 (46)	Image Y:	0.9594 (20)

RMSE Significant Digits: 4

$$M_{\text{horizontal}} = 1.28\text{m}$$





Product : DOM 1967 field-bund

Accuracy can  
achieved





Overlap comparison:  
1967DOM(field-bund) &  
2008SurveySheet(1:1000)



Overlap comparison:  
1967DOM(field-bund) &  
1967SurveySheet(1:1200)





## Exterior Orientation in LPS

### Model 73 field-bund -- Triangulation Summary (73)

Based on the 73' survey sheet

Control Point RMSE:		Check Point RMSE:	
Ground X:	0.8553 (25)	Ground X:	0.8072 (14)
Ground Y:	0.9287 (25)	Ground Y:	0.9129 (14)
Ground Z:	0.9073 (25)	Ground Z:	0.8425 (14)
Image X:	4.7928 (50)	Image X:	0.0293 (28)
Image Y:	4.9146 (50)	Image Y:	1.0160 (28)

Triangulation Iteration Convergence: Yes  
Total Image Unit-Weight RMSE: 4.4502

RMSE Significant Digits: 4

Buttons: Close, Update, Accept, Report..., Review..., Help

Control/Check Point  
Type: "Y"/"T" field-bund crossing

Unit: Meter —Ground  
Unit: Pixel —Image

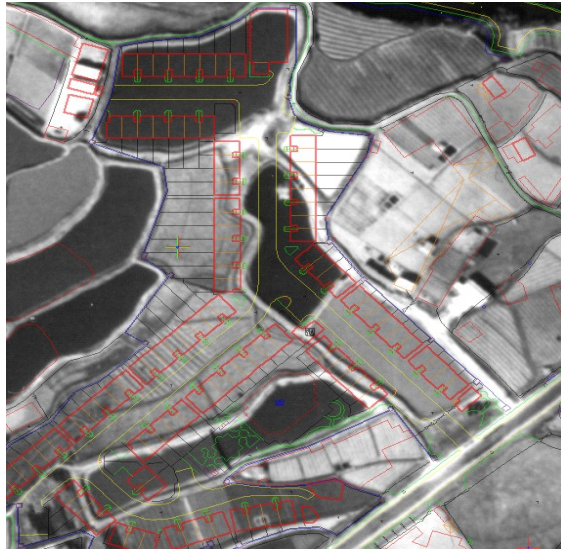
$$M_{\text{horizontal}} = 1.22\text{m}$$



Product : DOM 1973 field-bund

Accuracy can  
achieved





Overlap comparison:  
1973DOM(field-bund) &  
2008SurveySheet(1:1000)



Overlap comparison:  
1973DOM(field-bund) &  
1973SurveySheet(1:1200)



## Exterior Orientation in LPS

**Model 73 well**

-- Triangulation Summary (73)

Based on the 73' survey sheet

Control Point RMSE:		Check Point RMSE:	
Ground X:	0.1003 (4)	Ground X:	0.6511 (5)
Ground Y:	0.1006 (4)	Ground Y:	0.8507 (5)
Ground Z:	0.2010 (4)	Ground Z:	0.9541 (5)
Image X:	0.3139 (8)	Image X:	0.0139 (10)
Image Y:	0.4379 (8)	Image Y:	0.4982 (10)

RMSE Significant Digits: 4

Control/Check Point  
Type: Old well

Unit: Meter —Ground  
Unit: Pixel –Image

$$M_{\text{horizontal}} = 1.08\text{m}$$

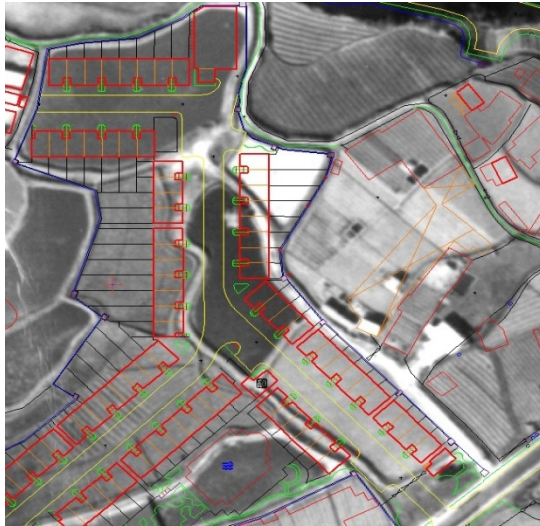




Product : DOM 1973 well

Accuracy can  
achieved





Overlap comparison:  
1973DOM(well) &  
2008SurveySheet(1:1000)



Overlap comparison:  
1973DOM(well) &  
1973SurveySheet(1:1200)



## Exterior Orientation in LPS

**Model 73 field-bund** \*

-- Triangulation Summary (73)

-- similar control point distribution with Model 73 well

Based on the 73' survey sheet

Control/Check Point

Type: "Y"/"T" field-bund crossing

Unit: Meter —Ground

Unit: Pixel –Image

Control Point RMSE:		Check Point RMSE:	
Ground X:	0.3087 (5)	Ground X:	1.2478 (5)
Ground Y:	0.4196 (5)	Ground Y:	2.4473 (5)
Ground Z:	0.7005 (5)	Ground Z:	1.1089 (5)
Image X:	1.4688 (9)	Image X:	0.0256 (10)
Image Y:	1.8161 (9)	Image Y:	0.9085 (10)

RMSE Significant Digits: 4

$$M_{\text{horizontal}} = 2.75\text{m}$$



## Exterior Orientation in LPS

**Model 2009 well**

-- Triangulation Summary (2009)

RTK technique is used to acquire the coordinate of control point (2009)

Control/Check Point  
Type: Old well

Unit: Meter —Ground  
Unit: Pixel –Image

Triangulation Iteration Convergence: Yes		Close
Total Image Unit-Weight RMSE: 0.7362		
Control Point RMSE:		Update
Check Point RMSE:		Accept
Ground X: 0.0499 (5)	Ground X: 0.1441 (5)	Report...
Ground Y: 0.0378 (5)	Ground Y: 0.2596 (5)	Review...
Ground Z: 0.0627 (5)	Ground Z: 0.6853 (5)	Help
Image X: 0.2108 (10)	Image X: 0.0219 (10)	
Image Y: 0.3613 (10)	Image Y: 0.5292 (10)	
RMSE Significant Digits: 4		

$$M_{\text{horizontal}} = 0.30\text{m}$$

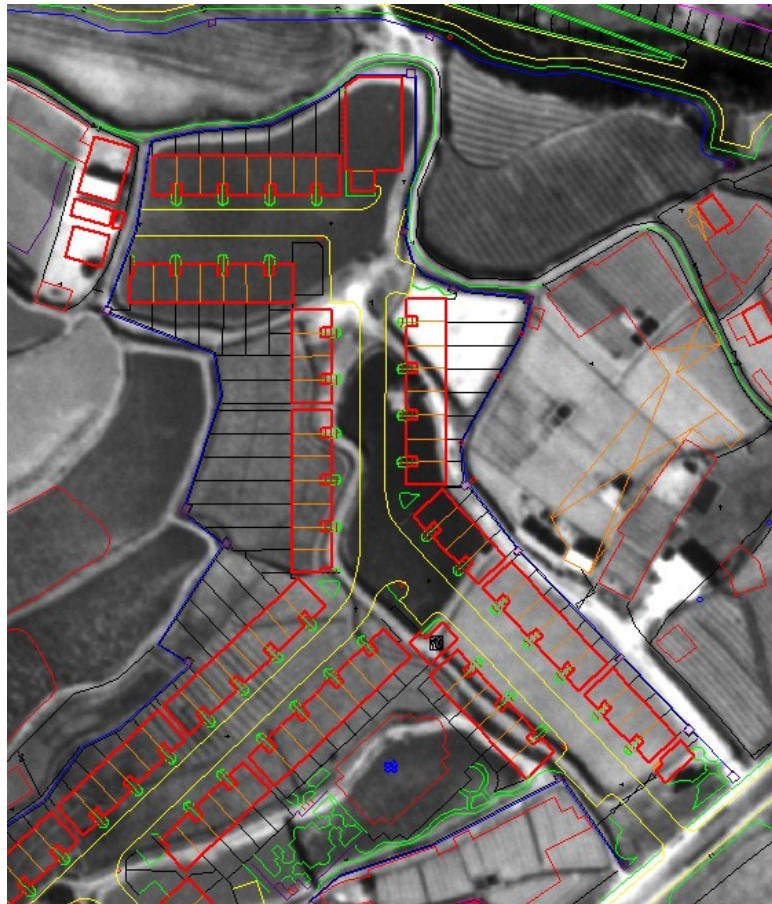




Product : DOM 2009 well

Accuracy can  
achieved





Overlap comparison:  
2009DOM(well) &  
2008SurveySheet(1:1000)



## Model 60 field-bund

Using Field Work Result To Test Model Accuracy

Internal Accuracy=1.15m

WellNo.	Xsurvey	Ysurvey	XcaptureFromModel	YcaptureFromModel	Dx	Dy	D(horizontal)
A	826661.21	832303.53	826660.42	832300.51	-0.79	-3.02	3.12
B	826765.06	832306.01	826764.64	832302.90	-0.42	-3.11	3.14
D	826824.97	831596.05	826824.68	831593.52	-0.28	-2.52	2.54
No20(field-bund)	826271.70	831768.01	826271.49	831766.17	-0.21	-1.84	1.85

System error may existed  
Using mean to rectify



## Model 67 field-bund

Using Field Work Result To Test Model Accuracy

# Internal Accuracy=1.28m

1967Model field-bund							
WellNo.	Xsurvey	Ysurvey	XcaptureFromModel	YcaptureFromModel	Dx	Dy	D(horizontal)
A	826661.21	832303.53	826660.27	832303.22	-0.94	-0.31	0.98
B	826765.06	832306.01	826764.66	832305.75	-0.40	-0.25	0.47
D	826824.97	831596.05	826825.84	831595.95	0.87	-0.09	0.88
No20(field-bund)	826271.70	831768.01	826271.80	831767.66	0.10	-0.35	0.36





## Model 73 field-bund

Using Field Work Result To Test Model Accuracy

# Internal Accuracy=1.22m

1973Model field-bund							
WellNo.	Xsurvey	Ysurvey	XcaptureFromModel	YcaptureFromModel	Dx	Dy	D(horizontal)
A	826661.21	832303.53	826660.56	832303.06	-0.65	-0.47	0.80
B	826765.06	832306.01	826764.57	832305.55	-0.49	-0.46	0.67
D	826824.97	831596.05	826824.95	831596.70	-0.01	0.66	0.66
No20(field-bund)	826271.70	831768.01	826271.64	831768.54	-0.06	0.53	0.54



## Model 73 field-bund\*

Using Field Work Result To Test Model Accuracy

# Internal Accuracy=2.75m

1973Model field-bund*							
WellNo.	Xsurvey	Ysurvey	XcaptureFromModel	YcaptureFromModel	Dx	Dy	D(horizontal)
A	826661.21	832303.53	826660.81	832303.87	-0.40	0.34	0.52
B	826765.06	832306.01	826765.08	832306.40	0.02	0.39	0.39
D	826824.97	831596.05	826826.91	831594.84	1.94	-1.21	2.29
No20(Ran)	826271.70	831768.01	826272.12	831768.69	0.42	0.68	0.80



# Model Comparison

## 1. Model 60 field-bund

27 control points used in the exterior orientation

$$M_{\text{horizontal}}=1.15\text{m}$$

## 2. Model 67 field-bund

24 control points used in the exterior orientation

$$M_{\text{horizontal}}=1.28\text{m}$$

## 3. Model 73 field-bund

25 control points used in the exterior orientation

$$M_{\text{horizontal}}=1.22\text{m}$$

## 4. Model 73 field-bund\*

5 control points used in the exterior orientation

$$M_{\text{horizontal}}=2.75\text{m}$$

## 5. Model 73 well

4 control points used in the exterior orientation

$$M_{\text{horizontal}}=1.08\text{m}$$

## 6. Model 09 well

5 control points used in the exterior orientation

$$M_{\text{horizontal}}=0.30\text{m}$$



Though the formed DOM and the old survey sheet are at same accuracy level, we still suggest to adopt the DOM as priority reference.

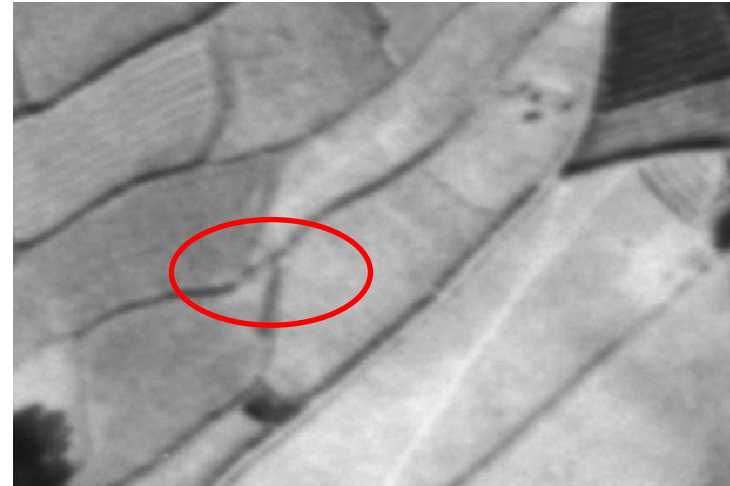
- More reliable than old survey sheet  
(2 Cases will be given)
- have 3D property (better for measurement)



# Maps should be used together with photos



Area in 1960



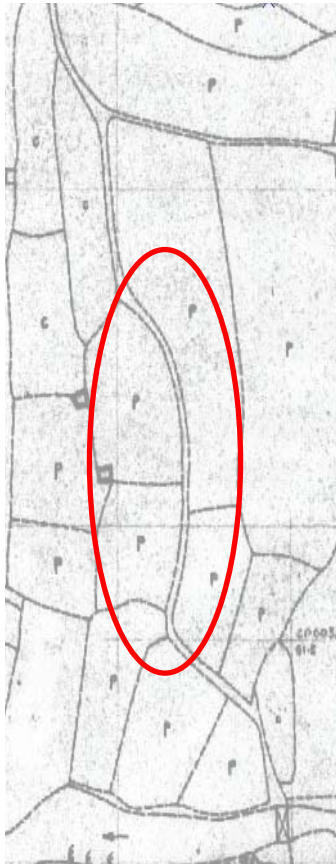
Area in 1963(photo)



Area in 1967 (without update)



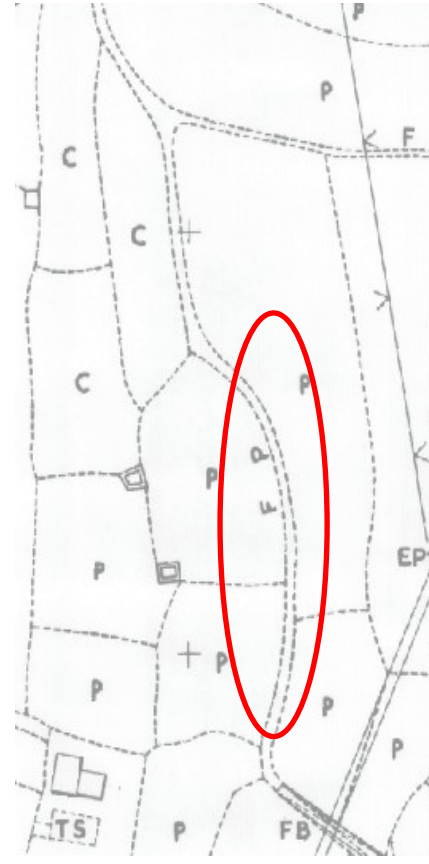
Area in 1973 (finally update)



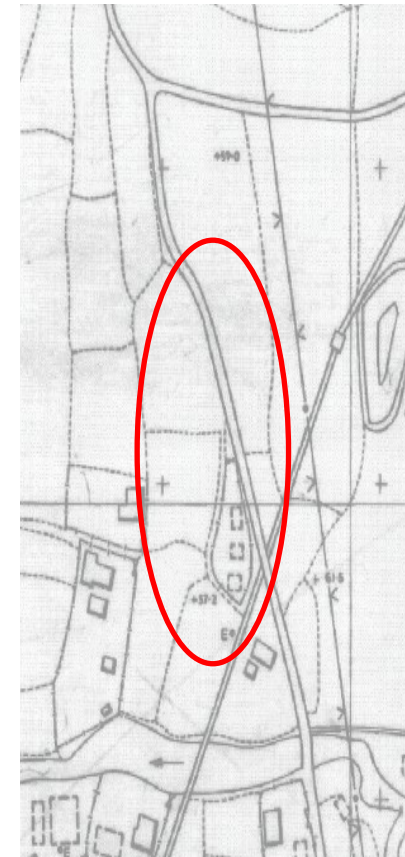
Path in 1960  
(curved)



Path in 1963  
(straight)



Path in 1967  
(curved)



Path in 1973  
(straight)



## Conclusion

- Precise exterior orientation reference points control the model accuracy
  - Best accuracy achieved – Wells 0.3 m
  - General accuracy using old maps - 1.2 m



# Thank You !



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